ASSOCIATION OF ENGINEERS, ARCHITECTS AND GRADUATES IN TECHNOLOGICAL SCIENCES IN ISRAEL

OASIS 8

International Conference & Exhibition on Optics & Electro-Optics

Digital Abstract Book

Conference Website:
www.oasis8.org.il

KALEIDOSCOPE Conferences Events Multimedia 03-5445015 kldltd.com ארגון והפקה

Table of Contents

Conference Program

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Monday December 12, 2022

08:00 - 09:00

09:00 - 10:55 **Opening session - Plenary Hall**

09:00 - 09:25 **Chairperson:** Professor **Abraham Katzir,** Chairman of Oasis 2022

09:25 - 09:30 **Mr. Guy Shasha** Chairman of the Association of Engineers, Architects and Graduates in Technological Sciences in Israel

09:30 - 10:15 **Plenary lecture:**

The future of Organic Optoelectronics beyond OLED
Prof. Stephen Forrest,
College of Engineering; University of Michigan, Michigan, USA

10:15 - 10:55 **Plenary lecture:**

Attosecond Science
Prof. Nirit Dudovich,
Department of Physics, The Weizmann Institute, Rehovot, Israel

10:55 - 11:20 **Coffee break and Posters review of topics: *Lasers and Applications & Electro-Optics in Defense & Nonlinear Optics***

12:50 - 11:20 | Parallel Session 1

Hall A

Optical Engineering
Dr. Hanni Inbar

11:20 **Invited speaker** | Paradigm-shifts in Neurosurgery with Lensless 3D Fiber Endoscopy using Deep Learning
Prof. Jürgen Czarske, *Center Biomedical Computational Laser Systems (BIOLAS), Faculty Electrical and Computer Engineering, Co-opted Professor for Physics, School of Science, TU Dresden, Dresden, Germany*

11:47 **Invited speaker** | Deep Learning for Extreme Optical Compressive Imaging | **Prof. Adrian Stern,** *Electrooptical Engineering Department, School of Electrical and Computer Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel*

12:12 How to turn a Puddle of Liquid into a Diffractive Optical Element
Mr. Jonathan Ericson, *Faculty of Mechanical Engineering, Technion - Israel Institute of Technology, Haifa, Israel*

12:25 Squared TopHat Profiles for Laser Material Processing
Mr. Silvio Vater, *asphericon GmbH., Jena, Germany*

12:38 Current Freeform Metrology Methods
Dr. Jessica DeGroote Nelson, *Edmund Optics, USA*

Hall B

Atomic and Quantum Optics
Prof. Dan Oron

11:20 **Invited speaker** | Hybrid Quantum Systems with Ultracoherent Mechanical Resonators
Prof. Albert Schliesser, *Niels Bohr Institute, Copenhagen University*

11:48 **Invited speaker** | Quantum Simulation with Ultracold Fermionic Atoms
Prof. Yoav Sagi, *Associate Professor, Physics Department Technion - Israel Institute of Technology, Haifa, Israel*

12:15 Shaping Entangled Photons Through Emulated Turbulent Atmosphere
Mr. Ronen Shekel, *The Hebrew University of Jerusalem, Jerusalem, Israel*

12:33 Free-Electron Entanglement and non-Gaussian Photonic States Through 'which-path' Information
Mr. Ron Ruimy, *Technion Israel Institute of Technology, Haifa, Israel*

Hall C

Lasers and Applications
Dr. Ariel Bruner

11:20 **Invited speaker** | High Power Single-Frequency Laser Systems for Gravitational Wave Detectors
Prof. Peter Wessels, *Laser Zentrum Hannover e.V., Germany*

11:50 Active and Passive Gain Switched Ho:YAG Laser with few Nanosecond Pulse Duration
Mr. Yechiel Bach, *Jerusalem College of Technology, Jerusalem, Israel*

12:05 Synchronized and Spectrally Overlapping Yb / Nd Chirped Pulse Amplifier
Dr. Yariv Shamir, *Soreq Nuclear Research Center, Yavne, Israel*

12:20 Femtosecond Inscription of a Spectral Array of Fiber Bragg Gatings at the same Spot, using a Single Uniform Phase-Mask
Dr. Aviran Halstuch, *Ben-Gurion University of the Negev, Beer-Sheva, Israel*

12:35 A Forward Brillouin Fiber Laser
Mr. Gil Bashan, *Bar Ilan University, Ramat-Gan, Israel*

Hall D

Electro-Optics in Industry
Dr. Rami Cohen

Sponsored by: IDEA Machine Development Design & Production Ltd.

11:20 **Invited speaker** | Space-Proof Based Packaging of Compact Single and Entangled Photon Sources for Secure Communication
Dr. Erik Beckert, *Fraunhofer-Institute for Applied Optics and Precision Engineering (IOF), Jena, Germany*

11:40 **Invited speaker** | Main Features of High-performance CW Laser Optics for High-power NIR Range Applications
Dr. Laurynas Lukoševičius, *PhD, Chief Scientist, Altechna, Vilnius, Lithuania*

12:00 **Invited speaker** | Common Path Interferometry: Towards Non-Destructive Testing of Functional Damage in CW Regime
Mr. Justinas Galinis, *UAB Lidaris, Vilnius, Lithuania Vilnius University, Laser Research Center, Vilnius, Lithuania*

12:20 Green Wavelength Lasers Improve Copper Materials Processing
Dr. Dror Shayovitz, *Civan Lasers, Israel*

12:35 On-tool Polarimetry for Detection Optimization
Dr. Ilan Harel, *Applied Materials, Israel*

Hall E

Electro-Optics in Defense
Dr. Ami Yaacobi

11:20 **Invited speaker** | Adaptive Wavefront Control with Coherent Fiber Array Systems
Prof. Mikhail A. Vorontsov, *Department of Electro-Optics and Photonics, University of Dayton, Ohio, and Optonica, Spring Valley, Ohio*

11:45 **Invited speaker** | Atmospheric Turbulence & Propagation Study with Deep Machine Learning
Prof. Mikhail A. Vorontsov, *Department of Electro-Optics and Photonics, University of Dayton, Ohio, and Optonica, Spring Valley, Ohio*

12:15 Phase Retrieval and More Approaches for Wavefront Sensorless Adaptive Optics
Dr. Bar Peled, *Rafael Advanced Defense Systems, Israel*

12:33 Diode Pumped Alkali Laser: Current Status and Prospects
Dr. Ilan Hakimi
Rafael Advanced Defense Systems, Israel

13:50 - 12:50 | Lunch Break

14:15 - 13:50 | Poster Review of Topics: Electro-Optic Devices & Optical Engineering

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

14:15 - 15:45 | Parallel Session 2

Hall A

Electro-Optics Devices
Dr. Ilya Goykhman

14:15 **Invited speaker** | Application of 2D Materials in Photonic Sensing and Electronics
Prof. Thomas Mueller, *Vienna University of Technology, Institute of Photonics, Vienna, Austria*

14:35 **Invited speaker** | Modelling Optoelectronic Applications based on Graphene
Prof. Elefterios Lidorikis, *Computational Materials Science Laboratory; Department of Materials Science and Engineering, University of Ioannina; Institute of Materials Science and Computing, University Research Center of Ioannina, Ioannina, Greece*

14:55 **Invited speaker** | Active Metasurfaces
Prof. Uriel Levi, *Department of Applied Physics, Center for Nanoscience and Nanotechnology, The Hebrew University of Jerusalem, Jerusalem, Israel*

15:15 Orthogonal Sub-Sampled Analog-to-Digital and Digital-to-Analog Conversion
Prof. Thomas Shneider, *Technical University of Braunschweig, Germany*

15:25 Transparent, Optically Lossless and Thermally Efficient 2D MoS2 Heaters Integrated with Silicon Microring Resonators
Mr. Dor Oz, *Technion - Israel Institute of Technology, Haifa, Israel*

15:35 Tunable Electro-Optical Blockade and Switching of Propagating Exciton-Polaritons
Mr. Dror Liran, *The Hebrew University of Jerusalem, Jerusalem, Israel*

Hall B

Spectroscopy and Optical Sensing
Dr. Ayala Ronen

14:15 **Invited speaker** | Coherent Free-Space Optical Communications
Dr. Szymon Gladysz, *Fraunhofer Institute of Optronics, System Technologies and Image Exploitation, Germany*

14:40 Characterization of Sub Inversion Layer Haze Pockets in the Summer Season of the israeli Coastline with IR Imager
Dr. Eyal Agassi, *Israel Institute for Biological Research, Ness Ziona, Israel*

14:53 Application of 3D Volumetric Scattering-Tomography to in-lab Cloud-Cell
Dr. Masada Tsabari, *Technion - Israel Institute of Technology, Haifa, Israel*

15:06 Optical Strain and Magnetic field Sensors based on Whispering Gallery Modes Microresonators
Dr. Eyal Yacoby, *Soreq Nuclear Research Center, Yavne, Israel*

15:19 Ellipsometric Surface Plasmon Resonance Sensor using Polarization Camera for Real-Time Sensing Applications
Mr. Nipun Vashishta, *Ben-Gurion University of the Negev, Beer-Sheva, Israel*

15:32 Forward Brillouin Point Sensor in a Multi-Core Optical Fiber
Ms. Keren Shemer, *Bar Ilan University, Ramat-Gan, Israel*

Hall C

Start-Up
Mr. Ran Bar-Sella

Sponsored by: bank hapoalim, MEITAR

1. 270o Field Of View pancake lens based compact Virtual Reality visual engine - hypervision
2. How to Treat Amblyopia by Watching Netflix - NovaSight
3. From a Pilot's Helmet to Ray-ban Glasses - Making Augmented Reality a Reality - OORYM
4. Cloud-Based, Non-Sequential Optical Simulation - 3DOptix
5. What Would Work Best for Inter-Satellite link in space? Laser or RF? Practical Lessons - BeetleSat
6. Solving hard problems in the speed of light - LightSolver
7. Applications of Temporal Optics - BIRAD
8. How cooling can be achieved under sunlight - SolCold
9. Video Based Predictive Maintenance - Scoutcam
10. Disruptive Multispectral Technologies - AGROWING
11. A New Paradigm In Vision Correction - nano drops
12. Nemo Nano Materials - A New Set of Material Toolbox for the Industry - NEMO

Hall D

Nonlinear Optics
Prof. Haim Suchowski

14:15 **Invited speaker** | Efficient Parametric Amplification via Hybridized Nonlinear Optics
Prof. Jeffrey Moses, *Cornell University, USA, School of Applied & Engineering Physics*

14:35 Soliton Pair Dynamical Transition in Mode-Locked Lasers
Mr. Offek Tziperman, *Hebrew University of Jerusalem, Jerusalem, Israel*

14:49 Co-located Two-Photon Absorption and AFM Imaging of CsPbBr3 Thin Films
Prof. Yaakov Tischler, *Bar Ilan University, Ramat-Gan, Israel*

15:03 Interaction-based Nonlinear Optics
Dr. Avi Niv, *Ben-Gurion University of the Negev, Beer-Sheva, Israel*

15:17 Direct time-of-flight Distributed Analysis of Nonlinear Forward Scattering
Mr. Alon Bernstein, *Bar Ilan University, Ramat-Gan, Israel*

15:31 Nanoscale Inverse Design of Strongly Coupled, Plexcitonic Metasurfaces for Linear and Broadband Nonlinear Interaction
Ms. Yael Blechman, *Technion - Israel Institute of Technology, Haifa, Israel*

Hall E

Optics in Medicine and Biology
Prof. Dror Fixler

14:15 **Invited speaker** | Nanoparticles and Cells - Making use of Different Microscopy Techniques
Prof. Wolfgang Parak, *Universität Hamburg, Hamburg Germany*

14:45 **Invited speaker** | Gold Quantum Dots-Transition Metal Dichalcogenides Composite Material for Photonic-sensing
Prof. Mustafa Yavuz, *Nano and Micro Systems Lab-Waterloo Institute for Nanotechnology-University of Waterloo, Ontario Canada*

15:05 **Invited speaker** | Multimodal Genetically Encoded Life-
Time Fluorescent Sensors for Theranostic Applications
Prof. Alexander Savitsky, *Professor of biochemistry, Head of*
the physical biochemistry lab A.N.Bach Institute of Biochemistry
Of the Federal State Institution"Federal Research Centre Fundamentals of Biotechnology" Of the Russian Academy of Science, Moscow, Russia

15:25 Spatiotemporal Sensing and Imaging using Fluorescent Single-Walled Carbon Nanotubes for Biomedical Applications
Dr. Gili Bisker, *Tel Aviv University, Tel Aviv, Israel*

15:35 Automatic Detection and Evaluation of Nasal Airway Obstruction in CT Scans of Newborns
Dr. Talia Yeshua, *The Jerusalem College of Technology*

16:15 - 15:45 | Coffee break and Posters review of topics: Optics in Medicine and Biology & Electro-Optics in Industry

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

16:17 - 15:45 | Parallel Session 3

Hall A
Quantum Computers
Prof. Nadav Katz

16:15 **Invited speaker** | Photonic Fault-Tolerant Quantum Computing, and how Single Atoms can Drastically Simplify it
Prof. Barak Dayan, *Dan Lebas & Ruth Sonnewend Professorial; Chair of Physics, Weizmann Quantum Optics Group*
Weizmann Institute of Science, Rehovot, Israel

16:45 Increasing Communication Rates Using Photonic Hyperentangled States
Mrs. Liat Nemirovsky Levy, *Technion - Israel Institute of Technology, Haifa, Israel*

17:00 Erasure Qubits: Overcoming the T1 Limit in Superconducting Circuits
Prof. Alex Retzker, *The Hebrew University of Jerusalem*

17:15 Creation of Optical Cat and GKP States Using Shaped Free Electrons
Mr. Raphael Dahan, *Technion - Israel Institute of Technology, Haifa, Israel*

17:30 Fast Entanglement of Weakly Interacting Harmonic Oscillators with Superconducting Qubits for Bosonic Encoded Quantum Computation
Mr. Asaf Diringer, *Technion - Israel Institute of Technology, Haifa, Israel*

Hall B
Micro and Nano Optics
Prof. Alina Karabchevsky

16:15 **Invited speaker** | Optoelectronic Cardiac Biointerfaces
Prof. Igor Efimov, *Professor of Biomedical Engineering, Professor of Medicine, Northwestern University*

16:30 **Invited speaker** | High-index Chalcogenides for Static and Active Mie-resonant Metaoptics
Dr. Tomer Lewi, *Faculty of Engineering and Institute for Nanotechnology and Advanced Materials (BINA), Bar Ilan University, Ramat-Gan, Israel*

16:45 High-Index Deep-Subwavelength Topological Insulator Metastructures for Mid-Infrared Photonics
Dr. Sukanta Nandi, *Bar Ilan University, Ramat-Gan, Israel*

17:10 Explosives Detection using SERS Substrate Based on 3D Plasmonic Hot Spots network
Prof. Ibrahim Abdulhalim, *Ben-Gurion University of the Negev, Beer-Sheva, Israel*

17:20 Spin-Valley Rashba Monolayer Laser
Dr. Kexiu Rong, *Technion - Israel Institute of Technology, Haifa, Israel*

17:30 Mycotoxins Raman Detection with Vertical Carbon Nanotubes
Prof. Uros Cvelbar, *Jozef Stefan Institute, Ljubljana, Slovenia*

Hall C
Ultrafast Phenomena
Dr. Marcus Gilad

16:15 **Invited speaker** | Nanoscale Control of Extreme Ultraviolet Light
Prof. Giulio Vampa, *National Research Council of Canada*

16:40 Tunable Photo-Induced Free-Electron Spatial Modulation using Ultrafast Plasmonic Fields
Mr. Shai Tsesses, *Technion - Israel Institute of Technology, Haifa, Israel*

16:52 Observation of Interband Berry Phase in Laser-Driven Crystals
Mr. Lior Faeyrman, *Weizmann Insitute of Science, Rehovot, Israel*

17:04 Sub-cycle phase resolved attosecond interferometry
Mr. Chen Mor, *Weizmann Institute of Science, Rehovot, Israel*

17:16 Ultrafast High-Harmonic Microscopy
Dr. Sergey Zayko, *Max-Planck Institute, Germany*

17:28 Kerr Lens Time Space Coupling Mechanism for Contrast Enhancement of Ultrashort Pulses
Mrs. Zaharit Refaeli, *Soreq Nuclear Research Center, Yavne, Israel*

Hall D
Artificial Intelligence in Optics
Prof. Yoav Shechtman

16:15 **Invited speaker** | Learning to see in the Data Age
Prof. Alex Bronstein, *Dan Broida Academic Chair; Schmidt Chair in Artificial Intelligence, The Henry & Marilyn Taub Faculty of Computer Science; Technion - Israel Institute of Technology, Haifa, Israel*

16:45 **Invited speaker** | Deep Learning Metamaterials
Prof. Willie Padilla, *Department of Electrical and Computer Engineering, Duke University, North Carolina, USA*

17:15 Image and Video From Coded Motion Blur Using Dynamic Phase Coding
Mr. Erez Yosef, *Tel Aviv University, Tel Aviv, Israel*

17:30 Optical Compressive Imaging for Defending Deep Neural Networks from Adversarial Attacks in the Physical Domain
Prof. Adrian Stern, *Ben-Gurion University of the Negev, Beer-Sheva, Israel*

Hall E
Lasers and Applications
Dr. Ariel Bruner

16:15 **Invited speaker** | Laser Defense Systems - Science Fiction
Materializing
Dr. Yehonatan Segev, *Rafael Advanced Defense Systems, Israel*

16:45 High Power Picosecond MOPA System with Yb-doped Tapered Double-Clad Spun Fiber
Dr. Valery Filippov, *Ampliconyx Oy, Tampere, FInland*

17:00 Dynamic Beam Lasers offer new Parameters for Material
Processing Optimization
Dr. Benayahu Orbach & Dr. Yaniv Vidne, *Civan Lasers, Israel*

17:15 Insight into the Epitaxy Process of a VCSEL from the Calibration of a Single Layer to the LIV Curve
Mrs. Rimon Tamari, *Israel Center for Advanced Photonics (ICAP), Yavne, Israel*

17:30 A Novel Laser Resonator
Mr. Avigdor Zajdman, *Private Consultant*

17:45 First Light at the Israeli THz Superradiant Free Electron Laser
Dr. Ariel Nause, *Ariel University, Ariel, Israel*

Tuesday December 13, 2022

08:00 - 09:00 Coffee and registration

09:00 - 10:00 **Opening session - Plenary Hall**

09:00 - 09:10 **Chairperson:**
Professor Abraham Katzir, Chairman of Oasis 2022

09:10- 09:50 **Plenary lecture:**
The James Webb Space Telescope: First Science Results
Dr. Mark Clampin, Director Astrophysics Division, Science Mission Directorate, NASA

09:50 - 10:30 **Plenary lecture:**
Quantum computation: The second quantum revolution in physics
Prof. Dorit Aharonov, School of Computer Science and Engineering, The Hebrew University of Jerusalem, Israel and CSO of the Company Qedma D

10:30 - 10:50 Coffee break and Posters review of topics: *Spectroscopy and Optical Sensing & Quantum Computers*

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Tuesday December 2022 ,13

10:12 - 50:20 | Parallel Session 4

Hall A

Atomic and Quantum Optics
Prof. Dan Oron

10:50 **Invited speaker** | Quantum Nonlinear Optics: Strong Interaction Between Individual Photons
Prof. Ofer Firstenberg, *Weizmann Institute of Science, Rehovot, Israel*

11:18 **Invited speaker** | Transforming a Strain-Stabilized Ferroelectric into an Intrinsic Polar Metal with Light
Dr. Alon Ron, *Tel Aviv University, Tel Aviv, Israel*

11:46 Universal Photonic-Atomic Interfaces for Ultra-Cold Atoms
Dr. Grisha Spektor, *National Institute Of Standards and Technology and Colorado University, USA*

12:03 Benchmarking of Photon Counting and Number Resolving Techniques in Cameras
Dr. Sebastian Beer, *Hamamatsu Photonics GmbH, Germany*

Hall B

Nonlinear Optics
Prof. Haim Suchowski

10:50 **Invited speaker** | Versatile Laser Sources with Integrated
Nonlinear Photonics
Prof. Scott Papp, *National Institute of Standards and Technology, Gaithersburg, Maryland, USA*

11:10 High-power, Squeezing-Enhanced Interferometry in Optical Fibers
Dr. Yosef London, *Bar Ilan University, Ramat-Gan, Israel*

11:24 The Nonlinear Optical Response and Non-Equilibrium Electron Dynamics in ITO
Prof. Yonatan Sivan, *Ben-Gurion University of the Negev, Beer-Sheva, Israel*

11:38 Compton Scattering Driven by Quantum Light
Mr. Majed Khalaf, *Technion - Israel Institute of Technology, Haifa, Israel*

11:52 **Invited speaker** | Multiresonant and Active High-Q Nonlinear Metasurfaces
Dr. Mikko Huttunen, *Tampere University, Finland*

12:06 Enhanced THz Generation and Dynamic Emission from Metasurfaces
Mr. Eviatar Minerbi, *Tel Aviv University, Tel Aviv, Israel*

Hall C

Electro-Optics Devices
Dr. Ilya Goykhman

10:50 **Invited speaker** | Surface Acoustic Wave - Photonic Devices in Silicon Integrated Circuits
Prof. Avi Zadok, *Faculty of Engineering and Institute for Nano-Technology and Advanced Materials, Bar Ilan University, Ramat-Gan, Israel*

11:10 **Invited speaker** | Photonics on Thin-Film Lithium Niobate
Dr. Boris Desiatov, *Faculty of Electrical Engineering at Bar-Ilan University, Ramat-Gan, Israel*

11:30 **Invited speaker** | Semiconductor-Superconductor Quantum Optoelectronic Devices
Prof. Alex Hayat, *Department of Electrical Engineering Technion, Israel Institute of Technology, Haifa, Israel*

11:50 **Invited speaker** | Time Scale Dependent Dynamics in Quantum Dot Lasers: from Modulation to Coherent Interactions
Prof. Gadi Eisenstein, *Electrical and Computer Engineering departement, Technion - Israel Institute of Technology, Haifa, Israel*

12:10 Heralded Relativistic Free Electrons
Dr. Ofer Kfir, *Tel Aviv University, Tel Aviv, Israel*

Hall D

Optical Engineering
Dr. Hanni Inbar

10:50 **Invited speaker** | Nonlinear Near-Field Microscope for Real-Time Contactless Detection of Surface and Guided Waves
Prof. Guy Bartal, *The Viterbi Electrical and computer engineering, Technion - Israel Institute of Technology, Haifa, Israel*

11:17 First Lenses Fabricated in Space: Fluidic Shaping Onboard the International Space Station
Prof. Moran Bercovici, *Faculty of Mechanical Engineering, Technion - Israel Institute of Technology, Haifa, Israel*

11:38 Sub-Wavelength Optical Functionalities Directly Imprinted on Chalcogenide Glasses
Mrs. Sivan Tzadka, *Department of Materials Engineering, Ilse Katz Institute for Nanoscale Science and Technology, Ben-Gurion University of the Negev, Beer-Sheva, Israel*

11:52 High Speed Large Aperture Tunable Lenses and their Applications
Dr. David Leuenberger, *Optotune, Dietikon, Switzerland*

12:06 A Theoretical Model for Automotive Lidar Performance in the Rain
Dr. Boaz Nemet, *Innoviz Technologies, Israel*

Hall E

Solar Energy
Prof. Adi Salomon

10:50 **Invited speaker** | In-situ Tools for Studying Dynamics and Electronic Structure at Functional Interfaces in Energy Conversion Devices
Prof. Elizabeth Von Hauff, *Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology (FEP), Faculty of Electrical and Computer Engineering, Technical University of Dresden, Dresden, Germany*

11:25 **Invited speaker** | Looking at Photovoltaic Devices with New Eyes
Mr. Jean-Francois Guillemoles, *Research Director, CNRS, Director, UMR Institut Photovoltaïque d'Ile de France, IPVF; Ecole Polytechnique Institut Polytechnique de Paris, PSL Chimie ParisTech*

11:55 Operando Characterization of Charge Extraction and Recombination Profiles in Solar Cells with Nanoscale Resolution
Mr. Tamir Yeshurun, *Tel Aviv University, Tel Aviv, Israel*

12:10 Amino Acids Additives for Efficient and Stable Perovskite Solar Cells
Dr. Said Kassou, *Ben-Gurion University of the Negev, Beer-Sheva, Israel*

13:20 - 12:20 | Lunch Break

13:50 - 13:20 | Poster Review of Topics: Micro and Nano-Optics & Artificial Intelligence in Optics

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

13:15 - 50:20 | Parallel Session 5

Hall A

Ultrafast Phenomena
Dr. Marcus Gilad

13:50 **Invited speaker** | High Harmonic Generation Driven by Quantum Light
Prof. Oren Cohen, *Technion - Israel Institute of Technology, Haifa, Israel*

14:10 Controlling Coherent Exciton Dynamics in TMDs
Mr. Omri Meron, *Tel Aviv University, Tel Aviv, Israel*

14:22 Molecular Orientation-Induced Second Harmonic Generation: Deciphering Different Contributions Apart
Ms. Amit Beer, *Tel Aviv University, Tel Aviv, Israel*

14:34 Dynamics of Modal Self-Cleaning
Ms. Yuval Tamir, *Bar Ilan University, Ramat-Gan, Israel*

14:46 Ultrafast Low-Energy Electron Microscopy
Dr. Michael Krueger, *Technion Israel Institute of Technology, Haifa, Israel*

14:58 Spectral Splitting in Phase-Mismatched Harmonics
Mr. Raz Halifa Levi, *Tel Aviv University, Tel Aviv, Israel*

15:10 Ultrafast "Hot" Nonlinear Photoluminescence from Metals
Mrs. Imon Kalyan, *Ben-Gurion University of the Negev, Beer-Sheva, Israel*

Hall B

Spectroscopy and Optical Sensing
Dr. Ayala Ronen

13:50 **Invited speaker** | Underwater Wireless Optical Communication: State-of-the-Art and Next Challenges
Dr. Amir Handelman, *Faculty of Electrical Engineering, Holon Institute of Technology, Holon, Israel*

14:10 DNA Recognition with Nanoplasmonic Raman Spectroscopy
Dr. Vasyl Shvalya, *Josef Stefan Institute, Ljubljana, Slovenia*

14:24 Super-Resolution Raman Spectroscopy - Applications to Diamond Identification
Mr. Yishai Amiel, *Bar Ilan University, Ramat-Gan, Israel*

14:38 A Phase Stable Hybrid Dual Comb Spectrometer
Mrs. Sutapa Ghosh, *Technion - Israel Institute of Technology, Haifa, Israel*

14:52 Long Wavelength QCL with Pulsed Operation for Spectroscopy
Mr. Mathieu Carras, *MirSense*

15:06 Enhanced Molecular Orientation via NIR-delay-THz scheme: Experimental Results at Room Temperature
Mr. Ran Damari, *Tel Aviv University, Tel Aviv, Israel*

Hall C

Optics in Defense
Dr. Ami Yaacobi

13:50 Non-Line-of-Sight Passive Localization around Corners with Light and with Sound
Mr. Jeremy Boger-Lompbard, *Hebrew University of Jerusalem, Jerusalem, Israel*

14:08 A Novel Large Optics Mounting Design
Mr. Oded Lahav, *Rafael Advanced Defense Systems, Israel*

14:26 Dead-Time effect on SPAD Efficiency
Dr. Yishai Albeck, *Soreq Nuclear Research Center, Yavne, Israel*

14:44 Narcissus Reduction in Advanced Thermal Imaging Zoom Lenses
Dr. Nissim Asida, *MKS Instruments, Israel*

15:02 Deployable Asymmetric Space Telescope
Dr. Erez N. Ribak, *Department of Physics, Technion, Hifa, Israel*

Hall D

Electro-Optics in Industry
Dr. Rami Cohen

Sponsored by: IDEA Machine Development Design & Production Ltd.

13:50 **Invited speaker** | Automated Assembly and Testing of Electro-Optical Systems
Mr. Tobias Müller, *Technical Director, Aixemtec GmbH, Herzogenrath, Germany*

14:08 KLA Optical Metrology Division and the key challenges in Overlay Metrology of advanced Semiconductor Integrated Circuits
Mr. Ohad Bachar, *KLA, Israel*

14:26 **Invited speaker** | Combining Electrons and Energetic Photons Information in a Scanning Electron Microscopy for Advanced Semiconductors Applications
Dr. Martin Chauvin, *Applied Materials*

14:44 **Invited speaker** | SWIFT-EI Event-based Imager and Laser Multi-spot Sensor in SWIR
Dr. Claudio Jakobson, *SCD - Semiconductor Devices, Israel*

15:02 Spectral Transmission of Materials used for Laser Safety
Dr. Shimshon Lashansky, *ELOP/Elbit, Israel*

Hall E

Micro and Nano Optics
Prof. Alina Karabchevsky

13:50 Broad-Band Impedance Matching of Dispersive Waveguides Using Exceptional Points and White Light Cavities
Prof. Jacob Scheuer, *Tel Aviv University, Tel Aviv, Israel*

14:05 **Invited speaker** | Micro and Nano-Optics: Ongoing Research and Future Directions | **Prof. Alina Karabchevsky,** *Ben-Gurion University of the Negev, Beer-Sheva, Israel*

14:20 **Invited speaker** | Introducing New Phases of Matter to Microphotonics | **Prof. Tal Carmon,** *Photonic Enhancement Laboratory, School of Electrical Engineering, Faculty of Engineering, Tel Aviv University, Tel Aviv, Israel*

14:30 Structuring Light out of Optical Fibers Using Integrated Micro-Optics | **Dr. Shlomi Lightman,** *Soreq Nuclear Research Center, Yavne, Israel*

14:40 Displacement Trajectory of Gold Nanoparticles Under Photonic Hook | **Ms. Maya Shor Peled,** *Ben-Gurion University of the Negev, Beer-Sheva, Israel*

14:50 Development of Nanostructured Metallodielectric Substrates for Surface Enhanced Spectroscopies and Sensing
Dr. Nikolaos Papanikolaou, *NCSR "Demokritos", Aghia Paraskevi, Athens, Greece*

15:00 Arbitrary On-Chip Polarization Manipulation with Twisted Waveguides | **Mr. Fedar Marozka,** *Ben-Gurion University of the Negev, Beer-Sheva, Israel*

15:10 **Invited speaker** | Novel polaritonic phenomena in 2D materials | **Dr. Itai Epstein,** *School of Electrical Engineering, Faculty of Engineering, Tel Aviv University, Israel*

15:50 - 15:20 | Coffee break and Posters review of topics: Ultrafast Phenomena & Atomic and Quantum Optics

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

15:17 - 50:20 | Parallel Session 6

Hall A

Quantum Computers
Prof. Nadav Katz

15:50 Machine Learning Detection of Quantum Many-Body Localization Phase Transition
Mr. Ron Ziv, *Technion - Israel Institute of Technology, Haifa, Israel*

16:05 High-dimensional Time-Bin Quantum Key Distribution
Mr. Kfir Sulimany, *The Hebrew University of Jersualem, Jerusalem, Israel*

16:20 Segmented Composite Design of Robust Quantum Gates
Mr. Yonatan Piazetsky, *Tel Aviv University, Tel Aviv, Israel*

16:35 Global and Local Quantum Sensing Across >100THz of Optical Bandwidth
Prof. Avi Pe'er *Bar Ilan University, Ramat-Gan, Israel*

16:50 Suppression of Logical Error in Linear Optic Quantum Computer using Composite Pulses
Mr. Ron Cohen, *Tel Aviv University, Tel Aviv, Israel*

Hall B

Optics in Medicine and Biology
Prof. Dror Fixler

15:50 **Invited speaker** | Motion Tolerant Remote Vital Signs Monitoring using Optical and Depth Cameras
Prof. Ofer Levi, *University of Toronto, Ontario, Canada, Institute of Biomedical Engineering;The Edward S. Rogers Sr. Department of Electrical and Computer Engineering*

16:15 **Invited speaker** | Twist of Light in Tissue Diagnosis
Prof. Igor Meglinski, *Aston University, College of Engineering & Physical Sciences, Aston University, Birmingham, UK*

16:40 Optoacoustic Micro-Tomography using a Silicon-Photonics Acoustic Detector
Prof. Amir Rosenthal, *Technion - Israel Institute of Technology, Haifa, Israel*

17:00 Recent Advances in Rapid and Highly Sensitive Detection of Proteins and Specific DNA Sequences using a Magnetic Modulation Biosensing System
Prof. Amos Danieli, *Bar Ilan University, Ramat-Gan, Israel*

Hall C

Artificial Intelligence in Optics
Prof. Yoav Shechtman

15:50 **Invited speaker** | Learned Optics - Improving Computational Imaging Systems through Deep Learning and Optimization
Prof. Wolfgang Heidrich, *Computational Imaging Researcher*

16:20 DBlink: Dynamic Localization Microscopy in Super Spatiotemporal Reolution via Deep Learning
Mr. Alon Saguy, *Technion - Israel Institute of Technology, Haifa, Israel*

16:32 Sperm-Cell DNA Fragmentation Prediction Using Label-Free Quantitative Phase Imaging and Deep Learning
Mr. Lioz Noy, *Tel Aviv University, Tel Aviv, Israel*

16:44 A Machine Learning Approach to Generate Quantum Light
Mr. Eyal Rozenberg, *Technion - Israel Institute of Technology, Haifa, Israel*

16:56 Single Molecule QR Codes Provide Extreme Multiplexing for Gene Expression Analysis
Mr. Jonathan Jeffet, *Tel Aviv University, Tel Aviv, Israel*

17:08 Recent Advancements in Model-Based Super-Resolution Microscopy
Dr. Shay Elmalem, *Weizmann Institute of Science, Rehovot, Israel*

Hall D

Solar Energy
Prof. David Cahen

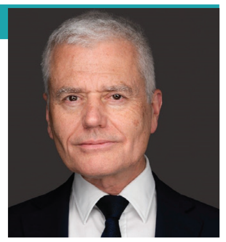
15:50 **Invited speaker** | Characterization of Interfaces by Simple Far-Field Optics
Prof. Adi Salomon, *Chemistry department, BINA nano center for advance materials, Bar Ilan university, Ramat-Gan, Israel*

16:20 **Invited speaker** | Thermodynamic Aspects of PV Power Generation Process
Dr. Avi Niv, *Solar Energy and Environmental Physics, The Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of The Negev, Beer-Sheva, Israel*

16:50 Modular Concentrated Solar Power for Dispatchable Reliable and Affordable Solar Electricity
Prof. Carmel Rotschild & Dror Mimron, *Technion - Israel Institute of Technology, Haifa, Israel*

Keynote Speakers

Dr. Mark Clampin,



Director, Astrophysics Division in the Science Mission Directorate, NASA, Washington, USA

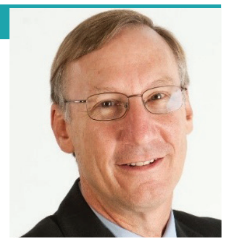
Dr. Mark Clampin is the Astrophysics Division Director in the Science Mission Directorate at NASA Headquarters in Washington, DC. The goals of the Astrophysics Division are to understand how the universe works, understand how we got here and to address the question, are we alone?

Until August 2022, Dr. Clampin was the Director of the Sciences and Exploration Directorate (SED) at the Goddard Space Flight Center (GSFC) where he led the Astrophysics, Solar System, Heliophysics and Earth Science Divisions, together with the high performance computing office.

At GSFC, he previously served as the James Webb Space Telescope (JWST) Observatory Project Scientist, and subsequently as Director of the Astrophysics Science Division and Deputy Director of SED. Prior to joining GSFC, Dr Clampin was the Advanced Camera for Surveys (ACS) Group Lead at the Space Telescope Science Institute (STScI), where he worked on the first four Hubble Space Telescope (HST) Servicing Missions. Dr. Clampin is a Co-Investigator with the Transiting Exoplanet Survey Satellite (TESS), and the Advanced camera for Surveys (ACS) science team and served as the Detector Scientist, responsible for the delivery of three focal plane camera systems. His research interests focus on studying the formation and evolution of planetary systems. Dr. Clampin has also designed ground-based telescope instruments including adaptive optics systems, coronagraphs and detectors.

Dr. Clampin graduated from the University of London with a BS in Physics and from the University of Saint Andrews in Scotland, with PhD in Astronomy. Dr. Clampin is the recipient of the Meritorious Presidential Rank Award, NASA's Exceptional Achievement and Scientific Achievement Medals, and is a Fellow of SPIE and the Royal Astronomical Society,. Until recently he was the Chief Editor of the SPIE peer-reviewed Journal of Astronomical Telescopes, Instruments and Systems, a position he held for 7 years. He is married with one daughter, and enjoys running and his lifelong passion scuba diving.

Stephen R. Forrest



Peter A. Franken Distinguished University

Paul G. Goebel Professor of Electrical Engineering, Physics and Materials Science and Engineering

Education: B. A. Physics, 1972, University of California, MSc and PhD Physics in 1974 and 1979, University of Michigan. In 1985, Prof. Forrest joined the Electrical Engineering and Materials Science Departments at USC. In 1992, Prof. Forrest became the James S. McDonnell Distinguished University Professor of Electrical Engineering at Princeton University. From 1997-2001, he chaired Princeton's Electrical Engineering Department. In 2006, he rejoined the University of Michigan as Vice President for Research, where he is the Peter A. Franken Distinguished University Professor. A Fellow of the APS, IEEE and OSA and a member of the National Academy of Engineering, the National Academy of Sciences, the American Academy of Arts and Sciences, and the National Academy of Inventors, in 1998 he received the IPO National Distinguished Inventor Award as well as the Thomas Alva Edison Award for innovations in organic LEDs. In 1999, Prof.

Forrest received the MRS Medal for work on organic thin films. In 2001, he was awarded the IEEE/LEOS William Streifer Scientific Achievement Award for advances in photodetectors for optical communications.

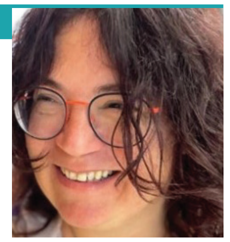
In 2006 he received the Jan Rajchman Prize from the Society for Information Display for invention of phosphorescent OLEDs, and is the recipient of the 2007 IEEE Daniel Nobel Award for innovations in OLEDs.

In 2017 he was the recipient of the IEEE Jun-Ichi Nishizawa Medal and the William Cherry Award in 2022 for innovations in solar cells. Prof. Forrest has authored ~655 papers in refereed journals, and has 372 US patents. He is co-founder or founding participant in several companies, including Sensors Unlimited, Epitaxx, Inc., NanoFlex Power Corp. (OTC: OPVS), Universal Display Corp. (NASDAQ: OLED) and Apogee Photonics, Inc., and is on the Board of Directors and the Growth Technology Advisory Board of Applied Materials. He is past Chairman of the Board of the University Musical Society. He has also served from 2009-2012 as Chairman of the Board of Ann Arbor SPARK. He has served on the Board of Governors of the Technion - Israel Institute of Technology where he is a Distinguished Visiting Professor of Electrical Engineering.

He received an honorary doctorate from the Technion in 2018, and the Henry Russell Lectureship at the University of Michigan in 2019.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Prof. Dorit Aharonov



School of Computer Science and Engineering,
The Hebrew University of Jerusalem, Israel
and CSO of the Company Qedma D
waves in 2015.

Dorit Aharonov is the CSO of QEDMA quantum computing and a Professor at the school of computer science and engineering at the Hebrew university of Jerusalem. In her PhD, Aharonov proved the quantum fault tolerance theorem together with her advisor Ben-Or; this theorem is one of the main pillars of quantum computation today. She later contributed several pioneering works in a variety of areas within quantum complexity and algorithms, including quantum walks, quantum adiabatic computation, Hamiltonian complexity, quantum cryptography and quantum verification. Much of her research can be viewed as creating a bridge between physics and computer science, attempting to study fundamental physics questions using computational language.

Aharonov was educated at the Hebrew university in Jerusalem (BSc in Mathematics and Physics, PhD in Computer Science and Physics) and then continued to a postdoc at IAS Princeton (Mathematics) and UC Berkeley (Computer Science). She had joined the faculty of the computer science department of the Hebrew university of Jerusalem in 2001. In 2005 Aharonov was featured by the journal Nature as one of four theoreticians making waves in their chosen field; In 2006 she won the Krill prize, and in 2014 she was awarded the Michael Bruno award. In 2020 she joined forces with Dr. Asif Sinay and Prof. Netanel Lindner to co-found QEDMA quantum computing.

Prof. Nirit Dudovich

Department of Physics, The Weizmann Institute, Rehovot, Israel

Prof. Dudovich works at the forefront of laser physics and optics. She investigates ultrafast interactions between light and matter on a attosecond time scale. Prof. Dudovich earned a BSc in physics and computer science from Tel Aviv University in 1996. She received an MSc and PhD in physics from the Weizmann Institute in 1999 and 2004. In 2004 she received the Rothschild Fellowship for postdoctoral studies and joined the group Prof. Paul Corkum. In 2007 she joined the Weizmann Institute of Science and established the first research group for attosecond science in Israel.

Prof. Dudovich is a recipient of a number of prestigious fellowships and awards, including the 2013 Krill Prize for Excellence in Scientific Research, the IPS Prize for Young Physicist in 2012, the IUPAP Young Scientist Prize in 2012, and the Weizmann award in 2021. She received the ERC Starting investigator grant (2015) and consolidator grant (2019). Prof. Dudovich was elected to the Young Israel Academy of Sciences and Humanities and in 2016, she was elected to be a Fellow of the American Physical Society (APS).

Oral Presentations

Monday, December 12

Opening Session

The future of Organic Optoelectronics beyond OLED

Prof. Stephen Forrest
College of Engineering; University of Michigan, Michigan, USA

The extremely rapid adoption of organic LEDs in both mobile and television display markets has been driven by their ultrahigh efficiency, large color gamut, thin form factors and long lifetimes. But this successful experience has only given rise to the question: what's next for organic electronics? To be sure, there are other opportunities waiting in the wings. Examples include OLED lighting, organic solar cells, and even organic transistor electronics. In this talk I will present a review of what is past and present in organic electronics, and most importantly, what lies ahead. The physics and engineering of a range of organic devices will be discussed. And I will try to answer the question: what is the next big application of this emerging and exciting field of optoelectronics.

"Waiting for Act 2: What lies beyond OLED displays for organic electronics?", S. R. Forrest, Nanophotonics, 1 doi.org/10.1515/nanoph-2020-0322 (2020).

Attosecond Science

Prof. Nirit Dudovich, Department of Physics, The Weizmann Institute,
Rehovot, Israel

Attosecond science is a young field of research that has rapidly evolved over the past decade. One of the most important aspect of attosecond spectroscopy lies in its coherent nature. Resolving the internal coherence is a primary challenge in this field, serving as a key step in our ability to reconstruct the internal dynamics. As in many other branches in physics, coherence is resolved via interferometry.

In this talk, I will describe advanced schemes for attosecond interferometry. The application of these schemes provides direct insights into a range of fundamental phenomena in nature, from tunneling and photoionization in atomic systems to ultrafast chiral phenomena and attosecond scale currents in solids.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session: Optical Engineering - Dr. Hanni Inbar

Invited speaker |

Paradigm-shifts in Neurosurgery with Lensless 3D Fiber Endoscopy using Deep Learning

Prof. Jürgen Czarske
Center Biomedical Computational Laser Systems (BIOLAS), Faculty Electrical and Computer Engineering, Co-opted Professor for Physics, School of Science,TU Dresden, Dresden, Germany

Light has the potential to recognize the origins of diseases, enabling to prevent them, or to cure them early and gently. The early diagnosis is the key to improve the survival rate and cure rate of patients. Latest developments in modern optical engineering are promising for paradigm - shifts in neuroscience. Endoscopy plays an important role in the early stages of diagnosis by a guiding biopsy.

Conventionally, it takes several hours to a few days for the surgeon to know the results of the diagnosis. Optical histopathology offers real-time intraoperative diagnosis. The paradigm-shift of lensless fiber endoscopy is highlighted towards virtual staining. We demonstrate an end-to-end lensless fiber imaging using deep neural networks. The well-trained resolution enhancement network helps improving tumor recognition rate. It is promising for minimally invasive intraoperative treatment of cancer in neurosurgery.

Advanced manufacturing of retinal organoid samples from human induced pluripotent stem cells represents a promising way to study the development of retinal diseases. We study the capability of the optical transmission matrix, measured by digital holography for retinal organoid tissues. Inducing of age-related macular degeneration (AMD) results in distinct changes of the transmission matrix. The promising development of imaging biomarkers for human retinal AMD will be discussed.

Invited speaker |

Deep Learning for Extreme Optical Compressive Imaging

Prof. Adrian Stern, Vladislav Kravets, Yaron Heiser
Electrooptical Engineering Department, School of Electrical and Computer Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israe

Traditional Compressive Sensing (CS) oracle suggests employing some kind of randomized sensing process followed by a sparsity-promoting reconstruction algorithm in order to reduce the sensing effort below classical sampling rates (e.g., Nyquist). By employing a physics-aware Deep Learning (DL) approach, we have demonstrated 1-2 orders of magnitude higher compression than traditional CS. The random sensing scheme is replaced by physics-aware DL optimization of the sensing design, which is trained in tandem with a reconstruction Deep Neural Network. We demonstrate the realization of this new approach for hyperspectral remote sensing with as few as 4 CS samples per pixel, and 2D imaging with an optical compression ratio of 500:1.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

How to turn a Puddle of Liquid into a Diffractive Optical Element

Mr. Jonathan Ericson
Faculty of Mechanical Engineering, Technion - Israel Institute of Technology, Haifa, Israel

Ericson[1,†], Valeri Frumkin[1,†,§], Ran Eshel[1,†], Matan Nice[1], Omer Luria[1], Boris Ferdman[2], Nadav Opatovski[2], Khaled Gommed[1], Maxim Shusteff[3], Yoav Shechtman[2],and Moran Bercovici[1*]

1 *Faculty of Mechanical Engineering, Technion, Haifa, 3200003 Israel*
2 *Department of Biomedical Engineering, Technion, Haifa, 3200003 Israel*
3 *Lawrence Livermore National Laboratory, 7000 East Ave, Livermore, CA 94550, USA*
§ *Current affiliation: Department of Mathematics, MIT Cambridge, MA, 02139, United States*
† *The author equally contributed*

Diffractive optical elements (DOEs) are used to manipulate light by introducing non-uniform phase accumulation through carefully designed geometries and are key components in a wide range of optical applications. DOEs are typically created using clean room fabrication techniques, such as lithography or by precise multi-axis mechanical processes such as diamond machining or magnetorheological finishing.

However, such processes require significant and expensive infrastructure, which lowers accessibility and drives high component costs. Furthermore, existing techniques do not allow for rapid prototyping which is much desired for driving research and design innovation. When localized heating is imposed on the gas-liquid interface of a thin liquid film, the liquid will flow outward along the free-surface from warmer regions with lower surface tension to colder regions with higher surface tension. This results in local deformation of the liquid film and is known as the thermocapillary effect. Here we present a rapid fabrication method that leverages the thermocapillary effect to shape thin liquid films into useful DOEs with sub-nanometeric surface roughness. We developed a theoretical model that provides the required projection pattern to achieve a desired topography. We experimentally implement the method using a computer controlled light projector, which illuminates any desired pattern onto the bottom of a fluidic chamber patterned with heat-absorbing metal pads. We measure the resulting deformations in real time with a Shack Hartmann Wavefront Sensor, providing insight onto the liquid dynamics and allowing closed loop optimization of the deformed liquid. Finally, by using UV curable polymers for the liquid film, the resulting topography can be solidified to yield a DOE within minutes. We demonstrate the fabrication of several DOEs, including corrector plates, phase masks for extended depth of field imaging, and for 3D localization microscopy.

Squared TopHat Profiles for Laser Material Processing

Mr. Silvio Vater, Ulrike Fuchs
asphericon GmbH., Jena, Germany

In modern laser material processing, the type and quality of beam shaping is becoming increasingly important. Especially quadratic intensity distributions offer great potential. An adaptation of the focus intensity distribution to the required interaction process between laser and material can be enabled by appropriate beam shaping elements. In addition to the extension of the achievable structure types and the improvement of the surface properties, laser processing can thus be made much more flexible, precise and effective. Our presentation covers a refractive beam shaping element that can generate different square intensity distributions starting from a Gaussian output beam of a femtosecond laser (fs). The beam shaping of asphericon's a|SqAiryShape is based on the combination of a refractive beam shaper and a conventional f-theta lens. By varying the working distance, different intensity distributions and focal diameters (top-hat, donut) can be generated. The generation of laser-induced periodic structures (LIPSS) on steel samples in the micro- and nanoscale demonstrated the suitability of a|SqAiryShape for fs-laser material processing. The experimental patterning results are in correlation with the beam profile measurements performed in advance and the numerical simulations of the beam shaping unit. To evaluate the influence of the intensity distributions on the generated surface structures and their surface quality, channels were generated by means of top-hat and donut profiles using different pulse energies. The structuring results showed that with square intensity profiles and lower laser peak fluences, significantly steeper channel walls and better surface qualities were generated than with Gaussian intensity distributions. Also, large-scale scalings of LIPSS structures could be generated at low laser fluences, higher scanning speeds (factor 2) and line spacing. The experimental results show the high flexibility of the a|SqAiryShape in laser processing, which still offers the possibility to control the ablation geometry in the fabrication of microchannels at lower process times and laser fluences.

Current Freeform Metrology Methods

Dr. Jessica DeGroote Nelson
Edmund Optics, USA

Advancements in freeform optical manufacturing have been substantial in the last decade. The current limiting factor in the production of higher precision freeform optical manufacturing is metrology. In discussion of the metrology required for precision freeforms, the concept of the Freeform Metrology Spectrum will be introduced.

The Freeform Metrology Spectrum incorporates surface position (or location), surface form error (or irregularity), midspatial frequency (MSF) errors and surface roughness.

This presentation will survey freeform metrology methods used in the industry today and highlight opportunities for future advancement in the field of freeform metrology to further higher precision freeforms.

Monday, December 12 | Parallel Session 1 | 11:20 - 12:50

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session: Atomic and Quantum Optics - Prof. Dan Oron

Invited speaker |
Hybrid Quantum Systems with Ultracoherent Mechanical Resonators

Prof. Albert Schliesser
Niels Bohr Institute, Copenhagen University

In this talk, I will discuss two different methods to control the motion of an object visible to the bare eye at the quantum level (Figure 1). The moving object is a drum-like island, shieled by a ”phononic” perforation pattern, in the center of a thin silicon nitride membrane [1].

In the first approach - termed coherent control - the motion of the membrane is coherently coupled to another quantum degree of freedom, namely a supercurrent in a microwave resonator. The excitations of the microwave resonator are frozen out at the milliKelvin operation temperature. Driving the system with a coherent microwave tone then allows the mechanical system to effectively dissipate into a low-entropy microwave bath. Such electromechanical sideband cooling allows us reach thequantum ground state of motion [2].

This is enabled, not least, by the remarkable coherence of the mechanical system, with heating rates below 10 phonons/sec.

Measurement-based quantum control is a complementary approach. Here, one takes a continuous measurement of the mechanical position. For quantum control, these measurements need to be both strong (yield high precision in short time) and efficient (no excess backaction). Then it is possible to control the quantum state with high fidelity, by feeding back a force conditioned on the measurement record. We have been the first to show in 2018 that it is possible to reach the quantum ground state using measurement-based control combined with gentle cryogenic pre-cooling [3].

More recently, we have applied the same techniques to a mechanical resonator held at room temperature. Meausrement-based feedback cooled the device close to the ground state,corresponding to effective milliKelvin temperatures [4].

These techniques are important stepping stones towards the preparation of more complex quantum states, as required for the application of mechanical systems in quantum sensing and quantum information processing.

References
[1] Tsaturyan, Y. et al. Nature Nanotechnology 12, 776-783 (2017)
[2] Seis, Y. et al. Nat Commun 13, 1507 (2022)
[3] Rossi, M. et al. Nature 563, 53-58 (2018)
[4] Saarinen, S. A. et al. arXiv:2206.11169 (2022)

Invited speaker |
Quantum Simulation with Ultracold Fermionic Atoms

Prof. Yoav Sagi
Associate Professor, Physics Department Technion - Israel Institute of Technology, Haifa, Israel

In recent years, the experimental toolbox available with ultracold atoms has dramatically expanded, which opens a wide variety of uses in quantum simulation and computation. In this talk, I will focus on two frontiers: engineering the Hamiltonian using periodic external driving (‘Floquet engineering’) and single atom manipulation using microscopic optical traps (‘optical tweezers’). I will describe our recent experiments with ultracold fermions on both of these topics. Using Floquet engineering, we implemented a uniform trapping potential for a degenerate Fermi gas at two spin states. Furthermore, we observed pair condensation in the driven gas, a hallmark of fermionic superfluidity. With optical tweezers, we have been pushing forward our ability to prepare single atoms and control their tunneling dynamics. I will discuss the prospects of this approach for quantum computation with neutral atoms.

Monday, December 12 | Parallel Session 1 | 11:20 - 12:50

Shaping Entangled Photons Through Emulated Turbulent Atmosphere

Mr. Ronen Shekel, Ohad Lib, Alon Sardas and Yaron Bromberg
The Hebrew University of Jerusalem, Jerusalem, Israel

Introduction and Background: Scattering by atmospheric turbulence is one of the main challenges in creating long free-space optical links, and specifically links of entangled photons. Classical compensation methods are hard to apply to entangled photons, due to inherently low signal to noise ratios and the fragility of entanglement.

Objectives and Methods: In this presentation we show that we can use a bright laser beam that stimulates generation of entangled photons to shape the spatial correlations between these entangled photons in order to compensate for scattering. We apply this method, which we term pump-shaping, to compensate for scrambling of correlations between entangled photons that scatter by emulated atmospheric turbulence. We use a spatial light

modulator and Kolmogorov's turbulence model to emulate atmospheric turbulence in the lab.

Results and Conclusions: We show that using pump-shaping we can enhance the entangled photons' signal by a factor of fifteen. We show this for both a static and dynamic emulated atmosphere. We also demonstrate the compensation of the scattering of a higher-order mode. This may be useful for sending information encoded in the spatial domain and is efficient since the same spatial light modulator used for compensating the scattering is used to encode the data. Our results can open the door towards realizing free-space quantum links with entangled photons, used in applications such as quantum key distribution.

References

- Shekel, R., Lib, O., Sardas, A. and Bromberg, Y., 2021. Shaping entangled photons through emulated turbulent atmosphere. OSA Continuum, 4(8), pp.2339-2350.
- Lib, O., Hasson, G. and Bromberg, Y., 2020. Real-time shaping of entangled photons by classical control and feedback. Science Advances, 6(37), p.eabb6298.

(a) We us a spatial light modulator to shape the profile of the pump beam that stimulates generation of entangled photons via spontaneous parametric down conversion, to control the spatial correlations between the entangled photons. Both the pump beam and the entangled photons are sent through emulated turbulent atmosphere. The optimization algorithm uses feedback from the classical pump beam and enhances the correlations between the photons. Pump-shaping can enhance the classical pump signal and the quantum correlations signal, simultaneously, even though the wavelength of the pump beam (λp = 404nm) is half the wavelength of the entangled photons. The reason is that despite the speckle being an interference effect, which is wavelength sensitive, the classical pump speckle pattern and the entangled-photon speckle pattern are highly correlated.

The two speckle patterns depicted in the figure were measured pre-optimization, exhibiting a high degree of correlation between the pump and the entangled-photons patterns. (b) The correlations between the photons before and after employing the optimization algorithm.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Monday, December 12 | Parallel Session 1 | 11:20 - 12:50

Free-Electron Entanglement and non-Gaussian Photonic States Through 'which-path' Information

Mr. Ron Ruimy
Technion Israel Institute of Technology, Haifa, Israel

The free electron double slit experiment (Fig 1a) is one of the most famous experiments in the history of physics [1]. This experiment demonstrates the particle-wave duality and wavefunction collapse, being at the very foundations of quantum mechanics. The double-slit experiment and its many variants also inspired numerous applications such as electron holography [2]. Universal to all variants of the double-slit experiment is the concept of 'which-path' information, in which the measurement of which path the electron has taken (Fig 1b) causes the destruction of the interference fringes on the screen. Here we propose a multi-electron variant of the double-slit experiment (Fig 1c) in which the electrons couple to vacuum fluctuations of a photonic cavity with very high coupling efficiency (e.g., as in [3]). The cavity mode becomes highly entangled with the path that the electron has taken, which seems to guarantee that the fringes visibility will be reduced (Fig 1b). However, the photonic cavity can introduce memory, whereby each electron is influenced by the paths of the previous electrons. Our predictions hold as long as the cavity mode's frequency is smaller than the electron's energy uncertainty. We discovered that this kind of 'which-path' coupling excites the cavity with non-Gaussian photonic states that are desirable for photonic quantum computation [4]. The coupling further induces nontrivial electron correlations, with potential applications in quantum electron microscopy [5].

Fig. 1. The multi-electron double-slit experiment: inducing multi-electron entanglement and creating non-Gaussian photonic states. (a) The conventional double-slit experiment, creating fringes on the screen. (b) The fringes disappear once the which-path information is measured. (c) Placing a photonic cavity under one of the slits entangles the electrons with each other and with the photonic cavity mode. The histograms in (a-c) present the number of electrons hitting red pixels on the screen: (a) the distribution is strongly skewed due to the electron interference fringe, (b) becoming symmetric when the which-path information is measured, and (c) forming a double-peaked distribution when the electrons become entangled. Simulations performed for 16 electrons. (d) Schematic of a possible implementation by using a microwave cavity in off-axis holography in a transmission electron microscope.

References

[1] P. G. Merli et al., Am. J. Phys. 44, 306 (1976).
[2] A. Tonomura, Rev. Mod. Phys. 59, 639 (1987).
[3] Y. Adiv et al., CLEO FM1L.6 (2021); arXiv:2203.01698.
[4] D. Gottesman et al., Phys. Rev. A. 64, 012310 (2001).
[5] S. A. Koppell et al., Appl. Phys. Lett. 120, 290502 (2022).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session: Lasers and Applications - Dr. Ariel Bruner

Invited speaker |

High Power Single-Frequency Laser Systems for Gravitational Wave Detectors

Prof. Peter Wessels
Laser Zentrum Hannover e.V., Germany

Interferometric gravitational wave detectors enabled the first direct observation of a gravitational wave in 2015. For this groundbreaking detection, the Nobel Prize in Physics was subsequently awarded in 2017. High-power single-frequency laser are a key element of the km-scale Michelson-interferometers of those gravitational wave detectors (GWD). Future GWD will require increasing laser power and might also operate at multiple wavelengths. Fiber amplifiers are a promising technology to fulfill the challenging requirements of next generation GWD.

In this contribution, an overview of the laser development for GWD at LZH will be given. This includes the development of single-frequency fiber amplifiers operating at 1064nm as well as at 1.5µm. Furthermore, an uninterrupted operation of these devices needs reliable fiber components. These were developed for this particular application as well and enabled the demonstration of long-term continuous operation. Finally, further power scaling was demonstrated by coherently combining two identical fiber amplifier systems.

Active and Passive Gain Switched Ho: YAG Laser with few Nanosecond Pulse Duration

Mr. Yechiel Bach, Shaul Golan, Rotem Nahear, Salman Noach
Jerusalem College of Technology, Jerusalem,Israel

The 2 µm wavelength range offers the basis for a variety of applications. In specific applications there is importance to a high atmospheric transmittance, short pulse duration and high peak power.
Commonly The Ho:YAG is a suitable laser for these applications. In this spectral range, only short pulses with low energies for the cavity dumping method or high energies with longer pulse durations for the Q- switch method were found in the literature. Here we present for the first time a Gainswitched Ho:YAG laser with the combination of high energy and a short pulse duration.
The big advantage of using the Gain- switching, rather than Q- switching is that a short cavity can be designed, hence enabling short pulse durations. In our demonstrations, Active (AOM) or passive (Cr:ZeS) Q- switched Tm:YLF laser, served as seed laser. The laser was tuned by an etalon to the Ho:YAG absorption peak. In both set-ups the Gain switched Ho:YAG laser emitted at 2090nm.
For the passive Tm:YLF configuration: 3.35ns pulse duration and maximal energy of 700µJ,
at 1.3kHz repetition rate for 2.8mJ of the Tm:YLF was achieved, corresponding to a
slope efficiency of 37% and optical to optical conversion of 25%. For the active Qswitch setup, 3.5ns pulse duration and maximal energy of 400µJ for 1kHz repetition rate obtained, for 2.2mJ of the Tm:YLF laser, corresponding to a slope efficiency of 30% and optical to optical conversion of 18%. The maximal pulse energy and shortest pulse duration were limited by the damage threshold of the laser mirrors. For the best of our knowledge, these are the highest results reported in terms of pulse duration and energy per pulse using gain switch method.

Synchronized and Spectrally Overlapping Yb / Nd Chirped Pulse Amplifier

Dr. Yariv Shamir[1], M. Wyszkin[1] and Z. Refaeli[1,2]
1 Applied Physics Division, Soreq NRC, Yavne 81800, Israel
2 Applied Physics Department, Givat-Ram, The Hebrew University, Jerusalem, 9190401, Israel

A chirped pulse amplifier (CPA) [1] system of two synchronized ultrashort pulse amplifiers of different materials, Nd doped glass (Nd:gl) [2,3] and Ytterbium doped fiber (Yb), partially sharing emission spectrum, is presented. Its purpose is optimal exploiting advantages from both: while Yb fibers excel in high repetition frequency (fR) high average power multi-µJ energies, maturely used in industrial / scientific fields, Nd:gl amplifiers dominate the multi-Joule laser systems [4,5]. To our knowledge, previous reports on Ybfiber seeding Nd amplifiers are rare [6-9]. However, such pairing introduces a three-fold advantage: rugged fiber generation of µJ-pulses, optical level time synchronization of both amplifiers, and a simultaneous dual pulse output, each excelling in different experiments. Here, a multi µJ Yb fiber CPA seeded low fR Nd:gl CPA, providing multi millijoule (mJ) pulses, while each output is compressed separately and can be used independently or in conjunction. This pairing is based on significant spectral emission-cross-section overlap (Fig. 1), which is exploited for a dual exit front-end scheme (Fig. 2(a)). The Yb fiber operate around MHz fR, ending with a rod-like fiber amplifier (85 µm core) around 1053 nm. Its estimated B-integral is ~5 Radians. Four sequential Nd amplifiers with total of 8-pass synchronously boost the energy to ~3 mJ, with fR=½Hz output. The high fR fiber pulses were directed to an aperiodic frequency conversion contrast enhancement study [10,11] (Fig. 2a bottom).

The Nd:gl amplifier's yielded sub-ps pulses of few-GW power, as it experienced gain-narrowing from ~10 nm of the fiber output (~450 fs, ~2 MW) to sub 5 nm. Preliminary results included: 40-dB contrast improvement using the aperiodic crystal, and preliminary results with Kerrlens contrast study, both run in parallel. Further work shall enhance the scheme for synchronous CPA / OPCPA [12] system, seed for higher energies Nd:gl, and advancing stable seed for larger ultrafast systems.

References

1. D. Strickland and G. Mouru "Compression of amplified chirped optical pulses" Opt. Comm., V.56, N.3 (1985).
2. J. Furenther and A. Penzkofer, "Emission spectra and cross-section spectra of neodymium laser glasses" Opt. and Quant. Elect. V.24 p.591-601 (1992).
3. I. Iparraguirre et-al "Spontaneous and stimulated emission spectroscopy of a Nd3+-doped phosphate glass under wavelength selective pumping" Opt. Exp., V.19, N.20 p. 19440 (2011). 4. C.N. DANSON et-al "Vulcan petawatt: Design, operation and interactions at 5-3´10^{20} W/cm²" Las. and Part. Beams, V.23, p. 87-93 (2005).
5. J. Bromage "Technology development for ultraintense all-OPCPA systems" Hi. Pow. Las. Sci. and Eng., V.7, N.4, (2019).
6. J. Dawson et-al "Fiber Laser Front Ends for High Energy, Short Pulse Lasers" Proc. SPIE conf., V.5709, (2005).
7. J. Dawson et-al "Fiber Laser Front Ends for High Energy, Short Pulse Lasers" Proc. CLEO OSA conf., ThL3, p. 777 - 777 (2007).
8. Sensen Li et-al "Hundred-Joule-level, nanosecond-pulse Nd:glass laser system with high spatiotemporal beam quality", High Power Laser Sci. and Eng., V.4 (2016).
9. C. Dorrer et-al "Spectrally tunable, temporally shaped parametric front end to seed high-energy Nd:glass laser systems" Opt. Exp. V.25, N.22, pp. 26802- 26814 (2017).
10. Z. Refaeli et-al, "Optical Parametric Amplifier Pulse Cleaning Driven by Aperiodic Frequency Converter," IPS conf. (2020).
11. Z. Refaeli et-al, "Optical Parametric Amplifier Pulse Cleaning Driven by Aperiodic Frequency Converter," Phys Script V.97, N.7, p. (2022).
12. A. Dubietis et-al. "Powerful femtosecond pulse generation by chirped and stretched pulse parametric amplification in BBO crystal", Opt. Comm. V.88, 433 (1992).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Femtosecond Inscription of a Spectral Array of Fiber Bragg Gatings at the same Spot, using a Single Uniform Phase-Mask

Dr. Aviran Halstuch, A. A. Ishaaya
Ben-Gurion University of the Negev, Beer-Sheva, Israel

A very simple novel method for same-spot femtosecond inscription of an array of fiber Bragg gratings (FBGs) using a single uniform phase-mask (PM) is presented. This method is experimentally demonstrated on a commercial XP1060 (Nuferm) fiber at a Bragg wavelength around ~1.6 μm. This technique is based on the same-spot inscription of cascaded FBGs that have a center Bragg wavelength shift from each other. An array of three FBGs is inscribed at the same spot. The inscription setup consists of an 800 nm femtosecond laser, a PM, a negative defocusing spherical lens and a cylindrical focusing lens. The wavelength tunability of the center Bragg wavelength is achieved by a defocusing lens, and by shifting the PM. An FBG is inscribed, followed by two cascading FBGs, which are inscribed exactly at the same spot only after the PM is shifted 380 μm away from the fiber core. The second order Bragg at ~1.59 μm transmission spectra of these three FBGs is measured, showing a spectral shift of ~1.2 nm between each one, and a total spectral shift of ~2.4 nm. The transmission dip of each FBG is -17 dB. The third order Bragg at ~1.06 μm transmission spectra shows a transmission dip of - 8 dB and a wavelength separation of ~0.8 nm between each one, and a total wavelength shift of ~1.6 nm. Finally, the fourth order Bragg at 805 nm is also measured, showing a wavelength separation of ~0.5 nm, and a total wavelength shift of ~1 nm. These wavelengths cover the telecommunication wavelength band at the same time, the ~1.06 μm wavelength band of Ytterbium, and the ~800 nm window used by Ti-Sapphire lasers and laser diodes. In the future, this technique can be used for inscribing such FBG arrays in other wavelengths, and with different wavelength separations.

A Forward Brillouin Fiber Laser

Mr. Gil Bashan, H. H. Diamandi, E. Zehavi, K. Sharma, Y. London, A. Zadok
Bar Ilan University, Ramat-Gan, Israel

Optical fibers support Brillouin scattering in the backward and forward directions. While highly coherent fiber lasers based on backward Brillouin scattering amplification are studied and employed for 30 years, to the best of our knowledge a forward Brillouin fiber laser is yet to be demonstrated. Forward Brillouin scattering in fiber has an amplification bandwidth of only tens of kHz [1]. In contrast to the backward process, forward Brillouin scattering within a single optical spatial mode produces phase modulation of incident pump waves rather than the amplification of a signal [2]. Forward Brillouin lasers have been demonstrated through inter-modal stimulated scattering between two spatial modes of photonic-integrated, suspended membrane circuits [3].

In this work, we demonstrate a forward Brillouin laser in a standard, off-the-shelf polarizationmaintaining (PM) fiber [4]. Pump light is applied along the fast axis of a 30 meters-long, bare fiber (Fig. 1(a)). The pump wave provides forward Brillouin scattering amplification of a sideband signal polarized along the slow axis, through guided acoustic modes that are supported by the PM fiber. Two fiber Bragg gratings at the ends of the fiber cavity provide feedback for slow-axis signals only. The laser may operate in single-mode (Fig. 1(b)), few-mode, and multi-mode regimes. The pump power lasing threshold was 400 mW. The laser linewidth was 5 kHz, limited by thermal drifting of longitudinal modes within the long fiber cavity. The output power of the laser was 250 μW, restricted by the onset of parasitic backward Brillouin lasing processes [4]. The lasing threshold is sensitive to the elastic properties of media outside the cladding, even though the optical properties of the cavity are unaffected [4]. The results establish a new class of fiber lasers.

References

[1] R. M. Shelby et al., “Guided acoustic waves Brillouin scattering,” Phys. Rev. B 31, 5244 (1985).
[2] C. Wolff et al., “Cascaded forward Brillouin scattering to all Stokes orders,” N. J. Phys. 19, 023021 (2017).
[3] N. T. Otterstrom et al., “A silicon Brillouin laser,” Science 360, 1113-1116 (2018).
[4] G. Bashan et al., “A forward Brillouin fibre laser,” Nat Commun. 13, 3554 (2022).

Monday, December 12 | Parallel Session 1 | 11:20 - 12:50

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session: Electro-Optics in Industry - Dr. Rami Cohen

Invited speaker |

Space-Proof Based Packaging of Compact Single and Entangled Photon Sources for Secure Communication

Dr. Erik Beckert, Fabian Steinlechner, Sakshi Sharma, Emma Brambila, Rodrigo Gomez, Christoph Damm, Oliver DeVries

Fraunhofer-Institute for Applied Optics and Precision Engineering (IOF), Jena, Germany

Physically secure communication by Quantum Key Distribution (QKD) based encryption of sensitive data becomes of high interest, as the dawn of the quantum computer puts traditional, mathematics-based encryption at risk. QKD instead makes use of quantum physics, encoding information in quantum properties of matter, e.g. the polarization of photons, that can only ne determined by the recipients, while any attempt to spy on the encryption by an eavesdropper can be detected.

Delivering QKD photons over long ranges >200 km is only feasible by free-space links, thus making satellite based QKD a key technology for building future quantum networks across continents, and over the whole world - an approach that many space agencies currently align their future roadmaps with. A key building block for satellite QKD are high performant photon sources that deliver enough QKD photons to be detected and evaluated on the ground, despite the high loss of satellite-to-ground atmospheric links.

The talk will report about the development and testing of high-performant single and entangled photon sources that meet both the requirement of a high photon rate at GHz, while being integrated in a compact and robust way to serve for space environments. VCSEL based setups for single photons, as well as sagnac-interferometer based setups for entanglement demonstrate the requirements and approaches for ultra-stable and miniaturized setups that use only space-proof materials, components and integration technologies. An outlook will provide information about the current satellite missions for low-earth and geo-stationary orbits to be implemented in order to respond to the Chinese challenge, set by their ground-breaking MICIUS mission.

Invited speaker |

Main Features of High-performance CW Laser Optics for High-power NIR Range Applications

Dr. Laurynas Lukoševičius, PhD, Chief Scientist, Altechna, Lithuania[1], M. Gželka[1], J. Butkus[1], A. Pečiulis[1], G. Batavičiūtė[2]

1 Altechna Ltd., Lithuania
2 Lidaris Ltd., Lithuania

Introduction: Rapidly growing irradiation fluences of continuous-wave (CW) laser systems require up-to-date optical components that can withstand demanding working conditions. This could only be achieved after controlling and fine-tuning all parameters of the manufacturing process and optimizing the optical components specifically for the application.

Background: The main problem occurring for CW optical components is overheating due to the absorption of laser irradiation. It might lead to beam quality and beam focusing distortions, potentially causing optical component damage, or introducing inaccuracies in the application.
Therefore, to operate as intended, absorption of laser irradiation must be minimized, and laser- induced damage threshold (LIDT) increased.

Objectives: The aim of this study, was to compare different manufacturing technologies and evaluate the main features that contribute to overheating and low LIDT in CW laser optics.

Methods: Electron beam evaporation, magnetron sputtering, and ion beam sputtering technologies were employed for CW-optimized AR and HR coatings deposition on different substrate materials. For this purpose, Ta_2O_5, HfO_2, Al_2O_5 and SiO_2 material layers were used. Subsequently, absorption, LIDT and surface heating under CW laser irradiation measurements were performed.

Results: AR (R<0.1% @ 1070 nm, AOI=0°) coatings were optimized for high-power CW laser systems by achieving sub-ppm absorption and >39.9 MW/cm2 LIDT levels. While the best coating technology and process parameters were determined to reach <1.5 ppm absorption of HR (R>99.5% @ 1064-1070 nm, AOI=45°) mirrors.

Conclusions: In this study, we defined optimal manufacturing parameters' combination for high-performance CW laser optics operating around the 1.07 µm wavelength range and evaluated the main features of the final components.

Acknowledgments: "STAR" Project (J05-LVPA-K-04-0110), funded by European Regional Development Fund.

Monday, December 12 | Parallel Session 1 | 11:20 - 12:50

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Invited speaker |

Common Path Interferometry: Towards Non- Destructive Testing of Functional Damage in CW Regime

Mr. Justinas Galinis[1], Edvinas Zacharovas[1], Linas Smalakys[1], Gintarė Batavičiūtė[1], Erikas Atkočaitis[2], Andrius Melninkaitis[1]

1 *UAB Lidaris, Vilnius, Lithuania*

2 *Vilnius University, Laser Research Center, Vilnius, Lithuania*

Laser-Induced Damage Threshold (LIDT) is a well-known parameter that characterizes maximum fluence or irradiance of pulsed laser irradiation tolerated by optical element. By exceeding LIDT, optic is irreversibly damaged. In long-pulse or continuous-wave (CW) regime, however, optical elements tend to distort wavefront of transmitted or reflected irradiation due to strong thermal effects: changes in refraction index or thermal expansion.

Thermal lensing may strongly distort laser radiation in a way it may not be usable. In other words, optical laser elements lose their specified (functional) performance even below LIDT in CW regime. Approximate limit, where optical element loses functional performance can be regarded as a "Functional" Laser-Induced Damage Threshold (or F-LIDT). A main reason for such distortion is a thermal heat due to absorption losses of irradiation in optical element, characterized by absorptance coefficient. Accordingly, characterized absorptance coefficient might be a good predictor variable for functional performance of optical element in CW regime.

In this talk we show that a minimum set of test procedures based on Photothermal Common- path Interferometry (PCI) technique allows to characterize optical absorption losses as low as 0.1 ppm. We will show that "L-scan", "T-scan", and "Time-scan" measurements can not only evaluate the absorption value but also allow to predict functional optics performance in CW regime. While 2D "area-scans" can be useful to disclose inhomogeneity of optical element. Direct thermal imaging of optical elements that were previously characterized by PCI was employed to show good "anticorrelation" between PCI measurements and thermal performance. Furthermore, PCI approach is not limited to CW regime only. Applying pulsed irradiation PCI can be useful to explore both nonlinear absorptance and absorptance changes in time (fatigue effect) via multiphoton absorptance and pertinent cumulative processes. The possibilities CW optics characterization via PCI technique will be exemplified and discussed in detail during the presentation.

Green Wavelength Lasers Improve Copper Materials Processing

Dr. Dror Shayovitz

Civan Lasers, Israel

A 500 W continuous wave (CW) green laser improves copper welding, cutting, and additive manufacturing. This true single-mode high-power green laser offers unprecedented beam quality and focusing. Coherent beam combination (CBC) technology enables rapid and precise control of beam power. Efficient second harmonic generation (SHG) of single-mode IR fiber amplifier outputs provide an in-optical head solution with separation of the pump at 1064 nm and output at 532 nm. The result is a clean 532 nm beam with less than 1% residual IR power and a highly polarized beam with a polarization extinction ratio (PER) greater than 20 dB. Copper has roughly 10 times more absorption at the 532 nm wavelength that at 1064 nm - such that a 500 W green laser can deposit the same energy into a copper workpiece as a 5 kW laser at 1064 nm, resulting in significant energy savings. In addition, the diffraction limited beam size decreases due to SHG, providing additional advantages for the 532 nm laser compared to a 1064 nm laser. The 500 W, 532 nm, CW single-mode laser has a measured M2 of less than 1.1, which is unprecedented in the field of high-power green lasers. The focused output beam enables higher-precision machining, higher power density and a smaller heat affected zone, along with short- and long-term power stability in CW or quasi-CW (QCW) modes without time restrictions. In QCW mode, maximum and minimum power levels can be defined, along with the time duration for each. CBC technology enables extremely fast (~100 kHz) switching between the desired output powers, so the beam can be tailored for each material processing application.

Monday, December 12 | Parallel Session 1 | 11:20 - 12:50

On-tool Polarimetry for Detection Optimization

Mr. Amir Shoham, Mr. Ilan Harel
Applied Materials, Israel

Purpose: OPWI (Optical Wafer Inspection) tools utilize various optical configurations to maximize detection of different defects on different layers. Optimized polarization control can dramatically improve defect detection performance.
One challenge of using full polarization control is optimization flow: tool's polarization consists of four degrees of freedom space. There are two optics channel (illumination and collection) and two parameters for polarization state (angle and ellipticity).
We developed novel method to optimize detection by finding the optimal polarization state from a very large configuration space by using only small number of images at different polarizations.

Description of Approach:
Our optimization method consists of 5 steps:
1. Model the tool polarization state (one time, during the calibration flow).
2. Collect a small number of wafer images at different polarization states.
3. Calculate a model for polarization interaction on the wafer.
4. Calculate wafer images, for any arbitrary tool polarization state.
5. Impose the detection algorithm flow on the extrapolated images and predict the optimized polarization state.

The use of this optimization flow predicts not only the best polarization but also the detection performance.

In this work we will demonstrate:
1. A method to predict an output image for any arbitrary tool polarization state in high correlation to the real measurement.
2. A method to optimize detection by finding the optimal polarization state.

Evaluation of Results:
1. show 4 dimenation wafer polarization model
2. Extrapolate wafer images for any tool polarization state, and calculate SNR for any polarization mode
3. Find optimized polarization for best defect detection

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Monday, December 12 | Parallel Session 1 | 11:20 - 12:50

Session: Electro-Optics in Defense - Dr. Ami Yaacobi

Invited speaker |

Adaptive Wavefront Control with Coherent Fiber Array Systems

Prof. Mikhail A. Vorontsov
Department of Electro-Optics and Photonics, University of Dayton, Ohio, and Optonica, Spring Valley, Ohio

Fiber integrated elements of coherent (coherently combinable) fiber collimator array-based transceiver systems allow extremely fast (< 10-9 sec. time response) control of the outgoing phase (piston phase) at each fiber collimator subaperture. In systems with a large number of subapertures, this ultrafast wavefront phase shaping offers the unparalleled and yet mostly unexplored possibilities for adaptive optics (AO) and engineering of laser beams with complex spatio-temporal characteristics, including the creation of laser beams with controllable coherence properties. This overview presentation provides several examples of laser beam engineering and adaptive turbulence effects mitigation using coherent fiber array systems in the following three applications: (a) laser beam projection for achieving maximum power density at a remotely located target - the so-called directed energy application, (b) power beaming for optical power transfer over extended range distances for optical-to-electrical power conversion; and (c) laser illumination for scintillations and speckle-noise mitigation in active imaging.

Dr. Vorontsov is a recognized expert in atmospheric and adaptive optics, coherent fiber-array laser systems, atmospheric imaging, and beam control. Before joining the University of Dayton as Professor and Endowed Chair in 2009, he held positions as Research Professor, University of Maryland, College Park (2009-2012); Senior Physicist and Director of the Intelligent Optics Laboratory, U.S. Army Research Laboratory, Adelphi, MD (1997-2009); Professor, New Mexico State University (1993-1997) and Professor, Moscow State University (1990-1993), Russia. Prof. Vorontsov founded Optonicus LLC in 2009 and was CEO until its acquisition by II-VI A&D in 2018. After this date he supported Optonicus LLC technology transition to II-VI as the Chief Scientist until August 2021. Dr. Vorontsov co-founded Optonica LLC in 2021 and serves as the company CTO. His research expertise includes adaptive optics systems based on the stochastic parallel gradient descent (SPGD) control technique; discovery of the laser beam super-focusing effect; development of lucky-region fusion techniques for anisoplanatic atmospheric imaging; evaluation and modeling of turbulence and refractivity effects in imaging and laser beam propagation; development of adaptive coherent fiber-array technology and the first demonstration of coherent beam combining in the turbulent atmosphere. Dr. Vorontsov has over 7,000 citations to >350 journal articles and several books. He is a Fellow of the Optical Society of America, ARL and SPIE.

Invited speaker |

Atmospheric Turbulence & Propagation Study with Deep Machine Learning

Prof. Mikhail A. Vorontsov

Department of Electro-Optics and Photonics, University of Dayton, Ohio, and Optonica, Spring Valley, Ohio

In this presentation we discuss different aspects of deep machine learning tools applications for optical wave propagation in atmospheric turbulence. One of the major attractions of the machine learning approach for atmospheric characterization is that it offers a wide range of capabilities for real-time fusion of data flows coming from various optical and meteorological sensors. To better reveal the complexity of atmospheric turbulence dynamics, the sensor outputs should be differently affected by atmospheric turbulence; e.g., have enhanced sensitivity to the location of turbulence layers, or to specific spatial and / or temporal characteristics of atmospheric refractive index inhomogeneities, or changes in atmospheric refractivity, visibility, etc. From this viewpoint diversity in sensing data that enter a DNN-based signal processing system is highly desired.

This capability is especially important for prediction and in-situ adjustment of electro-optics system parameters based on atmospheric sensing information. For example, in adaptive optics systems, in-situ prediction of turbulence conditions that may occur within the time scale of a few seconds may provide opportunities to correspondingly adjust wavefront sensing and control system parameters for optimal system performance.

Another important role machine learning could play for a wide range of atmospheric sensing applications is related to calibration of different sensors. “Agreement” between different sensor types, for example for measurements, is currently difficult to achieve even if these sensors operate side-by-side to simultaneously take measurements at the same atmospheric propagation site. This is not a surprise, as the operational principles of different sensors are commonly based on different assumptions and formulas that are derived from atmospheric turbulence theory and link with the statistical characteristics of measured signals. With the machine learning-enhanced atmospheric sensing approach that is based on extraction of spatial and temporal features of inputting DNN sensory information, rather than obtaining the “right” statistically averaged characteristics, it would be more straightforward to calibrate different sensors against a “reference” machine learning-based sensing system utilizing a “standard” topology DNN with identical parameters and training datasets.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Phase Retrieval and More Approaches for Wavefront Sensorless Adaptive Optics

Dr. Bar Peled, Mara Baraban

Rafael Advanced Defense Systems, Israel

We consider using a deformable mirror (DM) in conventional model-based wavefront sensorless adaptive optics (WFSless AO) to correct phase aberrations in an optical system. Initially, the system, including the DM, must be calibrated in order to achieve accurate DM-actuators control. We investigate several approaches to build a set of orthogonal mirror modes (like Zernike).

We consider the simplest approach of calibrating the DM on the optical table using a wavefront sensor and also more advanced approaches, inducing phase retrieval optimization, which allow for DM calibration using only the DM-camera feedback loop. Then we can use those basic modes to implement sequential correction scheme that requires at least 2N images to correct N modes. Simulations and experiments have been done for both point-like and extended objects in such a system

Diode Pumped Alkali Laser: Current Status and Prospects

Dr. Ilan Hakimi

Rafael Advanced Defense Systems, Israel

The historical aspect, present status, and future prospects of diode pumped alkali lasers (DPAL) are discussed. Since the first DPAL demonstration with an output power of 130 mW in 2005, a significant progress in this field was achieved. The DPAL is characterized by a gaseous gain medium (allowing it to easily convect heat from the laser resonator), extremely high scalability, good beam quality and intrinsically high efficiency. In spite of major achievements in the field, there are still several physical and engineering challenges in DPAL that must be addressed. We present a review of the alkali laser research and development, discuss the most important achievements and future perspectives in this field of research. Some of the research results of our group are also introduced.

Monday, December 12 | Parallel Session 1 | 11:20 - 12:50

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session: Electro-Optics Devices - Dr. Ilya Goykhman

Invited speaker |

Application of 2D Materials in Photonic Sensing and Electronics

Prof. Thomas Mueller

Vienna University of Technology, Institute of Photonics, Vienna, Austria

Photonic sensing devices measure the rich physical properties of incident light, such as its power, polarization state, or spectrum. Recently, the development of integrated sensing solutions using miniaturized devices together with advanced machine learning algorithms has accelerated rapidly, and optical sensor research has evolved into a highly interdisciplinary field, encompassing device and materials engineering, condensed matter physics and machine learning. In this talk, I will present a geometric picture of photonic sensing: physical properties of light and the corresponding sensor output signals can be regarded as points in two high- dimensional vector spaces and the sensing process can be understood as a mapping of one vector space into the other. This mapping may be linear or non-linear, where in the latter case a neural network represents the method of choice. Based on this framework, I will present examples in which a reconfigurable optical sensor can directly detect spectral and spatial features of incident light, enabled by device reconfigurability and the implementation of machine learning algorithms for information encoding and decoding, respectively. This new sensing scheme may find wide applications in ubiquitous light detection and imaging systems, thanks to its simplicity, scalability, and versatility.

Invited speaker |

Modelling Optoelectronic Applications based on Graphene

Prof. Elefterios Lidorikis

Computational Materials Science Laboratory; Department of Materials Science and Engineering, University of Ioannina; Institute of Materials Science and Computing, University Research Center of Ioannina, Ioannina, Greece

Graphene's optical response is characterized by constant absorption in the visible, electrically tunable absorption in the NIR-SWIR and plasmonic excitations in the MIR-THz spectrum. These traits make for interesting applications in photodetection, light modulation and sensing. To make the response more efficient and competitive, however, the small overall absorption in graphene must be overcome by integrating graphene with resonant photonic or plasmonic cavities. Strong light absorption within the resonators creates hot electrons and temperature gradients. A comprehensive multi-physics modeling and design scheme of graphene-based optoelectronic applications needs to consider the optical, thermal, and electrical responses, alongside the hot-carrier heating and electron-phonon cooling. Here, we present a self-consistent multi-physics framework for the simulation and design of graphene-based photodetectors, sensors, and modulators, with different applications operating in different spectral regimes from the NIR to THz. We put our models to the test by direct comparison and excellent agreement to experiments. The presented framework can be used to design different optoelectronic devices reliably and realistically, across a broadband spectral regime, using a plethora of materials alongside graphene.

Invited speaker |

Active Metasurfaces

Prof. Uriel Levi

Department of Applied Physics, Center for Nanoscience and Nanotechnology, The Hebrew University of Jerusalem, Jerusalem, Israel

We present our recent results related to active metasurfaces. Several mechanisms for implementing active devices will be discussed. We will describe the demonstration of tunability in dielectric and metallic metasurfaces for diverse applications using tunability mechanism such as MEMS technology integrated with metasurfaces and the electro optic effect in lithium niobate integrated with metasurfaces, as well as the tunability of a metasurface by controlling an external medium. We also discuss the role of nanoscale structures in enhancing functionalities such as light emission and light detection.

Orthogonal Sub-Sampled Analog-to-Digital and Digital-to-Analog Conversion

Janosch Meier, Karanveer Singh, Arijit Misra, Paulomi Mandal, Younus Mandalawi and Prof. Thomas Schneider*

** Corresponding author*

Technical University of Braunschweig, Germany

The standard technology for electronic analog-to-digital (ADC) and digital-to-analog converters (DAC) might limit the further increase of data rates in the worldwide optical and wireless communication systems, in radar applications and measurement devices. Here we present photonics assisted ADC and DAC based on orthogonal sub-sampling as a possible solution. Due to the orthogonality of sinc-pulse sequences, each bandwidth limited signal can be generated, error-free by the superposition of time-shifted sinc-pulse sequences, weighted with the sampling points, fulfilling the main functionality of a DAC [1]. Additionally, if the analog signal is multiplied with time-shifted sinc-pulse sequences with the right bandwidth, the orthogonality enables an error-free sampling, or the first step of an ADC [2]. Since sinc-pulsesequences are a superposition of single sinc-pulses, time-shifted to each other by a multiple of the sampling rate N, the analog signal can be generated or sampled in N parallel branches. In each branch the required minimum bandwidth of the single DAC or ADC will be B/N, with B as the bandwidth of the analog signal. Sinc-pulse sequence generation and orthogonal sampling can simultaneously be carried out by driving an intensity modulator with one or a number of radio frequencies. The schematic of a three-branch transmitter and receiver, reducing the required electrical bandwidth by three, is shown in Fig.1. Since only low-bandwidth standard devices are required, the method can straight forwardly be integrated into any platform and might be a solution to keep pace with increasing data rates.

References

[1] K. Singh, et al., IEEE Phot. Techn. Lett. 32, 1544 (2020)
[2] A. Misra, et. al., Opt. Express 27, 29972 (2019).

Transparent, Optically Lossless and Thermally Efficient 2D MoS2 Heaters Integrated with Silicon Microring Resonators

Mr. Dor Oz[1], Nathan Suleymanov[1], Boris Minkovich[1], Vladislav Kostianovskii[1], Dmitry Polyushkin[2], Thomas Mueller[2] and Ilya Goykhman[1]

1 *Micro Nanoelectronics Research Center, Department of Electrical and Computer Engineering, Technion, Haifa, Israel*

2 *Institute of Photonics, Vienna University of Technology, Vienna, Austria*

Active control of photonic integrated devices by refractive index adjustment to change the light phase accumulation in Silicon devices is essential in optical communication systems [1-3]. The most efficient way to tune the optical phase in Silicon-photonics (SiPh) is using the thermo-optic effect, where temperature variations induced by a heater modify the optical refractive index of silicon [4]. Conventional thermal heaters currently employed in SiPh are mainly realized by metal lines that conduct an electrical current and generate a heat source due to the Joule heating. However, the metallic heaters can produce an excess optical loss because of free carriers' absorption, and as a result should be placed far away from photonic structures (~1µm), thus compromising the efficiency of the heater [5]. To improve the efficiency, one should target to bring a heater in close proximity to the photonic waveguide. Recently, there were several demonstrations of using graphene heaters integrated with the SiPh platform [6-8]. Own to the two-dimensional (2D) nature of graphene, being an atomically thin electrical conductor (i.e. semi-metal), allows pushing graphene-heater closer (~200nm) to the waveguide [7,8], improving heater efficiency and lowering the insertion loss. Nevertheless, optically lossless and efficient integrated heaters haven't been demonstrated yet.

Here we report the design, fabrication and characterization of the first single-layer MoS2 (1L-MoS2) heater, integrated on a micro-ring resonator operating at telecom wavelengths of 1550nm. 1L-MoS2 is a two-dimensional semiconductor with the energy bandgap in the visible wavelengths (1.9eV), therefore it is transparent for telecom photons with an energy of 0.8eV (1550nm). We demonstrate that a 1L-MoS2 heater can be placed in direct contact with Silicon waveguide providing minimal insertion loss degradation. The demonstrated heaters' efficiency is ~15.15[mW/full FSR] with a rise time of ~27[uS], which can be significantly improved by optimizing the 1L-MoS2 contact resistance. Our results pave the way for developing novel energy-efficient, optically transparent and lossless 2D heaters for photonic integrated circuits.

References

H.-Y. Ng et al., Optical Engineering 47(4), 044601, (2008).
W. D. Sacher et al., Optics Express Vol. 22, Issue 4, pp. 3777-3786, (2014).
P. Dong et al., Optics Express Vol. 18, Issue 10, pp. 9852-9858, (2010).
G. Cocorullo et al., Appl. Phys. Lett. 74, 3338, (1999).
T. Barwicz et al., Proc. SPIE 6872, Laser Resonators and Beam Control X, 68720Z (2008).
S. Gan et al., Nanoscale, 7, 20249-20255, (2015).
D. Schall, Optics Express Vol. 24, Issue 8, pp. 7871-7878, (2016).
S. Nakamura et al., ACS Nano, 16, 2, 2690-2698, (2022).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Monday, December 12 | Parallel Session 2 | 14:15 - 15:45

Tunable Electro-Optical Blockade and Switching of Propagating Exciton-Polaritons

Mr. Dror Liran[1], J. Hu[2], H. Deng[2], L. Pffiefer[3], R. Rapaport[1]

1 *Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem, Israel*

2 *University of Michigan, Ann Arbor, MI 48109, USA*

3 *Department of Electrical Engineering, Princeton University, Princeton, NJ, 08544 USA*

Electrically biased, low-loss waveguided exciton-polaritons (WGP) are suggested for future highly functional, on-chip quantum-photonic circuits: these high-momentum polaritons can be controlled through their photon part using standard dielectric waveguide technology, and through their excitonc part using quantum confined Stark effect. It was recently demonstrated that electrically biased WGPs can be guided to propagate over macroscopic distances in curved waveguide geometries [1], and that their energy and optical non-linearity can be tuned continuously via direct electrical gating [2], that results in enhanced dipolar interactions [3]. These demonstrations make electrically biased WGPs promising candidates for observing dipolar quantum blockade of polaritons towards polariton quantum-logic devices. Here we demonstrate a controlled electrical blockade of WGPs, using a potential landscape shaped as a tunable electrical potential barrier for propagating WGPs in a channel (see image). WGPs are injected into a fixed-biased optical channel and propagate towards the potential barrier. As the bias of the barrier is changed with respect to that of the channel, we observe strong modifications of the transmission and reflection of the WGP into the corresponding waveguide-out couplers. We find that when the electrical bias in the barrier is larger than in the channel, a strong blockade of polaritons occurs, leading to a to minimal transmission. This method of electrical shaping the potential-landscape for propagating polaritons, which can also be dynamically tuned, is an important building block towards a full configurable logical circuitry for polaritons.

References

[1] Liran et al., ACS Photonics 2018, 5, 4249-4252
[2] Rosenbeg et al.,PRB 93, 195151 (2016)
[3] Rosenberg et al., Sci. Adv. 2018;4:eaat8880
[4] Liran et al., In submission (2022)

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session: Spectroscopy and Optical Sensing - Dr. Ayala Ronen

Invited speaker |

Coherent Free-Space Optical Communications

Dr. Szymon Gładysz, Szymon Gladysz, Douglas McDonald, Raphaël Bellossi

Fraunhofer Institute of Optronics, System Technologies and Image Exploitation, Germany

Free-space optical communications (FSOC) systems are an emerging technology with a number of interesting use cases in both defence and civilian contexts. Current commercially available FSOC systems are based on intensity modulation / direct detection (IM/DD), where digital data is encoded and detected via the intensity of the transmitted optical signal. However, due to the development of coherent optical transceivers for the fibre optic communications industry, coherent FSOC systems could soon become feasible. Compared to intensity modulation systems, coherent systems encode data using the entire optical field, that is: the amplitude and phase of the transmitted signal can be independently modulated. As a result, coherent systems enable the use of spectrally efficient modulation formats, which can pave the way to significantly higher data rates compared to conventional IM/DD systems. Despite this promise, coherent FSOC systems are difficult to implement, particularly in the presence of strong atmospheric turbulence.

In the context of FSOC, a number of effects caused by atmospheric turbulence can degrade system performance, including: phase-front distortions, scintillation, and beam-wander. Of particular importance in coherent systems is the effect of phase-front distortions, which can lead to significant reduction in the received signal-to-noise (SNR) ratio, and therefore increase the system's bit error ratio (BER). This is because in order to extract the full-field information of a received optical signal, it must be mixed with a local oscillator (LO), typically located at the receiver, before detection. If mixing is performed in free-space, the mixing efficiency depends on the spatial overlap between the electric fields of received signal and LO, which in the presence of phase-front distortions, can be poor. Analogously, in systems that utilize commercially available fibre-coupled receivers, the received signal must be first coupled to a single-mode optical fibre (SMF). In this case, fibre-coupling efficiency depends on the spatial overlap between the electric fields of received signal and the fundamental mode of the fibre, which is similarly impacted by phase-front distortions.

In this work, the effect of phase-front distortions caused by atmospheric turbulence on the performance of a coherent data transmission was examined using a two-pass 800 m free-space link. Experimental data was obtained over several days and the effect of turbulence was quantified by simultaneously measuring link performance (e.g. BER) and turbulence metrics. This work serves to both demonstrate data transmission using a coherent FSOC system, and as a platform to investigate the atmospheric channel. Future goals of this work include: the comparison of alternative coherent free-space optical communications system architectures and the evaluation and implementation of various turbulence mitigation strategies.

Characterization of Sub Inversion Layer Haze Pockets in the Summer Season of the israeli Coastline with IR Imager

Eitan Hirsch[1],Tamir Tsadok[1], Dr. Eyal Agassi[1], Ilan Keren[2], Orit Altaratz[2]

1 Department of Environmental Physics, Israel Institute for Biological Research, Nes-Ziona, Israel
2 Department of Earth and Planetary Sciences, Weizmann Institute of Science, Rehovot, Israel

The summer season over the Israeli coast is characterized by an absence of an active weather, low and persistence inversion layer, and clear skies with shallow sub LCL clouds. However, carefully planned measurements campaign with IR and visible whole sky imagers, had reviled the presence of low travel haze pocket that have a significant IR radiative signature. The physical mechanism that produced these haze pockets in not fully understood, but it is clear that this phenomenon occurs almost on a daily basis during daytime. While the optical depth of this hazy substances is low, it forms a strong spatial and dynamic interference in the IR sky image. Therefore, it forms a strong clutter background in the IR band, even though that to sky looks completely clear to the naked human eye, or in a visible imager. We will present a detailed description and analysis of this newly discovered phenomenon, and how it observed with whole sky IR imager.

Monday, December 12 | Parallel Session 2 | 14:15 - 15:45

Application of 3D Volumetric Scattering-Tomography to in-lab Cloud-Cell

Masada Tzabari[1], Vadim Holodovsky[1], Tamar Klein[1], Yoav Y. Schechner[1], Omer Shubi[1], Ofer Yaron[2], Ayala Ronen[3], Ilan Salame[3]

1 *Viterbi Faculty of Electrical and Computer Engineering, Technion - Israel Institute of Technology, Haifa, Israel*
2 *Rafael Advanced Defense Systems, Haifa, Israel*
3 *Department of Environmental Physics, Israel Institute of Biological Research, Nes Tziona, Israel*

We introduce an experiment of 3D scattering tomography of clouds created in a cloud chamber. The main objective of this research is to assess the suitability of polarimetric imaging for 3D scattering tomography of clouds. This is done as part of the CloudCT mission, funded by the ERC.

Classic remote sensing has fundamental deficiencies in the analysis of the radiative transfer effects and microphysics of small clouds. This is greatly due to the underlying assumption of a plane-parallel geometry of the atmosphere. This effectively degenerates, to some extent, 3D radiative transfer to a 1D form. To allow better understanding, a 3D retrieval approach is essential. CloudCT will acquire simultaneous multi-angular images of cloud-fields from 10 custom 3U nanosatellites, orbiting in a formation. The multi-angular images will then be processed using 3D scattering tomography methods to derive micro-physical properties of cloud droplets on a volumetric scale. These will include the effective radius and liquid water content spatial distributions.

The experiment aimed to imitate a spaceborne mission, with controlled micro-physical properties. It was performed at the Israel Institute of Biological Research (IIBR). A closed cylindrical chamber was filled with cloud droplets of known size distribution. A high-intensity, distant, narrow-angle halogen light source was used to imitate solar illumination. The chamber had a sliding side panel. When it was opened, as in Fig. 1 (left), a steady cloud was maintained for several seconds. Five polarized imagers acquired multi-view images of the cloud. Two droplet size distributions were used, equivalent to those of small warm clouds and mist. In addition, the chamber was divided in the middle, creating a heterogeneous medium, with a different distribution on each side.

For retrieval, we use the pySHDOM [1] code developed by Levis et al. [2-4]. PySHDOM yields 3D scattering CT, based on the vectorized Spherical Harmonic Discrete Ordinate Method (vSHDOM) for radiative-transfer. It retrieves cloud properties within a cloud domain (see Fig. 1, right) by optimization, fitting multi-view Stokes-vector images to a physics-based 3D radiative-transfer forward-model.

References

[1] A. Levis, J. Loveridge, and A. Aides, "pySHDOM," https://github.com/aviadlevis/pyshdom, 2019
[2] A. Levis, Y. Y. Schechner, A. Aides, and A. B. Davis, "Airborne three-dimensional cloud tomography," in ICCP. IEEE, 2015, pp. 3379-3387.
[3] A. Levis, Y. Y. Schechner, and A. B. Davis, "Multiple-scattering microphysics tomography," in CVPR. IEEE, July 2017.
[4] A. Levis, Y. Y. Schechner, A. B. Davis, and J. Loveridge, "Multi-view polarimetric scattering cloud tomography and retrieval of droplet size," Remote Sens., vol. 12, no. 17, p. 2831, 2020.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Monday, December 12 | Parallel Session 2 | 14:15 - 15:45

Optical Strain and Magnetic field Sensors based on Whispering Gallery Modes Microresonators

Dr. Eyal Yacoby, Yosef London
Soreq Nuclear Research Center, Yavne, Israel

Optical sensors based on Whispering Gallery Mode (WGM) resonators have been extensively studied. Their extremely high Q factors (106 - 109) pave the way for various types of highly sensitive sensing. Here we present strain [1], and magnetic field sensors [2] based on stretchable silica microspheres.
A stretchable microsphere is a microsphere having two fiber tails serving mechanical purposes. By pulling on the fiber tails, the microsphere's WGMs resonances are altered due to small changes in the radius and refractive index of the microsphere. Here we study the dependence of the strain-sensitivity of the stretchable microspheres on the geometry, structure, and modal properties of the structure.
The high sensitivity of the WGMs resonances to mechanical deformation is routed to detect the mechanical deformation of a magnetostrictive material (Terfenol-D) which endures strain as a response to varying magnetic fields. The sensitivity and the vectorial nature of the suggested magnetic sensors are studied. In addition, a unique packaging technique of high mechanical stability is presented. The simplicity, low cost, high mechanical stability, and lack of electrical wiring make the magnetic sensor attractive for remote, quasi-distributed magnetic sensing.

References

[1] Yacoby, E., and London, Y., " Mechanical tuning of WGM silica microspheres and WGM-based strain gauge - geometrical considerations," J. Light Technol., to be published, DOI:10.1109/JLT.2021.3138134.
[2] Yacoby, E., Meshorer, Y. and London, Y., "Magnetic sensor based on a Whispering Gallery Mode double-tailed silica microsphere," Opt. Laser. Technol., 151(108019), (2022).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Ellipsometric Surface Plasmon Resonance Sensor using Polarization Camera for Real-Time Sensing Applications

Mr. Nipun Vashishta, Marwan J. Abuleil, Anand M. Srivastava, and Ibrahim Abdulhalim
Ben-Gurion University of the Negev, Beer- Sheva, Israel

Surface plasmon resonance (SPR) sensors are well-known optical sensing tools having variety of applications in monitoring chemical and biological label-free, highly-sensitive, and real-time molecular interactions. SPR sensors can be divided into four categories depending upon their information parameter: angle, wavelength, intensity, and phase interrogation. Phase interrogated SPR sensors generally have higher sensitivity and throughput among other SPR sensors. Some of the widely known SPR phase interrogation techniques includes, optical heterodyne detection, ellipsometry, shear interferometry, spatial phase modulation interferometry, and temporal phase modulation interferometry. Phase interrogated SPR sensors require complex optical configurations. Ellipsometric surface plasmon resonance (SPR) sensors are known for their relatively simple optical configuration as compared to Interferometric and Optical Heterodyne phase interrogation techniques. However, previously explored ellipsometric SPR sensors based on intensity measurements are limited by their real-time applications because phase or polarization shifts measurements are done serially. Here we present an ellipsometric SPR sensor based on Kretschmann-Raether (KR) diverging beam configuration and a pixelated microgrid polarization camera. The proposed methodology has the advantage of real-time and higher precision sensing applications. The short-term stability of the measurement using the ellipsometric parameters and is found superior over direct SPR or intensity measurements in particular with fluctuating sources such as laser diodes. Refractive index and dynamic changes measurement in real-time are presented.

Forward Brillouin Point Sensor in a Multi-Core Optical Fiber

Ms. Keren Shemer, Gil Bashan, Elad Zehavi, Hilel Hagai Diamandi, Alon Bernstein, Kavita Sharma, Yosef London, and Avi Zadok (Corresponding author)
Bar Ilan University, Ramat-Gan, Israel

Forward Brillouin scattering interactions support the sensing and analysis of media outside of standard optical fibers, where light cannot reach [1]. Most protocols reported to-date provide position-integrated measurements: scattering signals are accumulated over the entire length of a fiber under test, and local information is lost [2-3]. Several demonstrations of spatially distributed forward Brillouin fiber sensing have been reported, with resolution reaching 1 meter [4]. However, quantitative point-sensing based on forward Brillouin scattering has yet to be demonstrated. In this work [5], we report a forward Brillouin scattering point-sensor in a commercially available, multi-core fiber. Pump light at the inner, on-axis core stimulates a guided acoustic mode of the entire fiber cross-section. The acoustic wave induces photoelastic perturbations to the reflectivity of a Bragg grating inscribed in an outer, off-axis core of the same fiber. The measured spectra distinguish between air, ethanol, and water outside the centimeter-long grating. The measured linewidths agree with predictions. The acquired spectra are unaffected by forward Brillouin scattering outside the grating region. The results add point-analysis to the portfolio of forward Brillouin scattering optical fiber sensors.

References
[1] Y. Antman, et al., Optica 3, 510-516 (2016).
[2] D. Chow et al., Nature Commun. 9, 2990 (2018).
[3] G. Bashan et al., Nature Commun. 9, 2991 (2018).
[4] S. Zaslawski et al., Optica 8, 388-395 (2021).
[5] K. Shemer et al., Opt. Express 30, 39321-39328 (2022).

Monday, December 12 | Parallel Session 2 | 14:15 - 15:45

Session: Start-up - Mr. Ran Bar-Sella

Sponsored by: bank hapoalim | MEITAR

Hypervision

270o Field Of View pancake lens based compact Virtual Reality visual engine

Shimon Grabarnik

The vision for the metaverse is to become a universal and immersive virtual world. Companies like Meta, Apple, Google, and many others - alongside the largest Venture Capital firms - are investing tens of billions of dollars a year toward making the Metaverse a reality. The VR/XR market is huge and growing exponentially. Today, the biggest industry challenges to overcome are headset size, computational abilities, and the constrained field of view. Available headsets on the market are generic, undifferentiated, and suffer from similar drawbacks,

offering a narrow, -90degrees field of view which is only one-third of the full human field of view. This lack of peripheral vision leads to headaches, vertigo, and nausea. This is exactly what Hypervison is here to solve. Our mission is to become a leading Metaverse enabler. Our Optical architecture creates an end-to-end, truly immersive user experience, by tripling the standard -90degree FOV, and creating the first-of-its-kind full human FOV headset in a compact form factor based on a pancake lens. Our solution is foundational to immersive content and services, and dramatically improves user experience across verticals.

The company will launch its product on December 2022 and is looking to collaborate with investment partners and XR headset vendors.

Hypervision Ltd.
Contact:
S. Grabarnik, PhD, Director of optical engineering
email: shimon@hypervision.ai, tel: (9754049-054 (972+
A. Rabner, PhD, CTO
email: arthur@hypervision.ai, tel: (4447948-054 (972+

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Monday, December 12 | Parallel Session 2 | 14:15 - 15:45

NovaSight NovaSight

How to Treat Amblyopia by Watching Netflix

Ran Yam

Founded in 2016, NovaSight has experienced rapid growth by delivering end-to-end eye-tracking - based vision care solutions. The company focuses on three major verticals: vision treatment, vision diagnostics and prevention and monitoring of visual health conditions.The CureSightTM is an FDA cleared eye tracking-based system for treatment of lazy eye designed to replace the traditional eye patching. CureSight trains the visual system to use both eyes simultaneously, by blurring the center of vision of the image that is shown to the strong eye while the user watches any streamed video content of choice at the comfort of his home.

With 3 unique CPT codes for its technology and excellent clinical outcomes that were published in the industry's leading peer reviewed journal, NovaSight intends to launch CureSight in the US in December. The EyeSwift®PRO system is a comprehensive vision diagnostics device which provides fast, accurate and objective measurements of multiple visual performances as well as lenses' recommendations.
TrackSightTM, is a pipeline software solution that monitors real-time visual health and promotes myopia prevention when using screens.

Backed by venture capital and strategic partners, NovaSight had raised to date 26$M and is in the midst of a 25$M B round.
For more information visit www.nova-sight.com or reach out to us at info@nova-sight.com

Ran@nova-sight.com
7591609-050

OORYM

From a Pilot's Helmet to Ray-ban Glasses - Making Augmented Reality a Reality

Yaakov Amitai

Existing solutions for Near Eye Displays, whether diffractive or reflective, suffer from one or more of the following problems: very low brightness efficiency, poor image quality, limited Field of View, bulky form factor, and high manufacturing cost. Oorym's novel waveguide technology provides a solution to those problems. With the highest brightness efficiency, widest Field of View, and best image quality, Oorym's products are unparalleled. And due to the simple manufacturing process, it is price competitive. Moreover, though Oorym's technology is the most novel technology, it is entirely mature and ready for mass production.
Oorym products' offering includes light and small form-factor displays, immersive Field of View (>70 degrees) systems, Head-up Displays, and more.
In addition to the unique waveguide technology, Oorym is developing a sophisticated display technology that can be combined with the waveguide to create an extremely compact and efficient display system.
We are looking for new partners - customers in every market segment, manufacturers with optical fabrication capabilities, and suppliers of novel display sources to join us in creating great products together. Investment proposals are welcome.

Please contact us at info@oorym.com for inquiries.
yaakov@oorym.com
5222214-054

3DOptix

Cloud-Based, Non-Sequential Optical Simulation

Gil Noy

3DOptix optical, ray tracing, simulation software is running for over two years and has the biggest optical design community in the world with thousands of active users.
The new 3DOptix software is the fastest non-sequential, Industry grade, ray tracing, optical simulation software in the market.
The novelty GPU, cloud-based ray tracing engine, can trace billions of rays/sec, faster than any other simulation.
The new 3DOptix software will introduce CAD integration, advanced analysis tools, scattering, and many new features with a unique easy to use GUI and a simple user experience.
We are excited about the new release and are waiting to get the community's feedback.

More information can be found at: www.3doptix.com
https://onlinelibrary.wiley.com/doi/epdf/10.1002/phvs.202100054
gilnoy@3doptix.com
2554945-052

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Monday, December 12 | Parallel Session 2 | 14:15 - 15:45

BeetleSat

What would work best for inter-satellite link in space? Lasers or RF? Practical lessons

Raz Itzhaki

BeetleSat is a new LEO (Low Earth Orbit) constellation delivering truly global Ka-band connectivity for point to point secure communications, cellular backhaul, mobility and additional premium services, in the commercial and government sectors.
Based upon groundbreaking Ka-band deployable antennas, developed by NSL Comm based in Israel, BeetleSat is deploying 250 communication satellites comprising high speed intersatellite links, delivering exceptionally low-latency, high throughput, non-terrestrial networks, able to link selected points anywhere on Earth.
BeetleSat is a premium complementary LEO layer for terrestrial and MEO/GEO networks, suitable for global and regional operators and telecom service providers looking to boost their existing solutions with truly global, high quality, high speed, affordable communications.

raz@beetlesat.com
5096555-052

LightSolver

Solving hard problems in the speed of light

Chene Tradonsky

Many functional optimization problems are too hard to solve efficiently with the computation resources available today. Supercomputers would need to be expanded extensively, which requires enormous resources, and quantum computing has not yet reached the right maturity to tackle complex optimization problems.
LightSolver has developed an all-optical quantum-inspired platform to achieve optimal solutions to complex optimization problems faster than ever, elevating organizations to their best performance. In some cases, LightSolver can calculate an equation up to 1 million times faster than the current quantum computers and up to 1 billion times faster than the current supercomputers.
LightSolver offer an end-to-end solution. Our team reformulates your complex problems, runs them through our laser-based platforms, and analyzes the results, providing you with complete guidance and support.
Our clients include companies, security agencies and research institutes dealing with complex optimization problems in various fields, including finance, communications, machine learning and AI, logistics and transportation.

chene@lightsolver.com
4299227-052

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

BIRAD

Ultrafast spectrometer based on temporal optics

Moti Fridman

Temporal optics is a new field that adopts optical systems from space to time. We developed several devices and will focus on our ultrafast spectrometer which can measure the spectrum of input signals faster than any other spectrometer.

mordechai.fridman@biu.ac.il
8040636-054

SolCold

How cooling can be achieved under sunlight...

Yaron Shenhav

SolCold developed an innovative, patented, nano-technological material that cools everything under the sun, without any power consumption! The material uses the sunlight and the skyline for cooling and is most effective when it is very hot and the sun is strongest. The material can be used as a coating for cooling cars, buildings, containers, apparels, airplanes, etc., and is expected to bring tremendous savings in cooling and air-conditioning expenses and significantly reduce greenhouse gas emissions.

yaron@solcold.co
7769687-054

ScoutCam

Video Based Predictive Maintenance

Arik Priel

ScoutCam is pioneering the Predictive Maintenance (PdM) and Condition Based Monitoring (CBM) markets with its visualization and AI platform. Providing video sensor-based solutions for critical systems in the aviation, transportation, and energy industries, ScoutCam leverages proven visual technologies and products from the medical industry. ScoutCam's unique video-based sensors, embedded software and AI algorithms are being deployed in hard-to-reach locations and harsh environments across a variety of PdM and CBM use cases. ScoutCam's platform allows maintenance and operations teams visibility into areas which are inaccessible under normal operation, or where the operating ambience otherwise is not suitable for continuous real-time monitoring.

arik.priel@scoutcam.com

Agrowing

Disruptive Multispectral Technologies

Ira Dvir

Agrowing was established with the vision of taking aerial remote-sensing from the imprecise NDVI and NDRE to accurate leaf-level multispectral AI analysis. Such analysis enables precise detection and identification of pests, diseases, and vegetation irregularities, resulting in "Actionable Data".
For a long time, remote-sensing was based on low-resolution multispectral imagery, which was acquired by satellites and low resolution multispectral sensors.
Agrowing's award-winning sensors of 10 and 14 narrow spectral bands of 8 to 12 Megapixels per band, were designed for multispectral data acquisition from high altitude and from very low one. They are based on panchromatic Sony's latest greatest Full Frame CMOS sensors, having adjacent Dual, Quad, or Sextuple lenses in a single lens mount.
Aerial scanning with our sensors provides from high altitude exceptionally refined NDVI maps, enabling the user to identify the smallest outlying areas of the field. Low altitude drone is sent to such areas and acquires leaf level multispectral imagery samples at from altitude as low as 3 meters, providing sub-0.5mm per pixel imagery. Such data enables AI classification and accurate identification, eliminating the need to send an agronomist to check the vegetation in the field.
Agrowing's two essential patents were granted in the US, EU, Australia, China, Euro-Asia, Japan, Canada, and more.
The technology is proven and deployed by AI service-providing companies like the Israeli SeeTree and the Brazilian VetorGeo, and drone makers like Vertical Technologies and GermanDrones.
The technology is applicable to other markets and we found lately that our sensors also enable detection of camouflage nets in broad daylight.

ira@agrowing.com
3409760-052

Monday, December 12 | Parallel Session 2 | 14:15 - 15:45

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Nano Drops

A New Paradigm In Vision Correction

David Smadja

Nanodrops in a seed-stage Israeli company backed by Sanara Ventures, Philips Healthcare & TEVA Pharmaceuticals, IIA and private investors, co-founded by experts in medical device, ophthalmology, optics and nanotechnologies.
Nano-drops is developing a unique solution for treatment of presbyopia (aging eye) and myopia (near-sightedness) that may be an alternative to reading glasses, contact lenses and laser vision correction.
Our innovation technology is combining a small portable laser device with nanoparticle eye-drops to enable vision correction. Briefly, proprietary software transforms prescription into a pattern that is imprinted onto the corneal epithelium, using ultra-fast eye-safe laser, which is then optically activated by eye-drops containing biocompatible nanoparticles.
Our product addresses a huge population of about half of the world population and a market projection to reach close to 94$ billion by 2027.

We are interested in exploring potential collaboration with companies that has expertise in laser technologies for co-development and/or laser manufacture.

Contact:
Dr. David Smadja, CEO NanoDrops
smadj.david@gmail.com
Tel: 548855850 972+

Nemo

Nemo Nano Materials - A New Set of Material Toolbox for the Industry

Jonathan Antebi

Nemo Nano materials develops and manufactures well dispersed concentrates based on Single Walled Carbon Nano Tubes. Nemo's materials are ready-to use solution on existing industrial equipment enabling new set of properties like lightweight Carbon based EMI shielding in plastics, thermal management and more.

jonathan@nemonano.com
2260515-052

Session: Nonlinear Optics - Prof. Haim Suchowski

Invited speaker |

Efficient Parametric Amplification via Hybridized Nonlinear Optics

Prof. Jeffrey Moses
Cornell University, USA, School of Applied & Engineering Physics

The efficiency of optical parametric amplification (OPA) is fundamentally limited by its cyclic evolution behavior, which creates inefficient, asynchronous spatiotemporal conversion due to the local dependence of the conversion cycle on the field intensity. For Gaussian beam and pulse shapes, the pump photon depletion efficiency is typically only 10-30%, with only 1-20% of the pump energy going to the signal. This longstanding limitation to OPA efficiency dramatically raises the cost of entry for research involving high power and ultrafast lasers.

Using a new approach of hybridized nonlinear parametric processes in an ordinary OPA crystal using birefringent phase matching, we have achieved a mid-infrared parametric amplifier with 44% pump-to-signal conversion efficiency and with a high single-stage gain of 48 dB. Our method uses simultaneously phase matched OPA and second harmonic generation (SHG) phase matched at the idler wavelength to enhance the signal conversion efficiency via suppressed back-conversion while preserving the idler energy in a coherent copropagating field at twice its frequency. This "hybridized parametric amplification (HPA)" approach is a promising efficient alternative to ordinary OPA.

In addition to an experimental demonstration of the hybridized parametric amplifier, we will present a theoretical explanation and an experimental verification of the underlying wave evolution dynamics, which can be theoretically described using a damped Duffing oscillator model where the idler SHG process, acting like an effective loss channel, induces a damped behavior in the OPA dynamics [Flemens, et al., Opt. Express 29, 30590 (2021)]. This phenomenon may be further described in the language of non-Hermitian physics, in which idler SHG may be seen as mimicking the action of an incoherent heat bath, providing an effective evolving loss channel (despite no real loss) that creates exceptional points and PT-symmetry breaking in a sub-system of the four-wave nonlinear system [Flemens, et al., Phys. Rev. Lett. 129, 153901 (2022)].

Soliton Pair Dynamical Transition in Mode-Locked Lasers

Kfir Sulimany, Offek Tziperman, Yaron BrombergOmri Gat

Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem, 91904 Israel 1 Co-first authors with equal contribution

The self-assembly of solitons into nonlinear superpositions of multiple solitons plays a key role in the complex dynamics of mode-locked lasers [1-2]. These states are extensively studied in light of their potential technological applications and their resemblance to molecules that offers new opportunities for studying molecular interactions. However, progress along these endeavors is still held back by the lack of effective means to manipulate multi-soliton waveforms. Here, we show it is possible to control inter-soliton interactions in a mode-locked fiber laser, (Panel a) using a single control knob, the laser gain [3]. We experimentally demonstrate a two-orders-ofmagnitude reduction in the separation of bound soliton pairs by sweeping the pumping current of the laser (c). The sweep induces a dynamical transition between a loosely, phase-incoherent bound state, and a tightly, phase-locked bound state, as indicated by the fringes that appear in the spectrum (d). Fig 1. (a) Illustration of the dynamical transition.

(b) The mode-locked laser mode locked by nonlinear multimode interference based saturable absorber. Experimental soliton pair dynamical transition in time (c) and spectral (d) domain. Using numerical simulations and a simplified analytical model we find that the dynamical transition is governed by noise-mediated interactions [4-5], which can be switched between repulsion and attraction. The discovery of a single control parameter that sets the nature of the inter-soliton interaction points to new possibilities for controlling multi-soliton states for optical communication systems and pump-probe spectroscopy.

References

[1] Nimmesgern, Luca, et al. "Soliton molecules in femtosecond fiber lasers: universal binding mechanism and direct electronic control." Optica 8.10 (2021): 1334- 1339.
[2] Liu, Shilong, et al. "On-demand harnessing of photonic soliton molecules." Optica 9.2 (2022): 240-250.
[3] Sulimany, Kfir, et al. "Soliton-pair dynamical transition in mode-locked lasers." arXiv preprint arXiv:2112.07136 (2021). Accepted Optica.
[4] Sulimany, Kfir, et al. "Bidirectional soliton rain dynamics induced by casimir-like interactions in a graphene mode-locked fiber laser." Physical review letters 121.13 (2018): 133902.
[5] Weill, Rafi, et al. "Noise-mediated Casimir-like pulse interaction mechanism in lasers." Optica 3.2 (2016): 189-192.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Monday, December 12 | Parallel Session 2 | 14:15 - 15:45

Co-located Two-Photon Absorption and AFM Imaging of CsPbBr3 Thin Films

Bharathi Rajeswaran, Shalom Avadyayev, and Prof. Yaakov R. Tischler*

Department of Chemistry and Bar-Ilan Institute for Nanotechnology and Advanced Materials, Bar-Ilan University, Ramat-Gan, Israel, 52900

Perovskite halides are promising materials for various light-harvesting and light-emitting applications. Recently nonlinear absorption coefficients and refractive indices have been reported, rendering these materials useful for non-linear photonics1,2. Two-Photon Absorption (TPA) is a non-linear optical process in which the simultaneous absorption of two photons takes place in order to promote a molecule from its ground state to excited state3,4. Because there is a simultaneous absorption of two photons, the probability of such a process is proportional to the square of the light intensity. Two-Photon Emission (TPE) is the follow-on process whereby a molecule or material that has been excited via TPA, then fluoresces light. Combining TPE with AFM can help spectroscopically identify materials such as halide perovksites, provided the TPE signal is tip-enhanced, leading to TPE signals with a greatly improved spatial resolution - on the order of the tip-diameter. To the best of our knowledge, here we show for the first time that AFM can also be combined with the TPA spectroscopy technique, to achieve co-located topographic information and we present preliminary evidence for a simultaneous tip-enhancement. In this work, TPA and TPE measurements were carried out using a fsec laser with a central wavelength of 1028 nm. The TPA was generated in a transmission geometry using a tuning-fork based AFM from Nanonics (Jerusalem, Israel) that was situated between upright and inverted microscopes. We developed different approaches to observe the tip-enhancement.

We then used co-located TPA and TPE spectroscopy to map the optical and topographic properties of thin films of CsPbBr3 perovskites. We observe strong TPE and TPA in the CsPbBr3 films. Indeed, the CsPbBr3 perovskite has a prominent excitonic absorption peak centered at a wavelength of 520 nm, which is nearly in "2-photon resonance" with the fsec pulsed excitation. We use a balanced detection scheme with a boxcar integrator to measure differential absorption. We also use an ultra-fast detector to measure TPE. The variation of the TPE signal was measured at different powers for different laser repetition rates. With this technique, we have the scope to characterize the CsPbBr3 films and identify changes in the optical properties at the nanoscale grain boundaries.

References

1 The importance of relativistic effects on two-photon absorption spectra in metal halide perovskites, Nature Communications | (2019) 10:5342.
2 Visualizing Buried Local Carrier Diffusion in Halide Perovskite Crystals via Two-Photon Microscopy, ACS Energy Lett. 2020, 5, 1, 117-123.
3 M. Rumi and J. W. Perry, Adv. Opt. Photonics, 2010, 2, 451.
4 C. Lee, B. G. Jeong, S. J. Yun, Y. H. Lee, S. M. Lee and M. S. Jeong, ACS Nano, 2018, 12, 9982-9990.

Interaction-based Nonlinear Optics

Dr. Avi Niv
Ben-Gurion University of the Negev, Beer-Sheva, Israel

We show small-scale opportunities in nonlinear optics without a large-scale counterpart. Accordingly, we study nonlinear optics from deep subwavelength-sized domains with a predominantly linear response. We will show that these domains produce substantial nonlinear optical activity. Comparing our experimental findings to theory, we conclude that the observed nonlinearity is not a material property but emerges from electrostatic interaction between oscillating charges. We propose a simple coupled oscillator model that captures the salient features of this interaction-based nonlinearity. We then use this model to explore parameter regimes outside our experimental reach, including intensified nonlinear response due to resonance excitation and the possibility of chaos.

Direct time-of-flight Distributed Analysis of Nonlinear Forward Scattering

K. Sharma, E. Zehavi, H. H. Diamandi, G. Bashan, Y. London, Mr. Alon Bernstein, and A. Zadok (Corresponding author)
Faculty of Engineering and Institute for Nano-Technology and Advanced Materials, Bar-Ilan University, Ramat-Gan 5290002, Israel

Optical fibers constitute an excellent platform for spatially distributed sensing. However, the analysis of media outside the fiber is fundamentally challenging, as light is confined in the core and does not reach a substance under test. A solution is possible through forward stimulated Brillouin scattering (F-SBS) [1]: modulated light in the core stimulates guided acoustic waves through electro-striction. The transverse profiles of the acoustic waves span the entire cross-section of the fiber, and they interact with the boundary of the cladding and coating. The monitoring of photoelastic scattering by the acoustic waves supports the analysis of media outside the fiber. Spatially distributed analysis of F-SBS faces, however, yet another inherent difficulty: The locations of scattering contributions in the forward direction may not be simply identified using time-of-flight considerations. Previous protocols were based on the indirect mapping of auxiliary backscattering mechanisms [2,3]. Here we propose and demonstrate for the first time the direct, spatially distributed mapping of forward scattering spectra [4]. Acoustic modes of a polarization maintaining (PM) fiber are stimulated by two pulsed pumps, one in each principal axis. The acoustic waves switch a counter-propagating optical probe from one principal axis to the other. Measurements of the switched component as a function of time of arrival directly retrieves the local spectra of forward scattering. Measurements distinguish between dissimilar PM fiber connected in series and identify the local immersion of a coated fiber section in liquid [4]. The measurement range was 1.1 km, with a spatial resolution of 60 meters.

References

[1] Y. Antman, et al., Optica 3, 510-516 (2016).
[2] D. Chow et al., Nature Commun. 9, 2990 (2018).
[3] G. Bashan et al., Nature Commun. 9, 2991 (2018).
[4] K. Sharma et al., Optica 9, 419-428 (2022).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Monday, December 12 | Parallel Session 2 | 14:15 - 15:45

Nanoscale Inverse Design of Strongly Coupled, Plexcitonic Metasurfaces for Linear and Broadband Nonlinear Interaction

Y. Blechman[1], S.Tsesses[1], M. Feinstein[2,3], G.Bartal[1] and E.Almeida[2,3]

1 *Andrew and Erna Viterbi Department of Electrical Engineering, Technion - Israel Institute of Technology, Haifa 32000, Israel*
2 *Department of Physics, Queens College, City University of New York, Flushing, New York 11367, USA*
3 *The Graduate Center of the City University of New York, New York, New York 10016, USA*

Room-temperature strong coupling between plasmonic nanocavities and monolayer semiconductors is a prominent path towards efficient, versatile, and integrated devices. However, designing such systems for optimal subwavelength interaction is challenging. In this work, we provide a general methodology for obtaining strongly-coupled hybrid metasurfaces consisting of plasmonic nanocavities coupled to atomically thin semiconductor layers, achieving extreme values of Rabi splitting, by inverse design of the near-field plasmonic response. Our method obtains plasmonic hot-spots matching the excitonic emitter material in terms of spatial location and dipole polarization, by developing a novel figure of merit (FOM), and employing genetic algorithm optimization on a very large parameter space describing all the possible structures. We experimentally demonstrate large values of Rabi splitting in a nanoantenna design, while exhibiting theoretically optimal configurations for additional types of nanostructures.

We next apply our method for designing hybrid strongly coupled plexcitonic meta-surfaces which support a parametric nonlinearity at the excitonic frequency. Our simple yet powerful strategy enables to greatly enhance the nonlinear signal, its magnitude mainly determined by the Rabi splitting, while making the response robust to geometrical variations of the metasurface. Furthermore, the large Rabi splitting attained by these hybrid structures enables broadband operation over the frequencies of the hybridized modes.

Our results provide a significant step toward maximizing light-matter interactions in integrated platforms, achieving flexible linear and nonlinear control, which can benefit classical and quantum-optical applications in nonlinear frequency conversion, all-optical switching, and phasecontrolled nonlinear metasurfaces.

References

[1] Blechman, Y.; Tsesses, S.; Feinstein, M.; Bartal, G.; Almeida, E. Room-Temperature Strong Coupling at the Nanoscale Achieved by Inverse Design. arXiv:2203.14151.
[2] Blechman, Y.; Tsesses, S.; Bartal, G.; Almeida, E. Inverse Design of Broadband, Strongly-Coupled Plexcitonic Nonlinear Metasurfaces. New J. Phys. 2022, 24 (9), 095003.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session: Optics in Medicine and Biology - Prof. Dror Fixler

Invited speaker |

Nanoparticles and Cells - Making use of Different Microscopy Techniques

Prof. Wolfgang Parak
Universität Hamburg, Hamburg, Germany

The interaction of colloids with biology, in particular their endocytosis by cells and the formation of the protein corona can be studied with several optical techniques, including optical microscopy, flow cytometry, and fluorescence correlation spectroscopy. However, as scattering of light imposes limitations on these techniques non-optical methodologies would be helpful. A discussion about some of those methodologies and comparison to their optical counterparts will be made.

Invited speaker |

Gold Quantum Dots-Transition Metal Dichalcogenides Composite Material for Photonic-sensing

Prof. Mustafa Yavuz
Nano and Micro Systems Lab-Waterloo Institute for Nanotechnology-University of Waterloo, Ontario Canada

Two-dimensional (2D) materials have attracted researchers' attention since the discovery of graphene. 2D TMDs are one of the most promising materials in this area due to their unique properties, such as comparatively high electron mobility, photoluminescence, mechanical strength, and flexibility. On the other hand, TMDs are hard to work with in certain photonic applications in visible spectra. Functionalizing TMDs with noble plasmonic materials, such as gold, has been demonstrated1,2 to have a great potential to enhance their photonic properties in visible spectrum (VIS) for sensing applications.

Invited speaker |

Multimodal MRI and life-time fluorescence sensors for theranostic applications

A.P. Savitsky[1], I.D. Soloviev[1], I.G. Meerovich[1], I.E. Granovsky[1], N.K. Marynich[1], D.K. Tuchina[2], A. B. Konovalov[1], V.V. Vlasov[1], VV. Tuchin[2]
1 Research Center of Biotechnology of the RAS, Moscow, Russia
2 Saratov State University, Saratov, Russia

With the advancement of nanotechnology, it is possible to tailor nanoparticles (NPs) with responsive conjugation and activatable probes, that can only respond to specific biological stimuli, enzymes or microenvironments. Both the GNPs and FRET-sensors based on red fluorescent proteins are now well established with their advantages in optical imaging. Thus, we prepare a FP-based FRET-sensors and GNP-FRET-sensors nanohybrids by different chemical methods and to evaluate these new probes for FLIM. For obtaining nanosensors based on GNP and FP-based FRET pair we use the (strept)avidin-biotin interactions. To obtain biotinylated FRET pair, we genetically engineered production of biotinylated FRET pair fused to peptide with site of biotinylation in E.coli strain overexpressing biotin ligase. One of the problems of optical fluorescence tomography when observing labeled objects in vivo is the binding of a fluorescence image to the anatomy and morphology of an organism. Determining the parameters of the fluorescent signal makes it possible to judge the molecular events that occur with the label. At the same time, magnetic resonance imaging (MRI) makes it possible to obtain high-resolution images of the structure of the living object under study. With the development of MRI instrumentation, relatively affordable MRI tomographs based on permanent magnets have appeared, having a resolution of tenths of millimeters and requiring lower costs to maintain their operation compared to devices based on superconducting magnets. The combination of magnetic resonance and fluorescence imaging will make it possible to link molecular events to their location in the body and use them for new preclinical studies. In this work, a fiber probe was prototyped for simultaneous registration of MRI and a fluorescent signal for optical reconstruction of the luminescence region.

Authors are thankful for support to:
Russian Foundation for Basic Research, grant No. 19-54-06008 MNTIa (Russia-Israel)

Monday, December 12 | Parallel Session 2 | 14:15 - 15:45

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Spatiotemporal Sensing and Imaging using Fluorescent Single- Walled Carbon Nanotubes for Biomedical Applications

Dr. Gili Bisker
Tel Aviv University, Tel Aviv, Israel

Single-walled carbon nanotubes (SWCNTs) have unique optical and physical properties, and they benefit from the ease of surface functionalization and biocompatibility1. Semiconducting SWCNTs fluoresce in the near-infrared (nIR) part of the spectrum, which overlaps with the transparency window of biological samples where absorption, scattering, and autofluorescence are reduced. Further, they do not photobleach or blink2. Upon tailored surface functionalization, adsorption of target analytes onto the nanotube corona can result in spectral modulations manifested as either an intensity change or a shift in the peak emission wavelength. Hence, SWCNTs can be used as nIR optical probes for imaging and sensing in biological samples enabling real-time optical detection with both spatial and temporal resolution3-5. I will present recent demonstrations of real-time feedback on insulin secretion by beta-cells using SWCNT sensors6, real-time monitoring of enzymatic activity7,8, and in vivo imaging of fluorescent SWCNT within nematodes9. Moreover, I will describe the development of SWCNTs functionalized by melanin-inspired material, obtained by enzymatic oxidative polymerization of a fluorenylmethyloxycarbonyl-tyrosine (FmocY) precursor10. The resulting multicomponent system (SWCNT-FmocYOx) serves as a metal-ion scavenging platform that concurrently reports on metal binding with optical signal transduction. Finally, I will present a novel platform for incorporating near-infrared fluorescent SWCNTs into Fmoc-diphenylalanine hydrogels as fluorescent probes, reporting in real-time on the morphology and time-dependent structural changes of the self-assembled hydrogels in the transparency window of biological tissue11. These results open new avenues for imaging and sensing in complex biological systems and hold great promise for biomedical applications.

References

(1) Hendler-Neumark, A.; Bisker, G. Fluorescent Single-Walled Carbon Nanotubes for Protein Detection. Sensors 2019, 19 (24), 5403. (2) Iverson, N. M.; Bisker, G.; Farias, E.; Ivanov, V.; Ahn, J.; Wogan, G. N.; Strano, M. S. Quantitative Tissue Spectroscopy of Near Infrared Fluorescent Nanosensor Implants. J. Biomed. Nanotechnol. 2016, 12 (5), 1035-1047. (3) Bisker, G.; Dong, J.; Park, H. D.; Iverson, N. M.; Ahn, J.; Nelson, J. T.; Landry, M. P.; Kruss, S.; Strano, M. S. Protein-Targeted Corona Phase Molecular Recognition. Nat. Commun. 2016, 7 (1), 10241. (4) Bisker, G.; Bakh, N. A.; Lee, M. A.; Ahn, J.; Park, M.; O'Connell, E. B.; Iverson, N. M.; Strano, M. S. Insulin Detection Using a Corona Phase Molecular Recognition Site on Single-Walled Carbon Nanotubes. ACS Sensors 2018, 3 (2), 367-377. (5) Shumeiko, V.; Zaken, Y.; Hidas, G.; Paltiel, Y.; Bisker, G.; Shoseyov, O. PeptideEncapsulated Single-Wall Carbon Nanotube-Based near-Infrared Optical Nose for Bacteria Detection and Classification. IEEE Sens. J. 2022, 1-1. (6) Ehrlich, R.; Hendler-Neumark, A.; Wulf, V.; Amir, D.; Bisker, G. Optical Nanosensors for Real-Time Feedback on Insulin Secretion by B-Cells. Small 2021, 17 (30), 2101660. (7) Wulf, V.; Slor, G.; Rathee, P.; Amir, R. J.; Bisker, G. Dendron-Polymer Hybrids as Tailorable Responsive Coronae of Single-Walled Carbon Nanotubes. ACS Nano 2021, 15 (12), 20539-20549. (8) Loewenthal, D.; Kamber, D.; Bisker, G. Monitoring the Activity and Inhibition of Cholinesterase Enzymes Using Single-Walled Carbon Nanotube Fluorescent Sensors. Anal. Chem. 2022, 94 (41), 14223-14231. (9) Hendler-Neumark, A.; Wulf, V.; Bisker, G. In Vivo Imaging of Fluorescent SingleWalled Carbon Nanotubes within C. Elegans Nematodes in the near-Infrared Window. Mater. Today Bio 2021, 12 (November), 100175. (10) Wulf, V.; Bichachi, E.; Hendler-Neumark, A.; Massarano, T.; Leshem, A. B.; Lampel, A.; Bisker, G. Multicomponent System of Single-Walled Carbon Nanotubes Functionalized with a Melanin-Inspired Material for Optical Detection and Scavenging of Metals. Adv. Funct. Mater. 2022, 2209688. (11) Wulf, V.; Bisker, G. Single-Walled Carbon Nanotubes as Fluorescent Probes for Monitoring the Self-Assembly and Morphology of Peptide/Polymer Hybrid Hydrogels. Nano Lett. 2022

Automatic Detection and Evaluation of Nasal Airway Obstruction in CT Scans of Newborns

Dr. Talia Yeshua[1], Yoav Ben-Haim[1], Eliyahu Nezri[1], Shlomo Grinzaig[1], Yehuda Schwarz[2], Eliel Ben-David[3,4]

1 *Department of Applied Physics/Electro-Optics Engineering, The Jerusalem Collage of Technology, Jerusalem, Israel*
2 *Department of Otorhinolaryngology, Head and Neck Surgery, Shaare Zedek medical center, Jerusalem, Israel*
3 *Department of Radiology, Shaare Zedek medical center, Jerusalem, Israel*
4 *Faculty of Medicine, Hebrew University Jerusalem, Jerusalem, Israel*

Introduction: Nasal airway patency is vital for normal breathing in neonates. Currently airway evaluation does not always provide objective information for assessing the presence, location and severity of nasal airway obstruction.

Background: Airway evaluation is based on clinical examination and on CT imaging. However, it does not provide quantitative parameters for determining the required medical or surgical intervention in obstructed cases.

Objectives: Develop an algorithm for automatic segmentation of the nasal airway in CT examinations of neonates to detect obstructions and define locations of low airflow.

Methods: Twenty-five anonymized CT scans of neonates aged 2-30 days were analyzed. Ten neonates suffered from congenital nasal obstruction. The algorithm automatically found the nasal airway region and applied global and local thresholds for segmenting the nasal airway. Then, the algorithm distinguished between connected and disconnected nasal airway regions and calculated the volume and the surface area of the connected nasal airway regions and the volume of the disconnected regions. The algorithm calculated the airway areas in successive coronal slices to detect the location of narrowed regions. Finally, the algorithm reconstructed a 3D model of the nasal airway for airflow simulations.

Results: The 3D segmentation results of the nasal airway were highly accurate, as confirmed by expert radiologist and clinician. In the obstructed cases, the average volume of the disconnected airway regions was higher by 340% from that in the normal cases ($P<0.01$). The average surface area and the volume of the connected airway regions were lower in the obstructed cases by 33% and 25%, respectively ($P<0.05$ for both).

Conclusions: The parameters provided by the algorithm indicate its potential use for early detection and evaluation of congenital obstruction, using CT imaging. Future simulation of the nasal airflow in the segmented airway will provide information regarding the local velocity and pressure drop.

Session: Quantum Computers - Prof. Nadav Katz

Invited speaker |

Photonic Fault-Tolerant Quantum Computing, and how Single Atoms can Drastically Simplify it

Prof. Barak Dayan
Dan Lebas & Ruth Sonnewend Professorial; Chair of Physics, Weizmann Quantum Optics Group
Weizmann Institute of Science, Rehovot, Israel

The photonic effort is one of the leading candidates for universal quantum computing. In particular, it is the only technology that has been originally designed to reach the massive scaling required for fault-tolerant universal quantum computation (> million physical qubits).

In my talk I will describe the photonic approach, which combines topological error correction and measurement-based quantum computation.

I will then describe how cavity-QED with single atoms can drastically simplify this effort, solve its main bottleneck, and improve its scaling to even larger numbers of physical qubits.

References

[1] Fusion-based quantum computation: arXiv:2101.09310 [quant-ph]
[2] Photon-Atom Qubit SWAP gate: Nature Physics 14 996 (2018)

Increasing Communication Rates Using Photonic Hyperentangled States

Liat Nemirovsky-Levy[1], Uzi Pereg[2] and Mordechai Segev[1,2]
1 Physics Department and Solid-State Institute, Technion, Israel
2 Department of Electrical Engineering, Technion, Israel

Introduction: We propose a technique for increasing transmission rate of quantum communication channels, by multiplexing spin and orbital angular momentum (OAM) states on a single photon, transmitting the photon, and demultiplexing them to different photons. Background and **Objectives:** Entanglement is a fundamental resource in quantum communication protocols, where photons are an optimal carrier of information, given their resilience to decoherence and ease of creation and transportation. Due to the ever-increasing demand for highcapacity communication, hyperentangled states are an excellent platform for various quantum communication protocols, as it allows to encode a greater amount of information in a single physical photon. Here, we present a scheme for transmitting qubits at a higher rate by multiplexing N qubits on a single photon via a quantum teleportation protocol, transmitting the single photon, and eventually demultiplexing the quantum information to N photons each carrying a single qubit, where the information can be processed in parallel exploiting the nonlocality of quantum information processing.

Methods and Results: For our protocol, we use quantum teleportation. Our scheme has two parts: a multiplexing part, where we teleport the spin and the OAM of two separate photonsto a single photon (using hyperentangled states); and a demultiplexing part- where we teleport again the spin and OAM from the single photon to separate photons. After the multiplexing part, the single photon can be transmitted to a desired destination, where the information can be demultiplexed into multiple, separate photons. The transmission is over a single communication channel - a transmission of a single photon carrying two qubits, which doubles the quantum transmission rate. This technique can serve also for generating non-local entanglement at twice the rate.

Conclusions: Our setting paves the way towards quantum communication with a higher transmission rate, more efficient entanglement generation, and refined control over scalable quantum technologies

Erasure Qubits: Overcoming the T1 Limit in Superconducting Circuits

Aleksander Kubica, Arbel Haim, Yotam Vaknin, Fernando Brandao and Prof. Alex Retzker
The Hebrew University of Jerusalem

We address a question of leveraging the noise bias to simplify quantum error correction (QEC) protocols and improve their performance. We focus on the previously unexplored bias between the amplitude damping and dephasing errors that is fundamental to many quantum technologies. We propose a simple scheme to convert amplitude damping errors into erasure errors. Despite its simplicity, our scheme significantly improves the performance of QEC protocols. Importantly, we provide two concrete realizations with superconducting circuits, analyzing their performance both from the analytical and numerical perspective. Our results provide a breakthrough shift in the current architecture paradigm. Namely, they suggest that engineering efforts should focus on improving the dephasing and the quality of quantum coherent control, as they effectively limit the performance of fault-tolerant protocols.

Creation of Optical Cat and GKP States Using Shaped Free Electrons

Mr. Raphael Dahan[†1], Gefen Baranes[†1], Alexey Gorlach[1], Ron Ruimy[1], Nicholas Rivera[2] and Ido Kaminer[*1]

1 Technion - Israel Institute of Technology, Haifa 32000, Israel
2 Massachusetts Institute of Technology, Cambridge MA 02139, USA
† equal contributors

Introduction: Cat states and Gottesman-Kitaev-Preskill (GKP) states play a key role in quantum computation and communication with continuous variables. The creation of such states relies on strong nonlinear light-matter interactions, which are widely available in microwave frequencies as in circuit quantum electrodynamics platforms. However, strong nonlinearities are hard to come by in optical frequencies, severely limiting the use of continuous variable quantum information in the optical range.

Results: Here we propose using the strong interactions of free electrons with light as a source for optical cat and GKP states. The strong interactions can be realized by phase-matching of free electrons with photonic structures such as optical waveguides and photonic crystals. Our approach enables the generation of optical GKP states with above 10 dB squeezing and fidelities above 90% at post-selection probability of 10%, even reaching >30% using an initially squeezed vacuum state. We analyze the different factors that affect the fidelity, such as electron dispersion, inhomogeneity, non-ideal interaction, and limited detection efficiency. Furthermore, the free-electron interaction implements a conditional displacement on the photonic state, enabling to entangle a pair of GKP states into a GKP Bell state.

Conclusions: Since electrons can interact resonantly with light across the electromagnetic spectrum, our approach could be envisioned for the generation of cat and GKP states over the entire electromagnetic spectrum, from radio-waves to X-rays.

Fast Entanglement of Weakly Interacting Harmonic Oscillators with Superconducting Qubits for Bosonic Encoded Quantum Computation

Mr. Asaf Diringer, Eliya Blumenthal, Shay Hacohen-Gourgy
Technion - Israel Institute of Technology, Haifa, Israel

Bosonic encoding is a relatively nascent path to quantum computation in circuit QED. Dispersively coupling multiple Bosonic modes to a single superconducting ancilla qubit can be used to create entanglement between the bosonic modes. Typically these schemes use a large coupling of the bosonic modes to the ancilla for fast operation, however, this creates undesired anharmonicity in the form of Kerr nonlinearities, which degrade performance.

We use a symmetry-inspired approach for fast displacement gates conditioned on the state of the qubit, and utilize this to produce and measure both entangled and disentangled cat states in a multi-mode cavity weakly coupled to a single transmon qubit. Even though the typical coherence times of our setup are of the same order of magnitude as the coupling strength, through our control scheme we are able to measure a violation of CHSH inequality with an entanglement witness value of ~ 84%.

Session: Micro and Nano Optics - Prof. Alina Karabchevsky

Invited speaker |

Optoelectronic Cardiac Biointerfaces

Prof. Igor Efimov
Professor of Biomedical Engineering, Professor of Medicine, Northwestern University

Heart failure is a global pandemic afflicting over 60 million people worldwide. Myocardial infarction, valve disease, genetic mutations, numerous infections, including COVID-19, and cancer therapies are among the leading causes of heart failure. Sudden cardiac death caused by arrhythmia is often the immediate cause of death in patients with cardiac pathology. Arrhythmias are the manifestations of disrupted generation and/or propagation of electrical impulses, known as action potentials, which synchronize normal mechanical contraction in the heart muscle. Electrocardiography and optocardiography have emerged as the leading methods for diagnosing and investigating normal and pathological cardiac electrophysiology. Electrical stimulation is the leading modality of arrhythmia therapies delivered by implantable, interventional, or external (transthoracic) stimulators and defibrillators. Recently, the development of optogenetics presented an opportunity for optical stimulation of the heart, expressing optically switchable ion channels. The development of novel approaches to cardiac biointerfaces combining optical and electrical sensing and actuation is needed to advance therapies for heart diseases.

Toward this goal, we have recently developed a novel platform for optoelectronic biointerfaces, which possesses the following properties: (1) flexible and stretchable electronics which allow seamless mechanical coupling with soft contracting cardiac tissue; (2) electrical sensing and stimulation; (3) optical sensing and stimulation; (4) sensing of many physiological parameters: temperature, pH, strain, etc.; (5) wireless coupling into networks of implantable and wearable devices; (6) neuromorphic distributed signal processing for real-time diagnosis and therapy of arrhythmias. In addition, we have developed a platform for transient electronics, which is needed for temporary diagnostics and heart disease therapy.

We have tested novel implantable optoelectronic devices in small animal models of cardiac arrhythmias. A mouse model of the atrioventricular block was used to test an implantable flexible and stretchable battery-free pacemaker, including permanent and transient pacemakers. We demonstrated the efficacy and safety of the developed devices driven by inductive power transferred from an external circuit embedded into the animal's cage. We also showed the safe dissolution of a transient pacemaker after one week of pacing the heart without evidence of inflammation or significant fibrosis. A rat model was used to test a large surface implantable device for optical and electrical sensing, machine learning diagnostics, and real-time treatment of life-threatening arrhythmias with low-energy stimuli.

Conclusions: we have developed novel biointerfaces for optoelectrical sensing and control o
f cardiac physiology, which can be used for future real-time diagnostics and therapy of sudden cardiac death. We validated this technology in rodent models of heart disease.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Invited speaker |

High-index Chalcogenides for Static and Active Mie-resonant Metaoptics

Dr. Tomer Lewi

Faculty of Engineering and Institute for Nanotechnology and Advanced Materials (BINA), Bar Ilan University, Ramat-Gan, Israel

In nanophotonic, small mode volume and high-quality factor (Q-factor) resonances fundamentally scales with high refractive index values. Chalcogenides are excellent candidates for implementing nanophotonic and metasurface devices as they can possess ultra-high permittivities and support large modulation of optical constants through various mechanisms such as, phase-change, photon-darkening, and anomalous thermo-optic effects. In this talk, I will present our latest results on various chalcogenide compositions that are used for static and active meta-optic devices, including deep-subwavelength ultra-high index topological insulator metasurfaces with unit cell sizes <λ/10, thermo-optically reconfigurable resonators, and temperature invariant meta-optic devices.

High-Index Deep-Subwavelength Topological Insulator Metastructures for Mid-Infrared Photonics

Dr. Sukanta Nandi[1,2], Danveer Singh[1,2], Shany Z. Cohen[1,2], Pilkhaz Nanikashvili[1,2], Doron Naveh[1,2]and Tomer Lewi[1,2]

1 *Faculty of Engineering, Bar-Ilan University, Ramat-Gan 5290002, Israel*
2 *Institute of Nanotechnology and Advanced Materials, Bar-Ilan University Ramat-Gan 5290002, Israel*

Introduction and Background: In nanophotonics, light-matter interaction is strongly determined by the optical constants of a material. This has led to the quest for search of materials beyond silicon (Si). One such promising class of materials are the chalcogenides, that have demonstrated better static and dynamic operations compared to Si. Particularly, chalcogenide topological insulators (TIs), with insulating bulk and topologically protected dissipationless metallic surface states have emerged to be interesting systems for designing novel nanophotonic components.

Objectives: To study the mid-infrared (MIR) optical characteristics, in both the far and near-field, of two well-known topological insulators, Bismuth selenide (Bi2Se3) and Bismuth telluride (Bi2Te3).

Methods: The far-field Fourier-transform infrared spectroscopy (FTIR), in reflection mode, was carried out using a FTIR spectrometer coupled to an IR microscope. Near-field nanospectroscopy was performed using s-SNOM (scattering-type Scanning Near-field Optical Microscopy), coupled to a broadband IR laser source.

Results: Far-field measurements revealed extremely large MIR optical constants of this family (n~6 & 11, respectively for Bi2Se3 & Bi2Te3), arising from the contribution of both surface and bulk states. Single particle microspectroscopy of Bi2Se3 nanobeams (NBs) demonstrated MIR resonances with unpolarized extinction spectra being decomposed of distinct TE and TM polarized resonant responses.

Furthermore, nanospectroscopy of these beams, enabled by the s-SNOM provided both amplitude and phase information of z-polarized resonant modes. A 2π phase shift across the resonance was experimentally demonstrated for these NBs, coupled to gold substrate. The other part of work demonstrates Mie-resonances in deep subwavelength Bi2Te3 metasurfaces (d/λ <10) with extremely large electromagnetic field enhancements in between closely spaced resonators. Finite-Difference Time-Domain simulations further supported the experimental findings of these works, demonstrating a good match.

Conclusions: Deep subwavelength resonant metaphotonics enabled by high-index TI was demonstrated and studied. Among various applications, these metastructures are ideal for polarization sensitive MIR detectors and chemical/biological sensing.

Monday, December 12 | Parallel Session 3 | 16:15 - 17:45

Explosives Detection using SERS Substrate Based on 3D Plasmonic Hot Spots network

Neetika Singh†, Anand M. Shrivastav†, Nipun Vashistha and Prof. Ibrahim Abdulhalim*

Department of Electro-optics and Photonics Engineering, School of Electrical and Computer Engineering and The Ilse-Katz Institute for Nano-scale Science and Technology, Ben Gurion University, Beer Sheva, 84105, Israel

*† Equal contribution * Corresponding Author*

Microporous deep (12µm depth) silicon substrate coated with optimum Au layer is fabricated for ultrahigh SERS enhancement factor and employed for explosives trace detection. Being microporous with quasi-periodicity, short lived extended plasmons can be excited via scattering and coupled to localised ones thus providing ultrahigh local optical field, thus SERS ultrahigh enhancement is achieved. SERS activity of the substrate is checked using 4-ATP monolayer immobilized over the proposed substrate and analysed using two different methods including peak absolute intensity and peak ratios, to find best suitable method for higher reproducibility. The obtained enhancement factor for Raman signal is found to be the order of 106 -107, explained due to the existence of 3D hot-spot network and coupling between localized to extended plasmons. The coupling is verified through the Rabi splitting observed in the reflectivity dip. A 2-3 times fewer signal variability is obtained using peak ratio between highest peak intensity of Raman receptor and that of the substrate. The substrate is then employed for picric acid sensing providing the detection limits of 7.48 nM and 2.87 nM, determined based on peaks height and ratio measurements respectively. The proposed work suggests deep micro-porous silicon coated with 200nm Au layer deposited over a large area as promising candidate for SERS and sensing of ultratrace amount of chemicals.

Keywords: SERS, Porous Silicon, Explosive detection, SPR-LSPR coupling, chemical sensing

Acknowledgements: This research is performed within the project titled "Nanomaterials for explosive traces detection with SERS" (NOOSE), funded by NATO Science for Peace and Security Programme under contract number MYP G5814. The project is partially funded from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 872662.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Monday, December 12 | Parallel Session 3 | 16:15 - 17:45

Spin-Valley Rashba Monolayer Laser

Dr. Kexiu Rong[1], Xiaoyang Duan[1], Bo Wang[2], Dror Reichenberg[1], Assael Cohen[3], Chieh-li Liu[1], Pranab K. Mohapatra[3], Avinash Patsha[3], Vladi Gorovoy[1], Subhrajit Mukherjee[1], Vladimir Kleiner[1], Ariel Ismach[3], Elad Koren[1], and Erez Hasman[1]

1. *Technion - Israel Institute of Technology, Israel*
2. *Shanghai Jiao Tong University, China*
3. *Tel Aviv University, Israel*

Introduction: Light sources are indispensable components of optical systems. Specifically, miniaturized spin-optical light sources stand out due to great potentials in chiroptical studies and multidimensional optical communications by exploiting the additional spin degree of freedom. Moreover, these spin-empowered designs offer the opportunity to interface spin-optics and spintronics for an interchange of spin information between photons and electrons to construct advanced optoelectronic devices.

Background: Direct-bandgap transition metal dichalcogenide (TMD) monolayers are appealing candidates to construct atomic-scale spin-optical light sources owing to their unique valley-contrasting optical selection rules. However, previous works were restricted by low-Q propagating chiral modes, and only incoherent additions of valley excitons' spontaneous emission were achieved [1], imposing undesired limitations on applications requiring both high spatial and temporal coherence.

Objectives: Coherent manipulations of valley pseudospins in TMD monolayers by incorporating a WS2 monolayer into a heterostructure microcavity supporting high-Q spin-valley resonances.

Methods: Inspired by the creation of valley pseudospins in monolayers, the spin-valley modes are generated from a photonic Rashba-type spin splitting of a bound state in the continuum, which gives rise to opposite spin-polarized ±K valleys due to emergent photonic spin-orbit interaction under inversion symmetry breaking.

Results: The Rashba monolayer laser shows intrinsic spin polarizations, high spatial and temporal coherence, and inherent topological protection features, enabling valley coherence in the WS2 monolayer upon arbitrary pump polarizations at room temperature.

Conclusions: We envision the monolayer-integrated spin-valley microcavities as a multidimensional platform to study coherent spin-dependent phenomena in both classical (e.g., lasing, superfluorescence, nonlinearity, and polariton) and quantum (e.g., single-photon sources and entanglement sources) regimes, opening new horizons in fundamental research and optoelectronic devices exploiting both electron and photon spins.

Reference

[1] Rong, K. et al. Photonic Rashba effect from quantum emitters mediated by a Berry-phase defective photonic crystal. Nat. Nanotechnol. 15, 927-933 (2020).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Mycotoxins Raman Detection with Vertical Carbon Nanotubes

V. Shvalya[1], N. M. Santhosh[1], J. Zavašnik[1], M. Modic[1], N. Hojnik[1], I. Abdulhalim[2], Prof. Uros Cvelbar[1]

1 *Department of Gaseous Electronics, Jožef Stefan Institute, Jamova cesta 39, SI-1000 Ljubljana, Slovenia, EU*

2 *Department of Electrooptics and Photonics Engineering and the Ilse Katz Center for Nanoscale Science and Technology, School of Electrical and Computer Engineering, Ben-Gurion University of the Negev, Beer Sheba 84105, Israel*

Advanced carbon nanomaterials play a significant role in electronic devices, starting from the improvement of electrodes, batteries and supercapacitors [1] toward high-performing functional optical, electronic, and mechanical sensors design.[2] Carbon-related nanomaterials demonstrated a rising potential in developing plasmonic substrates due to their ultrafast electron-driven charge transfer properties. Secondly, carbon can form morphologies of various types and dimensionality (nanodots, nanowires, nanosheets, nanotubes, nanostructures) that can assist in optimising plasmonic hot-spots (nanovolume with confined electric field) population and their intensity across the material surface. In the present work, a catalyst-supported plasma-enhanced chemical vapour deposition approach was employed to design vertically aligned multiwalled carbon nanotubes with tunable length and diameter using CH4 gas precursor. Working within conditions of tip-growth mechanism, the substrates prepared with different plasma exposure time were deposited by a gold layer for plasmonic properties study.

SERS (surface-enhanced Raman spectroscopy) was tested and the best-performing morphology with enhancement factor (AEF = 5 × 107) was used to investigate vibrational spectra of fungi-originated toxic metabolites (fumonisin B1, zearalenone, alternariol and aflatoxin B1) operating at the nanogram analytes quantities. The spectra of mycotoxins were classified by data dimensionality reduction principal component analysis for analyte distinguishment puprosed. The findings observed during research reveal the high analytical capabilities of the nanotube's morphology on a flexible Ni foil surface. Finally, plasma-driven synthesis can be proposed as SERS chips design approach for advancing optical diagnostics of hazardous chemical species in agriculture and food-quality inspection industries.

References

[1] Chen, Z., Ye, S., Evans, S. D., Ge, Y., Zhu, Z., Tu, Y., & Yang, X. (2018). Confined assembly of hollow carbon spheres in carbonaceous nanotube: a spheres-in-tube carbon nanostructure with hierarchical porosity for high-performance supercapacitor. Small, 14(19), 1704015.

[2] Mendes, R. G., Wróbel, P. S., Bachmatiuk, A., Sun, J., Gemming, T., Liu, Z., & Rümmeli, M. H. (2018). Carbon nanostructures as a multi-functional platform for sensing applications. Chemosensors, 6(4), 60

Session: Ultrafast Phenomena - Dr. Marcus Gilad

Invited speaker |

Nanoscale Control of Extreme Ultraviolet Light

Prof. Giulio Vampa

National Research Council of Canada

Extreme ultraviolet light, delivering radiation with a wavelength shorter than 100 nm, is now available from solid state sources. However, despite exceptional progress, efficient focusing of extreme ultraviolet photons to their ultimate di ffraction limit remains a formidable challenge because of the precision of the focusing by curved, optical surfaces. Here we integrate generation and focusing of coherent short-wavelength high-order harmonics from a nanostructured MgO crystal, achieving a focused spot size of 150 nm with a 112 nm harmonic. Moreover, I'll present a new coherent diffractive imaging method to characterize the XUV field at the nanostructured crystal. Future developments may demonstrate nanoscale laser ablation, and miniaturization of extreme ultraviolet coherent sources on a chip.

Tunable Photo-Induced Free-Electron Spatial Modulation using Ultrafast Plasmonic Fields

Mr. Shai Tsesses, Raphael Dahan, Kangpeng Wang, Tomer Bucher, Kobi Cohen, Ori Reinhardt, Guy Bartal and Ido Kaminer

Andrew and Erna Viterbi Department of Electrical and Computer Engineering, Technion - Israel Institute of Technology

Introduction & Background: Spatially shaping electron beams has great importance in industrial and academic applications, such as nanolithography, microscopy, material studies and fabrication inspection. To this end, the frontier of research in recent years has been spatial coherent shaping, achieved via phase and amplitude holograms for electrons. Recently, a new method to generate such spatial electron modulation was proposed, based on the ultrafast interaction of electron pulses and near-field electromagnetic waves, attracting attention for the ability to correct and purify electron beams. Tunable spatial modulation of electron beams, on the other hand, is still an open challenge by any means and has yet to be performed experimentally with electron-light interactions.

Objectives: In this work, we present active spatial modulation of electrons by engineering their interaction with ultrafast surface plasmon interference patterns in an ultrafast transmission electron microscope (UTEM).

Methods & Results: First, in the low-intensity interaction regime, we directly determine the electron distribution through shaping of the plasmonic field, by engineering the plasmonic coupling slit or the polarization of the laser pulse impinging it. Thereafter, in the high-intensity interaction regime, we demonstrate how different interaction orders possess a different shape, while the entire electron distribution undergoes free-electron Rabi-like oscillations.

Conclusions: Our work presents new degrees of freedom to actively shape electron wavefunctions, with possibilities for improving state-of-the-art electron microscopy with tunable and tailored electron beams.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Monday, December 12 | Parallel Session 3 | 16:15 - 17:45

Observation of Interband Berry Phase in Laser-Driven Crystals

Ayelet J. Uzan-Narovlansky[1,2*], Lior Faeyrman[1*], Sergei Shames[1], Vladimir Narovlansky[3], Jiewen Xaio[4], Talya Arusi-Parpar[1], Omer Kneller[1], Barry D. Bruner[1], Olga Smirnova[5,6], Rui E. F. Silva[7], Binghai Yan[4], Álvaro Jiménez-Galán [5,8], Misha Ivanov[5,9,10], and Nirit Dudovich[1]

1 *Department of Complex Systems, Weizmann Institute of Science, 76100, Rehovot, Israel*
2 *Department of Physics, Princeton University, Princeton, NJ 08544, USA*
3 *Princeton Center for Theoretical Science, Princeton University, Princeton, NJ 08544, USA*
4 *Department of Condensed Matter, Weizmann Institute of Science, 76100, Rehovot, Israel*
5 *Max-Born-Institut, Max-Born Strasse 2A, D-12489 Berlin, Germany*
6 *Technische Universität Berlin, Ernst-Ruska-Gebäude, Hardenbergstr. 36A, D-10623 Berlin, Germany*
7 *Instituto de Ciencia de Materiales de Madrid (ICMM), Consejo Superior de Investigaciones Científicas (CSIC), Madrid, Spain*
8 *Joint Attosecond Science Laboratory, National Research Council of Canada and University of Ottawa, Ottawa, Canada*
9 *Blackett Laboratory, Imperial College London, South Kensington Campus, SW7 2AZ London, United Kingdom*
10 *Department of Physics, Humboldt University, Newtonstrasse 15, 12489 Berlin, Germany*
* *These authors contributed equally to this work*

Ever since its discovery [1], the notion of Berry phase has permeated through all branches of physics, being at the heart of a large variety of quantum phenomena. In condensed matter physics, the geometric phase manifests itself in the electronic Bloch states, quantum Hall effect, electric polarization, exchange statistics and many other physical observations. In such systems, applying an electric field drives the electronic wavefunction in the crystal momentum space, leading to the accumulation of a Berry phase due to the parameter space topology, also known as Zak's phase.

Here, we present a conceptually new manifestation of the Berry phase in light driven crystals, where the electronic wavefunction accumulates a geometrical phase during discrete evolution between different bands, while preserving the coherence of the process. Driven by the strong laser field [2], the electron tunnels across the energy gap between the valence and the conduction bands, initiating an electron-hole wavepacket. Such excitation is followed by the propagation of the electron-hole wavepacket, dictated by the temporal shape of the laser field, and electron-hole photo-recombination, projecting the k-space trajectories onto the emission of higher-order harmonics (known as interband HHG spectroscopy [3]). We resolve the interband Berry phase in an α-quartz crystal, by inducing an interferometric type measurement, controlling the laser field's instantaneous polarization. [1] M. Berry, A. Mathematical and Physical Sciences, 392 (1984) 45-57 [2] S. Ghimire et al., Nature Physics, 15 (2019) 10-16 [3] G. Vampa et al Phys. Rev. Lett. 113, 073901 (2014)

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Sub-cycle phase resolved attosecond interferometry

Omer Kneller[*1], Chen Mor[*1], Noa Yaffe[1], Serguei Patchkovskii[2] and Nirit Dudovich[1]

1 *Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 76100, Israel*
2 *Max-Born-Institute, Berlin, Germany*
* *Equal contribution*

Strong-field light-matter interactions have revolutionized the ability to manipulate quantum systems on extremely short time scales. Attosecond transient absorption spectroscopy has emerged to be one of the most potent metrology schemes in attosecond science[1,2]. This scheme resolves the instantaneous response of a quantum system as it interacts with a laser field, and maps it into the absorption spectrum of attosecond pulses in the extreme-ultraviolet (XUV) regime.

While attosecond transient absorption has been at the heart of attosecond science for more than a decade, it imposes fundamental challenges[3,4]. The first is associated with the measurement itself. The quantum attosecond dynamics are imprinted in both amplitude and phase of the attosecond pulse.

However, the measurement accesses only the spectral intensity while the phase information is lost. The lack of phase information prevents the direct measurement of the full complex dynamics encoded in the attosecond signal. The second challenge is imposed by the nonlinear nature of the interaction, which initiates multiple quantum channels, which are all coherently mapped into the XUV absorption spectrum. Decoupling these different quantum paths is instrumental to the ability to reveal the complete rich dynamics, hidden in existing experimental observations. Here we introduce Subcycle Phase Resolved attosecond INTerferometry (SPRINT), recovering the lost phase information so far hidden in absorption measurements. The basic approach of SPRINT integrates two fundamental schemes in attosecond science: attosecond transient absorption and XUV-XUV interferometry. Adding a reference XUV source for XUV-XUV interferometry to a transient absorption experiment allows us to resolve the complex instantaneous interaction of the quantum system with light over a temporal range of 200 femtosecond. Next, we take an important step forward and reveal the significant role of phase information. We demonstrate that phase information enables a direct decoupling of the various quantum paths induced by a nonlinear interaction, isolating their coherent contribution. Our methods allow a direct separation between the resonant and off-resonant quantum paths in a light-driven Helium atom, revealing their full complex temporal evolution.

References
[1] Holler, M., et al. "Attosecond electron wave-packet interference observed by transient absorption." Physical review letters 106.12 (2011): 123601.
[2] Chini, Michael, et al. "Subcycle ac stark shift of helium excited states probed with isolated attosecond pulses." Physical review letters 109.7 (2012): 073601.
[3] Kaldun, Andreas, et al. "Extracting phase and amplitude modifications of laser-coupled fano resonances." Physical review letters 112.10 (2014): 103001.
[4] Stooß, Veit, et al. "Real-time reconstruction of the strong-field-driven dipole response." Physical Review Letters 121.17 (2018): 173005.

Ultrafast High-Harmonic Microscopy

Dr. S. Zayko[1,4], O. Kfir[2], Hung-Tzu Chang[1], M. Heigl[3], J. Hagen[1], M. Sivis[1,4], M. Albrecht[3], and C. Ropers[1,4]

1 *Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany*
2 *School of Electrical Engineering, Tel Aviv University, Tel Aviv, Israel*
3 *Experimental Physics IV, Institute for Physics, University of Augsburg, Germany*
4 *IV Physical Institute - Solids and Nanostructures, Georg-August University, Germany*

The ability to manipulate matter properties at ultrafast timescales sparked broad interest in multiple research fields due to their promises for future technological applications. For example, the metalinsulator transitions in charge density wave materials and spin dynamics induced by ultrafast laser excitation occur at tens of femtoseconds [1,2]. Electronics based on such phenomena may operate at comparable rates - orders of magnitude faster than state-of-the-art information technologies. The microscopic mechanisms responsible for the transformation of structural and magnetic states involve both femto- to picosecond time and nanometre length scales which makes such research particularly challenging due to the lack of appropriate ultrafast real-space imaging tools. In particular, the required nanometer spatial resolution is difficult to achieve while maintaining the femtosecond time resolution.

Here, we demonstrate the first ultrafast microscopy based on high-harmonic radiation and capture movies of femtosecond spin dynamics at the nanoscale. The employed harmonic generation scheme [3] produces circularly polarized extreme ultraviolet radiation needed to access element- specific spin information via magnetic circular dichroism. The ultrahigh spatial resolution (down to 13.5 nm) is provided via an advanced lensless imaging scheme, while the femtosecond pulse duration, inherent to the HHG process, ensures sufficient temporal accuracy. We capture and follow femtosecond spin dynamics in ferro- and ferrimagnetic materials [4]. Owing to the element specificity of the developed imaging tool, the spin textures are accurately mapped even at the compensation point of ferrimagnetic material systems when the absence of stray magnetic fields makes it inaccessible to other imaging mechanisms, including, e.g. electron and magnetic force microscopy. Due to the accessibility of high-harmonic sources and the unprecedented resolution they may offer, we believe that this ultrafast microscope will become an indispensable tool for fundamental research and, in particular, application-oriented studies.

References
[1] Yang et al., Annu. Rev. Mater. Res. 2011. 41:337-67 (2011)
[2] Beaurepaire et al., Phys. Rev. Lett. 76 4250-3 (1996)
[3] O. Kfir et al., Appl. Phys. Lett. 108, 211106 (2016);
[4] S. Zayko et al., Nat. Commun. 12, Article number: 6337 (2021)

Monday, December 12 | Parallel Session 3 | 16:15 - 17:45

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Kerr Lens Time Space Coupling Mechanism for Contrast Enhancement of Ultrashort Pulses

Z. Refaeli[1,2], M. Wyszkin[1], G. Marcus[2] and Y. Shamir[1]

1 Applied Physics Division, Soreq NRC, Yavne 81800, Israel

2 Applied Physics Department, The Hebrew University, Jerusalem, 9190401, Israel

Since the appearance of high-energy short pulse lasersystems based on Chirp Pulse Amplifiers (CPA) [1], pulse contrast has become an extremely important laser quality in high-field experiments. The most demanding in this context are those involving intense light-solid matter interactions [2, 3]. Solids start to dissociate into plasma under intensities of over 1010 W/cm2. Hence, at intensities of the order of 1017 - 1021 W/cm2 the contrast level must be kept in ranges of 107 - 1011. Several methods for pulse cleaning have been explored, mostly based on instantaneous non-linear processes, such as, Cross-Polarized Wave (XPW) [4], Plasma Mirrors (PM) [5, 6], Self-Diffraction (SD) [7], etc. Methods as those described above typically enhance pulses contrast by ~2-3 orders of magnitude, but not without an efficiency penalty that can even drop below 10%. In this work, we propose novel approach show preliminary results with very low-cost, robust and easy-to-implement method for improving pulse contrast. Utilizing the instantaneous χ(3) nonlinear self-focusing effect, our setup couples the timeintensity profile to spatial energy distribution. A computational model and early experimental findings show promising potential for improving pulse contrast with high efficiency in comparison to well-established techniques. While pulse features of low-intensity remain unchanged propagating in a χ(3) nonlinear-medium, high intensities, mainly around the peak, experience spatial-modifications (Fig.1), i.e. pass temporal-spatial coupling. A sequential spatial filter discriminates the unwanted parts, thereby recouples the spatial to temporal features by screening out higher spatial-frequencies. The model points between ½-upto-2 orders of magnitude contrast-enhancement with ~90- 40% efficiencies (Fig.2), correspondingly, accounting for Gaussian beam with additive temporal noise. The model relies on the interaction pulses in the sub-mJ in fused silica. The 100s-MW pulse-peak enabled significant Kerr-Lens within few mm's of glass. Experimental scheme with resembling parameters well supports our model. (Fig.2 (b)), opening new branch of spatial-temporal nonlinear ultrafast contrast manipulation.

References

[1] P. Maine, D. Strickland, P. Bado, M. Pessot, and G. Mourou, Generation of ultrahigh peak power pulses by chirped pulse amplification, IEEE Journal of Quantum electronics 24, 398 (1988).

[2] M. Murnane, H. Kapteyn, and R. Falcone, High-density plasmas produced by ultrafast laser pulses, Physical review letters 62, 155 (1989).

[3] D. Neely, P. Foster, A. Robinson, F. Lindau, O. Lundh,A. Persson, C.-G. Wahlstr ̈om, and P. McKenna, Enhanced proton beams from ultrathin targets driven by high contrast laser pulses, Applied Physics Letters 89, 021502 (2006).

[4] A. Jullien, X. Chen, A. Ricci, J.-P. Rousseau, R. Lopez-Martens, L. P. Ramirez, D. N. Papadopoulos, A.Pellegrina, F. Druon, and P. Georges, High-contrast ultra-broadband frontend source for high intensity few-cycle lasers, arXiv preprint arXiv:1109.1992 (2011).

[5] G. Doumy, F. Qu ́er ́e, O. Gobert, M. Perdrix, P. Martin, P. Audebert, J. Gauthier, J.-P. Geindre, and T. Wittmann, Complete characterization of a plasma mirror for the production of high-contrast ultraintense laser pulses, Physical Review E 69, 026402 (2004).

[6] M. Kalashnikov, E. Risse, H. Sch ̈onnagel, and W. Sandner, Double chirped-pulse-amplification laser: a way to clean pulses temporally, Optics letters 30, 923 (2005).

[7] J. Liu, K. Okamura, Y. Kida, and T. Kobayashi, Temporal contrast enhancement of femtosecond pulses by a self-diffraction process in a bulk kerr medium, Optics Express 18, 22245 (2010)

Session: Artificial Intelligence in Optics - Prof. Yoav Shechtman

Invited speaker |

Deep Learning Metamaterials

Prof. Willie Padilla

Department of Electrical and Computer Engineering, Duke University, North Carolina, USA

Electromagnetic metamaterials derive their properties from geometry rather than chemistry, and have achieved exotic properties not realizable with conventional materials. However, as metamaterials and metasurfaces have become more complex, the relationship between the structure and its properties is increasingly less understood or completely unknown. In these cases, the only means of estimating metamaterial properties is through computational electromagnetic simulations, making it difficult to achieve optimal results for high dimensional problems. Recently, deep neural networks have been shown to effectively infer the relationship between metamaterial geometry and its properties using simulated training data. Here we show several examples of deep learning techniques applied to both forward and inverse metamaterial design problems. We give an overview of the field, including open challenges and potential future directions along this research line.

Invited speaker |

Learning to see in the Data Age

Prof. Alex Bronstein

Dan Broida Academic Chair; Schmidt Chair in Artificial Intelligence, The Henry & Marilyn Taub Faculty of Computer Science; Technion - Israel Institute of Technology, Haifa, Israel

Recent spectacular advances in machine learning techniques allow solving complex computer vision tasks - all the way down to vision-based decision making. However, the input image itself is still produced by imaging systems that were built to produce human-intelligible pictures that are not necessarily optimal for the end task. In this talk, I will try to entertain ourselves with the idea of including the camera hardware (optics and electronics) among the learnable degrees of freedom. I will show examples from optical, ultrasound, and magnetic resonance imaging demonstrating that simultaneously learning the "software" and the "hardware" parts of an imaging system is beneficial for the end task.

Image and Video From Coded Motion Blur Using Dynamic Phase Coding

Mr. Erez Yosef, Shay Elmalem and Raja Giryes
Tel Aviv University, Tel Aviv, Israel

Motion blur is a known issue in photography, caused while capturing moving objects. The proposed framework enables reconstruction of a sharp image or a video utilizing the inherent motion blur captured in a single image. Since conventional imaging motion blur is ambiguous, such a task is highly ill-posed. To circumvent this issue, a computational imaging approach is proposed. Using dynamic phase-coding in the lens aperture during the image acquisition, the trajectory of the motion is encoded in the intermediate optical image. This encoding embeds cues for both the motion direction and the extent by coloring the spatial blur of each object along its trajectory (Fig.1). These color cues serve as prior information for the reconstruction process. We suggest both image-to-image and image-to-frames reconstruction models based on CNN architectures. Using only a single coded motion-blurred image, our model can be configured parametrically to generate a sharp image or a short frame burst of the scene during exposure at a controlled frame rate. Moreover, we learn the optical coding parameters along with the network weights using end-to-end optimization. While other state-of-the-art methods fail to assess the motion direction due to the inherent ambiguity correctly, our approach, based on optically encoded spatiotemporal motion cues, is much more reliable. Both simulation and experimental results will be presented, showing the advantage of our approach over existing solutions.

References

[1] Elmalem, Shay, Raja Giryes, and Emanuel Marom. "Motion deblurring using spatiotemporal phase aperture coding." Optica 7.10 (2020): 1332-1340.
[2] Yosef, Erez, Shay Elmalem, and Raja Giryes. "Video Reconstruction from a Single Motion Blurred Image using Learned Dynamic Phase Coding." arXiv preprint arXiv:2112.14768 (2021).

Optical Compressive Imaging for Defending Deep Neural Networks from Adversarial Attacks in the Physical Domain

Vladislav Kravets and Prof. Adrian Stern
Ben-Gurion University of the Negev, Beer- Sheva, Israel

We overview an optical approach we have recently introduced for defending deep learning algorithms from adversarial attacks in the physical domain. The approach uses optical compressive sensing to remove the attacks and avoid counterattacks. We present optical defense methods we have developed for 2D and 3D images and discuss their robustness and security.

Session: Lasers and Applications - Dr. Ariel Bruner

Invited speaker |

Laser Defense Systems - Science Fiction Materializing

Dr. Yehonatan Segev
Rafael Advanced Defense Systems, Israel

Laser technology has advanced rapidly from the invention of the laser in the 1960's to the Mega-Watt lasers of the late 1980's. Alongside the rapid technology development comes an expectation for laser defense systems which have long been a part of science fiction literature. Nevertheless, the latter have yet to be fielded, coining the popular joke that high power laser systems have been three years away from us, for three decades. Over the last few years, the technology has matured and the operational need for this innovative and game-changing defense system has increased making their entrance to the battlefield imminent.

This Seminar describes how these systems work and focuses on the technological breakthroughs that finally allows their realization- fiber laser power scaling via beam combining, beam focusing and pointing and real-time atmospheric turbulence disturbance correction.

Yehonathan Segev has been the head of the R&D group that specializes in Laser Systems in Rafael Advanced Defense Systems LTD since 2020. He is with the group in Rafael since 2011, after receiving a PhD from the Weizmann Institute of Science.

High Power Picosecond MOPA System with Yb-doped Tapered Double-Clad Spun Fiber

Evgeny Savelyev, Andrey Chumachenko and Dr. Valery Filippov
Ampliconyx Oy, Tampere, Finland

We addressed the problem of a state of polarization (SOP) drift caused by heating due to intense clad pumping in different types of active double-clad fibers. Variations of a SOP and degree of polarization (DOP) under clad pumping in polarization maintaining (PANDA type) and regular (non-PM) Yb-doped double-clad large mode area tapered fibers have been investigated experimentally. We discovered that the birefringence of active fibers is strongly dependent on the launched pump power, exhibits hysteresis and has a memory of a fiber pumping history. To solve the problem of a SOP drift in active large mode area fibers, we, resented an active double-clad fiber with low intrinsic birefringence (spun tapered fiber) as a gain medium. An Yb-doped spun tapered double clad fiber (sT-DCF) with intrinsic birefringence as low as 1.45×10^{-8} was manufactured and experimentally studied. We experimentally proved that the DOP and SOP drift in sT-DCF caused by clad pumping was in two orders of magnitude less comparing with similar PANDA-type DC fiber and regular non-PM tapered double-clad fibers. An active sT-DCF showing efficient amplification was demonstrated in all-fiber-based picosecond master-oscillator power-amplifier scheme. The all-fiber MOPA system delivered 50 ps pulses at 1035 nm with an average power of 72.5 W, 70% slope efficiency, 26 μm MFD and perfect beam quality is experimentally demonstrated.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Dynamic Beam Lasers offer new Parameters for Material Processing Optimization

Dr. Benayahu Orbach & Dr. Yaniv Vidne, Nina Armon, Asaf Nissenbaum, Eyal Shekel
Civan Lasers, Israel

Optical phased array (OPA), a type of coherent beam combining (CBC), merges many single-mode laser beams into one larger beam. Each laser emits its own light, which overlaps with other beams in the far field to create a diffraction pattern. This gives the flexibility to easily manipulate the beam shape in real time, without any moving parts, to create a dynamic beam laser (DBL). By using phase modulators to control individual beams, the resulting interference pattern can be changed to maximize the beam spot position and produce variously shaped patterns inscribed by the beam's motion - all of which can be done at speeds of up to hundreds of megahertz. The advent of this dynamic beam-shaping laser, based on OPA fiber lasers capable of delivering up to 100 kW of power, enables single-mode fiber lasers to deliver the control that multi-mode lasers lack. The latest DBL developments include the ability to control not only beam shape but also sequence, shape frequency, and focal depth. These four parameters allow for unprecedented control of laser material processing applications such as welding, cutting, drilling, and additive manufacturing. The defining characteristic of the DBL is the unique ability to easily change the beam shape to any arbitrary shape. The DBL allows laser users to design and build beam shapes and sequences independently. This means that as circumstances change, laser users have the flexibility to adjust beam shapes as needed to ensure optimal penetration and minimal defects. The DBL gives laser users a new set of parameters that can influence weld geometry and weld quality by stabilizing the keyhole and melt pool, as well as control and influence over the microstructure, making new material processing possibilities practical.

Insight into the epitaxy process of a VCSEL from the calibration of a single layer to the LIV curve

R. Tamari[1], D. Memram[1], O. Westreich[2], I. Shafir[2], N. Sicron[2], M. katz[2], R. Didi[2], M. Albo[2], S. Baor[2] and D. Cohen-Elias[2]
1 Israel Center for Advanced Photonics, Yavne 81800, Israel
2 Solid State Physics Department, Applied Physics Division, Soreq NRC, Yavne 81800, Israel

Vertical-Cavity Surface-Emitting Lasers (VCSELs) are gaining popularity due to their optical properties, ease of integration, scalability, manufacturing, and cost. These properties make VCSELs key components in various applications, including optical communication, spectroscopy, sensing, laser pumping, LiDAR, and more.

In this talk, we will present the 9XXnm GaAs/AlGaAs VCSEL grown and fabricated at the Israel Center for Advanced Photonics (ICAP). We will focus on the epitaxial growth process, using Metal Organic Chemical Vapor Deposition (MOCVD), beginning with the calibration of a single layer and all the way to a full layer structure. In addition, the characterization tools developed for calibrating the distributed Bragg reflector (DBR), quantum wells wavelength, cavity length, and the full structure and its corresponding L-I-V curve will be presented.

Novel Laser Resonator

Mr. Avigdor Zajdman
Private Consultant

A method for extracting high laser powers with good beam quality from large laser cavities, and particularly ones that have large gain-volume cross sections, is presented. This method is based on intra-cavity compound axiconical elements which readily lend themselves to MOPA configurations and to beam combining. It is shown that, given the right large gain volumes, megawatt order of power with high beam quality could be extracted.

Monday, December 12 | Parallel Session 3 | 16:15 - 17:45

First Light at the Israeli THz Superradiant Free Electron Laser

Ariel Nause[1], Aharon Friedman[1], Yehiel Vashdi[1], Eyal Farchi[1], Adnan Haj Yehye[1], Amir Weinberg[1], Leon Feigin[1], Eyal Magury[1], Michael Gerasimov[1], Paul Benishai[1], Avraham Gover[2]

1 Schlesinger Family Center for Compact Accelerators and Radiation Sources, Ariel University, Ariel
2 Tel Aviv University

We report a first observation of terahertz super-radiant emission from the Israeli Free Electron Laser. This is the first demonstration of a THz source based on the scheme of coherent spontaneous superradiant emission by an ultra-short e-beam bunch [1]
The FEL is driven by the ORGAD RF-LINAC at the Schlesinger Accelerator Center in Ariel University [2] and is operated by the FEL center of Ariel and Tel-Aviv universities. It is a compact RF gun accelerating to energies between 3.5 and 8.5 MeV. The gun is 64 cm long. It produces an ultra-short electron bunch of about 100 femto-seconds. Since the frequency of the emitted radiation is 3.5 Tera Hertz, that bunch duration is less than half a period of the radiation (~300 femto-seconds). This produces superradiance, a phenomenon where the electrons emit in phase with each other. In this situation the radiation field emitted by the electrons add up. Thus, the total radiation energy is proportional to the square of the number of electrons and not to the number of electrons as in conventional spontaneous emission.
This principle provides a significant advantage over THz FEL schemes based on simulated amplification of spontaneous emission (SASE) [2]. Since in our case we have about N=108 electrons, the total energy emitted is N2 =1016 times the energy emitted by a single electron. That is 108 times the energy that would have been emitted from a longer electron beam at the same circumstances, this is the same enhancement factor that was obtained by exponential growth in a SASE FEL using a much longer wiggler and higher beam energy [2]. Thus comparable THz radiation energies (we measured at first attempt ~30 nJoul/pulse) can be obtained with a very compact accelerator and a short wiggler.
In the framework of our FEL user center of the Ministry of Science, we aim to apply our special THz source to provide high energy tunable radiation to users in a wide range of disciplines in biology, chemistry, material research and medicine.

Reference

[1] A. Gover et al, Superradiant and stimulated-superradiant emission of bunched electron beams. Reviews of Modern Physics, 91(3), 035003.
[2] A. Nause et al "6 Mev Novel Hybrid (Standing Wave - Traveling Wave) Photo-Cathode Electron Gun for a THz Sperradiant FEL", Nuclear Inst. and Methods in Physics Research, A, Vol 1010, 165547 (2021).
[3] M. Krasilnikov et al "First Lasing of the THz SASE FEL at PITZ" International FEL Conference, Trieste, August 22, 2022, MOA08

Oral Presentations

Tuesday, December 13

Opening Session

The James Webb Space Telescope First Science Results

Dr. Mark Clampin
Director Astrophysics Division, Science Mission Directorate, NASA

Development, Commissioning and First Science Results from the James Webb Space Telescope.

The James Webb Space Telescope (JWST) is a successor to the Hubble Space Telescope, and was designed to discover the first galaxies and stars that formed in the universe, unravel how galaxies form and evolve, allow us to peer into stellar nurseries and set us on the path to searching for evidence of habitable planets outside our solar system. JWST embodies a number of major breakthroughs in the design of large space observatories including a deployable segmented primary mirror, passive cooling to achieve cryogenic operating temperatures, and large deployable structures. JWST was launched on the morning of the 25th December 2021, and successfully commissioned during the following six months. In this presentation, I will discuss the design of JWST in the context of its science goals, the on-orbit performance, and the first science results from the Observatory.

Quantum computation: The second quantum revolution in physics

Prof. Dorit Aharonov
School of Computer Science and Engineering, The Hebrew University of Jerusalem, Israel and CSO of the Company Qedma D

Quantum computation is in the news; there is a lot of excitement, a long time promise for a technological revolution, and quite a bit of hype. What are the main ideas underlying this important development in science? Why does quantum computation attract so much attention from industry and academics alike? I will try to survey this fascinating area, starting from a basic introduction to the model of quantum computation. I will then discuss quantum algorithms and their promising applications, attempting to give a taste for the origin of the potential exponential advantage of such algorithms compared to their classical counterparts. Due to the immense promise in quantum algorithms, the quantum computation industry is working very hard to realize quantum computers on which these algorithms can be implemented. Small computers were already built, but noise and inaccuracies make the process of reaching a full fledged quantum computer extremely challenging. I will touch upon where we stand on the path to overcoming the obstacles towards realization, and conclude with where we hope to go next, and what are the main open problems the field is facing.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session: Atomic and Quantum Optics - Prof. Dan Oron

Invited speaker |

Quantum Nonlinear Optics: Strong Interaction Between Individual Photons

Prof. Ofer Firstenberg
Weizmann Institute of Science, Rehovot, Israel

We realize effective interactions between propagating photons by coupling light to Rydberg atoms. In the strong-interaction regime, we obtain a large (>pi) conditional phase for two photons, accompanied by the generation of photonic quantum vortices. For three photons, we observe vortex lines and rings governed by a genuine three-photon interaction.

Invited speaker |

Transforming a Strain-Stabilized Ferroelectric into an Intrinsic Polar Metal with Light

Dr. Alon Ron
Tel Aviv University, Tel Aviv, Israel

We explore the effects of chemical and photodoping in the strain-induced multiferroic $EuTiO_3$ grown on $DyScO_3$ substrates. The polar order is probed experimentally using second harmonic generation (SHG) and modeled using ab initio calculations. At low photodoping concentrations, we observe a reduction in SHG signal, indicating a destructive coupling between charge carriers and polar order in accordance with our simulations and expectations for a second-order Jahn-Teller driven ferroelectric. However, under increased photodoping the reduction in SHG plateaus at 84% of its original magnitude, indicating resilience of the polar order in the presence of a high concentration of delocalized electrons. This behavior stands in contrast with our first principles simulations, indicating that $EuTiO_3$ undergoes a transition from ferroelectric to polar metallic character under photodoping. We suggest several hypotheses for the mechanism behind this change in distortion character

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Universal Photonic-Atomic Interfaces for Ultra-Cold Atoms

Dr. G. Spektor[1,2], A. R. Ferdinand[1,2], T. Briles[1], D. Carlson[1,3], Z. Newman[1,3], S. Jammi[1,2], Y. Jin[1,2], W. Zhu[6], J.L. Skarda[4], N. Sapra[4], L. Su[4], A. Agrawal[6], J. Vučković[4], and S. B. Papp[1,2]

1 *Time and Frequency Division, National Institute of Standards and Technology, Boulder, CO 80305 USA*
2 *Department of Physics, University of Colorado, Boulder, CO 80309, USA*
3 *Octave Photonics, LLC., Boulder, CO USA 80305 USA*
4 *Department of Electrical Engineering and Ginzton Laboratory, Stanford University, Stanford, 94305, California, USA*
5 *Vector Atomic, Inc., Pleasanton, CA 94566 USA*
6 *Microsystems and Nanotechnology Division, National Institute of Standards and Technology, Gaithersburg, MD 20899, USA*

Emerging applications of quantum information, precision measurement and signaling, and quantum sensing with ultracold atomic samples1,2 motivate the development of advanced photonics technologies for controlling and addressing atomic matter. Here we demonstrate a scalable, integrated-photonics-based infrastructure for quantum technologies aiming to forego bulk-optics-based lab-scale setups. We show the first Meta-photonic magneto-optical trap (MOT) demonstrating the trapping of all the strontium (Sr) isotopes, including 4×105 atoms in an 87Sr MOT, of particular interest due to the accessibility of its mHz linewidth 698 nm clock transition. Optical lattice clocks require precise laser frequency control at multiple different wavelengths due to the complex level structures of candidate atomic systems1. To address this, we created a tantala (Ta2O5) nanophotonic waveguide circuit to generate a supercontinuum spectrum covering all the wavelength bands required for an Optical Sr clock. Thus emphasizing that tantala's wide transparency window, high nonlinearity, and integration potential are critical features to realize practical devices3,4.

To enable the delivery of a multitude of free-space beams, we experimentally demonstrate5 an inverse-design approach based on the superposition of guided-mode sources, allowing the generation and complete control of free-space radiation directly from within a single 150 nm Ta2O5 layer. Our innovative design approach and its detailed experimental demonstration at the challenging 461 nm wavelength, compatible with Sr trapping, offer on-demand access to integrated circuits that generate arbitrary free-space laser configurations. Finally, to overcome efficiency limitations posed by integrated circuits, we envision and demonstrate an alternative pathway for beam shaping, polarization control, and delivery based on wrapped propagation of total-internalreflection-guided beams combined with >90% efficient meta-gratings6 realized in tantala and TiO2.
We present a general and versatile palette of devices enabling a broad new photonic-atomic paradigm. Our platforms will be critical for scaling and enabling quantum technologies as well as future fundamental explorations.

References
[1] A. Ludlow et. al., "Optical Atomic Clocks," in Rev. Mod. Phys. 87, 637; (2016).
[2] R. Folman et. al., "Microscopic Atom Optics: From Wires to an Atom Chip". Advances in Atomic, Molecular, and Optical Physics (2008).
[3] Jung, H. et al. "Tantala Kerr nonlinear integrated photonics". Optica 8, 811 (2021).
[4] K. F. Lamee et al. "Nanophotonic tantala waveguides for supercontinuum generation pumped at 1560 nm," Opt. Lett. 45, 4192 (2020).
[5] G. Spektor et. al. "Universal visible emitters in nanoscale integrated photonics", ArXiv, (2022).
[6] G. Spektor et. al. "Beamforming via wrapped transverse propagation for visible integrated photonics", CLEO (2022).

Benchmarking of Photon Counting and Number Resolving Techniques in Cameras

Dr. Sebastian Beer, Assaf Avraham
Hamamatsu Photonics GmbH, Germany

Introduction: Single Photon counting is a widely used technique that has been implemented using a variety of detectors - from vacuum tube type photodetectors to a variety of semiconductor photodetectors or a combination of both. Detectors capable of spatially detecting single photons - i.e. cameras - have been used for more than 4 decades. The output of those cameras is binary in nature, since their structure allows for the reliable discrimination between 0 and 1 photons in each pixel, but not between other numbers.

Since the first commercial camera providing photon number resolving capability was recently released, we are going to present some of the key performance differences between single photon counting and photon number resolution - both in a fundamental discussion as well as in specific implementations.

Objectives and Methods: A theoretical model of the different camera types has been developed in order to quantitatively compare photon number resolving with single photon counting in cameras. Seeding those models with simulated images at various light levels allows for a direct comparison of both methods in terms of precision and efficiency. Using identical seed images for both models eliminates statistical differences inherent in any experimental benchmarking approach.

Results: The results show that under the assumption of a poissonian distributed signal, current photon number resolving technology is superior to single photon counting if the input signal is higher than 10-1 photons/pixel. Other differences between the respective camera technologies for different applications will be discussed

Tuesday, December 13 | Parallel Session 4 | 10:50 - 12:20

Session: Nonlinear Optics - Prof. Haim Suchowski

Invited speaker |

Versatile Laser Sources with Integrated Nonlinear Photonics

Prof. Scott Papp
National Institute of Standards and Technology, Gaithersburg, Maryland, USA

Optical-frequency combs are versatile tools for measuring time, transmitting data, identifying chemicals, sensing distance, and supporting quantum-information science. A new direction is to produce frequency combs through intriguing nonlinear behaviors of light in integrated microresonators. I will discuss experiments at NIST with Kerr microresonators that explore exotic regimes of soliton dynamics and applications of these soliton combs

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Tuesday, December 13 | Parallel Session 4 | 10:50 - 12:20

High-power, Squeezing-Enhanced Interferometry in Optical Fibers

Dr. Yosef London, Nir Nechushtan, Saar Levine, Leon Bello and Avi Peer
Applied Physics Division, Soreq NRC,Rd 4111, Yavne, Israel
Physics Dept. and QUEST center for quantum technology, Bar-Ilan University, Ramat-Gan, Israel

Interferometers are a well-known optical sensing platform. Sensitivity of classical interferometers to phase variations are limited by shot noise. One avenue of surpassing this limitation is based on introducing squeezed light into the dark input port of the interferometers beam splitter. A separate road for improving interferometric sensitivity is by swapping the beam splitters with Optical Parametric Amplifiers (OPAs), generating quantum-squeezed light within the interferometer itself, which amplifies the optical signal with no noise penalty. These nonlinear interferometers are named SU(1,1) interferometers.

The concept behind the SU(1,1) interferometers has been established since 1986 [1] and various "free-space" setups have been demonstrated. Here we present an "in-fiber" SU(1,1) interferometer. The unique characteristics of standard optical fibers (single mode, low losses over long propagation length, dispersion control, and telecom device compatibility) make them ideal for achieving effective and simplistic improvement of interferometric measurements.

In the presented work, a highly-nonlinear fiber (HNLF) acts as the OPA in the SU(1,1), both for generating the quantum-correlated photons and detecting them. The use of high power optical pump pulses (up to 10 W peak power) provides high parametric gain (up to 25dB), which holds promise for very high squeezing values (>10dB). As opposed to other few photons quantum measurements, we seed the interferometer input with coherent light, which boosts the squeezed signal to optical power levels that are conveniently measured by standard detectors [2]. We show an in-fiber SU(1,1) with negligible losses in the phase varying region, thus securing the quantum correlation before measurement. The quantum measurement takes place in the second OPA, alleviating the degradation of the quantum enhancement due to the finite quantum efficiency of the detectors.

The presented interferometer can improve fiber based strain sensors, temperature sensors and other sensed metrics coupled to the optical path.

Reference

[1] Yurke, Bernard, Samuel L. McCall, and John R. Klauder. "SU(2) and SU(1,1) interferometers." Physical Review A 33.6 (1986): 4033.
[2] Plick, William N., Jonathan P. Dowling, and Girish S. Agarwal. "Coherent-light-boosted, sub-shot noise, quantum interferometry." New Journal of Physics 12.8 (2010): 083014.
[3] Shaked, Yaakov, et al. "Lifting the bandwidth limit of optical homodyne measurement with broadband parametric amplification." Nature communications 9.1 (2018): 1-12.
[4] Michael, Yoad, et al. "Squeezing-enhanced Raman spectroscopy." npj Quantum Information 5.1 (2019): 1-9.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

The Nonlinear Optical Response and Non-Equilibrium Electron Dynamics in ITO

Subhajit Sarkar[1,2], Ieng-Wai Un[1], Prof. Yonatan Sivan[1]

1 School of Electrical and Computer Engineering, Ben-Gurion University of the Negev, Beer Sheva, Israel

2 Department of Chemistry, Ben Gurion University of the Negev, Beer Sheva 84105, Israel

Introduction: Low electron density Drude (LEDD) materials such as transparent conducting oxides, plasmonic nitrides, have emerged as popular candidates for high-efficiency nonlinear optical applications, due to their unique "epsilon near zero" point near Infra-Red wavelengths. Their nonlinearity is extremely large as it can change the refractive index/permittivity by 100's of percent. Peculiarly, despite the large body of impressive experimental demonstrations of these effects, their theoretical modeling was mostly coarse, and has not yet conclusively elucidated the origins of the giant optical response. Here, we close this knowledge gap and provide a "first principles" modeling of the electronic response of LEDD materials to ultrafast illumination. For concreteness, we focus on Indium Tin Oxide (ITO).

Methods: Our model is based on the well-accepted Boltzmann equation (BE) approach, which is nevertheless ensured to include all the key ingredients necessary for the faithful description of the electron dynamics. This model is complemented by proper verification of energy and charge conservation, as well as by an easy-to-use coarse-grained effective two temperature model (eTTM).

Results and Discussion: We find the electron heat capacity to be smaller in ITO in a manner commensurate with the lower electron density, but the electron-phonon energy transfer rate to be comparable to that in noble metals. This leads to stronger heating of the electrons, and to a faster cooling compared to noble metals [Fig. 1(a)]. Surprisingly, because of the intense illumination and associated high electron temperature, the effective chemical potential dramatically decreases and becomes negative, thus, effectively converting the Drude metal into a semiconductor [Fig. 1(b)]. We find that the drastic increase of the real part of the permittivity causes a significant detuning of the pump from the resonance such that the absorptivity drops rapidly with increased illumination intensity [Fig. 2(a)]. Consequently, the maximum values of phonon temperature increases sub-linearly with the pump peak-intensity, reaching the melting

point of at 500 GW/cm2 [Fig. 2(b)]. This explains, for the first time to our knowledge, the experimental observation of the high damage threshold of ITO. This further shows that the type of nonlinearity observed in ITO is not saturable (i.e., it doesn't have a pure electronic origin), but rather thermal as for noble metals [1, 2].

References

1. I. Gurwich and Y. Sivan, Phys. Rev. E 96, 012212 (2017).
2. I. W. Un and Y. Sivan, Phys. Rev. Mater. 4, 105201 (2020).

Compton Scattering Driven by Quantum Light

Mr. Majed Khalaf, Ido Kaminer

Technion - Israel Institute of Technology, Haifa, Israel

Compton scattering is one of the cornerstones of quantum physics, describing the fundamental interaction of a charge particle with photons. The Compton effect and its inverse are utilized in experiments driving free electrons by high intensity lasers to create high-energy photons. When increasing the intensity of its driving field, the Compton effect transitions into its non-linear regime, dubbed non-linear Compton scattering (NCS) [1], wherein multiple photons are absorbed and converted into higher energy photons. So far, all theory and experiments of the Compton effect and NCS have relied on electromagnetic fields that can be described classically. Advances in the generation of intense squeezed light could enable driving NCS with non-classical light. For example, bright squeezed vacuum (BSV) picosecond pulses with an energy of have been generated [2].

Here we revisit the Compton effects, including NCS, and show how the emission spectrum changes when driven by light of an arbitrary quantum state. We combine quantum optics and strong field perturbation theory to develop a non-perturbative framework capable of describing virtually any strong field physics phenomenon when driven by light ascribed with an arbitrary (intense) state of light. We obtain analytical results for the Compton and NCS emission spectra when driven by thermal and BSV light states. We find that the emission spectra are noticeably broadened in these cases compared with a classical driving light (see Fig.1), allowing higher emission frequencies to be reached for the same average intensity. Looking forward, we envision utilizing the quantum properties of light, including photon statistics, squeezing, and entanglement, as novel degrees of freedom to control the wide range of radiation phenomena at the foundations of quantum electrodynamics.

References

[1] Di Piazza, A., et al. Rev. Mod. Phys. 84, 1177 (2012).
[2] Iskhakov, T. S., et al. Opt. Lett. 37, 1919-1921 (2012).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Invited speaker |

Multiresonant and Active High-Q Nonlinear Metasurfaces

Dr. Mikko. J. Huttunen, T. Stolt, J. Kelavuori and A. Vesala
Photonics Laboratory, Physics Unit, Tampere University, Tampere, Finland

Nonlinear optical phenomena play a key role in many photonic applications ranging from all-optical switches and generation of ultrashort pulses to frequency comb-based metrology. To realize energy-efficient the fabricated photonic components should be as small as possible, resulting in a demand for nano- or small-scale nonlinear components. This demand for miniaturized nonlinear photonic components is difficult to address with conventional nonlinear materials motivating the search for alternative material platforms. Nonlinear plasmonic and dielectric metasurface-based resonators have recently emerged as a potential platform to enable nanoscale nonlinear optics [1-3]. Despite steady progress, the so far achieved conversion efficiencies have not yet rivalled conventional material platforms.

Here, we present our recent work aimed to develop more efficient nonlinear metamaterials, focusing on plasmonic metasurfaces supporting collective responses known as surface lattice resonances (SLRs) [1-3]. These resonances are associated with very narrow spectral features, showing potential to dramatically boost nonlinear processes via resonant light-matter interaction [2]. First we will discuss of our recent experimental demonstration of a plasmonic metasurface operating at the telecommunications C band exhibiting a record-high Q-factor close to 2400, demonstrating an order-of-magnitude improvement compared to existing metasurface resonators [3]. Second, we will discuss how multiple such high-Q factor resonances could be also realized using CMOS-compatible aluminium metasurfaces [4-6]. We will show how high-Q Al metasurfaces (Q-factors ~800) can be realized [6], and how their resonances can be tuned simply by changing the angle of incidence [4,5]. Third, we will demonstrate means to tune the resonance positions and Q-factors of the fabricated metasurface resonators, simply by adjusting the ambient temperature of the device [6]. Finally, we will show how conversion efficiencies of nonlinear metasurfaces could be further enhanced by fabricating phase-matched stacked metasurfaces [7].

References

[1] Kravets V. G. et al. "Plasmonic Surface Lattice Resonances: A Review of Properties and Applications," Chem. Rev. 118, 5912-5951 (2018).
[2] Huttunen, M. J. et al., "Using surface lattice resonances to engineer nonlinear optical processes in metal nanoparticle arrays," Phys. Rev. A 97, 053817 (2018).
[3] Bin-Alam, M. S. et al. "Ultra-high-Q resonances in plasmonic metasurfaces," Nat. Commun. 12, 974 (2021).
[4] Stolt, T. et al., "Multiply-resonant second-harmonic generation using surface lattice resonances in aluminum metasurfaces," Opt. Express 30, 3620-3631 (2022).
[5] Stolt, T. and Huttunen, M. J., "Broadband frequency conversion of ultrashort pulses using high-Q metasurface resonators," New J. Phys. 24, 025004 (2022).
[6] Kelavuori, J. et al. "Thermal Control of Plasmonic Surface Lattice Resonances," Nano Lett. 22, 3879-3883 (2022).
[7] Stolt, T. et al., "Backward Phase-Matched Second-Harmonic Generation from Stacked Metasurfaces," Phys. Rev. Lett., 126, 033901 (2021).

Enhanced THz Generation and Dynamic Emission from Metasurfaces

Eviatar Minerbi[1-3,*], Symeon Sideris[1,2], Jacob Khurgin[4], Tal Ellenbogen[1,2]
1 *Department of Physical Electronics, School of Electrical Engineering, Tel-Aviv University, Tel Aviv, 6997801, Israel*
2 *Center for Light-Matter Interaction, Tel-Aviv University, Tel-Aviv 6779801, Israel*
3 *Raymond and Beverly Sackler Faculty of Exact Sciences, School of Physics & Astronomy, Tel-Aviv University, Tel-Aviv 6779801, Israel*
4 *Department of Electrical and Computer Engineering, Johns Hopkins University, Baltimore, Maryland 21218, USA*

The THz spectral regime witnessed an ever-growing number of advances in the last decade, however, there is still much need for efficient optically enabled THz sources.

Recently, various types of plasmonic metasurfaces were shown to generate remarkably strong THz radiation after illumination with femtosecond pulses of light. The THz field emission reported from an ultrathin gold metasurface, was comparable to that emitted from an orders of magnitude thicker Zinc Telluride nonlinear crystal. To explain the strong emission, several processes were proposed, including ponderomotive acceleration of photo-ejected electrons and optical rectification. However, none of them fully accounts for all the observations, and the underlying mechanism remains unclear. Here we study this effect thoroughly and compare the emission from a metasurface comprised of gold split ring resonators on bare glass to an equivalent metasurface on a thin layer of indium tin oxide (ITO). We find that the strong THz emission is due to the existence of the ITO film. This strong signal is explained by the large optical nonlinearities of ITO at wavelengths where the permittivity is near zero, in addition to further field enhancement. Next, we explore the rich dynamics of the coupling between the ITO and the gold nanoparticles and find new phenomena that have not yet been reported. We show that the generated THz pulse can be shortened in time, and thus broadened in frequency with twice the bandwidth compared to previous studies and to an uncoupled system. These dynamics are attributed to hot electrons, which alter the optical response of gold and ITO and shift the ENZ point at sub-picosecond time scale.

These concepts unveil the fundamental physical dynamics of THz emission from nonlinear plasmonic metasurfaces and can lead to the development of efficient, active, and ultracompact optical elements for generating and controlling THz radiation.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session: Electro-Optics Devices - Dr. Ilya Goykhman

Invited speaker |

Surface Acoustic Wave - Photonic Devices in Silicon Integrated Circuits

Prof. Avi Zadok
Faculty of Engineering and Institute for Nano- Technology and Advanced Materials,
Bar Ilan University, Ramat-Gan, Israel

Photonic integrated circuits in the standard silicon-on-insulator material platform are a cornerstone of communication technology. In this talk, I will present the introduction of surface acoustic wave as part of the silicon photonics platform. Acoustic waves are stimulated through thermo-mechanical excitation following the absorption of pump light in metallic grating elements. Signals are reconverted back to optics via photo-elastic modulation of guided probe light in a standard resonator circuit. Acoustic propagation allows for the accumulation of long time delays on-chip, up to 175 ns, within sub-millimeter paths. Specific examples include microwave-photonic filters with a single, 7 MHz-wide passband, the analysis of elastic properties of thin deposited layers, and the realization of GHz-frequency acousto-optic oscillators.

Invited speaker |

Photonics on Thin-Film Lithium Niobate

Dr. Boris Desiatov
Faculty of Electrical Engineering at Bar-Ilan University, Ramat-Gan, Israel

Invited speaker |

Semiconductor-Superconductor Quantum Optoelectronic Devices

Prof. Alex Hayat
Department of Electrical Engineering Technion, Israel Institute of Technology, Haifa, Israel

We demonstrate photon pair correlations from injected Cooper-pairs in superconductor-semiconductor structures, which enable enhanced two-photon gain, heralded single-photon sources, entangled-photon pair generation and Bell-state analyzers. We also show high-Tc Cooper-pair injection into semiconductors, and demonstrated ultrafast high-Tc superconducting photodetectors, paving the way for more practical applications.

Tuesday, December 13 | Parallel Session 4 | 10:50 - 12:20

Invited speaker |

Time Scale Dependent Dynamics in Quantum Dot Lasers: from Modulation to Coherent Interactions

Prof. Gadi Eisenstein
Electrical and Computer Engineering departement, Technion - Israel Institute of Technology,
Haifa, Israel

Semiconductor quantum dots (QD) have been envisioned to revolutionize opto-electronic devices, in particular lasers since the early 1980's. The three-dimensional carrier confinement, leading to a delta-like density of states enable, in principle, an infinite differential gain and zero temperature dependence of the threshold and gain thereby holding the potential for ideal device performance.

Tens of years later, the vast majority of QD lasers exhibited inferior to their two-dimensional (QW) counterparts. There were several reasons for that failure. First and foremost is the gain broadening inhomogeneity that stems from the fact that the only decent QDs are self-assembled, grown by the Stranski-Krastanov method. The self-assembly leads to a variation in dot sizes, mainly the height which means of course a distribution of transition energies, hence the inhomogeneity.

A second important issue is the fact that most QD laser research was for devices fabricated in the GaAs material system. However, in GaAs QD gain media, it is very easy to populated the first excited state what makes the gain spectrum asymmetric and hampers the atom-like nature of the QD system.

A much better QD gain material is based on the InP system. InAs/InP QD gain material has been demonstrated to avail very large dot densities, record homogeneities and in addition, the energy splitting of the first excited state is large resulting in the fact that the ground state never saturates, and no excited state emission is observed.

This all allowed development of superb QD lasers, mainly in the 1550 nm wavelength range. The talk will survey the development of state of the art QD materials as well as the various devices based on them.

Highlights include:

- Temperature dependent static laser properties
- Record narrow linewidth DFB lasers
- Temperature dependent modulation capabilities
- High temperature operation of QD optical amplifiers
- Quantum coherent effects
- QD lasers grown on silicon

Heralded Relativistic Free Electrons

Armin Feist[1,2], Guanhao Huang[3,4], Germaine Arend[1,2], Yujia Yang[3,4], Jan-Wilke Henke[1,2], Arslan Sajid Raja[3,4], F. Jasmin Kappert[1,2], Rui Ning Wang[3,4], Hugo Lourenço-Martins[1,2], Zheru Qiu[3,4], Junqiu Liu[3,4], Dr. Ofer Kfir[5], Tobias J. Kippenberg[3,4] and Claus Ropers[1,2]

1 *Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany*
2 *4th Physical Institute, University of Göttingen, Göttingen, Germany*
3 *Institute of Physics, EPFL, Lausanne, Switzerland*
4 *Center for Quantum Science and Engineering, EPFL, Lausanne, Switzerland*
5 *School of Electrical Engineering, Tel-Aviv University, Tel Aviv, Israel*

Introduction: Free electrons (e^-) are fundamental, massive, and charged particles, facilitating microscopy at subAngstrom resolutions [1]. Beams of relativistic free electrons are typically thought of as optical beams at a far smaller (De-Broglie) wavelength. However, the simple light-e^--beam analogy breaks when moving into the realm of quantum optics. There are no proven means to generate entangled electrons or electron-photon pairs. Even theoretically, the concept of free-electron entanglement with photons is new [2]. This work demonstrates the generation of electron-photon pairs within an electron microscope and verifies their heralding capabilities experimentally.

Methods: The experiment is done within a transmission electron microscope (TEM). It delivered a continuous beam at 100-200 keV, and was equipped with a spectrometer, and a pixelated singleelectron detector (See Fig. 1A). Our silicon photonics circuit (SiPhC) includes a micro-ring resonator (silicon nitride waveguide in silicon oxide matrix, uncapped) that is fiber-coupled to a single-photon detector. When the SiPhC is in the TEM, the e^--beam passes aloof to its uncapped surface. Interacting with the evanescent tail of the circulating optical-vacuum state, e^-photon pairs are formed - photon generation is accompanied by an e^-- energy loss

Results: Correlations between the detection of a photon and an electron losing the same energy are detected by tagging their relative timing (Fig. 1B). The co-incidence events are nearly background free (Fig. 1B, bottom). When the e^--beam path intersects the ring at two points, we observe an oscillatory e^-photon coupling efficiency, corresponding to Vacuum Ramsey fringes.

Conclusions: This work is a demonstration of heralded massive particles. It facilitates novel application for quantum optics, which for imaging and spectroscopy down to the atomic scale, offers an alternative for Poisson statistics. Future devices that couple electron and photon strongly may contribute to novel light sources for quantum computation [3].

References

[1] O. L. Krivanek et al., Atom-by-Atom Structural and Chemical Analysis by Annular Dark-Field Electron Microscopy, Nature 464, 571 (2010).
[2] O. Kfir, Entanglements of Electrons and Cavity Photons in the Strong-Coupling Regime, Phys. Rev. Lett. 123, 103602 (2019).
[3] R. Dahan, G. Baranes, A. Gorlach, R. Ruimy, N. Rivera, and I. Kaminer, Creation of Optical Cat and GKP States Using Shaped Free Electrons, arXiv:2206.08828.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Tuesday, December 13 | Parallel Session 4 | 10:50 - 12:20

Session: Optical Engineering - Dr. Hanni Inbar

Invited speaker |

Nonlinear Near-Field Microscope for Real-Time Contactless Detection of Surface and Guided Waves

Prof. Guy Bartal
The Viterbi Electrical and computer engineering, Technion - Israel Institute of Technology, Haifa, Israel

The rapidly evolving ability to explore information stored in evanescent electromagnetic waves has revolutionized the field of microscopy. Since the first demonstration of a super-resolution microscope in 1972 , near-field microscopy has become essential in material science, biology and light-matter interaction engineering. Current state-of-the-art near-field microscopes enable imaging and spectroscopy beyond the diffraction limit with up to a few nanometers spatial resolution and may generally be divided into two groups - optically-based and electron-based.

The most prevalent optically-based technique thus far is scanning near-field optical microscopy (SNOM). This method exploits the field perturbation by a nanometric aperture or a scattering probe, placed in close proximity to the sample, in order to collect the local evanescent fields. While achieving sub-10nm resolution, SNOM requires a scanning process that omits real-time detection, whereas the outcome might be disrupted due to surface-probe interaction.

Here, we present the first real-time imaging of surface waves, based on a nonlinear near-field microscopy method. By mixing the surface waves with a free-space pump beam, using the nonlinearity of the host material or interface, we demonstrate single-shot mapping of 2D evanescent plasmonic patterns and monitor externally-controlled changes to the patterns. By adjusting the pump beam polarization, we selectively extract the intensity of all in-plane electric field components, including a direct mapping of the information stored in the in-plane field rotation (the so called "local photonic spin"). Furthermore, by combining the information from real-space and Fourier-space images of the patterns, we obtain both the amplitude and phase of all electric field components of the near-field without the complexity associated with heterodyne detection. This ability allows not only scientific exploration of near-field topologies but also non-perturbative elaborative characterization of light inside Silicon-photonics devices

First Lenses Fabricated in Space: Fluidic Shaping Onboard the International Space Station

Omer Luria[1,#], Mor Elgarisi[1,#], Valeri Frumkin[1,§], Alexey Razin[1], Khaled Gommed[1], Sivan Perl[1], Daniel Widerker[1], Israel Gabay[1], Jonathan Ericson[1], Ruslan Belikov[2], Edward Balaban[2,*] and Prof. Moran Bercovici[1,*]

1 Faculty of Mechanical Engineering, Technion - Israel Institute of Technology, Haifa, Israel
2 NASA Ames Research Center, Moffett Blvd., Moffett Field, CA, USA
 # These authors contributed equally to this paper
§ Current affiliation: Department of Mathematics, MIT Cambridge, MA, United States
** Corresponding authors: mberco@technion.ac.il (M.B), edward.balaban@nasa.gov (E.B)*

We report the first in-space fabrication of optical lenses, in a set of experiments performed by private astronaut Eytan Stibbe on the international space station (ISS). The lenses were fabricated by the Fluidic Shaping method, as illustrated in Fig 1. In the first part of the experiment, conducted within the life sciences glovebox (LSG), the astronaut injected photocurable polymers into 30 mm (diameter) cylindrical frames contained with a custom polymerization box (Fig 1a-b). Under weightlessness, surface tension dominates and drives the liquid into a minimum energy state in which the free surfaces assume a constantmean-curvature shape. In the case of a cylindrical bounding frame, the result is a bi-convex lens with spherical surfaces. Once the liquid stabilized (Fig 1c), the polymerization box's lid was closed, and the lenses were solidified (Fig 1d). In the second part (not shown here), conducted outside of the glovebox, the astronaut injected water onto a 172 mm frame and created a planoconvex water lens. By injecting and aspirating water from the lens, we demonstrated the ability to dynamically control the lens' power.

We provide videos of the experiments, present the hardware we constructed, and discuss the design details, tradeoffs, and associated challenges in implementing this experiment in space. We view this set of experiments a first milestone in expanding in-space manufacturing capabilities to also include optical components. Due to its simplicity, low power consumption and essentially zero waste, Fluidic Shaping can serve as a fabrication infrastructure for future long-duration space missions that must be self-sufficient. In addition, due to its scale invariance, the method could potentially be used for the creation of large space telescopes, thus overcoming launch constraints.

The experiment was performed as part of the RAKIA mission, led by the Ramon Foundation with support from the Israel Ministry of Innovation, Science and Technology.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Tuesday, December 13 | Parallel Session 4 | 10:50 - 12:20

Sub-Wavelength Optical Functionalities Directly Imprinted on Chalcogenide Glasses

Sivan Tzdaka[1,2], Natalie Ostrovsky[1,2], Eviatar Kassis[3], Shay Josef[3], Mark Schvartzman[1,2]

1 Department of Materials Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel
2 Ilse Katz Institute for Nanoscale Science and Technology, Ben-Gurion University of the Negev, Beer-Sheva, Israel
3 Optical Component Center, Rafael Advanced Defense Systems, Haifa, Israel

Chalcogenide glasses are attractive materials for infrared optics. However, their applications are often hampered by signal losses due to the high surface reflection. Traditional thin-film-based antireflective coatings are hardly applicable on chalcogenide glasses, as they often generate mechanical stresses that result in the film delamination. An attractive alternative to the film-based coatings are surface-pattered moth-eye subwavelength structures, which are made of the same material as the bulk, and thus do not generate stress. Among various methods of the surface patterning of chalcogenide glasses, thermal nanoimprint is the most attractive due to the low their low glass transition point - around 200 oC. Still, one major challenge remains - how to directly imprint the surface of chalcogenide glass without deforming the shapes of the substrate?

Here, we present three novel approaches for the direct soft imprint of chalcogenide glasses without deforming the shape of the imprinted substrate. The first approach is based on the imprint with IR radiative heating using a soft mold. Here, the mold is produced from PDMS reinforced with carbon nanotubes, making it a good radiation absorber. Since chalcogenide glasses are transparent in IR, only a thin layer at the mold-glass interface is sufficiently heated above the glass transition point during the radiative imprint. At the same time, the rest of the bulk remains below its glass transition point and therefore is not deformed [1]. Using this approach, we demonstrated the full pattern transfer of micron and sub-micron-sized features on flat surfaces, as well as on a lens.

The second approach is based on soft imprinting of a solvent-plasticized glass layer formed on the glass surface. Here, we established a methodology for surface plasticizing by controlling its glass transition temperature through process conditions. This control allowed us to imprint the surface of chalcogenide glass with features sized down to 20 nm and achieved an unprecedented combination of full pattern transfer and complete maintenance of the shape of the imprinted substrate. We demonstrated two applications of this approach: a diffraction grating and a multifunctional pattern with both antireflective and highly hydrophobic water-repellent functionalities - a combination that has never been demonstrated for chalcogenide glasses [2].

The third recently explored and still unpublished approach is based on elastomeric stamps soaked in an organic solvent, which diffuses into the imprinted chalcogenide glass, plasticizes its surface, and thereby allows its imprint at the temperature below its glass transition point. Using this approach, we imprinted features at the 20-nm scale, which is comparable to that demonstrated by convention nanoimprint techniques. Here, we again illustrated the applicability of our approach by producing functional antireflective nanostructures onto flat and curved optical polymeric substrate[3].

Overall, these three approaches open a new route for the nanofabrication of optical devices based on chalcogenide glasses and pave the way to numerous future applications for these important optical materials.

References

[1] N. Ostrovsky, D. Yehuda, S. Tzdaka, E. Kassys, S. Joseph, and M. Schvartzman Adv. Opt. Mater.,1900652 (2019)
[2] S. Tzadka, N. Ostrovsky, E. Toledo, G. Le Saux, E. Kassis, S. Joseph, and M. Schvartzman,Opt. Express, 28 (19), 28352 (2020)
[3] S. Tzadka Shalit, N.Ostrovsky, H. Frankenstein Shefa, E. Kassis, S.Joseph, M.Schvartzman - submitted

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

High Speed Large Aperture Tunable Lenses and their Applications

Dr. David Leuenberger, Mark Ventura, Dr. Manuel Aschwanden
Optotune, Dietikon, Switzerland

Introduction: Rigid glass & plastic lenses have the downside that their depth of field is limited. Focus tunable liquid lenses overcome this issue by using membranes that change their curvature in response to an electrical signal. Optotune's liquid lens portfolio covers clear apertures from 3mm to 33mm.

Results: In the presentation different lens architectures are discussed. Key issues of liquid lenses such as thermal drift, gravity coma and lack of suitable AR coatings are addressed, and solutions presented: a) the thermal drift issue is solved by advanced thermal calibration of the lens, b) the gravity coma appearing in applications with non-vertical optical axis could be reduced by a factor 25 by means of a passive gravity compensation solution, c) our latest membrane AR coating process reduces membrane reflection from 3.5% to 0.7%.

Conclusion: In this presentation we give an overview over the latest technical advancements in the field of focus tunable liquid lenses. Solutions for 3 of the key issues could successfully implemented. Applications are shown in the fields of imaging, laser processing, ophthalmic devices, and head-mounted displays for AR/VR.

Tuesday, December 13 | Parallel Session 4 | 10:50 - 12:20

A Theoretical Model for Automotive Lidar Performance in the Rain

Dr. Boaz Nemet
Innoviz Technologies, Israel

Lidars are likely to play a major role in the Automotive industry in the coming years as one of main sensors for autonomous vehicles due to their ability to generate accurate 3D images in the range of > 200m with high resolution < 0.1° at a very fast pace and over a large field of view > 100°. Atmospheric disturbances such as rain, snow, fog etc. can degrade the Lidar performance and it is therefore instructive to develop a physical model for this interaction.

In the first part of the talk we present a general physical model that is made to answer the following questions:

1. What attenuation does the lidar beam undergo as it propagates in the atmosphere while rain is falling at a rate R [mm/h]?
2. What is the mathematical expression for the maximum range of the lidar in the presence of rain?

We characterize the rain by a log-normal drop size distribution - DSD that is a function of R. Raindrops scatter the light in all directions, so we assume loss of photons is mainly due to scattering. Since the number density of drops is relatively small and their dynamics is very slow compared to the laser pulse, we can treat the attenuation in a similar way to the Beer-Lambert law of optical attenuation.

The maximum range of a general lidar can be calculated based on its physical parameters. By incorporating the atmospheric optical attenuation, we can predict the relative degradation in terms of reduced range and thus establish a general procedure for predicting a Lidar behavior at a given rain intensity.
In the second part of the talk we will show 'point cloud' data videos from road trips demonstrating the high resolution and range of Innoviz' lidars.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session: Solar Energy - Prof. Adi Salomon

Invited speaker |

In-situ Tools for Studying Dynamics and Electronic Structure at Functional Interfaces in Energy Conversion Devices

Prof. Elizabeth Von Hauff
Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology (FEP), Faculty of Electrical and Computer Engineering, Technical University of Dresden, Dresden, Germany

Functional interfaces are at the heart of solid state and electrochemical energy conversion technologies, such as solar cells and batteries. Impedance spectroscopy is well-suited for studying in-situ interfacial dynamics and electronic structure in these devices, and can be applied as a diagnostic tool to identify performance losses under different operational conditions [1,2]. In this talk I will give a brief introduction to impedance spectroscopy, including the mathematical background and conventions for data representation, as well as how to choose the operational point for measurement, check data reliability, and finally how to parameterise the spectra [1,2]. In the case of solar energy conversion, combining electrical techniques, such as impedance spectroscopy, with steady-state and time-resolved optical spectroscopy can offer complementary insights into dynamics related to fundamental processes and loss mechanisms [3, 4]. As an outlook, I will present arguments for considering non-equilibrium dynamics as fundamental signatures in energy conversion, and the role of spectroscopic tools for identifying these dynamics [5].

References
[1] E. von Hauff, Impedance Spectroscopy for Emerging Photovoltaics, J. Phys. Chem C, 123 (2019) 11329.
[2] E. von Hauff and D. Klotz, Impedance Spectroscopy for Perovskite Solar Cells: Characterization, Analysis, and Diagnosis, J. Mater. Chem. C, 10 (2022) 742-761.
[3] E. M. Hutter, T. Kirchartz, B. Ehrler, D. Cahen, E. von Hauff, Pitfalls and prospects of optical spectroscopy to characterize perovskite-transport layer interfaces, Appl. Phys. Lett. Perspective, 116 (2020) 100501.
[4] S. Maity, C. Ramanan, F. Ariese, R. C. I. MacKenzie, E. von Hauff, Adv. Elect. Mater., 8 (2002) 2101208.
[5] R. Alicki, D. Gelbwaser-Klimovsky, A. Jenkins, E. von Hauff, Dynamical theory for the battery's electromotive force, Phys. Chem. Chem. Phys. 23 (2021) 9428-9439.

Invited speaker |

Looking at Photovoltaic Devices with New Eyes

Mr. Jean-Francois Guillemoles
Research Director, CNRS, Director, UMR Institut Photovoltaïque d'Ile de France, IPVF; Ecole Polytechnique Institut Polytechnique de Paris, PSL Chimie ParisTech

The development of advanced photovoltaic devices, including those that might overcome the single junction efficiency limit, as well as the development of new materials, all rely on advanced characterization methods. Among all the existing methods, optically based ones are very well adapted to probe quantitatively optoelectronic properties at any stage. We here present the use of multidimensional imaging techniques that record spatially, spectrally and time resolved luminescence images. We will discuss the benefits (and challenges) of looking into direct photon energy conversion systems through some examples, mostly drawn from halide perovskite materials and device. These examples will help visit questions related to efficient transport and conversion in solar cells, as well as questions related to chemical and operational stability of the devices.

Tuesday, December 13 | Parallel Session 4 | 10:50 - 12:20

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Operando Characterization of Charge Extraction and Recombination Profiles in Solar Cells with Nanoscale Resolution

Tamir Yeshurun, Mor Fiegenbaum-Raz, Gideon Segev
Tel Aviv University, Tel Aviv, Israel

Background: The next generation of solar energy conversion systems requires design and integration of new semiconductor materials. Detailed understanding of the opto-electronic properties of these materials, their driving forces and the loss mechanisms that limit device performance is essential to the development of high efficiency systems. However, these materials and systems are difficult to model and only few experimental methods are available for direct characterization of dominant loss processes under relevant operating conditions. To this end, empirical extraction of the spatial collection efficiency (SCE) and the spatial external luminescence efficiency (SELE) are operando, analytical tools that provide functional depth profiles of the active regions in the device.

Methods: By coupling external quantum efficiency measurements and optical modeling, SCE extraction allows quantifying charge transport properties and loss mechanisms across the device depth profile under real operating conditions with very few assumptions. Similarly, combining optical modeling with wavelength dependent photoluminescence quantum yield (PLQY) measurements enables extracting the SELE- the probability that an electron hole pair photogenerated at a specific point will contribute to photoluminescence.

Results: In this contribution we will introduce the SELE concept and will show a first demonstration of the SELE extraction method applied to GaAs samples. Extracting the SELE enables simple distinction between different losses such as surface recombination and self-absorption. The quantification of surface recombination losses makes this an excellent tool for characterizing the effect of surface passivation layers. Furthermore, since the PLQY is directly related to the obtainable photovoltage from the device, the SELE also maps the contribution of different regions in the device to the photovoltage. As a result, combining the SELE and SCE profiles at specific operating points provides detailed spatial information on charge extraction, contribution to the photovoltage, and discrimination between radiative and non-radiative recombination processes at the surface and in the bulk of the device.

Amino Acids Additives for Efficient and Stable Perovskite Solar Cells

Dr. Said Kassou[1], Hadar Peled[2], Nurit Ashkenasy[2,3], and Iris Visoly-Fisher[1,3]

1 *Yersin Department of Solar Energy and Environmental Physics, Swiss Institute for Dryland Environmental and Energy Research, Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Midreshet BenGurion 8499000, Israel*
2 *Department of Materials Engineering, Ben-Gurion University of the Negev, Beer Sheva, Israel*
3 *Ilse Katz Institute for Nanoscale Science & Technology, Ben-Gurion University of the Negev, Beer Sheva, Israel*

Perovskite solar cells have recently demonstrated high power conversion efficiency (PCE), comparable with the commonly used Si photovoltaics. Despite this progress in efficiency, their long-term stability is one of the main bottlenecks towards their commercialization. Interfaces in the device, including the electron transport layer (ETL)/perovskite interface, grain boundaries in the perovskite layer and the perovskite/ hole transport layer (HTL) interface, were found to greatly influence the PCE and stability of the devices. Interface treatment by molecular additives was previously found to be an effective strategy to increase the device performance by improving perovskite crystallinity and passivating defects. Herein, amino acids were utilized to modify interfaces in n-i-p perovskite solar cells, towards improving the devices' PCE and operational photostability. Amino acids were chosen because of their diversity enabling, for example, introducing amino and carboxyl functional groups, known to bind to perovskite surface defects. Moreover, peptides can be de-novo designed based on the functional behavoiur of the amino acids, providing an easy platform for engineering the perovskite interface. We found that modifying the perovskite/ HTL interface with amino acids has the largest effect on the device performance, compared to grain boundaries and ETL/ perovskite interface modification. Modification with glutamic acid and tryptophan were found to improve both the efficiency and the photostability of the devices compared to control devices and devices modified with lysine. We therefore postulate that carboxylic acid and indole rich peptides can improve the efficiency and stability of perovskite solar cells when introduced at the perovskite/ HTL interface.

Session: Ultrafast Phenomena - Dr. Marcus Gilad

Invited speaker |

High Harmonic Generation Driven by Quantum Light

Prof. Oren Cohen, Matan Even Tzur, Alexey Gorlach, Michael Birk, Michael Krüger, Ido Kaminer
Technion - Israel Institute of Technology, Haifa, Israel

High harmonic generation (HHG) is an extremely nonlinear process in which a system driven by an intense laser emits coherent ultraviolet and X-ray radiation. I shall present theoretical and experimental advances towards HHG driven by quantum light. Firstly, we show that squeezed states of light such as bright squeezed vacuum can dramatically extend the cutoff energy of HHG, relative to classical light of the same intensity. Then, we show that the non-classical photon statistics of the driving field steers the underlying electronic trajectories of HHG, through an effective photon statistics force. As a result, squeezing of the driver's photonic state modifies the temporal profile of the emitted attosecond pulses. Finally, we show that the quantum state of the driving IR field imprints on the emitted XUV radiation, enabling, for example, the generation of squeezed high harmonics if driven by squeezed light.

Controlling Coherent Exciton Dynamics in TMDs

O. Meron[1,2†], U. Arieli[1,2†], E. Bahar[1,2], S. Deb[1], M. Ben-Shalom[1], H. Suchowski[1,2]

1 Condensed Matter Physics Department, School of Physics and Astronomy, Faculty of Exact Sciences, Tel Aviv University, Tel Aviv, 6997801, Israel
2 Center for Light-Matter Interaction, Tel-Aviv University, Tel-Aviv, 6779801 Israel
† These authors contributed equally to this work

The unique exciton characteristics arising from the extreme confinement in monolayer transition metal dichalcogenides (TMDs) have drawn increasing attention both in fundamental physics and applications [1]. While the excitons' linear optical properties have been extensively studied [2], their rapid coherent ultrafast dynamics, which lead to significant nonlinear properties [3], are yet not fully understood nor exploited. In this work, we introduce ultrafast pulse shaping methods for controlling the coherent exciton dynamics in [4]. By tailoring the spectral phase of a laser pulse, far shorter than the exciton resonance decoherence timescale, we obtain full control over its' third-order nonlinear optical emission, in excellent agreement with the anharmonic oscillator model. In particular, we show that by a properly chosen pulse shape, the nonlinear yield increases by a factor of 2.5. Apart from the 1s exciton state, we probe the higher 2s state, which lies beyond our pulse bandwidth and displays selective control of the nonlinear response from the two resonant states. Our findings are the first step towards achieving noninvasive control and selectivity of the rich exciton dynamics in TMDs. Such control of the ultrafast transient response may revolutionize on-chip photonic and optoelectronic technology.

References

[1] Mak, K. F. Shan, J. Photonics and optoelectronics of 2D semiconductor transition metal dichalcogenides. Nat. Photonics 10, 216-226 (2016).
[2] He, K. et al. "Tightly Bound Excitons in Monolayer WSe2" Phys. Rev. Lett. 113, 026803 (2014).
[3] Autere, A. et al. "Nonlinear Optics with 2D Layered Materials " Adv. Mater. 30, 1705963 (2018).
[4] Weiner, A. M. "Femtosecond pulse shaping using spatial light modulators " Rev. Sci. Inst. 71, 1929-1960 (2000).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Molecular Orientation-Induced Second Harmonic Generation: Deciphering Different Contributions Apart

Amit Beer[1,2], Ran Damari[1,2], Sharly Fleischer[1,2]

1 Raymond and Beverly Sackler Faculty of Exact Sciences, School of Chemistry, Tel Aviv University 6997801, Israel
2 Tel-Aviv University center for Light-Matter-Interaction, Tel Aviv 6997801, Israel

$|\langle cos\theta\rangle|^2 - d\langle\langle cos\theta\rangle\rangle/dt$ In this work we present 'molecular orientation-induced second-harmonic generation' (MOISH) as a desirable new technique for direct, spatially localized detection of orientation dynamics in THzexcited gas phase molecules [1]. Orientation refers to the preferential pointing of molecular dipoles toward a specific lab-frame direction [2] and manifest by the repetitive emission of Free-InductionDecay signals (FID) [3]. The MOISH technique developed here, utilizes the lifted inversion symmetry posed by oriented molecular ensembles. This manifest as an effective (non-zero) X2 nonlinear susceptibility, which enables the SHG of an ultrashort near-IR probe. Different from the TFISH method that utilizes the SH generated by a near-IR probe as it is temporally overlaps with the THz field to provide broad-band detection of the latter, MOISH enables the detection of the nuclear rotational dynamics, long after the exciting THz field is over [5]. Special efforts are put into deciphering the electronic from the nuclear contributions to the effective X2 and corresponding SHG signal. We show that while the traditional electro-optics sampling (EOS) [6,7] of the THz fields emitted upon molecular orientation are proportional to the time derivative of the transient orientation [2,8], MOISH is directly proportional to transient orientation ". In addition, we show that while EOS practically emanates from the entire volume of the gas cell, the MOISH signal emerges from a dramatically smaller volume governed by the Rayleigh-length of the near-IR probe. Moreover, from the comparison of different polar gas samples at varying pressures we find that the SHG signals are induced by both the electronic (TFISH) and nuclear (MOISH) contributions to the effective X2 of the medium. We show the ramifications of these different, interfering contributions and decipher between them using the 'reporter-gas' approach developed for this task, revealing the elusive effects of the (very small) transient FID emissions to the MOISH signals.

References

[1] A. Beer, R. Damari, Y. Chen, and S. Fleischer, J. Phys. Chem. A, vol. 126, no. 23, pp. 3732-3738, 2022.
[2] S. Fleischer, Y. Zhou, R. W. Field, and K. A. Nelson, Phys. Rev. Lett., vol. 107, no. 16, 2011.
[3] H. Harde, S. Keiding, and D. Grischkowsky, Phys. Rev. Lett., vol. 66, no. 14, pp. 1834-1837, 1991.
[4] D. J. Cook, J. X. Chen, E. A. Morlino, and R. M. Hochstrasser, Chem. Phys. Lett., vol. 309, no. 3-4, pp. 221-228, Aug. 1999.
[5] J. Dai, X. Xie, and X. C. Zhang, Phys. Rev. Lett., vol. 97, no. 10, 2006.
[6] A. Nahata, A. S. Weling, and T. F. Heinz, Appl. Phys. Lett, vol. 69, no. May, p. 2321, 1996.
[7] Q. Wu and X. -C. Zhang, Appl. Phys. Lett., vol. 67, no. 24, pp. 3523-3525, Dec. 1995.
[8] P. Babilotte et al., Phys. Rev. A, vol. 94, no. 4, p. 043403, Oct. 2016.

Tuesday, December 13 | Parallel Session 5 | 13:50 - 15:20

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Dynamics of Modal Self-Cleaning

Ms. Yuval Tamir, Hamootal Daudi, Moti Fridman
Bar Ilan University, Ramat-Gan, Israel

Sending an ultrafast pulse in multimode fiber can lead to nonlinear interactions between the different modes. When sending such a pulse in graded-index fibers there are cases where all the energy is transferring from the high-order modes into the lowest one. This effect is called modal self-cleaning. We developed a multimode time-lens which measures the temporal and spatial dynamics of ultrafast signals in multimode fibers. In this study, we investigate the modal dynamics of short pulses, around 200 fs, at the normal group velocity dispersion regime around 1550 nm, in graded-index few-modes fibers. With our setup, we have full control over the intensities and polarizations of the different modes. This enables us to revel the temporal dynamics between these modes, depending on their intensities and polarizations.

With our system, we detect the dynamics of each mode in time with high temporal resolution, and identify which mode is coupled to which. By analyzing the results we reveal how the energy transfers between the modes. Finally, we insert a strong multimode pulse into the system and study the self cleaning effect as a function of time. In this talk, We will present our measurement system in details and describe our novel results on modal self-cleaning. We will also comment on other multimode effects which our system can measure for the first time.

Ultrafast Low-Energy Electron Microscopy

Avraham Eitan, Maor Eldar, Salma Abo-Toame, Adi Goldner, Yiming Pan and Michael Krüger
Department of Physics and Solid State Institute, Technion - Israel Institute of Technology, Haifa, Israel

Introduction and Background: Attosecond science probes ultrafast quantum dynamics using strong laser fields. The coherent modulation of swift electron beams (10keV-200keV) with light has enabled the generation of attosecond electron pulses, opening up new research avenues in ultrafast microscopy. The low-energy regime of electron pulses (~20-1000eV) provides new opportunities and advantages, such as negligible damage to samples, but has remained largely unexplored. Here we show the generation of low-energy attosecond electron pulses and investigate the applications of these pulses for imaging plasmonic fields and resonant light-matter interactions.

Generation of attosecond electron pulses: In our experiment, we trigger photoemission from a metal nanotip by plasmonic nanofocusing and find signatures of attosecond tunneling emission. Numerical simulations show that these electrons can retain the sub-cycle temporal fingerprint in a point-projection microscope setup where nanotip electron emitter and sample are separated by a distance of about 1μm.

Imaging of plasmonic fields: Low-energy electron pulses interact strongly with electric charges located at a sample. Here we perform a theory study of these interaction at a nanoplasmonic structure and find that our point-projection microscope approach enables imaging of plasmonic fields with sub-fs and nanometer resolution.

Resonant slow-electron light interactions: Here we investigate electron-light interaction in the low-energy regime for the first time. Our analytical and numerical study shows that slow electrons are subject to strong confinement in the energy domain due to the non-vanishing curvature of the electron dispersion. This spectral trap is tunable and an appropriate choice of light field parameters can reduce the interaction dynamics to only two energy states.

Conclusions: Our simple alternative to complex schemes based on transmission electron microscopes provides new avenues for attosecond science and plasmonics. The capacity to trap low-energy electrons expands the scope of electron beam physics, free-electron quantum optics and quantum simulators.

Tuesday, December 13 | Parallel Session 5 | 13:50 - 15:20

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Spectral Splitting in Phase-Mismatched Harmonics

Raz Halifa Levi[1,2], Ori Ildis[1,2], Assaf Levanon[1,2], Avner Fleischer[2,3], Alon Bahabad[2,4], and Ishay Pomerantz[1,2]

1 *The School of Physics and Astronomy, Tel Aviv University, Tel Aviv 6997801, Israel*
2 *Tel-Aviv University Center for Light-Matter-Interaction, Tel Aviv 6997801, Israel*
3 *The School of Chemistry, Tel Aviv University, Tel-Aviv 69978, Israel*
4 *The School of Electrical Engineering, Tel Aviv University, Tel Aviv 6997801, Israel*

High harmonic generation (HHG) from the interaction of intense laser pulses with gas has been abundantly studied both theoretically [1-2] and experimentally [3-4] for over three decades. The generated extreme-ultraviolet (XUV) pulse trains enabled new means for probing molecular dynamics on femtosecond to attosecond time scales. However, since the spectral content of these pulses is formed out of discrete odd harmonics of the fundamental frequency, they are suboptimal for accessing specific molecular excited states.

In this talk, I will show how when using multi-TW laser pulses with extreme temporal chirp, a variety of quasi-phase-matching conditions emerge which enable manipulation of the spectral content of the XUV beam, broadening it and even splitting each harmonic into multiple discrete frequencies. I will explain the macroscopic origin of these splits and why a multi-TW laser system is necessary to observe it.

References

[1] A. L'Huillier, K. J. Schafer, and K. C. Kulander, Journal of Physics B: Atomic, Molecular and Optical Physics 24, 3315 (1991).
[2] M. Lewenstein, et al, Phys. Rev. A 49 (1994).
[3] T. Popmintchev, et al, PNAS, 1 (2009).
[4] C. M. Heyl, et al, Optica 3 (2016).

Ultrafast "Hot" Nonlinear Photoluminescence from Metals

Mrs. Imon Kalyan, Ieng Wai Un, Yonatan Sivan
Ben-Gurion University of the Negev, Beer- Sheva, Israel

We provide a complete quantitative theory for the important, 50-year old, yet unresolved problem of nonlinear photoluminescence from metals [1]. Remarkably, the countless previous experimental works are not accompanied by a complete theory because it requires knowledge of the hard-to-calculate electron non-equilibrium distribution under illumination. This results in disagreement on a long series of fundamental aspects associated with the emission.

Recently, we computed the steady-state non-equilibrium quantum electron distribution in metals and from it, the emission spectra. This solution reveals what is to our knowledge, the first ever explanation of the (polynomial) dependence of the metal emission on the electric field, see Fig. 1(Right) and its (exponential) dependence on the electron temperature. We characterized different scenarios determining the measurable emission lineshape and elucidate the deviation of the emission lineshape from the local density of photonic states, see e.g., Fig. 1(Left). Further, we resolved the arguments associated with the effects of electron and lattice temperatures on the emission, and which of them can be extracted from which spectral portion of the emission and showed that the emission statistics is a direct result of the non-thermal electron distribution and has the form of a series of boson-like emission terms.

In the current contribution, we extend our analysis to transient photoluminescence following illumination by an ultrashort pulse, elucidate the previously misunderstood transition from non-thermal to thermal emission, reconcile our predictions with earlier thermal analysis [3] and explain the many contradicting experimental observations on the dependence of the emission intensity on the electric field, particle shape, density, wavelength etc.. Our work puts to rest decades-long arguments and motivates improved steady-state and transient thermometry protocols based on the anti-Stokes emission.

References

[1] Y. Sivan, Y. Dubi, ACS Nano 15, 8724 (2021).
[2] Y. Dubi, Y. Sivan, Light: Science & Applications 8, 89 (2019).
[3] L. Roloff, P. Klemm, I. Gronwald, R. Huber, J. M. Lupton, S. Bange, Nano Lett. 17, 7914 (2017).

Tuesday, December 13 | Parallel Session 5 | 13:50 - 15:20

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session: Spectroscopy and Optical Sensing - Dr. Ayala Ronen

Invited speaker |

Underwater Wireless Optical Communication: State-of-the-Art and Next Challenges

Dr. Amir Handelman

Faculty of Electrical Engineering, Holon Institute of Technology, Holon, Israel

Although water is known to be a poor media for propagation of light beams due to significant scattering and absorption properties, Underwater Wireless Optical Communication (UWOC) has attracted a lot of attention recently. UWOC systems may be used for oceanographic studies, such as sea-floor survey and pollution control and for military applications, such as aircraft- submarines communication, and could be deployed in underwater imaging systems, such as light detection and ranging (LIDAR). In this talk, I will introduce the research field of UWOC, discuss its recent applications and outline the current research directions in this field.

DNA Recognition with Nanoplasmonic Raman Spectroscopy

V. Shvalya[1], A. Vasudevan[1], M. Modic[1], M. Abutoama[2], J. Zavašnik[1], C. Skubic[3], N. Nadižar[3], D. Rozman[3], I.Abdulhalim [2],U. Cvelbar[1]

1 *Department of Gaseous Electronics (F6), Jožef Stefan Institute, Jamova cesta 39, SI-1000 Ljubljana, Slovenia, EU*
2 *Department of Electrooptics and Photonics Engineering and the Ilse Katz Center for Nanoscale Science and Technology, School of Electrical and Computer Engineering, Ben-Gurion University of the Negev, Beer Sheba 84105, Israel*
3 *Centre for Functional Genomics and Bio-Chips, Institute of Biochemistry and Molecular Genetics, Faculty of Medicine, University of Ljubljana, Zeloška*
4 *SI-1000 Ljubljana*

Raman scattering plasmonic enhancers represent a significant interest in developing optically-driven sensing accessories with non-destructive, fast diagnostics of biological macromolecules like monolayers of DNA, RNA, and lipids. DNA/RNA-related investigations are of certain relevance in modern nanomedicine applications due to bionanotechnology, DNA vaccines and functional gene engineering progress. DNA is among the most valued objects for medical researchers and microbiologists because of its nucleotide composition and arrangement, which can provide valuable information about bio-species' nature.[1] However, this biological substance is challenging to investigate. Currently, the number of molecular-sensitive methods for DNA-level study is quite limited, among which PCR (polymer chain reaction) related methods dominate the field. Spectroscopic techniques (Raman, FTIR) that could elaborate on structural and dynamic molecular properties can be used to improve diagnostics; nevertheless, they have certain analytical limitations. The Raman scattering possesses the highest potential, but the low scattering cross-section still hinders its application for DNA-type analysis. These restrictions are challenged in SERS (surface-enhanced Raman spectroscopy). SERS provides significantly improved photon scattering processes by using plasmonic nanomaterials due to the field confinement effect.[2] In prior work, a high-performing nanoplasmonic sensor was designed involving a plasma-accelerated electrochemical reduction mechanism. By this method, nanogold aggregates were obtained from the nebulised ionic gold liquid precursor. With an analytical enhancement factor of about 107, the substrate was allowed to obtain Raman fingerprints of bacterial DNA fragments (M. luteus and S. aureus, E. coli, J. lividum) at nanovolume sample quantities. Further, key DNA vibrational signatures were linked to the nucleotide in-plane modes that were successfully used to differentiate the bacterial strains reliably by statistical principal component analysis.

References

[1] Garcia-Rico, E., Alvarez-Puebla, R. A., & Guerrini, L. (2018). Chemical Society Reviews, 47(13), 4909-4923.
[2] Shvalya, V., Filipič, G., Zavašnik, J., Abdulhalim, I., & Cvelbar, U. (2020). Applied Physics Reviews, 7(3), 031307.

Super-Resolution Raman Spectroscopy - Applications to Diamond Identification

The project was made by Yishai Amiel (Jerusalem College of Technology, Jerusalem - Bar Ilan University, Ramat-Gan) in the Device Spectroscopy Lab, at Bar Ilan University together with Prof. Yaakov R. Tischler and Dr. Hadass Tischler

Supervisors:

Prof. Yaakov R. Tischler - Device Spectroscopy Lab (BINA), BIU

Mr. Yaakov Mandelbaum - Jerusalem College of Technology, JCT

Introduction: In this project, we present a method to super-resolved Raman spectroscopy, which improves the resolution of obtained spectra, and allows unambiguous detection of molecules with similar spectra. Experimental investigations were carried out on the spectra of a Natural and Lab-Grown Diamond, where a spectral resolution improvement of at least 2.5X of the original spectrum has been obtained.

Methods: A Fabry-Perot (F-P) Etalon filter (Finesse <30, FSR = 2/cm), mounted on an angle-tunable motor, was added to the classical Raman setup in which automatically measuring the spectra for many different states of the F-P filter coupled with decoded experimental results yielded a spectrum of higher resolution having a reduced linewidth in Diamonds spectrum. Therefore, in addition for it being helpful for improving the detection of substances using a low-resolution Raman spectroscopy system, this method can also be a potential method for improving the differentiation of Natural vs. Lab-Grown Diamonds. In addition, this can also be an efficient solution for the improvement of imaging systems with low-resolution sensors. Unlike previous published experiments, which varied the mirror distances (d) or the refractive index (n) of the Etalon, we will be varying the angle (θ). The rationale and benefits of varying the angle is that the etalon itself can be fabricated plane and parallel by design, obviating the need to maintain parallelism of the etalon plates if the gap, d, was to be scanned. Also, the motion is only required around one axis, which simplifies both the actuation and metrology.

Results and Conclusions: After experimenting and improving the proposed setup we finally got to several sets of repeatable data, for two positions of two sorts of diamonds mentioned above. This Data should be compared to the theoretical model which should lead to a significant improvement in resolution and to a potentially differentiation of the two Diamonds.

A Phase Stable Hybrid Dual Comb Spectrometer

Sutapa Ghosh and Gadi Eisenstein

Andrew and Erna Viterby Department of Electrical Engineering and Russell Berrie Nanotechnology Institute, Technion-Israel Institute of Technology, Haifa 32000, Israel

We have demonstrated a hybrid design of a dual comb spectrometer (DCS) comprising a commercial broadband fibre laser system and an active mode locked semiconductor laser having a widely tunable, relatively narrow spectrum. The DCS system exhibits very long, 100 seconds, mutual coherence between the two combs. The long-term absolute stability of the DCS system is measured to be 5×10-12 at 1 second and is attained by stabilizing the broadband laser on high finesse cavity.

Introduction: Dual comb spectroscopy (DCS) offers significant advantages over other broadband spectroscopy methods mainly in terms of high frequency resolution, fast data acquisition and mechanical stability due to the absence of any moving part [1]. DCS involves two frequency combs with slightly different repetition rates. Generally, one laser interrogates a sample such that the properties of the sample get mapped onto that laser spectrum, which is consequently sampled by the second laser, generating beats in the RF domain at multiples of the difference between the repetition rates. The sample properties are detectable on the RF spectrum. A crucial property of a DCS system is the mutual coherence of the two combs which must be long in order to allow characterization of weak molecular interactions. It is more challenging to establish high mutual coherences between hybrid system since it uses vastly different lasers[2].

Methods: The hybrid dual comb interferometer comprised a commercial erbium doped fiber-based FC with a repetition rate, frep of 250 MHz and a MLL whose repetition rate is detuned from the FC by δfrep of 25 kHz. Fig. 1 shows a general schematic of the experimental set up. The MLL is injection locked by a tunable CW laser which controls the carrier envelop offset (CEO) of the MLL. The CW laser is stabilized on a single tooth of the FC. This allows the CEO of the MLL to follow the frequency fluctuation of the FC what eliminates the need to stabilized the CEO using the conventional f-2f scheme [3, 4] which requires an octave wide spectrum. The repetition rate of the MLL is set by its RF drive drive whose frequency is derived from the FC repetition rate. This allows the MLL to continuously follow the timing and phase fluctuations of the FC in real-time, yielding the long coherence times between the two combs. The MLL was phase modulated at 12 kHz and transmitted through the cavity at the output of which it was demodulated by a lock-in amplifier. This error signal fed the feedback control of the FC CEO through AOM1 and provided slow feedback to the length of the FC. The free spectral range of the cavity is 6 GHz, which means that every 24th mode of the MLL passes through the cavity and contributes to the error signal. The contributions of multiple comb lines stabilizing the entire comb spectrum with a high signal to noise ration (SNR).

Results: To quantify the quality of our locking scheme, we performed a heterodyne measurement of the MLL with a second CW laser which was locked to the high finesse cavity and has a linewidth below 100 Hz. This yielded the short-term frequency noise. For the free-running MLL, the linewidth of the heterodyne beat was around 880 kHz while under a stabilized condition, the linewidth reduced to 17 kHz as shown in Fig. 2 (a). The heterodyne beat frequency between the MLL and the CW laser was recorded over 500 seconds to calculate the Allan deviation as shown in Fig. 2(b). The stability was found to be 5 × 10-12 at 1 second and 5 × 10-14 at 350 seconds. The mutual coherence of the system we devised was characterized by measuring the rubidium Doppler spectrum at 313 K with different integration times. Both the FC and MLL were tuned to 1560 nm and were amplified before being frequency doubled to

780 nm. The frequency doubled FC was focused on the rubidium cell and combined with the frequency doubled MLL. The beat between them reveals the Doppler profile of the rubidium atoms as shown in Fig. 2(c). Due to the technical limitations of the data acquisition system, the averaging was performed on the Fourier domain data. A Doppler width of 535 MHz (FWHM) is extracted from the absorption spectra of 87Rb and 85Rb after averaging for 100 seconds. The calculated SNR for different integration times is shown in Fig. 2 (d). The slope of 0.51 confirms the square root dependence of the SNR on the integration time [5].

Conclusions: Mutual coherence is independent of the absolute stability of the FC. However, long data acquisition times demand that the long-term FC frequency fluctuations should be much lower than the sample absorption width so as not to degrade the SNR. This limitation is severe for Doppler free spectroscopy. The direct locking of a pulsed laser to a high finesse cavity, which we have implemented, simplifies the stabilization set up and ensures high, long term absolute stability. Since the error signal is generated in the transmission mode, the restriction that all comb laser lines have to be resonant with the cavity mode (which is the case in reflection mode) is eliminated. The repetition rate of the comb is tuned such that some lines at the spectrum edges are resonant iii with the cavity mode and contribute to the error signal. This lead to the stabilization of entire comb spectrum.

References

[1] N. R. Newbury, I. Coddington, and W. Swann, Sensitivity of coherent dual-comb spectroscopy, Opt. Express 18, 7929 (2010).
[2] L. Consolino, M. Nafa, M. D. Regis, F. Cappelli, K. Garrasi, F. P. Mezzapesa, L. Li, A. G. Davies, E. H. Linfield, M. S. Vitiello, S. Bartalini, and P. D. Natale, Quantum cascade laser based hybrid dual comb spectrometer, Communications Physics 3, 69 (2020).
[3] H. Telle, G. Steinmeyer, A. Dunlop, J. Stenger, D. Sutter, and U. Keller, Carrier-envelope offset phase control: A novel concept for absolute optical frequency measurement and ultrashort pulse generation, Appl Phys B 69, 327-332 (1999).
[4] D. J. Jones, S. A. Diddams, J. K. Ranka, A. Stentz, R. S. Windeler, J. L. Hall, and S. T. Cundiff, Carrier-envelope phase control of femtosecond mode-locked lasers and direct optical frequency synthesis, Science 288, 635 (2000).
[5] I. Coddington, N. Newbury, and W. Swann, Dual-comb spectroscopy, Optica 3, 414 (2016).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Tuesday, December 13 | Parallel Session 5 | 13:50 - 15:20

Long Wavelength QCL with Pulsed Operation for Spectroscopy

Roland Teissier, Mathieu Carras
mirSense, Palaiseau, France

The unique antimonide quantum cascade lasers (QCL) technology developed by mirSense extends the accessible spectral range into the long wavelength infrared up to 20 μm [1] at room temperature and address new molecules such as benzene and the BTEX family [2][3]. The CW regime is generally presented as a requirement for high-resolution, high-sensitivity spectroscopy applications using QCLs. However, the large power consumption of the laser and its temperature regulation system can be a strong limitation for real applications. Driving the laser with short current pulses the pulsed mode allows a wider and higher temperature range of the QCL chip to be exploited. This leads to a wider spectral coverage for a given QCL chip and facilitates its integration into a system. We present here a study of the chirp of the Unimir QCLs and demonstrate that narrow linewidth, suitable for gas sensing applications close to atmospheric pressure, can be easily achieved with pulsed operation of the lasers. This is a specificity of the QCL operating at long wavelength with low current densities.

References

[1] https://mirsense.com/
[2] J. Karhu, H. Philip, A. Baranov, R. Teissier, and T. Hieta, 'Sub-ppb detection of benzene using cantileverenhanced photoacoustic spectroscopy with a long-wavelength infrared quantum cascade laser', Opt. Lett., OL 45, no. 21, pp. 5962-5965, (2020). https://doi.org/10.1364/OL.405402.
[3] D. Ayache, W. Trzpil, R. Rousseau, K. Kinjalk, R. Teissier, A. N. Baranov, M. Bahriz, and A. Vicet, 'Benzene sensing by Quartz Enhanced Photoacoustic Spectroscopy at 14.85 μm', Opt. Express, OE 30, no. 4, pp. 5531-5539, (2022). https://doi.org/10.1364/OE.447197.

Enhanced Molecular Orientation via NIR-delay-THz scheme: Experimental Results at Room Temperature

Mr. Ran Damari, A. Beer, D. Rosenberg, S. Fleischer
Tel Aviv University, Tel Aviv, Israel

Introduction: Molecular orientation and alignment of gas-phase molecular ensembles is a constantly evolving field of research. Molecular alignment is commonly induced by an ultrashort laser pulse (typically near-IR) that exerts torque via non-resonant interaction with the anisotropic polarizability tensor of the molecules. Orientation, however, requires a resonant dipole-field interaction that is provided by a broad-band, single-cycle terahertz field (THz).

Background: While each of the above-mentioned 'rotational drivers' (near-IR and THz fields) has been vastly utilized alone, experimental applications of THz and near-IR pulses in judiciously orchestrated excitation schemes have remained very scarce. A recent development of a new detection method of molecular orientation, MOISH [1,2], allows for detection of the near-IR-THZ concerted signals in the gas phase.

Objectives: Experimental demonstration of an efficient and relatively simple scheme for inducing molecular orientation enhancement in gas phase molecular rotors. Methods: Molecular orientation enhancement is obtained by pre aligning the molecular ensemble via a near-IR pulse which is then followed by a THz pulse timed for optimum effect. Detection of the orientation responses is provided by the recently developed MOISH technique.

Results: While near-IR excitation of cold molecules prior to their interaction with a THz field have shown to yield significantly larger degree of orientation [3]. Here we demonstrate a 6-fold enhancement in the orientation of room-temperature molecular ensembles by a near-IR rotational excitation prior to the THz field excitation [4].

Conclusions: Concerted THz and near-IR rotational excitations, supported by the all-optical MOISH detection, provide a practical and efficient means of experimental realization of orientational enhancement. A needed tool for various research endeavors that utilize oriented molecular ensembles.

References

[1] A. Beer, D. Hershkovitz, and S. Fleischer, Iris-Assisted Terahertz Field-Induced Second-Harmonic Generation in Air, Opt. Lett. Vol. 44, Issue 21, Pp. 5190-5193 44, 5190 (2019).
[2] A. Beer, R. Damari, Y. Chen, and S. Fleischer, Molecular Orientation-Induced Second-Harmonic Generation: Deciphering Different Contributions Apart, J. Phys. Chem. A 126, 3732 (2022).
[3] K. N. Egodapitiya, S. Li, and R. R. Jones, Terahertz-Induced Field-Free Orientation of Rotationally Excited Molecules, Phys. Rev. Lett. 112, 1 (2014).
[4] I. Tutunnikov, L. Xu, Y. Prior, and I. S. Averbukh, Echo-Enhanced Molecular Orientation at High Temperatures, (2022)

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics
Tuesday, December 13 | Parallel Session 5 | 13:50 - 15:20

Session: Optics in Defense - Dr. Ami Yaacobi

Non-Line-of-Sight Passive Localization around Corners with Light and with Sound

Mr. Jeremy Boger-Lompbard and Ori Katz
Hebrew University of Jerusalem, Jerusalem, Israel

Non-line-of-sight (NLoS) imaging is an important challenge in many fields ranging from autonomous vehicles and smart cities to defense applications. Several recent works in the fields of optics and acoustics tackle the challenge of imaging targets hidden from view (e.g. placed around a corner) by measuring time-of-flight (ToF) information using active SONAR/LiDAR techniques, effectively mapping the Green functions (impulse responses) from several sources to an array of detectors [1-3]. In optics, inspired by techniques used for passive RADAR and geophysical mapping[4], we have shown that it is possible to retrieve femtosecond-scale temporal information from cross-correlations of ambient broadband light, without any active source or ultrafast detectors, and to use this information for 3D scene reconstruction, through scattering medium and around a corner[5]. In acoustics, leveraging passive correlations-based imaging techniques, we study the possibility of NLoS target localization around a corner without the use of controlled active sources. We demonstrate localization and tracking of a human subject hidden around the corner in a reverberating room, using Green functions that have been retrieved from correlations of broadband noise in multiple detectors. Our results demonstrate that the controlled active sources can be replaced by passive detectors, as long as a sufficiently broadband noise is present in the scene.

References

[1] A. Velten et al. Nature Communications 3, 745 (2012).
[2] D. Faccio et al. Nature Reviews Physics 2, 318-327 (2020).
[3] D. B. Lindell et al. in Proceedings of the IEEE/CVF,6780-6789 (2019).
[4] R. Snieder et al. Science 295, 2253-2255 (2002).
[5] J. Boger-Lombard et al. Nature Communications 10, 3343 (2019).

A Novel Large Optics Mounting Design

Mr. Oded Lahav
Rafael Advanced Defense Systems, Israel

As part of the worldwide transition into the new-space era, there is a need for ultrahigh-performance imaging systems while keeping low prices and high level of manufacturability. This, in turn, is critical for launching large constellation of earthobserving satellites.

Traditional electro-optical space systems are based on carbon-fiber structures that, thanks to their low CTE differences from the optical elements, enables using traditional mounting concepts such as bipods. This requires special knowledge and know-how in both design and manufacturing of the carbon-fiber structure, hence making the development process less straightforward, more expensive, and more time consuming. In addition, carbonfiber structures pose challenges in interfacing other materials.

The Spacecraft platform is usually metallic, hence metal inserts must be combined into the carbon-based chassis. The novel approach presented in this work (patent pending) allows mounting large optical elements, namely the main and secondary telescope mirrors, onto chassis that can be based on common metals, e.g. Aluminum. As a result, the optomechanical system development cycle becomes very simple, based on common manufacturing and machining techniques.

System price and time-to-market is significantly reduced, while also improving potential production capacity. The fundamental element allowing the above is the Passive Thermal Actuator. The Passive Thermal Actuator is a geometrical structure combining two materials of different CTE.

The effective CTE of the actuator can be tailored to the optomechanical design, so as to effectively cancel the thermal inspired movement of the metal chassis relative to optical mount points, leaving the optics undisturbed. A specific Passive Thermal Actuator design will be presented. Simulation results will be discussed, and recent experimental POD experiments will be shown.

Dead-Time effect on SPAD Efficiency

Dr. Yishai Albeck, Eran Greenberg and Talya Arusi-Parpar
Soreq Nuclear Research Center, Yavne, Israel

Single-Photon Avalanche Diodes (SPADs) are an advancing technology, that is finding use in more and more applications. These span fields from sensing and surveillance as well as quantum research of entangled photons. In addition to the high sensitivity to a single photon, the instant response allows in principle high temporal resolution for detection of fast events. However, to reduce false after-pulses, SPADs are activated with long dead-times following each recorded event that significantly reduce the effective efficiency of the detector.

When utilizing the advantages of SPADs for LIDAR (LIght Detection And Ranging) applications, especially involving challenging environmental conditions such as solar background, it is of utmost importance to define the optimal way to operate the SPAD. In our work we inspect the influence of the length of the dead-time on the detector efficiency, while emphasizing the difference between gated and ungated mode of operation. We show an analytical description together with simulated results of a Monte-Carlo model of the detector, and compare these to experimental results. From these results we conclude the mode of work recommended for different operation conditions.

Narcissus Reduction in Advanced Thermal Imaging Zoom Lenses

Gil Gurevitz, Avner Botbol, Dror Oskar, Dr. Nissim Asida
Ophir Optics, MKS Instruments

Introduction: Narcissus is one of the unwanted effects of thermal imaging. With narcissus, a cold detector images the reflection of itself and displays it in the processed video output. Typically, the source of the narcissus effect is the IR detector cold shield that is kept at cryogenic temperatures, while the lens' temperature is usually near ambient temperature. This creates a significant temperature difference between the detector cold-shield and the lens' inner surfaces.

Objectives: In this paper, we describe the process that allows us to predict, control, significantly reduce, and measure Narcissus in advanced thermal imaging zoom lenses.

Methods: First, we describe how we can simulate and predict both magnitude and shape of narcissus in various zoom positions, for specific zoom lens optical designs. Next, we describe three methods for controlling and reducing narcissus: a. Optical design b. AR coatings c. Filters In order to verify our narcissus predictions, we designed and implemented a setup that enables us to measure absolute narcissus values and set pass/fail criteria for each zoom lens we build.

Results: Narcissus magnitude and shape simulations + measurements setup results

Conclusions: In this paper we first demonstrate how we can analyze, simulate and predict narcissus. These capabilities enable us to take specific measures to control and suppress narcissus to acceptable levels either by modifying the optical design, or applying unique coatings. In order to verify our predictions and simulations, we built a test setup which measures absolute narcissus values. Utilizing this measurement setup in our assembly line ensures that the lenses we deliver are free of narcissus.

Deployable Asymmetric Space Telescope

B. M. Levine and Erez N. Ribak
Department of Physics, Technion - Israel Institute of Technology

Background: Designs for a deployable sparse space telescope use contiguous rectangular or hexagonal segments. The straight edges of these elements scatter a great deal of light in the focal plane of the telescope. This scattered light appears as coherent spokes, which limit the ability to detect faint objects next to a bright one. In addition, alignment is very lengthy and prone to errors.

Objectives: We wish to devise telescope panels shapes both for imaging and for initial alignment.

Methods: Our laboratory set-up is made of two 20cm parabolas facing each other, the first a collimator, the second being the segmented telescope model. Analysis of the images leads to computerized commands to the sectors PZT actuators, without additional sensors. The straight edges of the segments, sawn from a full parabola, diffract a great deal of light normal to their directions, so they had to be rounded. For reduced redundancy, they were oriented at different angles: we optimised the shapes and angles to increase the mid-frequency response.

Results: For ellipses with axes ratios a/b of 1.5 to 2.2, the azimuthal optimal angles between segments were 67°, 84°, 113° and 96°. Each sector has its own unique PSF, and sectors at different angles can be differentiated by their PSF orientation, even when overlapped. We used four matched filters to correct for their tip and tilt. Finally, the phases of the fringes between these ellipses enabled measurement of their mutual OPDs. Log PSFMTFStraight segment edgesRounded segment edges

Recommendations: Today aperture masking and segmented telescopes have a symmetrical design for the sub-apertures shapes; breaking that symmetry has its many benefits.

Reference

B M Levine, M Kaplun and E N Ribak: An asymmetric Sparse Telescope, Optics Continuum 1, 1603-12 (2022).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Tuesday, December 13 | Parallel Session 5 | 13:50 - 15:20

Session: Electro-Optics in Industry - Dr. Rami Cohen

Invited speaker |

Automated Assembly and Testing of Electro-Optical Systems

Mr. Tobias Müller
Technical Director, Aixemtec GmbH, Herzogenrath, Germany

With the help of a modular and open assembly and test platform, processes for the automated production of electrooptical systems can be easily implemented.

The assembly and testing of electrooptical systems often requires the optical coupling of single-mode or multimode fibers, collimation of lasers, assembly of resonators, visual inspection of optical elements and many more. In many cases like the alignment of fiber to waveguide or the alignment of a short focal length lens, such as an FAC, precision down to the deep sub-μm range must be achieved. Combined with a wide range of components and products, this results in high complexity for test and assembly machines to serve broad application spectrums, especially in research and development environments.

Based on Aixemtec's modular and open assembly and test platform, a highly flexible system has now been created that allows for testing and assembly tasks for Lasers, Cameras/Vision Systems or Silicon Photonics/PIC systems performed efficiently in an automated way. This platform provides the ability to address specific requirements depending on the end application. These essential tools and process chains are presented below:

- Modular machine architecture with open-source programming interface for (optional) independent process development of IP-relevant processes
- Generic feeding and handling solutions for the various optical elements needed
- Simultaneous precision alignment of up to 3 components with collaborating 6-axis micromanipulators
- Processing of single fibers and fiber arrays, mirrors, lenses, chips and many more
- Temperature-controlled assembly and test station, compatible with single chips, butterfly packages and customized packages
- motorized and automated landing electric needle probing unit
- highly integrated sensor system for pre-positioning and active alignment in up to six degrees of freedom
- Precision tools for automated UV-curing adhesive bonds

All applications are implemented on the same generic machine platform and can be combined into production lines for high throughput, if required.
Furthermore, AIXEMTEC has a broad offering of design for assembly, prototyping and small series production enabling sales of turn-key solutions for their end-customers and is executing project with leading Israeli photonics companies.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

KLA Optical Metrology Division and the key challenges in Overlay metrology of advanced Semiconductor Integrated Circuits

Mr. Ohad Bachar
KLA, Israel

KLA is a world leader in providing metrology and inspection tools and services for controlling the manufacturing process of advanced Semiconductor Integrated Circuits. Virtually every electronic device in the world is produced using KLA technologies.

Located at Migdal HaEmek in Israel, KLA Optical Metrology Division (OMD) is responsible for developing tools and services for the metrology of patterned layers misregistration (Overlay) which is one of the most critical challenges in the manufacturing process of advanced Integrated Circuits.

Utilization of optical wavelengths is key for penetrating through the Semiconductor stack as well as for enabling high measurement throughput which is needed for avoiding loss of manufacturing capacity, however it imposes several significant challenges, which are at the focus of the R&D work done by KLA OMD scientists and engineers. In this talk we will discuss 3 of these challenges and their solutions. The first challenge would be to sense nanometric Overlay when using optical wavelengths of hundreds of nanometers, with the solution being printing of dedicated measurable proxy targets and utilization of advanced algorithms for extracting the unresolved Overlay. The second challenge is in ensuring that the Overlay measured on the proxy targets is indeed representative of the Overlay of the Integrated Circuits. The solution for this challenge would be low frequency verification of the Overlay readings using other technologies that are accurate yet less effective or viable for inline use. Finally, we will also discuss the challenge of minimizing the tool systematic error, termed Tool Induced Shift (TIS), at minimal throughput impact through utilization of various hardware and software TIS management methods

Tuesday, December 13 | Parallel Session 5 | 13:50 - 15:20

Invited speaker |

Combining Electrons and Energetic Photons Information in a Scanning Electron Microscopy for Advanced Semiconductors Applications

Martin Chauvin, Ph.D
Senior physicist - SEM physics group - Applied Materials

Introduction: Over decades, the increase of transistors density was driven by the miniaturization of planar structures. However, more recently, planar FETs (field effect transistors) were replaced by finFET devices to overcome performance issues that arise when the channel is made shorter. By creating the channel as a fin protruding above the wafer surface, the gate can be wrapped around three sides of the fin to achieve better control over the charge carriers.

Applied Materials, the world leader in electron beam inspection, provides solutions for defect mapping and metrology of the smallest features in these devices with optimal SEM (scanning electron microscopy) techniques. Using a primary beam focused to a spot smaller than 1 nanometer in size, electrons emitted from the wafer are collected and analyzed to obtain topography as well as material contrast information with unprecedented resolution, throughput, and stability.

Perspectives: Because charge transport mechanisms have intrinsic limits at nanometer scale, device performances improvement cannot be driven further by miniaturization only. Instead, the industry is moving towards highly three-dimensional structures made with multiple novel materials. An example is the gate all around transistor in which the channel comprises several stacked Silicon nanosheets with a complex gate stack arrangement of layered materials down to ~1 nm thickness. This fundamental transition calls for novel metrology capabilities.

The uniqueness of Applied Materials approach is to leverage the optimal properties of the electron beam to locally excite the atoms of the nanostructures and additionally collect characteristic Xray photons emitted during their relaxation.

Local information contained in the electrons and photons signals is grabbed simultaneously to locally retrieve topography and material composition of three-dimensional structures, at unprecedented resolution and throughput - a critical capability to enable the next generation of semiconductor devices.

In this talk, advanced SEM and hybrid SEM-photon imaging techniques will be reviewed.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Invited speaker |

SWIFT-EI Event-based Imager and Laser Multispot Sensor in SWIR

Dr. Claudio Jakobson, R. Fraenkel, N. Ben Ari, R. Dobromislin, N. Shiloah, T. Argov, W. Freiman, G. Zohar, L. Langof, O. Ofer, R. Elishkov, E. Shunem, M. Labilov, M. Alcheck, Y. Kalfa, M. Nitzani, Y. Karni, T. Markovitz
SCD-Semiconductor Devices, Haifa, Israel

Grabbing video frames at high frame rates is highly desirable for various imaging applications. For instance autonomous navigation, collision awareness or wake-up on demand may benefit from video imaging with fast imaging frame rates. However, the conventional video imaging readout circuits present a bottleneck that practically limits video frame rate to hundreds of Hz. Event-based imaging is a new emerging imaging paradigm focused only on variations in the pixel target that breaks the speed bottleneck in conventional imaging. Typically, event vision aims at machine use.

In defense applications, event cameras may be applied to persistent surveillance, movement detection, object recognition and object tracking. Moreover, due to its fast response, they can detect and track gun muzzle. Active defense systems may benefit from event imaging for fast response to hostile threats. Navigation systems such as defense autonomous vehicles and drones can use event imaging for movement assistance and collision avoidance and at the same time assess motion-based depth information. Other processing options may enable its use to eliminate image artifacts caused by vibrations, turbulence or flow measuring. In addition, laser pulses are a specific case of fast event with many applications in defense at the SWIR wavelengths.

SCD is now developing a new product, SWIFT-EI, which is the first to introduce event-based imaging and laser-multispot in the SWIR wavelength regime. This new imager provides a simultaneous conventional high FPS image synchronized to the event-based or to the laser multi-spot output.

SWIFT-EI follows the line of multi-functional InGaAs/InP SWIR products. It is a multi-mode VGA 10µm pitch sensor, which is sensitive in the visible to SWIR bands, and provides integration of standard video at high frame rate. The fast image may be combined with either event-based vision or laser multi-spot detection. The laser multi-spot feature continues the line of Asynchronous Laser Pulse Detection (ALPD), introduced in previous SWIR products of the Cardinal family. The multi- spot ALPD works at an unprecedented fast detection rate that enables the decoding of the laser Pulse Repetition Frequency (PRF) and distinguish between different lasers in the image scenario.

Therefore, it is the 3rd generation of SCD's ALPD based products. SCD methods for combining imaging with event and LPD are patented.

Keywords: Event-based, SWIR, ALPD, InGaAs, ROIC, Machine Vision, Laser Pulse Detection, Multi-spot Detection, Fast Imaging

Spectral Transmission of Materials used for Laser Safety

Dr. Shimshon (Steven) Lashansky, Galit Zilberman and Mordechai Snir
Elbit Systems Electro-Optics - ELOP, P.O.B. 1165, IL-76111 Rehovot, Israel

The development of lasers at ELOP started in the early 1970's. For many years Nd:YAG laser at a wavelength of 1.06 microns dominated the R&D military laser market. The last two decades have seen the introduction of fiber lasers and many other exotic laser systems at different wavelengths. There are currently more than 200 laser laboratories at the facility most of which were designed for the development, production and maintenance of Nd:YAG laser at 1.06 microns. The laboratories had to meet the safety requirements delineated in the laser safety standards. Viewing portals protective goggles, filters, curtains and many other items were acquired to meet these requirements. The metamorphosis of laser systems and the evolution of new laser systems necessitated a constant reshuffle of laboratories and safety equipment. Clearly suitable laser safety goggles were procured for the new wavelengths though other materials used around the laboratory were overlooked.

Serendipity is defined as an unplanned fortunate discovery, in this case resulting in the detection of unexpected residual transmission of laser energy through opaque materials. Incorrect assumptions about the laser protective equipment could result in catastrophic effects. The spectral transmission of previously certified materials was reviewed. A calibrated spectrometer was used to measure the spectral transmission of the materials in question from the UV to the Mid Wave IR (MWIR). Other models and methods were used to authenticate the results.

The results were also compared to measurements made in previous studies. This paper describes the process and summarizes the results. Some interesting unexpected discoveries were made.

Tuesday, December 13 | Parallel Session 5 | 13:50 - 15:20

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session : Micro and Nano Optics - Prof. Alina Karabchevsky

Broad-Band Impedance Matching of Dispersive Waveguides Using Exceptional Points and White Light Cavities

Prof. Jacob Scheuer[1], Dimitry Filonov[1,2] and Pavel Ginzburg[1]

1 Department of Physical Electronics, Tel-Aviv University, Ramat-Aviv, Tel-Aviv 6997810 Israel
2 Center for photonics and 2D materials, Moscow Inst. Of Physics and Technology, Dolgoprudny, Russia

We present a new approach for multi-section broadband impedance matching, overcoming structural and material dispersion. The transformer constitutes a critically-coupled white light cavity, thus minimizing reflectivity. The approach is demonstrated in the millimeter waves band.

Introduction: Efficient injection of light into waveguides necessitates (among other things) matching between the impedance of the source waveguide to that of the target waveguide. A similar problem is the design of anti-reflection coating. One of the most commonly used approach is to use a quarter wavelength transformer with an impedance $Ztr = \sqrt{ZinZload}$. However, the bandwidth of this matching approach is relatively narrow and insufficient for many broadband applications. Broader impedance matching can be obtained by employing several l/4 layers/waveguides with properly selected impedances [1]. The choice of the impedances can be made using filter theory where the transformer serves as a maximally flat filter connecting the input and load waveguides [1]. The main drawback of this approach is that it does not account for neither the material nor the waveguide structure dispersion, thus reducing the potential bandwidth of the transformer. Here, we show how to utilize the concepts of white light cavity (WLC) and exceptional points in order to take the impact of dispersion into account and obtain broader impedance matching [2].

2. White light cavities A WLC can be obtained by introducing a phase compensation element into a regular cavity (see Fig. 1a) [3,4]. If the dispersion of the phase element is negative, it is possible to obtain a broad and flat resonance. Such phase compensator can be realized using an, additional, under-coupled cavity with proper choice of coupling coefficients. Specifically, if the reflection of additional cavity is considered as a frequency dependent mirror, then the overall structure (the two cavity) form a WLC if the following condition is satisfied: $d\theta/d\omega = \Delta\nu FSR$, where q is the phase response of the phase compensator mirror and $\Delta\nu FSR$ is the FSR of the original cavity [4]. It has also been shown that when that condition equivalent to the formation of an exceptional point in the eigen-values map of the coupled cavities [2]. In addition, if the WLC is also set to be critically coupled, its transfer function is flat, with maximal transmission (minimal reflectivity) as shown in Fig. 1a.
The WLC approach can be utilized to optimize the transmission between two different waveguides (Fig. 1b). Here the WLC serves as a broadband l/4 transformer. The length of each section is set to be a quarter of the central wavelength of the desired spectral band to be matched while the characteristic impedances are set such that the WLC and the critical coupling conditions are satisfied. These two conditions determine the refractive index of the dielectric filling the waveguides (or equivalently the refractive index of the layers in an AR coating). Because the WLC conditions depends to the FSR of the "first cavity (marked as Lcav in Fig. 1a) the dispersion properties of the material and the waveguide are automatically introduced. In addition, the dispersion also modifies the reflection and transmission q (w) Df w q (w) 2k0nLcav Lcav w S11 Input waveguide Z0, n0 Load waveguide Zend, nend "Main" cavity Z1, n1, L1 Phase component Z2, n2, L2 WLC (a) (b) Eimp Eref coefficients at the interfaces between the different waveguides. This dependence must also be take when calculating q (w) which in Fig. 1b correspond to the waveguide section marked as "2".

3. Broadband impedance matching As a concrete example we use this approach for obtaining broadband impedance matching between two metallic rectangular waveguides. The waveguides cross-section is 22.86mm X 10.16mm and it is filled with a low-loss, plastic, dielectric material with er which can vary between 1 and 2.5. The dielectric coefficient can be modified between these extreme values by controlling the density of the material. The central frequency of the impedance matching is set to 10GHz.

Fig. 2a depicts the measured dielectric coefficient of the waveguide filling material at 10GHz as a function of the filling factor. As the filling factor increases from 10% to 100% the dielectric coefficient increases monotonically from er=1.24 to er=2.5. Fig. 2b depicts a comparison between the calculated |S11| 2 parameter for two-section impedance matching based on the conventional approach (blue) and that of the WLC approach (red). While both approaches obtain low reflection level in the vicinity of the central frequency, the reflection of the WLC based impedance matched waveguides is lower than that of the conventional approach as the frequencies is tuned away from 10GHz. We note that the difference is not substantial (~3%) because the dispersion properties of the specific waveguide are relatively low. Nevertheless, the lower reflection obtained for the WLC approach clearly indicates that it provides a better design. The inset of Fig. 2b depict the measured reflection from the structure. The obtained bandwidth is lower than expected due to the losses of the material, however 3Ghz bandwidth of low reflection is obtained.

Conclusions: We have presented a new approach for broadband impedance matching that takes into account the both the material and structural dispersion. The design approach utilizes the concepts of WLC to form a multi-section structure which serves as abroad band, critically coupled cavity connecting between the input and the load waveguide. The WLC effect extends the bandwidth of the resonator while the critical coupling ensures that only a small fraction of the impinging power is reflected. This design approach is universal and can be applied for broadband AR coating, coupled-resonator filters and more. In the talk we will elaborate on the experiments and discuss additional applications of the design methods for optical AR coating and perfect absorption.

References

[1] R. E. Collin, Foundations for Microwave Engineering (Wiley-IEEE Press, 2001), Chap. 5.
[2] J. Scheuer, "White light cavity formation and superluminal lasing near exceptional points," Opt. Express 26, 32091-32102 (2018).
[3] A. Wicht, K. Danzmann, M. Fleischhauer, M. Scully, G. Müller, and R. H. Rinkleff, "White-light cavities, atomic phase coherence, and gravitational wave detectors," Opt. Commun. 134(1-6), 431-439 (1997).
[4] G. S. Pati, M. Salit, K. Salit, and M. S. Shahriar, "Demonstration of a Tunable-Bandwidth White-Light Interferometer Using Anomalous Dispersion in Atomic Vapor," Phys. Rev. Lett. 99(13), 133601 (2007).

Invited speaker |

Micro and Nano-Optics: Ongoing Research and Future Directions

Prof. Alina Karabchevsky
Ben-Gurion University of the Negev, Beer-Sheva, Israel

Micro- and Nano-optics is a fascinating research field resulting from the combination between optics and nanophotonics which carries the scientific extension of traditional optics at sub-wavelength scales and promotes the development of substantive innovations in nanotechnology with the help of optical platforms. Micro- and Nano-optics have a wide range of application prospects in many important fields such as optical communication, optical storage, solar energy utilization, semiconductor laser, and optical anti-counterfeiting technology. In my talk, I will summarise the development of micro-nano optics in four directions: integrated nanophotonics, micro-nano optical waveguide materials and devices[1], micro-nano optical detection materials and devices[2], and micro-nano optical structures and devices [3].

References

[1] A. Karabchevsky, A. Katiyi, A. S. Ang, and A. Hazan, "On-chip nanophotonics and future challenges," Nanophotonics, vol. 9, no. 12, pp. 3733-3753, 2020.
[2] A. Karabchevsky, "Single-shot circular dichroism spectroscopy," Light Sci Appl, vol. 11, no. 1, pp. 1-2, 2022.
[3] A. Karabchevsky, "On-chip optical vortex-based nanophotonic detectors," Light Sci Appl, vol. 9, 2020.

Introducing New Phases of Matter to Microphotonics

Prof. Tal Carmon
Photonic Enhancement Laboratory, School of Electrical Engineering, Faculty of Engineering, Tel Aviv University, Tel Aviv, Israel

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Structuring Light out of Optical Fibers Using Integrated Micro-Optics

Dr. Shlomi Lightman, Omer Porat, Raz Gvishi, Gilad Hurviz
Applied Physics Division, Soreq NRC, Yavne 81800, Israel

In this work we demonstrate for the first time a fiber-integrated parabolic lens followed by a twisted axicon, capable of transforming a TEM00 mode into a vortex beam, carrying orbital angular momentum (OAM). Recently, vortex beams raze attention, as they possess new degree of freedom that may allow higher bit-rate for fiber communication. However, integrating sophisticated refractive elements directly on fibers is challenging. By using 3D-direct laser writing, high-quality optical devices could be integrated directly on top of the fibers facet. This work provides the analysis and measurements of the generated beam, along with simulated predictions. The diffractive behavior was examined showing a factor of 1/10 in the final center ring increased width, compared to a Gaussian beam, along 20 mm from the beam waist. Near- and far-field profiles are investigated for the first time to our knowledge, upon increased laser power, reaching over 10MW/cm2. This work may pave the way for future integrated beam manipulation on fibers, enabling the use of intense laser outputs.

Displacement Trajectory of Gold Nanoparticles Under Photonic Hook

Maya Shor Peled[1], Paolo Maioli[2], Alina Karabchevsky[1]
1 *School of Electrical and Computer Engineering, Ben Gurion University, Israel*
2 *Institut Lumière Matière (ILM), CNRS and Université de Lyon, Villeurbanne, France*

The trapping and manipulation of particles by optical tools have been widely used in biological research and implemented in medicine [1], yet nanoscale objects cannot be manipulated by such tools due to the diffraction limit of light [2].

Therefore, achieving manipulation on the nanoscale requires auxiliary structures that generate a tightly confined electric field. Photonic nano-jets are high intensity, narrow light beams generated by dielectric structures that are subjected to illumination by a plane wave [3]. When the symmetry is broken, the generated structured light becomes curved, which is known as a photonic hook effect [4]. Here, we report the displacement trajectory of gold nanoparticles under photonic hook force generated with pulsed light beam. The studied system is composed of a micro-cylinder and metallic mask that partially blocks the incident light and creates an asymmetric illumination [5]. We show that the optical forces generated using pulsed illumination are fifteen orders of magnitude higher than forces generated under continuous-wave illumination, and result in the displacement of a gold nanoparticle. Our findings open a way for practical opto-mechanical manipulation of nanoparticles.

References

[1] Baker, James E., Ryan P. Badman, and Michelle D. Wang. "Nanophotonic trapping: precise manipulation and measurement of biomolecular arrays." Wiley Interdisciplinary Reviews: Nanomedicine and Nanobiotechnology 10.1 (2018): e1477.
[2] Karabchevsky, Alina, et al. "Super-Resolution Imaging and Optomechanical Manipulation Using Optical Nanojet for Nondestructive Single-Cell Research." Advanced Photonics Research 3.2 (2022): 2100233.
[3] Luk'yanchuk, Boris S., et al. "Refractive index less than two: photonic nanojets yesterday, today and tomorrow." Optical Materials Express 7.6 (2017): 1820-1847.
[4] Yue, Liyang, et al. "Photonic hook: a new curved light beam." Optics letters 43.4 (2018): 771-774.
[5] Minin, Igor V., …., Karabchevsky, Alina "Experimental demonstration of a tunable photonic hook by a partially illuminated dielectric microcylinder." Optics Letters 45.17 (2020): 4899-4902.

Tuesday, December 13 | Parallel Session 5 | 13:50 - 15:20

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Development of Nanostructured Metallodielectric Substrates for Surface Enhanced Spectroscopies and Sensing

A. Dimitriou[1], I. Kochylas[2], S. Gardelis[2], V. Likodimos[2], P. Petrou[3], G. Geka[3], A. Kanioura[3], G. Tasios[1], E. Gogolides[1] and N. Papanikolaou[1]

1 *Institute of Nanoscience and Nanotechnology, NCSR "Demokritos", Aghia Paraskevi, Athens, 15310, Greece*
2 *Section of Condensed Matter Physics, Department of Physics, National and Kapodistrian University of Athens, Panepistimiopolis, Athens 15784, Greece*
3 *Immunoassays/Immunosensors Lab, Institute of Nuclear & Radiological Sciences & Technology, Energy & Safety, NCSR "Demokritos", Aghia Paraskevi 15310, Greece*

Nanostructured metallic surfaces are well known for producing strong confinement of the electromagnetic field of impinging light. This is due to the excitation of collective oscillations of the electromagnetic field with the free electrons in the metal, so called surface plasmon polaritons, and was used in surface enhanced spectroscopies like, Raman or luminescence in the visible and infrared. The study of the optical properties of such surfaces was also pursued since they are considered a viable route for the development of ultrasensitive optical sensors with sensitivity down to single molecules.

The main objective of this work is to produce substrates for sensing different analytes using surface enhanced Raman scattering (SERS) and photoluminescence.

Several methods have been proposed to produce metal nanoparticles or nanostructured metallic surfaces. Metal assisted chemical etching (MACE) of silicon can produce metal decorated nanotexturing in Si substrates using a simple, controllable and inexpensive process, in terms of materials and fabrication equipment. The method produces Ag decorated Si nanowire (SiNW) substrates with different morphologies by treatment in aqueous AgNO3-HF solution and scanning electron microscopy micrographs of typical surface structures obtained are shown in the figure.

Moreover simple drop-casting of Au nanoparticles on the Ag decorated SiNW substrates, leads to strong photoluminecence enhancement of Rhodamine R6G, compared to the Ag decorated substrates. Optimized substrates could trace R6G at concentrations down to 10-12 M, with both Raman and photoluminescence. The substrates are currently used for the detection of cancer biomarker Ca125, as well as malondialdeide, and glutathione using appropriate protocols. Our efforts to produce SERS substrates using plasma etching on polymers will also be presented.

Different morphologies of Ag nanostructures produced by MACE by varying the etching

This work was supported by the European Union Regional Development Fund and Greek national funds (project code:T2EDK-03746), and by NATO SPS Programme, (Project: NOOSE).

Arbitrary On-Chip Polarization Manipulation with Twisted Waveguides

Fyodor Morozko[1,2], Andrey Novitsky[2], Alina Karabchevsky[1]

1 *School of Electrical and Computer Engineering, Ben-Gurion University of the Negev, BeerSheva, Israel*
2 *Department of Theoretical Physics and Astrophysics, Belarusian State University, Minsk, Belarus*

Keywords: twisted waveguides, integrated photonics, polarization manipulation

Introduction: Integrated photonics is a rapidly developing technology with applications in telecommunication, sensing, and quantum information processing. Making use of light polarization is advantageous as it serves as an additional degree of freedom for information encoding. That is why it is important to have robust integrated polarization manipulating building blocks.

Background: Traditionally, polarization manipulation on chip is performed with asymmetric waveguides having the structural linear birefringence with tilted optical axis thus acting as waveplates. This architecture, however, has several drawbacks: wavelength sensitivity, intolerance to fabrication imperfections, and coupling losses due to cross-section mismatch with normal symmetric waveguides. Moreover, such a waveplate can perform only a restricted class of polarization transformations. Direct writing integrated photonics fabrication technology allows to create waveguides with variable cross-sections particularly those with a twisted core able to rotate linear light polarization without suffering from neither of the mentioned problems due to utilization of a different physical principle of adiabatic mode evolution.

Objectives: We have theoretically investigated the ability of twisted waveguides to perform arbitrary polarization transformations beyond the rotations of linear polarization.

Methods: To analyze polarization dynamics in twisted waveguides we utilized an eigenmode solver in helical reference frame and applied the coupled mode theory. This allowed to obtain analytical expressions of the polarization transformation matrix (Jones matrix) of a twisted waveguide. To visualize polarization state, we use the Stokes parameters and Poincare (Bloch) sphere formalism.

Results: By analyzing obtained twisted waveguide's Jones matrix expression, we have found that twisted waveguides can perform arbitrary transformations of light polarization.

Conclusions: Twisted waveguide is a viable candidate as a new on-chip polarization manipulating building block which may facilitate exploitation of light polarization in integrated photonic applications. A particularly interesting application is as a quantum gate in polarization-encoded quantum information processing.

Invited speaker |

Novel polaritonic phenomena in 2D materials

Tomer Eini, Tal Asherov, Yarden Mazor and Itai Epstein

School of Electrical Engineering, Faculty of Engineering, Center for Light-Matter Interaction, QuanTAU, Quantum Science and Technology center, Tel Aviv University, Tel Aviv 6997801, Israel

Polaritons are light-matter quasi-particles in the form of optical excitations, which play a major role in nanophotonics owing to their ability to control, confine and enhance light at the nanoscale [1-4]. Even stronger confinement can be achieved by hyperbolic polaritons, i.e. polaritons supported by materials with an hyperbolic dispersion. Here [5], we show that such a dispersion can be realized in 2D semiconducting TMDs, supporting the generation of HEPs in the TMD structure. We show for the first time that TMDs can obtain a hyperbolic material response at VIS- NIR frequencies, at the frequency of the main exciton resonance, and at steady-state conditions (fig.1). This hyperbolicity stems from the combination of an in-plane negative permittivity, induced via the use high-quality van der Waals heterostructures at cryogenic temperatures [4], and an out-of-plane positive permittivity. The dispersion relation of the resulting visible frequency HEPs supported by multilayer TMDs is presented in fig. 1, showing very large momenta.

Furthermore, the inherent spin-valley selection rules for excitons in TMDs lead to HEPs that are coupled to the TMD's valley degree-of-freedom (fig1(c)).

Such highly confined polaritons in the visible spectrum can pave the way to new light-matter interaction possibilities based on 2D-materials.

References

[1] Basov D.N. et al, Science 354-95 (2016).
[2] Low T. et al, Nat. Mater. 16 182-94 (2017).
[3] I. Epstein et al, Science 368, 1219-1223 (2020).
[4] I. Epstein et al, 2D Materials 7, 035031 (2020).
[5] Tomer Eini, Tal Asherov, Yarden Mazor, and Itai Epstein, submitted 2022.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Session: Quantum Computers - Prof. Nadav Katz

Machine Learning Detection of Quantum Many-Body Localization Phase Transition

Ron Ziv[1], Antonio Rubio-Abadal[2], Anna Keselman[3], Ronen Talmon[1], Immanuel Bloch[2,4] and Mordechai Segev[1,3]

1 *Department of Electrical Engineering, Technion, Israel*
2 *Max-Planck-Institut für Quantenoptik, Germany*
3 *Department of Physics, Technion, Israel*
4 *Fakultät für Physik, Ludwig-Maximilians-Universität München, Germany*

Phase transitions are processes in physical (classical or quantum) systems where the system undergoes a fundamental change in behavior due to a change of its parameters. Deciphering the conditions of such transitionsis important to basic science and technology as different phases introduce different characteristics that can be exploited as a natural resource.

One such quantum phase transition is many-body localization. This phenomenon is related to the classical disorder-induced localization proposed by Anderson in 1958. Anderson analyzed the transport of a single quantum particle in a disordered lattice and found that under certain conditions transport comes to a complete halt. In quantum systems with many interacting degrees of freedom in the presence of a random disorder, the particles may localize, and the system fails to thermalize.

In many-body quantum (MBQ) systemsthe task of identifying the phase transition is especially hard and challenging. MBQ systems involve many quantum particles. As the dimension of a quantum system grows exponentially with the number of particles, it is notoriously hard to probe analytically and numerically, and even experimentally it is not always clear that a phase-transition has occurred and what are the correct measures that indicate a transition. As such, many aim at finding some alternative methods to identify phase transitions from experimental data. Here, machine learning methods are facing a difficult task - because simulations of 2D MBQ systems are extremely challenging on standard computers. Hence, the only option is data driven, by learning directly from experiments.

Here, we propose an algorithm for detection of quantum phase transitions in an unsupervised manner using Manifold Learning. We validate our methodology on a simulated 1D disordered BoseHubbard (BH) system, and then demonstrate it on experimental data of a 2D disordered BH system using unsupervised machine learning on the experimental data.

Tuesday, December 13 | Parallel Session 6 | 15:50 - 17:20

High-dimensional Time-Bin Quantum Key Distribution

Kfir Sulimany[1], Rom Dudkiewicz[2], Guy Pelc[1], Simcha Korenblit[1], Hagai S. Eisenberg[1], Yaron Bromberg[1], Michael Ben-Or[2]

1 *Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem, 91904 Israel*
2 *School of Computer Science & Engineering, The Hebrew University of Jerusalem, Jerusalem 91904, Israel*

Introduction and Background: High-dimensional Quantum Key distribution (QKD) protocols, based on encoding a set of states belonging to a high-dimensional Hilbert space, allows a higher secure key rate and improves the robustness to noise [1-2]. However, implementation of highdimensional QKD protocols in commercial systems is still held back, since present highdimensional schemes require significantly higher experimental resources.

Objectives and methods: In this work we present a novel approach for high-dimensional QKD with scrambled time-bin encoding, which can be implemented using a standard QKD system without any hardware modifications [3]. Instead, we show that Eve's information can be bounded by randomizing the time-bins order. We further analyze the security and expected secure key rate for Eve's optimal strategy. Finally, we experimentally demonstrate the protocol over a 40km long fiber using only two single-photon detectors and one interferometer at the receiver end (Figure 1 (a)).

Results and Conclusions: We demonstrate the improved secure key rate of our protocol in comparison to a binary protocol using the same hardware. Considering collective attacks [4], where the eavesdropper performs the same quantum operation separately for each quantum state, we show more than a two-fold increase in the asymptotically secure key rate for optimal pulse occupation, achieved for dimension D=8 (panel (b)). Considering coherent attacks [5], where the eavesdropper can perform a coherent operation on multiple quantum states, we show the optimal secure key rate is achieved at dimension D=3 (panel (c)).

References

[1] Bechmann-Pasquinucci, Helle, et al. "Quantum cryptography using larger alphabets." Physical Review A 61.6 (2000): 062308.
[2] Cerf, Nicolas J., et al. "Security of quantum key distribution using d-level systems." Physical review letters 88.12 (2002): 127902.
[3] Sulimany, Kfir, et al. "Fast and Simple One-Way High-Dimensional Quantum Key Distribution." arXiv preprint arXiv:2105.04733 (2022).
[4] González-Payo, Javier, et al. "Upper security bounds for coherent-one-way quantum key distribution." Physical Review Letters 125.26 (2020): 260510.
[5] Moroder, Tobias, et al. "Security of distributed-phase-reference quantum key distribution." Physical review letters 109.26 (2012): 260501.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Tuesday, December 13 | Parallel Session 6 | 15:50 - 17:20

Segmented Composite Design of Robust Quantum Gates

Y. Piasetzky, I. Kaplan, M. Erew, M. Goldstein, Y. Oz, H. Suchowski
School of Physics and Astronomy, Tel Aviv University, Israel

Integrated photonics, with its intrinsic phase stability and miniature devices, gives great promise in scaling quantum photonics devices into large numbers [1]. However, despite these advantages, the very high-fidelity requirement for quantum information processing still presents major challenges in the practical realization of integrated devices, which suffer from fabrication and other errors. With admissible errors in fault-tolerant quantum computations suggested to be smaller than 10-4 [2], more work is needed to improve such devices' fidelity and stability. Much work has been done to develop robust, error-free quantum gates[3]. Recently, a scheme that utilizes modulation of the detuning, and can be implemented in photonic integrated circuits, has been theoretically suggested [4], and implementation of a robust state-to-state transformation (as opposed to a unitary gate), has been demonstrated [5]. This scheme allows for the fabrication of robust quantum gates even without complex control over coupling parameters. In path-encoded photonic architecture, single photon gates are directional couplers that rely on evanescence coupling to create the coherent mixing of different photonic modes to represent the quantum information. Two qubit gates can be constructed from multiple such couplers (e.g. [6]).

In this work, we present a framework for creating robust single-qubit and two-qubit photonic unitary gates, employing an iterative optimization process that utilizes couplers that are created from multiple composite segments of different detuning, as opposed to conventional uniform cross-section couplers. We simulate solutions that minimize the error caused by a non-ideal fabrication process. We compare the average gate fidelity of both uniform and composite segmented photonic gates, over geometric error distribution acquired from a large commercial fabricator. The results are presented in Figure 1. They show significantly increased robustness and promise to help scale up the integrated-photonic quantum experiments toward a usable optical quantum computer.

References

[1] J. Wang, F. Sciarrino, A. Laing, and M. G. Thompson, "Integrated photonic quantum technologies," Nat. Photonics, vol. 14, no. 5, pp. 273-284, 2020, doi: 10.1038/s41566-019-0532-1.
[2] M. A. Nielsen and I. L. Chuang, Quantum Computation and Quantum Information. Cambridge University Press, 2012.
[3] A. J. Shaka, "Composite pulses for ultra-broadband spin inversion," Chem. Phys. Lett., vol. 120, no. 2, pp. 201-205, Oct. 1985, doi: 10.1016/0009-2614(85)87040-8.
[4] E. Kyoseva, H. Greener, and H. Suchowski, "Detuning-modulated composite pulses for high-fidelity robust quantum control," Phys. Rev. A, vol. 100, no. 3, pp. 1-6, 2019, doi: 10.1103/PhysRevA.100.032333.
[5] M. Katzman et al., "Robust Directional Couplers for State Manipulation in Silicon Photonic-Integrated Circuits," J. Light. Technol., 2022, doi: 10.1109/JLT.2022.3175128.
[6] A. Politi, M. J. Cryan, J. G. Rarity, S. Yu, and J. L. O'Brien, "Silica-on-silicon waveguide quantum circuits," Science (80-.)., vol. 320, no. 5876, pp. 646-649, May 2008, doi: 10.1126/science.1155441.

Global and Local Quantum Sensing Across >100THz of Optical Bandwidth

Prof. Avi Pe'er
Bar Ilan University, Ramat-Gan, Israel

I will present highly efficient quantum detection of ultra-broadband time-energy entanglement using stimulated broadband sum-frequency generation, which acts as a coherent global detector of the entire optical bandwidth. I will compare this new detection method to the standard concept of broadband SU1,1 interference, which provides parallel local detection of two-mode squeezing across the entire bandwidth simultaneously

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Suppression of Logical Error in Linear Optic Quantum Computer using Composite Pulses

Ron Cohen[1,2], Yonatan Piasetzky[1,2], Muhammad Erew[1,2], Ido Kaplan[1,2], Andrew S. Darmawan[3], Yaron Oz[1], Moshe Goldshtein[1], Haim Suchowski[1,2]

1 *School of Physics and Astronomy, Faculty of Exact Sciences, Tel Aviv University,Tel Aviv 69978, Israel*
2 *Center for Light-Matter Interaction, Tel Aviv University Tel Aviv 6779801, Israel*
3 *Yukawa Institute of Theoretical Physics, Kyoto University, Sakyo-ku, Kyoto 606-8502, Japan*

Fault-tolerant quantum information processing is essential for the realization of quantum computing devices [1]. A very popular quantum error correction architecture is the surface code, where every logical qubit is represented by several physical qubits. The physical qubits are arranged in a 2D array with stabilizers measured and errors detected and corrected so as to get a low logical error rate, which makes the device fault-tolerant [1]. As smaller physical errors could significantly reduce the error correction overhead, as it allows to use a smaller surface code per a single logical qubit, hence making the realization of the quantum processing device more achievable. In recent years, coherent errors have been recognized as a significant type of error to deal with, since they might sum up coherently. Reducing coherent errors is therefore one of the primary requirements to curtail the surface code's size, which would otherwise require thousands of physical qubits. The main metric to assess the improvement is to measure the shrinking of the required size of surface code for several target logical error levels [1]. A promising simulation method to measure the logical error probability is using tensor networks, which allows for reducing the numerical cost to scale exponentially with the square root of the array size rather than the size itself [2].

We have applied this methodology in the context of linear optics quantum computation, to evaluate the performance of a composite segmented design in a dual-rail realization [3], and show that it reduces the total amount of physical qubits by a factor of ~6.5 in common realistic scenarios. We also showed that, as opposed to the case where a constant angle rotation error applies to all the qubits, when sign of rotation is changing between qubits on the surface, the logical error is suppressed because of destructive superpositions.

References

[1] Fowler, Austin G., et al. "Surface codes: Towards practical large-scale quantum computation." Physical Review A 86.3 (2012): 032324.
[2] Darmawan, Andrew S., and David Poulin. "Tensor-network simulations of the surface code under realistic noise." Physical review letters 119.4 (2017): 040502.
[3] Katzman, Moshe, et al. "Robust Directional Couplers for State Manipulation in Silicon Photonic-Integrated Circuits." Journal of Lightwave Technology, doi: 10.1109/JLT.2022.3175128 (2022).

Tuesday, December 13 | Parallel Session 6 | 15:50 - 17:20

Session: Artificial Intelligence in Optics - Prof. Yoav Shechtman

Invited speaker |

Learned Optics - Improving Computational Imaging Systems through Deep Learning and Optimization

Prof. Wolfgang Heidrich
Computational Imaging Researcher

Computational imaging systems are based on the joint design of optics and associated image reconstruction algorithms. Historically, many such systems have employed simple transform-based reconstruction methods. Modern optimization methods and priors can drastically improve the reconstruction quality in computational imaging systems. Furthermore, learning-based methods can be used to design the optics along with the reconstruction method, yielding truly end-to-end optimized imaging systems that outperform classical solutions.

DBlink: Dynamic Localization Microscopy in Super Spatiotemporal Reolution via Deep Learning

Alon Saguy[1], Onit Alalouf[1], Nadav Opatovski[2], Soohyen Jang[3], Mike Heilemann[3], Yoav Shechtman[1]

1 *Department of Biomedical Engineering, Technion - Israel Institute of Technology, Haifa, 3200003, Israel*
2 *Russell Berrie Nanotechnology Institute, Technion - Israel Institute of Technology, Haifa, 3200003, Israel*
3 *Institute of Physical and Theoretical Chemistry, Goethe-University Frankfurt, 60438, Germany*

Single molecule localization microscopy (SMLM) has revolutionized biological imaging, improving the spatial resolution of traditional microscopes by an order of magnitude. However, SMLM techniques require long acquisition time, typically a few minutes, to yield a single super-resolved image, because they depend on accumulation of many localizations over thousands of recorded frames. Hence, the capability of SMLM to observe dynamics at high temporal resolution has always been limited.

In this work, we present DBlink, a novel deep-learning-based method for super spatiotemporal resolution reconstruction from SMLM data. The input to DBlink is a recorded video of single molecule localization microscopy data and the output is a super spatiotemporal resolution video reconstruction (Figure 1). We use bi-directional long short term memory (LSTM) network architecture, designed for capturing long term dependencies between different input frames.

We demonstrate DBlink performance on simulated filaments and mitochondria-like structures, on experimental SMLM data under controlled motion conditions, and finally on live cell dynamic SMLM. Our neural network based spatiotemporal interpolation constitutes a significant advance in super-resolution imaging of dynamic processes in live cells.

Sperm-Cell DNA Fragmentation Prediction Using Label-Free Quantitative Phase Imaging and Deep Learning

Lioz Noy, Itay Barnea, Simcha K. Mirsky, Dotan Kamber, Mattan Levi and Natan T. Shaked*
Department of Biomedical Engineering, Faculty of Engineering, Tel Aviv University, Tel Aviv 69978, Israel
**Correspondence to: Natan T. Shaked, Department of Biomedical Engineering, Faculty of Engineering, Tel Aviv University, Ramat Aviv*

Intracytoplasmic sperm injection (ICSI) is the most common practice for in vitro fertilization (IVF) treatments. In ICSI, a single sperm cell is selected and injected into an oocyte. The quality of the sperm and specifically the amount of DNA fragmentation have significant effects on the fertilization success rate. Currently, embryologists use general morphology to select the sperm cells that are likely not fragmented since different staining protocols cannot be applied to cells that will be used for fertilization. We wish to increase the success rate of ICSI by predicting the fragmentation amount from unstained images. In our research, we use computer vision and deep learning methods to perform fragmentation scoring for a single sperm cell. The data acquisition is performed using multiple techniques: brightfield, differential interference contrast (DIC), and phase contrast. Additionally, we use lowcoherence shearing interferometry with constant off-axis angle (LC-SICA) to acquire quantitative phase imaging (QPI) maps of the sperm cells. For the ground truth (GT), we later perform Acridine Orange (AO) staining assay on the cells and acquire using fluorescence microscopy. The dataset we produced contains over 1,500 sperm cells collected from 5 different donors. In our results, we see a strong correlation between the AO images and our fragmentation score. Eventually, we apply our deep learning network combine with tracking algorithms on live sperm QPI maps videos, produce a real-time application of sperm cells fragmentation scoring.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

A Machine Learning Approach to Generate Quantum Light

Eyal Rozenberg[1], Aviv Karnieli[2], Ofir Yesharim[3], Joshua Foley-Comer[3], Sivan Trajtenberg-Mills[2,4], Daniel Freedman[5], Alex Bronstein[1] and Ady Arie[3]

1 *Department of Computer Science, Technion, Haifa, Israel*
2 *School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel*
3 *School of Electrical Engineering, Tel Aviv University, Tel Aviv, Israel*
4 *Massachusetts Institute of Technology, Cambridge, MA, USA*
5 *Google Research, Haifa, Israel*

Quantum optics has proven to be an invaluable resource for the realization of many quantum technologies, such as quantum cryptography, sensing and computing. We show how to employ machine learning algorithms for inverse design problems in quantum optics [1]. Specifically, we developed an algorithm for generating spatially entangled photon pairs, using tailored nonlinear interactions in the spontaneous parametric down-conversion (SPDC) process. The learned interaction parameters can then be used to predict the generation of the desired quantum state, the correlations between structured photon-pairs, and the quantum state density matrix. Our model encompasses the relevant conservation laws, physical principles, and phenomenological behaviors as we solve Heisenberg's equations of motion for the quantum field operators along the optimization process (Fig. 1). We show how to make an inherent stochastic description of SPDC fully differentiable, making it amenable to gradient-descent based methods of optimization.

We validate our model against published experimental results, obtaining very good agreement for both on-axis spatial mode correlations, as well as to the quantum state tomography of the generated state. Moreover, we demonstrate the full process of inverse design to obtain the correct relations between crystal length and pump waist, as achieved in the experiments. We demonstrate the generation of maximally entangled bi-photons qubits, qutrits and ququarts in the Laguerre-Gauss or Hermite-Gauss bases. Moreover, we show how the generated quantum state can be coherently controlled by altering the pump shape. This work can readily be extended to the generation of biphotons in the spectral-temporal domain. The code of our model can be found here: https://github.com/EyalRozenberg1/SPDCinv.

References

[1] E. Rozenberg, A. Karnieli, O. Yesharim, J. F-Comer, S. T-Mills, D. Freedman, A. M. Bronstein, and A. Arie, Optica 9, 602-615 (2022).

Single Molecule QR Codes Provide Extreme Multiplexing for Gene Expression Analysis

Jonathan Jeffet[1,2,3], Barak Hadad[3,4], Sahar Froim[3,4], Kawsar Kaboub[5,6], Keren M. Rabinowitz[5,6], Jasline Deek[1,2], Sapir Margalit[1,2], Iris Dotan[5,6], Alon Bahabad[3,4], Yuval Ebenstein[1,2,3*]

1 *Raymond and Beverly Sackler Faculty of Exact Sciences, Tel Aviv University, Tel Aviv, Israel*
2 *Center for Nanoscience and Nanotechnology, Tel Aviv University, Tel Aviv, Israel*
3 *Center for Light Matter Interaction, Tel Aviv University, Tel Aviv, Israel*
4 *Department of Physical Electronics, School of Electrical Engineering, Fleischman Faculty of Engineering, Tel-Aviv University, Tel-Aviv, Israel*
5 *Division of Gastroenterology, Rabin Medical Center, Petah Tikva, Israel*
6 *Felsenstein Medical Research Center, Sackler Faculty of Medicine, Tel-Aviv University, Tel Aviv, Israel*

Transcriptome analysis provides a powerful tool to explore the physiological responses to environmental ques and various diseases including cancer. State-of-the-art transcriptome expression quantification methods require RNA amplification pre-processing, introducing biases. Direct RNA quantification at the single-molecule level introduced by NanoString1 overcomes these biases but is currently limited to panels of up to 870 unique targets. An outstanding goal is to expand the number of unamplified distinct targets to enable full transcriptome coverage (~20,000 protein-coding genes) in a single experiment.

DeepQR, a new microscopy concept combining compact spectral imaging with deep learning, allows rapid high-throughput acquisition and decoding of hundreds of unique native RNA targets directly without amplification. We demonstrate an increase in unique target multiplexing from 96 to 972 using a single-frame simultaneous acquisition with three detection windows. We validate our method with clinical samples analyzed with the NanoString gene-expression inflammation panel. We show a 92-95% accuracy and a 4-fold increase in speed compared to standard filter-based acquisitions. The new approach paves the path for a whole single-molecule transcriptome analysis with up to 54,432 unique unamplified targets.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Recent Advancements in Model-Based Super-Resolution Microscopy

Shay Elmalem*, Hilel Hagai Diamandi*, Dan Oron and Yonina C. Eldar
Weizmann Institute of Science
**Equal contribution*

Introduction and background: Super-resolved fluorescence microscopy is a Nobel prize-winning technique to overcome the fundamental diffraction limit of imaging systems. In order to achieve high spatial resolution while maintaining feasible acquisition times, a high emitter density configuration is desired. Thereafter, spatial resolution is restored in post-processing, by exploiting the stochastically uncorrelated nature of emitters.

Objectives: Following the deep learning (DL) revolution, a previous work of our group [1] has offered the use of L-SPARCOM: a model-based neural network (NN) based on the unfolding of an ISTA recovery algorithm, for fast and accurate image reconstruction. The model-based framework provides a size-efficient architecture combined with high interpretability of the trained network and better generalization compared with standard NNs [2]. Encouraged by the recent progress of DL algorithms for image processing [3] and super-resolution microscopy [4], we seek to incorporate these principles within the framework of a model-based NN in order to improve the performance of the offered system.

Methods and Results: In this work, several advancement paths for model-based super-resolution microscopy are proposed and discussed: (a) Self-Attention inspired Model-Based Architecture (SAMBA) - by preserving the temporal axis of the data and integrating self-attention blocks to the LISTA network, improved information extraction can be achieved; (b) the extension of the model-based architecture to the more challenging setting of 3D microscopy is proposed and examined; (c) finally, future work involving single-photon information will be discussed.

Recommendations and Conclusions: While NNs offer unprecedented performance for super-resolved imaging, their lack of explainability is a serious issue, especially in biology and medicine-related applications. A model-based architecture offers 'the best of both worlds'- performance and explainability, as the explainable 'skeleton' can be configured and integrated with novel and powerful processing blocks.

References

[1] Dardikman-Yoffe, Gili, and Yonina C. Eldar. Optics express 28.19 (2020): 27736-27763. [2] Monga, Vishal, Yuelong Li, and Yonina C. Eldar. IEEE Signal Processing Magazine 38.2 (2021): 18-44. [3] Dosovitskiy, Alexey, et al. arXiv preprint arXiv:2010.11929 (2020). [4] Nehme, Elias, et al. Nature methods 17.7 (2020): 734-740.

Session : Optics in Medicine and Biology - Prof. Dror Fixler

Invited speaker |

Motion Tolerant Remote Vital Signs Monitoring using Optical and Depth Cameras

Prof. Ofer Levi
University of Toronto, Ontario, Canada, Institute of Biomedical Engineering;The Edward S. Rogers Sr. Department of Electrical and Computer Engineering

Remote vital signs monitoring provides valuable information about a patient's health and wellbeing, in a low-cost, non-intrusive way. These systems have a variety of applications, from detecting patient deterioration in clinical settings to monitoring at-risk individuals at home.
We present our progress towards the design and development of a remote heart rate, breathing rate and tissue oxygenation measurement system that can map vital signs from various distances. We found that motion compensation algorithms using single camera and multicamera referencing reduced the effect of swaying motion on vital sign evaluation from standing subjects.

Tuesday, December 13 | Parallel Session 6 | 15:50 - 17:20

Invited speaker |

Angular Momentum in Tissue Diagnosis

Prof. Igor Meglinski[1,2]

1 Optoelectronics and Measurement Techniques, University of Oulu, Oulu, Finland
2 College of Engineering and Physical Sciences, Aston University, Birmingham, UK
Correspondence: i.meglinski@aston.ac.uk

We explore the potential of using shaped light with angular momentum in diagnosis of cells and biological tissues. The angular momentum of light contains a spin contribution, conditioned by the polarization of the electromagnetic fields and an orbital contribution, related to their spatial structure [1]. While the spin angular momentum (SAM) has been extensively employed in diagnostic studies (see for example [2-4]), the orbital angular momentum (OAM) has been added to the practical toolkit very recently [5]. When the shaped light propagates in a homogeneous transparent medium, both spin and orbital angular momenta are conserved. In the medium with complex structure and anisotropic scattering the spin and orbital angular momenta are changed significantly that leads to spin-orbit interaction. Such a spin-orbit interaction leads to the mutual influence of the polarization and the trajectories of twisted photons propagating in the medium. Significant increase of the visibility contrast and penetration depth when imaging through the homogeneous scattering media with OAM light beams was demonstrated [6,7]. Nevertheless, the potential of OAM for biomedical diagnosis and characterization of cells and tissues is far from being fully explored. In this report we present the results of our most recent studies of how the spin-orbit interaction leads to the mutual influence of trajectories of the shaped light beam propagated in tissue-like medium, and how sensitive OAM to subtle alterations in biological tissues and cells cultures.

References

[1] G. Molina-Terriza, J. Torres, L. Torner, Nature Physics, 3, 305-310 (2007).
[2] B. Kunnen, C. Macdonald, A. Doronin, S. Jacques, M. Eccles, and I. Meglinski, J. Biophoton. 8, 317 - 323 (2015)
[3] M. Borovkova, A. Popov, A. Bykov, and I. Meglinski, J. Biomed. Opt. 25, 057001 (2020).
[4] M. Borovkova, O. Sieryi, I. Lapushenko, N. Kartashkina, J. Pahnke, A. Bykov and I. Meglinski, IEEE Trans. Med. Imaging. 41, 977 - 982 (2022)
[5] A. Forbes, Structured light: Tailored for Purpose, OPN OSA, 26-31 June (2020) www.osa-opn.org/home/articles/volume_31/june_2020/features/structured_light_tailored_for_purpose/
[6] A. Doronin, N. Vera, J.P. Staforelli, P. Coelho, and I. Meglinski, Photonics, 6, 56 (2019).
[7] W. B. Wang, R. Gozali, T. A. Nguyen, and R. R. Alfano, Proc. SPIE, 9318, 931805 (2015).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Tuesday, December 13 | Parallel Session 6 | 15:50 - 17:20

Optoacoustic Micro-Tomography using a Silicon-Photonics Acoustic Detector

Yoav Hazan, Ahiad Levi, Michael Nagli and Prof. Amir Rosenthal

Technion - Israel Institute of Technology, Haifa, 3200003, Israel

Medical ultrasound and optoacoustic (photoacoustic) imaging commonly rely on the concepts of beam-forming and tomography for image formation, enabled by piezoelectric array transducers whose element size is comparable to the desired resolution. However, the tomographic measurement of acoustic signals becomes increasingly impractical for resolutions beyond 100 µm due to the reduced efficiency of piezoelectric elements upon miniaturization. For higher resolutions, a microscopy approach is preferred, in which a single focused ultrasound transducer images the object point-by-point, but the bulky apparatus and long acquisition time of this approach limit clinical applications. In this work, a new ultrasound-detection technology is developed for ultrahigh-resolution optoacoustic tomography and is experimentally demonstrated with bandwidths exceeding 200 MHz and lateral resolutions beyond 20 µm. Our technology is based on an optical resonator fabricated in a silicon-photonics platform, which is coated by a sensitivity-enhancing polymer, which also eliminates the parasitic effect of surface acoustic waves. Further improvement in sensitivity is achieved by a low-noise interferometric setup, which eliminates the effect of laser frequency noise on the measurement. In vivo optoacoustic tomography is performed on a mouse ear, revealing its vasculature at detail that has been previously reserved to optoacoustic microscopy.

Recent Advances in Rapid and Highly Sensitive Detection of Proteins and Specific DNA Sequences using a Magnetic Modulation Biosensing System

[Shira Roth, Michael Margulis] and Prof. Amos Danielli

Faculty of Engineering, The Institute of Nanotechnology and Advanced Materials, Bar-Ilan University, Max and Anna Webb Street, Ramat Gan, 5290002, Israel

In early disease stages, biomolecules of interest exist in very low concentrations, presenting a significant challenge for analytical devices and methods. Here, we provide a comprehensive overview of an innovative optical biosensing technology, termed magnetic modulation biosensing (MMB), its biomedical applications, and its ongoing development. In MMB, magnetic beads are attached to fluorescently labeled target molecules. A controlled magnetic force aggregates the magnetic beads and transports them in and out of an excitation laser beam, generating a periodic fluorescent signal that is detected and demodulated. MMB applications include rapid and highly sensitive detection of specific nucleic acid sequences, antibodies, proteins, and protein interactions. Compared with other established analytical methodologies, MMB provides improved sensitivity, shorter processing time, and simpler protocols.

Session: Solar Energy - Prof. David Cahen

Invited speaker |

Characterization of Interfaces by Simple Far- Field Optics

Prof. Adi Salomon

Chemistry department, BINA nano center for advance materials, Bar Ilan university, Ramat-Gan, Israel

Ultra-thin, transparent films are being used as protective layers on semiconductors, solar cells, as well as for nano-composite materials and optical coatings. Nano-sensors, photonic devices and calibration tools for axial super-resolution microscopies, all rely on the controlled fabrication and analysis of ultra-thin layers. I will present a simple, non-invasive, optical technique for simultaneously characterizing the refractive index, thickness, and homogeneity of nanometric transparent films. Characterization of molecular thin film emission pattern at the interface will be discussed as well.

Our technique is based on the detection in the far field and the analysis of supercritical angle fluorescence, i.e., near-field emission from molecular dipoles located very close to the dielectric interface. Our results compare favorably to that obtained through a combination of atomic force and electron microscopy, surface-plasmon resonance spectroscopy and ellipsometry. Our technique is cheap, versatile and it has obvious applications in microscopies, profilometry and optical nano-metrology.

Invited speaker |

Thermodynamic Aspects of PV Power Generation Process

Dr. Avi Niv

Solar Energy and Environmental Physics, The Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of The Negev, Beer-Sheva, Israel

The performance of photovoltaic solar cells is bound by the principle of detailed balance - the equality of electron-hole generation and depletion rates. The consensus among experts today is that DB is somehow immanent in thermodynamics. Despite that, attempts to settle the two succeeded only at open circuit conditions.

In the talk, we will study the consequences of upholding the detailed balance of a photovoltaic effect and its energy balance, which is thermodynamics first law. We will see that the mutual effect that these two governing laws have on each other may lead to unexpected, often surprising, results. For example, we will show that the open circuit voltage of a solar cell is bound not only from above, as our present understanding foresees, but also by a negative minimum value. Despite that, we will show that including heat conduction in the energy balance of the solar cell prohibits a thermoradiative power generation scheme, which is doing work by radiating to a cold environment. Finally, we will review situations where one cannot find a temperature and a potential that mutually solves the cell's energy and detailed balance requirements and discuss what it teaches us about the photovoltaic effect.

Modular Concentrated Solar Power for Dispatchable Reliable and Affordable Solar Electricity

Prof. Carmel Rotschild & Dror Mimron

Technion - Israel Institute of Technology, Haifa, Israel

Today, the effort in solar energy is to support a dispatchable, reliable, and affordable continuous power supply. A modular (Micro)-CSP (MCSP) is made of an array of small receivers where the heliostats shift from one receiver to the other along the day targeting the receiver next to the sun. This way the field efficiency is doubled with half the cost of a central CSP, allowing dispatchable reliable 24/7/365 electricity at grid parity. The modularity, also supports an exponentially growing market, as in PVs, with a potential for a global impact in a few decades. However, such a disruptive technology requires a small (40%) external-heat engine, not existing today due to thermodynamic considerations. Such an engine will also harvest low-temperature waste heat and will increase the green hydrogen production capacity factor, which will reduce its cost to the level of grey Hydrogen. In all heat engines that we know, only gases are used, and for two roles; i.) Perform the work by expansion and compression. ii.) Transfer the energy into the engine. This 2nd role is challenging for external heat sources, because gases carry negligible thermal energy per volume (volumetric heat capacity), and tend to behave as an ideal gas, resulting in poor efficiency due to the adiabatic expansion. Increasing energy density by 1000-fold and inducing isothermal gas expansion is what we solve by demonstrating a nozzle that mixes heat-transfer-liquid (HTL) and bubbles, where the HTL supplies the heat along with the bubble's expansion generating thrust. We experimentally demonstrate >95% of isothermal expansion is converted to electricity.

Our results may support total conversion efficiency > 75% of Carnot efficiency, which is far beyond the equivalent state-of-the-art. I will review the current status and the commercialization roadmap of this new technology.

Poster Presentations

Monday, December 12

Laser & Applications 10:55 - 11:07:30

Rapid Large-Scale Nanostructuring Techniques with up to 40401 Beams and Productivity up to 5.2 Min/m2

P. Hauschwitz[1*], J. Martan[2], R. Bičišťová[1], C. Beltrami[2], D. Moskal[2], A. Brodsky[3], N. Kaplan[3], J. Mužík[1], D. Š tepánková[1], J. Brajer[1], D. Rostohar[1], J. Kopeček[4], L. Prokešová[2], M. Honner[2], V. Lang[2], M. Smrž 1, T. Mocek[1]

1 *Hilase Centre, Institute of Physics, Academy of Sciences of the Czech Republic, Za Radnici 828, Dolni Brezany 25241, Czech Republic*

2 *New Technologies Research Centre (NTC), University of West Bohemia, Univerzitni 8, 30100 Plzen, Czech Republic*

3 *R&D Department, Holo/Or Ltd, Einstein 13b, Ness Tziona 7403617, Israel*

4 *Institute of Physics of the Czech Academy of Sciences, Na Slovance 2, Prague, Czech Republic*

Introduction: Suitable topography of structured surfaces may allow attaining innovative surface properties including friction reduction, superhydrophobicity, self-cleaning, anti-icing and many more. Despite a list of attractive applications of functional surfaces and demonstrated capability of lasers to produce them, the speed of laser micro and nanostructuring is still low with respect to many industry standards. In this work, we introduce a unique combination of high-energy pulsed ultrashort laser system HiLASE PERLA with up-to-date most promising multi-beam micro and nanostructuring technologies able to produce for example more than 40,000 beamlets with productivity over 1900 cm2 /min.

Methods: Stainless steel plates (AISI 316L) were treated by selected Ytterbium based diode pumped solid-state laser system Perla (HiLASE, Czech Republic) emitting 1.7 ps pulses with M2 of 1.15 and wavelength of 1030 nm. The laser system can be operated at different repetition rates reaching either high average power of 200 W with the repetition rate of 50 kHz and 100 kHz or high pulse energy up to 20 mJ with 1 kHz repetition rate. The input laser beam was guided through MS-805-I-Y-A or MS-835-J-Y-X (Holo/Or Ltd., Israel) generating a square shape matrix of 51x51 sub-beams with the spacing of 20 µm or matrix of 201x201 beams with the spacing of 5 µm, respectively. In both cases, the size of the square-shaped matrix on the sample was ~1 mm. In the following step, the beam was guided through the high dynamic galvo-scanner system (Scanlab GmbH, Germany) and focused on a sample using a telecentric F-theta lens with the focal length of 100 mm or used with a high NA lens to focus each sub-beam below 5 µm.

Results: 2601 nanostructured microcraters with diameter below 20 µm and 401 40 nanostructured microcraters with diameter below 5 µm ordered in square-shaped matrixes covering an area of 1X1 mm were fabricated simultaneously with 51x51 and 201x201 elements, respectively. To cover larger areas, the sample has to be moved to a different position for 201x201 element coupled with high NA objective or the whole matrix can be shifted by the galvanometric scanner in the case of 51x51 element. The advantageous square shape of the beam matrix allows %0 overlap and thus productive matrix stitching over the sample.

Conclusion: With the use of advanced multi-beam processing approaches the speed and efficiency of nanostructuring with high power ultrashort laser systems can be dramatically improved. Several approaches including DOE beam splitting, interference patterning and dynamic beam shaping have been introduced and compared with respect to the throughput during the production of nanogratings. The highest throughput reached 1910 cm2 /min with the use of high power and high quality ultrashort laser system HiLASE Perla

Optical Archimedes Screw Along Arbitrary Trajectories

Keren Zhalenchuck, Barak Hadad, Alon Bahabad

Department of Physical Electronics, School of Electrical Engineering, Fleischman Faculty of Engineering, Tel-Aviv University, Tel-Aviv 69978, Israel Tel-Aviv University Center for Light-Matter-Interaction, Tel-Aviv 6997801, Israel

Optical conveyors of airborne particles were previously demonstrated using different techniques allowing particles to be conveyed along straight trajectories either down or upstream the laser radiation direction. Here, we design a self-accelerating optical analog to the famous Archimedes' screw. This self-accelerating optical Archimedes screw, whose axial trajectory can be set arbitrarily within the paraxial approximation allows transfer of rotational movement of two Bessel-like beams to the curved focal axis movement of a trapped particle within the beam. We have used this screw experimentally to demonstrate conveying airborne, absorbing particles in a volume along arbitrary predesigned trajectories, up-and downstream of the curved axis of the beam. The velocity of the particles is mainly dependent on the rotation speed of the optical screw. A superposition of two beams which only differ in the magnitude of their linear momenta (i.e., in their wave-number). Their interference results in a periodic axial standing wave pattern along the beams' wave-vectors. Similarly, superposing two beams that differ only in their angular momenta would result in an angular standing wave pattern. If the two beams differ in both their wave-number and angular momentum, the resulting standing wave pattern would be periodic both axially and angularly - which results in a helical pattern. During its axial evolution, the cross section of such a beam is rotating and shifting with hardly any change in the overall shape. This was the principal behind the original optical Archimedes screw which propagated along a straight line. It was created by the superposition of two high-order Bessel beams with different linear momentum and a topological charge difference of two (the charge of each beam was ± 1). Particles trapped through the photophoretic force in dark volumes within the screw were carried with these dark volumes up or downstream as the screw was rotated one way or the other. The generalization of the optical Archimedes screw to a self-accelerating one keeps locally the principle of superposition of two modes with different linear and angular momenta, while allowing the direction of the linear momentum of both beams to change in space and trace a desired arbitrary trajectory.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Split well resonant phonon terahertz quantum cascade laser

Shiran Levy[1], Nathalie Lander Gower[1], Silvia Piperno[1], Sadhvikas J. Addamane[2], John L. Reno[2], Asaf Albo[1]

1 *Faculty of Engineering, Bar-Ilan University, Ramat Gan 5290002, Israel*
2 *Center for Integrated Nanotechnologies, Sandia National Laboratories, MS 1303, Albuquerque, New Mexico 87185-1303, USA*

Quantum cascade laser (QCLs) were first demonstrated in 1994 [1]. QCLs are semiconductor laser with emission in the mid to far portion of the electromagnetic spectrum.

QCLs have a large number of potential applications. Some of these applications are, communication [2], medicine [3], security [4], chemical analysis of protein [5], and high resolution measurements [6] in particular in the mid-infrared (MIR. THz QCLs proved to be beneficial for wireless communication and imaging technologies [7].

The emission occurs within the intersubband transition in the conduction band by achieving a population inversion. A single electron generates multiple photons ("cascade") and the wavelength is determined by the layer thickness, hence, it is possible to tune the emission wavelength of QCLs over a wide range in systems containing the same material.

Although terahertz (THz) QCLs have a lot of potential, since they were first demonstrated in 2002 [8] and at the other end of the spectrum, microwave and radio-frequency emitters enable wireless communications. But the terahertz region (1–10 THz; 1 THz = 1012 Hz, their use has been restricted due to lack of portability. The requirements for cooling THz QCLs prevent the laser from being a compact and portable system, confining THz QCLs to the laboratory environment. Therefore, raising the maximum operating temperature (Tmax) is the main goal in the field.

We present a highly diagonal "split-well resonant-phonon" (SWRP) active region design for GaAs/ THz QCLs. The design includes a thin intrawell barrier, that pushes the excited states to higher energies. By adjusting the barrier thickness the energy separation between LLL and the ground state can be tuned to match the exact LO-phonon scattering energy (36 meV). Negative differential resistance is observed at room temperature, which indicates the suppression of thermally activated leakage channels. The overlap between the doped region and the active level region is reduced relative to the design demonstrated before of the split well direct phonon (SWDP) design [9]. We believe that this design should serve an excellent platform to study the temperature performance of the THz-QCLs lasers.

Investigating the effect of doping concentration on the performance of Terahertz Quantum Cascade Lasers

N. Lander Gower[1], S. Piperno[1], A. Albo[1]

1Faculty of Engineering, Bar-Ilan University, Ramat Gan 5290002, Israel

Terahertz (THz) quantum-cascade laser (QCL) are noteworthy because of their range of potential applications. Although a maximum operating temperature () of 250 K was achieved and demonstrated [1] in 2020, room temperature performance has not been achieved yet.

Our goal was to improve the temperature performance. Achieving a system that is as close as possible to a clean n-level system proved to be the strategy that led to the best temperature performance in THz-QCLs [1-2]. We have studied the effect of doping on the temperature performance of a split-well (SW) direct-phonon (DP) THz QCL scheme (Fig. 1) supporting a clean three-level system [3-5]. We expected to obtain a similar improvement to that observed in resonant-phonon (RP) schemes after increasing the carrier concentration from 3 × to 6 × [6]. By increasing the doping, ideally the results should have improved. But, to our surprise, the results show the contrary.

Our unique designs have allowed us to observe experimentally the effect of doping on dephasing times and line broadening. We observed a significant increase in line broadening as the doping and temperature increased and attribute this effect to enhanced ionized-impurity scattering (IIS). These insights into the role of doping suggest an approach to improving THz QCLs by engineering the doping profile and its spatial location. Our approach should serve as an excellent platform for eventually achieving terahertz frequency lasing at room temperature.

References

[1] Khalatpour, A.; Paulsen, A.K.; Deimert, C. et al., “High-power portable terahertz laser systems”, Nat. Photonics, (2020).
[2] Albo, A.; Hu, Q.; and Reno, J. L., “Room temperature negative differential resistance in terahertz quantum cascade laser structures”, Appl. Phys. Lett. (2016).
[3] Albo, A.; Flores, Y. V.; Hu, Q.; and Reno, J. L., “Split-well direct-phonon terahertz quantum cascade lasers”, Appl. Phys. Lett., (2019).
[4] Lander Gower, N.; Piperno, S.; and Albo, A., “Self-consistent gain calculations and carrier transport analysis for split-well direct-phonon terahertz quantum cascade lasers”, AIP Advances (2020).
[5] Lander Gower, N.; Piperno, S.; and Albo, A., “The Effect of Doping in Split-Well Direct-Phonon THz Quantum-Cascade Laser Structures”, Photonics, (2020).
[6] Chan, C. W. I.; Albo, A.; Hu, Q.; and Reno, J. L., “Tradeoffs between oscillator strength and lifetime in terahertz quantum cascade lasers”, Appl. Phys. Lett. (2016).

Limitations in Length Matching Between Optical Channels in Fiber-based CBC Systems

Shmuel Stav[1,2], Shlomo Goldin[1],Yaakov Mandelbaum[1], Benayahu Urbach[2]

1 *Department of Applied Physics and Electro-optic Engineering, Faculty of Engineering, JCT Lev Academic Center, Jerusalem, Israel*
2 *Civan Advanced Technologies, Jerusalem, Israel*

Coherent Beam Combining (CBC) arouses great interest in the laser industry because it makes it possible to obtain a laser beam with a much higher power than is possible with a single source, and with high beam quality.

There are many methods for implementing coherent combining. In the MOPA (Master Oscillator Power Amplifier) configuration, a single laser source splits into several channels, each of which is optically amplified by an optical amplifier, and the beams are then recombined.

Coherent combining of the laser beams requires, among other things, precise matching of the channel lengths. Optical path differences (OPD) between the channels arise during the operation of the laser due to a variety of phenomena. They require a system response in order to maintain the synchronization between the lengths.

In this work two main factors that impact the coordination of fiber-based CBC amplifier channel lengths were examined:

- Variations in ambient temperature
- Variations in channel power

The effect of these factors was calculated theoretically and measured experimentally. The results of the measurements are in good agreement with the theory. The significance of these phenomena in different situations will be discussed, along with their implications for designing a laser system of this type.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Electro Optics in Defense 10:55 - 11:07:30

Mapping temperature service limits of ZnS Domes

Edi Shaul[1], Yarden B. Weber[1], Tal Azoulay[1], Elaad Mograbi[2], Amir Loyevsky[2], Evyatar Kassis[1], Shay Joseph[1], Doron Yadlovker[1],
Rafael - Advanced Defense Technologies
1 Optical Components Center, POB 2250, Haifa 31021, Israel
2 RD&E Division, POB 2250, Haifa 31021, Israel

High speed missiles require IR material domes resistant to high temperatures and high heating rates. The aerothermal heating characteristic to such applications can elevate the temperature of the dome well above 250˚C in a matter of seconds. In this work we explore the service temperature upper limits of ZnS and thermal shock resistance of ZnS domes.

The service temperature upper limit of ZnS was tested in two types of ovens, one at atmospheric pressure and the other under a vacuum of 4-10 torr. Coated ZnS samples were heated in atmospheric pressure up to 450˚C showing minimal loss of optical transmission. Uncoated ZnS samples were heated in atmospheric pressure up to 550˚C and also under vacuum up to 800˚C showing minimal loss of optical transmission. We examine the effect of the high temperatures on the optical properties of the ZnS samples such as transmission, reflection etc.

Thermal shock was tested on a total of 24 ZnS domes of different geometries, in two distinctly different methods, oil quenching and hot wind tunnel, simulating mild and severe thermal shock, respectively, reaching Biot numbers spanning 0.06 to 1.1, and maximal temperatures between 400÷250˚C. Eventually we witnessed the survival of the domes without a flaw.

These finding encourage us to further exploit ZnS for more demanding applications including developing of new optical coatings for the full temperature range, and further explore its thermal limits.

Quantum nonlinear optics in the strong photon-photon interaction regime

Tomer Danino Zohar, Ofer Firstenberg, Lee Drori and Bankim Chandra
Weizmann Institute of science

We explore effective photon-photon interactions by coupling light to Rydberg atoms. In the strong-interaction regime, we observe a large (>pi) two-photon phase, genuine three-photon interactions, high-order bound states, and the formation of optical quantum vortices.

Effect of cross-phase modulation on critical power for self-focusing

Alexey Sukhinin, University of Northern Carolina, Greensboro, USA

Co-propagation of two high-intensity beams under Kerr nonlinearity is considered. In this talk, I discuss the theoretical model for two-color selffocusing based on Nonlinear Schrodinger Equation. Soliton solutions as well as their dynamics and stability properties were investigated. The resonant and non-resonant self-focusing scenarios and the critical powers of the twocolor collapses were estimated numerically for beams with various topological charges.

Nonlinear Optics 11:07:30 - 11:20

Brillouin Optical Time-Domain Distributed Analysis of Cladding Modes in a Coated Fiber

E. Zehavi, A. Bernstein, G. Bashan, H. H. Diamandi, K. Sharma, Y. London, M. Hen, K. Shemer, and A. Zadok

Faculty of Engineering and Institute for Nano-Technology and Advanced Materials, BarIlan University, Ramat-Gan 5290002, Israel

Propagation in cladding modes of standard fibers enables the sensing of outside chemicals, where the single core mode cannot reach. Coupling to the cladding modes typically relies on the inscription of permanent gratings [1], which restricts the sensors to point measurements only. In addition, most applications rely on bare, uncoated fibers, which are difficult to deploy. An alternative coupling approach has been established based on Brillouin dynamic gratings (BDGs) [2]. Two counter-propagating optical pump waves generate a longitudinal acoustic wave in the core of the fiber through backward stimulated Brillouin scattering [2]. Unlike permanent gratings, BDGs are switched on and off through the pump waves. Our group demonstrated a first spatially distributed cladding modes sensor based on BDG coupling [3]. However, measurements were restricted to bare fibers only, and the range was limited to 2 meters and difficult to scale [3]. Here we report the Brillouin optical time-domain analysis (B-OTDA) of the cladding modes of coated fibers. BDGs are formed using one continuous pump wave and another that is modulated by short pulses, as in standard B-OTDA. A continuous probe wave is coupled to a cladding mode by the BDG, and its output intensity is measured as a function of time. Measurements distinguish between five short fiber sections connected in series, with 1 meter resolution. The concept holds promise for the distributed analysis of conditions that do not affect the core mode, such as the adsorption of chemicals in coatings. As a first example, the measurements identify the local immersion of a fiber section in acetone, based on the effect of the solvent on the coating layer.

References

[1] V. Bhatia et al., “Optical fiber long-period grating sensors,” Opt. Lett. 21, 692-694 (1996).
[2] K. Y. Song et al., “All-optical dynamic grating generation based on Brillouin scattering in polarization-maintaining fiber,” Opt. Lett. 33, 926-928 (2008).
[3] G. Bashan, et al., “Distributed cladding mode fiber-optic sensor,” Optica 7, 85-92 (2020).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

All passive 1.1mJ Tm:YLF/KGW Raman Laser at 2262nm,

Nachmen Gelbach, Menachem Honig, Rotem Nahear, Salman Noach, Yaakov Neustadter

Department of Applied Physics, Jerusalem College of Technology, Jerusalem, Israel

Passively Q switched external-cavity KGW Raman laser in the 2 um range with an energy per pulse record is presented. This Raman laser emits two distinct emission lines at 2197 nm and 2263 nm resulting from two Stokes shifts of 786 cm1- and 901 cm1- respectively. This non-linear conversion technique is known as stimulated Raman scattering (SRS) and is regularly implemented in converting near-infrared (NIR) or visible wavelengths by stokes shifts to longer wavelengths. The KGW crystal has attractive thermal properties and a very high damage threshold, thus it can withstand the increased pump power required to operate at longer wavelengths, making the KGW an excellent medium for SRS. The Raman laser, shown in Figure 1, is pumped via a Tm:YLF laser at a wavelength of 1879 nm. The pump beam collimated and coupled to the Raman cavity through an optical isolator and two half-wave plates. HWP1 affects the orientation of the Tm:YLF polarization, determining the input energy. HWP2 allows for full control of the pump beam's polarization which constitutes the method of interchanging between the two Raman wavelengths. Figure 2 presents the Raman laser output pulse energy versus the incident pulse energy of the fundamental laser at 0.63 KHz repetition rate. For the 2196 nm line output, maximum of 0.57 mJ per pulse was achieved, corresponding to conversion efficiency of %17.5. For the 2262 nm line output, maximum of 0.96 mJ per pulse was, corresponding to conversion efficiency of 33 %. To our knowledge, for the first time, an all passive KGW/Tm:YLF laser reaching 1mJ/pulse with such efficacy is presented. The achieved energy per pulse level, the compactness of this laser with other properties, associated with it, is necessary for many new potential applications.

Light Propagation in Time-Varying Environments using a Multipolar Multiple Scattering Method

Panagiotidis[1,2], E. Almpanis[1,2], N. Stefanou[2] and N. Papanikolaou[1]

1 Institute of Nanoscience and Nanotechnology, NCSR "Demokritos", Aghia Paraskevi, Athens, 153 10, Greece

2 Section of Condensed Matter Physics, Department of Physics, National and Kapodistrian University of Athens, Panepistimiopolis, Athens 157 84, Greece

Understanding light propagation in time-varying environments can lead to new ways to manipulate light and many applications. Using time-varying photonic structures it is possible to achieve very interesting optical responses like frequency conversion, optical isolation, parametric amplification, temporal cloaking, breaking of Lorentz reciprocity, and many others. Typically, most of these effects are possible only with magnetic, non-linear or active materials, however temporal variation provides an extra degree of freedom to realize them with ordinary linear, passive and non-magnetic materials. We recently developed a dynamical multiple scattering method for the solution of Maxwell's equations in time-varying environments and, specifically, in layered structures that consist of two-dimensional periodic arrays of scatterers. This method allows the description of dynamical metasurfaces, but also of photonic crystals and metamaterials. The multiple scattering formalism solves Maxwell's equations by first considering the scattering of a single particle using a multipole expansion of the wave field and, in a second step, the solution of the multiple scattering equations connects all scattering events to obtain the scattering matrix of an infinite periodic layer. We generalized this formalism by including a dynamic T-matrix that describes the scattering from time-varying spheres. The scattering from a single dielectric sphere with time-varying permittivity1 or radius2 have been considered, and examples will be presented. Moreover, we will present the dynamic multiple scattering theory and discuss the implications of light propagation through two-dimensional arrays of dielectric spheres with a time-varying permittivity.

Examples of optical isolation and frequency shifting, using multilayer structures made of time-varying dielectric materials, which exhibit non-reciprocal transmission, will also be presented. The generalization of multiple scattering theory offers very interesting possibilities to study novel optical phenomena in metasurfaces and photonic crystals. The method is very efficient and enables physical insight, since the scattering properties can be easily assigned on the optical response of the individual particles.

References

[1] I Stefanou, P.A. Pantazopoulos, N. Stefanou, Light scattering by a spherical particle with a time-periodic refractive index. JOSA B 38 (2), 407-414, (2021).

[2] E. Panagiotidis, E. Almpanis, N. Papanikolaou, N. Stefanou Inelastic light scattering from a dielectric sphere with a time-varying radius Phys. Rev. A 106 (1), 013524, (2022).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Optical deep learning with nonlinear multimode signals

Yuval Tamir, Hamootal Daudi, Moti Fridman

Bar Ilan University

A deep learning network requires high-performance computer systems for solving complex problems with millions of parameters. We suggest an optical machine learning system that is based on nonlinear interaction in a multimode fibers resonator. The input signal's wave as a function of time serves as the input to the network. It interacts with a specific pump wave in a graded-index multimode fiber. Next, a dispersive element shifts the different modes in time for mixing the signal in time. After each single pass we apply a gradient descent to train the system, and a new set of pump modes is generated, that are used in the next iteration. We tested the system using the MNIST database, where each number serves as an input signal, and the classification of this input as the idler. Details of our system and preliminary results will be presented.

Temporal SU(1,1) interferometer,

Sara meir, Hmootal Daudi, Moti Fridman

Bar Ilan University

Interferometers are highly sensitive to phase differences and are utilized in numerous schemes. Quantum interferometers are able to improve the sensitivity of classical interferometers beyond the shot-noise limit. This is done by employing squeezed states of light and destructive interference of the noise in the system. We analyze, theoretically and experimentally, a nonlinear quantum interferometer based on time-lenses, henceforth denoted as a temporal SU(1,1) interferometer. The temporal SU(1,1) interferometer is based on a temporal 4f-system by applying two time lenses. Each time lens impose Fourier transform on the input signal and the idler beam. We show that the outputs of such a device depend on quantum interference in the time and the frequency domains, namely, temporal SU(1,1) interferometer creates interference of the input signals at different times and frequencies. We can control the time and frequency differences by the properties of the time lenses for investigating the full temporal and spectral structure of the input signal. We utilized this temporal SU(1,1) interferometer for sensing ultrafast phase changes. We added phase by implementing electro optical phase modulator with various frequencies waves (4 GHz - 12 GHz) to the system. This leads to periodic changes of the fringes on the interference waves. Finally, we studied the correlations between the signal and the idler. This temporal SU(1,1) interferometer can be utilized also for quantum imaging, temporal mode encoding, and studying the temporal structure of entangled photons. In the talk, we will describe the basic properties of the time lenses, how the interferometer is designed, and the experimental results.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Temporal refraction, reflection and impedance matching of surface gravity water waves

Georgi Gary Rozenman[1,3], Yakir Hadad[1], Lev Shemer[2], and Ady Arie[1]

1 School of Electrical Engineering, Faculty of Engineering, Tel-Aviv University, Tel-Aviv 6997801, Israel
2 School of Mechanical Engineering, Faculty of Engineering, Tel-Aviv University, Tel-Aviv 6997801, Israel
3 Raymond and Beverly Sackler School of Physics & Astronomy, Faculty of Exact Sciences, Tel Aviv University, Tel Aviv 69978, Israel

When a wave that propagates in one medium encounter a medium with different properties, part of the energy will be reflected at the interface, and part of it will be transmitted to the second medium. This concept is well known for an interface in space, but in recent years, the concept was extended to the temporal domain, where the medium properties change abruptly at a certain moment[1]. Furthermore, adding a thin layer between the two media can either suppress the reflection or the transmission. Specifically, spatial impedance matching is widely used for electromagnetic waves in free space and for electric signals guided by transmission lines in electric circuits, and it was theoretically proposed to extend these concepts to the time domain as well. Here, we utilize surface gravity waves that propagate in time-modulated water flow[2] to experimentally study temporal reflection and refraction between time boundaries in a systematic manner, as illustrated in Fig. 1(a). Our measurements demonstrate temporal refraction and reflection between two boundaries, as well as suppressed reflection or the opposite case of nearly full reflection of the waves, by adding an intermediate temporal layer. Owing to the different continuity conditions, we observe a phenomenon that has no counterpart in electromagnetic waves, of full reflection when the flow is reduced abruptly. Whereas these effects are governed by linear wave dynamics, by increasing the wave steepness, we can also observe reflection and refraction of solitons between temporal boundaries. In Fig. 1(c) we show experimental results of temporal refraction on top of numerical simulations. When the temporal impedance matching is condition is applied, we observe nearly a full transmission of the waves, as shown in Fig. 1(d).

References
[1] V. Pacheco-Pena and N. Engheta, "Antireflection temporal coatings", 7, 4, Optica, (2020).
[2] G. G. Rozenman, S. Fu, A. Arie, L. Shemer, "Quantum Mechanical and Optical Analogies in Surface Gravity Water Waves", MDPI-Fluids, 4(2), 96, (2019).

Detuning Modulated Composite Segments for robust optical frequency conversion

Yuval Reches, Elazar Elias, Haim Suchowski

Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Ramat Aviv 6779801, Tel Aviv, Israel

The creation of efficient broadband frequency conversion devices while maintaining robustness to manufacturing and setup errors is crucial for accurate multiphoton spectroscopy, broadband imaging, and the design of robust optical sources. Traditionally, nonlinear optical conversion processes are either efficient but narrowband or broadband but with low photon conversion yield. Several methods for the creation of broadband and efficient conversion have been introduced in recent years, with great success, among them we can find the adiabatic frequency conversion and Shaka-Pines composite segmented design. However, the Shaka-Pines scheme does not include the full parameter-space of controls and non-composite schemes fail to offer a robust, broadband, and efficient conversion process while maintaining short nonlinear crystal length and low pump intensity.

Here we introduce a novel method of detuning modulated composite segmented (DMCS) and constant-length DMCS (CL-DMCS) schemes in nonlinear optics. We numerically demonstrate the use of the schemes and their ability to outperform other commonly used schemes under length and power constraints. We demonstrate their advantages for robust, broadband, and efficient optical frequency conversion. We also show that the CL-DMCS scheme can offer multiple efficient and robust wavelength regimes of broadband upconversion. We show that both schemes are robust to temperature and crystal length variations and can have a superior conversion bandwidth under length and power constraints compared to other conversion schemes, such as periodically poled and adiabatic chirped crystals. We believe that the new family of DMCS schemes will have many uses in applications of frequency conversion, due to their robustness, low energy demand, compact size, and high scalability.

Atomic & Quantum Optics 11:07:30 - 11:20

Towards femtotesla broadband AC diamond magnetometry

Yachel Ben Shalom[1,2], Under the supervision of Prof. Nir Bar Gill[1,3]

1 *Dept. of Applied Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel*
2 *ELTA Systems Ltd., Israel Aerospace Industries, Ashdod 77102, Israel*
3 *The Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel*

In recent years, the interest in quantum metrology has been growing both in Academia and in Industry. A significant aspect of quantum metrology relates to magnetic sensing and specifically sensing of AC magnetic fields, with several quantum systems being employed to enhance the sensitivity in this context. The quantum system we study is the Nitrogen Vacancy (NV) color center in diamond. The NV center is a nanoscale defect in diamond's crystal structure, and it can be initialized via optical pumping, read out via fluorescence intensity, and coherently manipulated by microwave (MW) fields.

While the NV center possesses very high sensitivity per unit volume, realizing an ensemble sensor that can overcome state-of-the-art classical sensors is still difficult. The main challenge is to achieve efficient control in a large volume of all relevant control fields - excitation, collection, microwave, and bias magnetic field.

In our work, we addressed these issues to enable high efficiency and homogeneity. We designed a MW resonator with <%1 inhomogeneity on 0.02 ??3, and an optical collection method coupling to the entire diamond volume with >%50 collection efficiency. Combining these advances could lead to a general system that pushes the sensitivity of NV based sensors toward the ~??/√?? limit with standard components. This system could be used also for sensing in the GHz regime with a sensitivity of ~10 ??/√??, by continuous dynamical decoupling techniques (CDD).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Electro Optic Devices 13:50 - 14:02:30

Deployable Asymmetric Space Telescope

B. M. Levine and Erez N. Ribak

Department of Physics, Technion - Israel Institute of Technology

Background: Designs for a deployable sparse space telescope use contiguous rectangular or hexagonal segments. The straight edges of these elements scatter a great deal of light in the focal plane of the telescope. This scattered light appears as coherent spokes, which limit the ability to detect faint objects next to a bright one. In addition, alignment is very lengthy and prone to errors.

Objectives: We wish to devise telescope panels shapes both for imaging and for initial alignment.

Methods: Our laboratory set-up is made of two 20cm parabolas facing each other, the first a collimator, the second being the segmented telescope model. Analysis of the images leads to computerized commands to the sectors PZT actuators, without additional sensors. The straight edges of the segments, sawn from a full parabola, diffract a great deal of light normal to their directions, so they had to be rounded. For reduced redundancy, they were oriented at different angles: we optimised the shapes and angles to increase the mid-frequency response.

Results: For ellipses with axes ratios a/b of 1.5 to 2.2, the azimuthal optimal angles between segments were 67°, 84°, 113° and 96°. Each sector has its own unique PSF, and sectors at different angles can be differentiated by their PSF orientation, even when overlapped. We used four matched filters to correct for their tip and tilt. Finally, the phases of the fringes between these ellipses enabled measurement of their mutual OPDs.

Recommendations: Today aperture masking and segmented telescopes have a symmetrical design for the sub-apertures shapes; breaking that symmetry has its many benefits.

Reference

B M Levine, M Kaplun and E N Ribak: An asymmetric Sparse Telescope, Optics Continuum 1, 1603-12 (2022).

Fast Electro-Optical Switching in KLTN Crystal at the Paraelectric Phase Near TC

Yehuda Elishevitz[1], Yehuda Vidal[2], Mulkan Adgo[2], Salman Noach[1], and Aharon j. Agranat[2]

1 *Applied Physics/Electro-Optics Engineering Department, Faculty of Engineering, JCT Lev Academic Center, Jerusalem 9372115, Israel*

2 *The Department of Applied Physics, Hebrew University of Jerusalem, Jerusalem 9190401, Israel*

Introduction: Potassium lithium tantalate niobate (KLTN) at the paraelectric (PE) phase close to the phase transition temperature (Tc) exhibits a strong electro-optic (EO) effect in the VIS-MWIR range. However, it was shown that close to TC formation of dipolar clusters affects the EO behavior. We present herein an indepth study of the EO response's temporal characteristics, attempting to quantify the relations between it and the working temperature.

Methods: The electrically induced birefringence (IBR) was measured in a "crossed polarizers" EO modulator. Fast EO switching was obtained by employing a special circuit that produces narrow highvoltage electrical square pulses while avoiding the formation of electrical ringing.

Results: In contrast to the uniform rise of the electrical pulse, the optical exhibits a "step", in which height is temperature dependent. It was observed that the optical output follows the electrical rise at the lower section, whereas a significant slowing down is exhibited in the upper. Previous DC studies indicate that close to TC the IBR can be written as a sum of two components, describing the IBR experienced by the part of the optical beam that propagated through the PE zone (ΔnPE), and through the dipolar clusters (Δn_{dip}). Accordingly, we modeled the IBR under fast switching to consist of two components:

$$(1)\quad \Delta n(E,T,\boldsymbol{r}) = \Delta n_{PE_{1-\chi}} + \Delta n_{dip_{\chi}} = \frac{1}{2}\left((1-\chi)\cdot\tanh\left(\tau_{PE}(t-t_{0_{PE}})\right) + \chi\cdot\tanh\left(\tau_{dip}\left(t-t_{0_{dip}}\right)\right)+1\right)$$

Figure 1 shows that expression (1) indeed provides an accurate approximation of the experimental results.

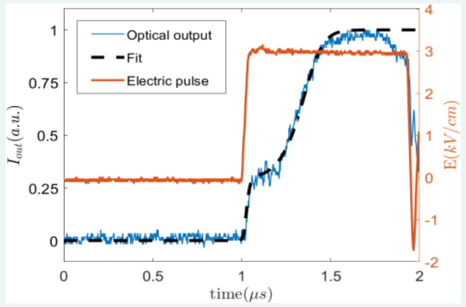


Figure 1: Fit our model to the experimental results

Conclusions: Crystal's operating close to TC leads to elongation in the rise time (t_r) due to the slow rearrangement of the dipolar clusters. This leads to a tradeoff: it is possible to achieve long t_r (~400ns) at low voltages (~10^2V) by operating close to TC, or short (~20ns) at high voltages (~10^3V), at a higher temperature. An optimal choice of the working temperature and switching threshold will allow optimization of the results in different applications

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

InGaN/GaN quantum wells by Molecular Beam Epitaxy at ICAP,

Ofer Sinai and Renana Didi

Soreq Nuclear Research Center / The Israel Center for Advanced Photonics

Epitaxially grown semiconductors from the III-N family are important both technologically and scientifically, with applications to efficient lighting (common Light emitting diodes - LEDs), power electronics, ultraviolet (UV) light sources and lasers, UV and infrared (IR) detectors, next-generation display technology, tandem photovoltaic cells and more. InxGa-1xN with different compositions possesses direct bandgaps with energies from 3.51 eV (near UV) to 0.7 eV (short-wave IR), straddling the entire visible spectrum.

Epitaxial growth can be performed with a sub-nm degree of precision using molecular beam epitaxy (MBE), which also enables access to the full range of InGaN compositions (as opposed to alternative epitaxial methods). Since mid2019-, the Israel Center for Advanced Photonics (ICAP) has been performing epitaxy of III-Nitrides as well as other III-V semiconductors, using both MBE and metal-organic vapor phase epitaxy (MOVPE), as part of its mission statement to provide research and development services to academic and industrial customers in Israel and abroad. In this talk I will present some recent results obtained from the III-N MBE machine at ICAP, demonstrating the growth of high-In InGaN and precise, repeatable epitaxy of InGaN-in-GaN multiple and single quantum wells (QWs). I will also |describe shutter-modulated techniques used to grow both bulk InGaN and GaN and InGaN/GaN QWs, detailing considerations made during their development.

Nanostructure Array Pixels for Surface-Plasmon Material Imager

Avi Huri[1], Ya'akov Mandelbaum[1,2], Raz Mottes[2], Zeev Zalevsky[1], David Zitoun[1], Avi Karsenty[2]

1 *Bar-Ilan Institute of Nanotechnology and Advanced Materials (BINA), Bar-Ilan University, Ramat-Gan, Israel*

2 *Department of Applied Physics and Electro-optical Engineering, Lev Academic Center - Jerusalem College of Technology (JCT), Jerusalem, Israel*

Background: In addition to strong enhancement of electromagnetic fields localized surface plasmons (LSP) also display a distinct resonant peak in both the optical scattering and absorption spectra. The precise location of the peak varies depending on the material properties of the surrounding medium. This property is ideal for use as a material detector - by measuring the shift of the resonant peak the composition of the ambient solution may be extracted.

Objectives: A plasmonic nanostructure array is presented, consisting of nanoscale protrusions or cavities formed in a layer of precious metal (Ag or Au). The pattern is designed to serve as a pixel in a material imaging device intended to provide spatially resolved measurements of solvent concentration, and ultimately, real-time mapping of a chemical reaction.

Design Simulations: Using analytic studies and numeric simulations, the shape and size of the nanostructures, as well as the properties of surrounding medium are tuned to maximize scattering and absorption. The spatial density and lattice arrangement of the nanostructures is optimized to obtain maximal responsivity, while minimizing undesirable interactions such as mutual suppression and crosstalk.

Results: Fabrication by Focused Ion Beam (FIB) and structural characterization using SEM imaging is presented for initial specimens. These prototype the use of gold vs. silver, as well as cavities vs. protrusions. The plasmonic behavior of the different prototypes is compared using hyperspectral imaging obtained via dark-field optical microscopy.

A preliminary experiment is described in which silver nanocubes were coated with a nanometric layer of PDA, which was then doped with platinum at varying concentrations. The resonant peak in the absorption was determined using UV-VIS spectrometry. From this the value of the dielectric function of the PDA coating, and its dependence on the concentration of the platinum dopant was estimated based on the shift in the peak location.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Efficient Fiber-to-Photonic Integrated Circuit Connection via Wafer-Scale Glass Molding

Robert Michels[1], Tim Grunwald[1], Thomas Bergs[1,2]

1 *Fraunhofer Institute for Production Technology IPT, 52074 Aachen, Germany*

2 *Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, 52074 Aachen, Germany*

Increasing demand for higher data rates in data centers is driving efforts to produce single-mode optics, which substantially improves the commonly used infrastructures. However, the fiber coupling to photonic integrated circuits (PICs) is currently a bottle neck. The optics needed to link optical fibers to PICs are sub-millimeter in size and call for extreme precision both at the manufacturing as well as the assembling stage. Using glass instead of plastic optics increases the optical performance and therefore, the transmissible data rates but results in higher production costs. Fraunhofer IPT and partners developed an innovative, efficient glass fiber coupling technology based on the replicative process of glass molding. In a glass molding process, a glass preform is heated until the viscous state and afterwards pressed into the desired shape using two high-precise molds.

This process permits the direct and efficient manufacture of high shape accuracy and surface quality optics without any mechanical post-processing steps. To fabricate the fiber couplers, two different glass molding technologies were explored and compared: The highly precise, but slow isothermal process of precision glass molding (PGM) and the more efficient, but less precise non-isothermal glass molding (NGM). A scale-up strategy has been developed which is based on a wafer-scale approach. This allowed producing a large number of identical elements in one molding operation out of a single glass wafer, which increased the efficiency both of the manufacturing process and of the subsequent assembly operations. The development covers all aspects of the realization of single-mode fiber coupling - from the optical and electrical design of the connectors and PICs through process technology, machine tool manufacture and assembly technology to application within the system and the analysis of the coupling efficiency from fiber to PIC.

Dielectric Response of a Novel LC Resonant Metamaterial Architecture using THz Impedance Spectroscopy for Application in Bio-Sensing

Heena Khand, Rudrarup Sengupta and Gabby Sarusi

Department of Photonics and Electro-Optics Engineering, School of Electrical and Computer Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel

Terahertz (THz) spectroscopy is a state-of-the-art implementation for analysing various biological materials, as well as nanoparticles. Using metamaterials in conjugation with THz spectroscopy is an important technique towards bridging the THz-gap by providing a large response to THz radiation of the inspected material and nano-particles that are in a low concentration, where most natural materials exhibit only weak responses to its electric and magnetic fields. With recent advances in THz spectroscopy, engineered metamaterial nanostructures are used to detect and determine dielectric properties of viruses, bacteria, and fungi, using the concept of inductor-capacitor (LC) resonance-based particle detection1. The nanostructure is designed as an LC element, with fundamental resonant frequency, $F0 = 1/2\pi\sqrt{LC}$. Here the factor L is decided by the geometric parameters of the fabricated nano-structure, and C is highly dependent on the capacitive gap (W) and effective dielectric constant (εeff) of the LC resonant nanostructure. A change in $F0$ of can be brought by any foreign substance deposited in the capacitive gap; changing the εeff and the capacitance, resulting in redshift of $F0$ (ΔF) with respect to the pristine LC circuit in the array2. For the detection of nanoparticles/biomolecules using metamaterial-based structures, we physically redesign the LC resonant geometry with the intention of maximizing the cap-gap-area3. The cap-gap width is reduced in order to obtain the plasmonic enhancement that is associated with the nanometric scale of such a capacitor gap. Placing the capacitor gaps at both geometric diagonals of a square inductor enables the exhaled viruses and particles to be detected in both S and P polarization states (when using a single polarization spectrometer) with a rectangular all-around singular inductor structure, for its resonance detection. This improvement enables low concentration particle detection by increasing the capacitive gap lengths compared to a basic split ring resonator. This effectively increases the sensitivity by 5-folds, by increasing the probability of biomolecules/particles falling inside the capacitive gap and yet maintaining a sub-micron capacitor gap, thereby enabling more pronounced resonance frequency shifts for breath samples even with a lower virus load3. Our results are supported with system level CST simulations and THz impedance spectroscopy with nanoparticles, Bovine Serum Albumin (BSA) solutions and viruses. To realize a kit for bio sensing, we have also designed a plastic enclosure (radome) for the metamaterial chip, which serves as a protective enclosure and an anti-reflective coating for the chip, thereby improving the THz transmission, by impedance matching techniques. Since our initial results have shown nearly 90% accuracy to detect coronaviruses in breath-test3, we further aim to detect various viruses/bacteria from breath/swab of individuals with higher accuracy, with our designed kit.

References

1. Kang, J.-H.; Kim, D.-S.; Seo, M. Terahertz Wave Interaction with Metallic Nanostructures. Nanophotonics 2018, 7 (5), 763-793. https://doi.org/doi:10.1515/nanoph-2017-0093.
2. Park, S. J.; Cha, S. H.; Shin, G. A.; Ahn, Y. H. Sensing Viruses Using Terahertz Nano-Gap Metamaterials. Biomed. Opt. Express 2017, 8 (8), 3551. https://doi.org/10.1364/boe.8.003551.
3. Rudrarup Sengupta, Heena Khand, and Gabby Sarusi; 'Terahertz Impedance Spectroscopy of Biological Nanoparticles by a Resonant Metamaterial Chip for Breathalyzer-Based COVID-19 Prompt Tests'; ACS Applied Nano Materials, 2022, 5 (4), 5803-5812, DOI: 10.1021/acsanm.2c00954.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Breathalyzer-based Prompt Coronavirus Screening Test using THz Spectroscopy of Viruses in LC-Resonant Metamaterial Nano-Antenna Array

Rudrarup Sengupta, Heena Khand and Gabby Sarusi

Department of Photonics and Electro-Optics Engineering, School of Electrical and Computer Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel

During the last three years, the coronavirus and its mutations caused a global upsurge in number of people being infected with COVID19-. Interestingly, a greater number of patients affected with mutated variations of COVID19- are reported to be asymptomatic that increases the risk of infecting other people. In the wake of this situation, there is a need for prompt, large-scale, accurate and cost-effective screening detection of COVID19- carriers of any genetic trait, to effectively trace symptomatic along with asymptomatic patients and isolate them, to stop the virulent spreading of the coronavirus and to gradually end the pandemic. Current biological based methods such as PCR tests require nearly 4 hours to obtain the result. Therefore, in this work, we propose a prompt, non-biological and effective testing solution, which can screen coronavirus infected patients within one minute, and segregate them from the healthy individuals, to be used at entry points. Our proposed method is based on the detection of shift in resonance frequency of a nano-gap LC-resonant metamaterial chip1, caused by viruses and mainly related exhaled particles, when performing a terahertz (THz) spectroscopy. The chip consists of thousands of micro-antennas arranged in an array, and enclosed in a plastic breathalyzer-like disposable capsule kit. After reaching appreciable agreement between numerical simulations and experimental results using our metamaterial design, low scale clinical trials were conducted with asymptomatic, symptomatic coronavirus patients and healthy individuals2. In our proposed coronavirus screening test with we detect a combination of viruses and related biological particles exhaled by an infected person, (e.g. virus debris, cytokines, cell debris and related proteins and fat molecules) which produces an effective change in dielectric constant of the resonant metamaterial at the capacitive gap regions. This phenomenon red shifts the resonance frequency (ΔF), which becomes the deterministic factor to effectively screen the infected patients from the healthy individual. We achieve a definite band of ΔF=1.5 GHz to 9 GHz for infected individuals, with a linear relationship of increasing ΔF with increasing viral load. In order to effectively differentiate between 'healthy' and 'SARS-CoV2- infected' patients in terms of ΔF, we included only 'completely healthy' and 'sick of SARS-CoV2-' individual, in order to design a screening test only and not a diagnostic test. The simplicity of this cost-effective breathalyzer-based testing kit lies in its ease of handling, which does not require a complex setup procedure. The entire testing and analysis are performed within 50 to 55 seconds, with %86.84 agreement with the RT-qPCR analysis (with both PPV and NPV values of %88.88), based on the law scale verification clinical trials conducted at Soroka medical centre, Israel3.

References

1. Park, S. J.; Cha, S. H.; Shin, G. A.; Ahn, Y. H. Sensing Viruses Using Terahertz Nano-Gap Metamaterials. Biomed. Opt. Express 2017, 8 (8), 3551. https://doi.org/10.1364/boe.8.003551.
2. Gabby Sarusi.; Rudrarup Sengupta. PROMPT VIRUSES INFECTION DETECTION USING THz SPECTROSCOPY IN A BREATHALYZER-LIKE CONFIGURATION. WO2021199036A1, 2021 (Worldwide Patent).
3. Rudrarup Sengupta, Heena Khand, and Gabby Sarusi; 'Terahertz Impedance Spectroscopy of Biological Nanoparticles by a Resonant Metamaterial Chip for Breathalyzer-Based COVID-19 Prompt Tests'; ACS Applied Nano Materials, 2022, 5 (4), 5803-5812, DOI: 10.1021/acsanm.2c00954.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Optical Engineering 14:02:30 - 14:15

Pulse compression comparison in Q-DAS systems: Ternary codes vs. Binary codes

Nadav Arbel, Yair Ben Naeh and Avishay Eyal

Department of Physical Electronics, School of Electrical Engineering, Fleischman Faculty of Engineering, Tel-Aviv University, Tel-Aviv 69978, Israel

Pulse compression techniques became popular in the last decade in many optical fields such as Laser Range Finders (LRF), Quasi and fully Distributed Acoustic Sensing (QDAS and DAS), Brillouin Sensing and more. In general, it allows increasing the transmitted energy while keeping the spatial resolution the same as that of a single pulse. A promising approach for implementing pulse compression is via Perfect Periodic Autocorrelation codes (PPA). Ideally, the autocorrelation of PPA codes is a sequence delta functions. This is a manifestation of the codes ability to achieve perfect compression. Therefore, replacing each transmitted pulse by a PPA code and compressing the received returns, leads to a significant improvement in the SNR. Out of the binary PPA codes, i.e. codes whose basic elements (bits) are two complex numbers, the largest families are the M-sequence and the Legendre code. In a Legendre code of length N the bits are of unit magnitude and phases: 0 1 1,cos ( ) 1 N N) ü - - í ý - î þ +. In practice, it is difficult to generate such sequences using typical optical modulators. An approximated sequence whose generation is more practical is obtained by using the phases {0,p }. A Legendre code with this alphabet has a periodic autocorrelation function of 1- everywhere except at the center where its value is N. Hence, its Peak to Sidelobe Ratio (PSLR) becomes N (rather than ¥ as in the ideal case). This may hinder the performance of systems which employ Legendre-codes as it may lead to increased crosstalk. This crosstalk can be alleviated without additional complexity to the system provided that the modulator can generate null bits. This is the case of the ternary code which has the same alphabet as before but with few additional zeros. The use of such ternary PPA is expected to offer better PSLR and improved crosstalk performance. In this research, we studied codes of 1-,0 ,1+ bits and experimentally compared binaryphase codes with ternary perfect periodic codes at different SNRs.

The results show that for the same transmitted energy, the ternary code has better performances in a high SNR scenario but this advantage is lost as the SNR decreases.

Near-field Projection Optical Microscope (NPOM):A New Approach to Nanoscale Super-Resolved Imaging

David Glukhov[1,2], Abhijit Sanjeev[3,4], Avi Karsenty[1,2], Zeev Zalevsky[3,4]

1 Lev Academic Center-Jerusalem College of Technology (JCT), Dept. of Applied Physics/Electro-Optics Eng., Advanced Lab. of Electro-Optics (ALEO), 21 Havaad Haleumi St., POB 16031, Jerusalem, 9116001, Israel

2 Lev Academic Center-Jerusalem College of Technology (JCT), Nanotechnology Center for Research & Education, Lev Academic Center, Jerusalem, 9116001, Israel

3 Faculty of Engineering, Bar-Ilan University, Ramat Gan, 5290002, Israel

4 The Nanotechnology Cente

A new super-resolution method, entitled Near-field Projection Optical Microscope (NPOM), is presented for near-field measurements and imaging. This novel imaging concept enables to reconstruct nanoscale measured objects without the need to scan them on the surface, as usually done in existing analysis methods such as NSOM (near-field scanning optical microscope). The main advantage of the proposed concept, besides the lack of mechanical scanning mechanism, is in the fact that the full field of regard/view is obtained simultaneously and not point by point like in scanning configuration and in addition, by using compressed sensing, the number of projected patterns, which decomposes the spatial information of the inspected object, can be smaller than the obtainable points of spatial resolution. In this paper, in addition to the mathematical formalism, series of complementary numerical tests were performed, using challenging objects and patterns to prove the accuracy of the reconstruction capabilities. As expected, the accuracy will increase with the number of projected patterns. Experimental complementary results shown also promising future for this new approach.

High-resolution wavefront measurement system for industrial applications

Audrius Jasaitis, Rafael Porcar, Xavier Levecq, Nicolas Lefaudeux, Pauline Treimany
Imagine Optic SA, 18 rue Charles de Gaulle, 91400 Orsay, FRANCE

In Shack Hartmann wavefront sensor, the spatial wavefront resolution is determined by a number of microlenses in a microlens array, each microlens offering one measurement of a local slope of the wavefront. However, in 2010 ONERA researchers opened the door to the possibility of improving the spatial resolution of Shack Hartmann wavefront sensor by analyzing the intensity distribution of each centroid in order to determine the local wavefront shape sampled by each microlens [3 ,2 ,1]. They called this technology 'LIFT' (Linearized Focal-Plane Technique) and we are now proposing a new implementation of the LIFT technology which results in a -16time improvement of the wavefront sensor spatial resolution. We will present an optical setup and a validation method, which we implemented to evaluate the resolution enhancement by the LIFT technology and we will show the results obtained characterizing various optical components. Below is shown an example of the wavefront resolution enhancement during phase plate optical characterization performed at SWIR spectral range.

Imagine Optic applied the LIFT technology in our new optical system, called MESO. This instrument is dedicated to interferometry applications, in particular for testing the large diameter flat surfaces in any environment, including industrial and at-line setup.

This new metrology solution stands out for its unique combination of features: insensitive to vibrations, at-design wavelength testing, including our proprietary testing procedure for the characterization of Parallel Optics (POP). The POP method takes advantage of the back reflection from the second surface of the component, when it usually represents a limitation in classic Fizeau interferometers as it affects the fringes pattern. Interestingly, it performs an analysis of both surfaces shape and transmitted wavefront in only two measurements. Moreover, it avoids the need of: i. moving (switching) the sample between measurements and therefore referencing the maps acquired, ii. preparing the sample applying coatings that affects the production process, the integrity of the components under test and possibly the precision of the measurements. We'll review these MESO features and showcase different implementations of surface shape and wavefront measurement for quality control.

References

[1] R. Gonsalves, "Small-phase solution to the phase-retrieval problem", Opt. Lett., Vol. 26, No 10, pp. 684-685 (2001).
[2] S Meimon, "LIFT: a focal-plane wavefront sensor for real-time low-order sensing on faint sources", Opt. Lett., Vol. 35, No 18 (2010).
[3] A. Tokovin et al, "Donut: Measuring optical aberrations from single extra-focal image" Pub. Astron. Soc. Pacific 118, 1165 (2006).

Monocular passive ranging by point-spread function engineering

Nadav Opatovski[1], Dafei Xiao[1], Gal Harari[2] and Yoav Shechtman[1]
1 RBNI Nanoscience Institute,
2 Physics Department and Solid State Institute, Technion, Haifa, Israel

Introduction: We present a passive-ranging apparatus based on a refractive telescope lens, using point-spread-function (PSF) engineering for monocular distance estimation. The optical system is experimentally demonstrated in a variety of challenging imaging scenarios, including adversarial weather conditions, dynamic targets and scenes of diversified textures, at distances extending beyond 1.7km.

Background: Imaging-based distance estimation is a difficult task, due to the 2D nature of image formation. As result, most range-estimation apparatuses in use today are active in nature, relying on emission of signal towards the measured object. The active approach suffers from drawbacks in terms of apparatus bulkiness, cost, safety and detectability. PSF engineering is a passive-imaging tool for computational 3D imaging, that had not been previously used for macroscopic systems at distances on the 1km range.

Objective: Perform PSF engineering in a telescope imaging system to produce monocular passive range estimation at large distances (hundreds of meters).

Method: We realize PSF engineering by mounting a -4f extension to a telescope, extending the optical path of the light towards the camera. In the pupil plane of the extension, a phase mask modulates the wavefront to manifest the PSF engineering. Distance recovery is obtained by regional computational analysis of the acquired PSF-engineered image.

Results: Experimental range estimations in a variety of challenging imaging scenarios are provided, including adversarial weather conditions, dynamic targets and scenes of diversified textures. The precision values are quantified, yielding precision of the order of %3.5 of the target distance at 650m and %14.5 at 1,700m at moderate turbulence conditions. Results are strongly dependent on atmospheric turbulence severity. Crucially, precision can be improved by incorporating multi-frame analysis. We also show that the passive imaging-based approach can be superior to active measures in presence of dust. In conclusion, we introduce and prove PSF engineering as a viable tool for distance estimation at long distances.

Creation and in-situ Measurement of All-Liquid Lenses in Microgravity,

Omer Luria[1], Mor Elgarisi[1], Valeri Frumkin[1,§], Alexey Razin[1], Jonathan Ericson[1], Khaled Gommed[1], Daniel Widerker[1], Israel Gabay[1], Ruslan Belikov[2], Edward Balaban[2], and Moran Bercovici[1]

1 Faculty of Mechanical Engineering, Technion - Israel Institute of Technology, Haifa, Israel
2 NASA Ames Research Center, Moffett Blvd., Moffett Field, CA, USA
§ Current affiliation: Department of Mathematics, MIT Cambridge, MA, United States

We present parabolic flight experiments demonstrating the creation and in-situ measurement of all-liquid optical lenses in microgravity, based on the novel method 'Fluidic Shaping'. By injecting optical liquid into a circular bounding frame in microgravity conditions, minimum energy and surface tension drive the liquid to form a spherical lens. We provide details of the two experimental systems designed to inject the precise amount of liquid within the short microgravity timeframe provided in a parabolic flight, while also measuring the resulting lens' characteristics in real-time using both resolution target-imaging and a Shack-Hartman wavefront sensing. We successfully created more than 20 liquid lenses during the flights, and we also present videos recording the process, from the lenses' creation during microgravity and up until their collapse upon return to gravity. Our demonstration clearly shows the feasibility of creating liquid optics in microgravity. Due to the scale invariance of the method, this may also allow reaching single-piece apertures that cannot be obtained using today's technologies.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Fabrication of Eyeglass Lenses Using Fluidic Shaping,

Mor Elgarisi[1], Omer Luria[1], Valeri Frumkin[1,§], and Moran Bercovici[1]

1 Faculty of Mechanical Engineering, Technion, Haifa, 3200003 Israel
§ Current affiliation: Department of Mathematics, MIT Cambridge, MA, 02139, United States

The current method for fabricating eyewear lenses relies on the machining and polishing of semi-finished blanks. This fabrication process has not changed significantly in the past 300 years, relies on heavy mechanical infrastructure, and produces tremendous amounts of non-recyclable polymer waste.

We present a simple method, based on free-energy minimization of liquid volumes, which allows to quickly shape liquids into a wide range of ophthalmic lenses, without the need for any mechanical processing. At present, the method allows to produce any single vision prescription, including spherical and astigmatic corrections.

The fabrication is performed by injecting a liquid polymer into a bounding frame submerged within an immiscible immersion liquid with equal (or nearly equal) density. Under these conditions, surface tension dominates, and the curable liquid takes the shape of a symmetric lens (bi-convex or bi-concave). A meniscus lens shape can then be obtained simply by enclosing the bottom part of the lens in an impermeable chamber and adding immersion liquid to it in order to 'inflate' the polymer. After the desired shape is achieved, the liquid can be cured to produce a solid object. Due to the natural smoothness of the liquid, the lens has sub-nanometric surface roughness without the need for any polishing processes. We developed a complete theoretical framework for the minimum energy state of the interface of the liquids, which describes the lens' diopter and cylinder power as a function of the bounding frame shape, the injected volumes, and the density differences between the liquids. We will show the utilization of the theory toward the fabrication of the first eyeglasses based on fluidic shaping, and provide measurements of their shape and surface roughness. Lastly, we will show that our method is also suitable for the fabrication of complex optical components (i.e., freeform) simply by controlling the frame shape.

Advances in Precision Glass Molding of Fused Silica

T. Grunwald[1,*], T. Bergs[1,2]
1 *Fraunhofer Institute for Production Technology, Steinbachstr. 17, 52074 Aachen, GERMANY*
2 *Machine Tool Laboratory WZL of RWTH Aachen University, Chair of Manufacturing Technology, Campus Boulevard 30, 52074 Aachen, GERMANY*
**Corresponding author: Dr.-Ing. Tim Grunwald*

Photonic systems are paving our way into the future. The manufacturing of these systems has to keep up with the fast developments. Fused silica as a highly durable material for laser beam shaping or optical communication plays an irreplaceable role in photonic and optical systems. The conventional, direct manufacturing processes for the production of fused silica optics (e.g. grinding and polishing) are increasingly reaching the limits of efficiency and complexity (scalability of production or production of complex geometries). The Precision Glass Molding of fused silica can overcome these limits but faces challenges that prevent it from becoming a significant industrial application. These include primarily the wear of the molding tools, which is caused by the challenging process conditions (temperatures of up to 1,400 °C, high forming stresses, etc.). Although the mold wear mechanisms are well understood in a qualitative sense, quantitative service lifetime prediction for the forming process cannot be provided. This study presents a mathematical model comprising a combined Monte-Carlo and Multi objective genetic algorithm approach in order to overcome this issue. The simulation is able to reproduce the dynamic surface alteration during the wear occurrence. The explanations close with an outlook concerning the transferability of the simulation to other issues in glass and manufacturing science.

Reduction of waste through digitally networking optics production

C. Rojacher[1,*], T. Grunwald[1], T. Bergs[1,2]
1 *Fraunhofer Institute for Production Technology, Steinbachstr. 17, 52074 Aachen, GERMANY*
2 *Machine Tool Laboratory WZL of RWTH Aachen University, Chair of Manufacturing Technology, Campus Boulevard 30, 52074 Aachen, GERMANY*
**Corresponding author: Cornelia Rojacher, M.Sc.*

The manufacturing of optical systems is a challenging and effortful task. Usually, many iteration cycles are performed in order to increase production yield.
The increasing demands on the quality of high-precision optical components mean that established manufacturing processes are reaching their technical limits. While individual processes can therefore hardly be improved, the digital networking of production machines across the entire process chain offers great potential for meeting the tight tolerances and the reduction of waste in the optics industry while simultaneously increasing production output.
Adjusted process parameters or tolerance matching can be used to influence the quality of the components instead of simply sorting out the bad parts at the end of production.
To network the various processes and use the generated data to optimize production as well as process development, three essential elements must be considered: Data acquisition, data storage, and data utilization.
In this presentation, these steps are performed for industry-relevant use cases, validating the potential of digitally networked optics production. For giving a holistic view on digitalization approaches, the costs, the energy demand as well as the effort for implementation are discussed.

Optics in Medicine& Biology 15:45 -16:00

Sensing the penetration of nanodiamond along different skin layers according to their optical properties

Channa Shapira[1,3], Daniel Itshak[2,3], Hamootal Duadi[1,3] and Dror Fixler[1,3,*]
1 *Faculty of Engineering, Bar Ilan University, Ramat Gan 5290002, Israel*
2 *Department of Chemistry, Bar Ilan University, Ramat Gan 5290002, Israel*
3 *The Institute of Nanotechnology and Advanced Materials, Bar Ilan University, Ramat Gan 5290002, Israel*

Introduction: Carbon-based nanoparticles (NPs) are widely used in nanotechnology. They can act as a drug reservoir with a tunable release. To be able to cross the skin barrier, the NP's diameter must be smaller than 100nm. Therefore, ND noninvasive detection and profiling its permeation along the skin depth (>100μm in human skin) are challenging tasks.
Background: The iterative multi-plane optical properties extraction (IMOPE) technique allows sensing hidden elements in turbid environment3-1, behind imaging resolution limitations. The sensing is based on evaluating the scattering properties of the media using a phase retrieval method.
Objectives: Sensing nanodiamond (ND) that can cross the skin within the skin and estimate its permeation profile noninvasively.
Methods: We use the IMOPE technique to detect NDs within tissue-like optical phantoms and when applied on ex vivo pigskin. The optical phantoms are made with fixed scattering and varying ND concentration. The IMOPE's measures are corroborated by TEM and Franz-cell measures.
Results: We show the effect of the absorption on the reconstructed phase image (Figure 1 (a)). Measuring the liquid optical phantoms shows high agreement with our theoretical model (Figure 1 (b)). We estimate the ND penetration to the different skin layers and show that their presence reduces as the layer is deeper. We calculate their relative concentration in the different skin layers (Figure 1 (c)). The IMOPE's results are corroborated by TEM and Franz-cell measures. These results confirm that the IMOPE profiled the ND skin permeation noninvasively.
Conclusions: In this research we extend the technique's capabilities for detection of smaller nanoparticles with negligible scattering by analyzing their absorption. Using the IMOPE technique we managed to extract the relative concentration of the ND within the different skin layers, noninvasively

References

1. Yariv, I.; Shapira, C.; Duadi, H.; Fixler, D., Media characterization under scattering conditions by nanophotonics iterative multiplane spectroscopy measurements. ACS omega 2019, 4 (10), 14301-14306.
2. Yariv, I.; Shapira, C.; Duadi, H.; Fixler, D. In Spectroscopy measurements of opaque material by nanophotonics iterative multi-plane technique, Nanoscale Imaging, Sensing, and Actuation for Biomedical Applications XVII, SPIE: 2020; pp 121-128.
3. Shapira, C.; Yariv, I.; Ankri, R.; Duadi, H.; Fixler, D., Effect of optical magnification on the detection of the reduced scattering coefficient in the blue regime: theory and experiments. Optics Express 2021, 29 (14), 22228-22239.
4. Shapira, C.; Itshak, D.; Duadi, H.; Harel, Y.; Atkins, A.; Lipovsky, A.; Lavi, R.; Lellouche, J. P.; Fixler, D., Noninvasive Nanodiamond Skin Permeation Profiling Using a Phase Analysis Method: Ex Vivo Experiments. ACS nano 2022.
5. Shapira, C.; Yariv, I.; Duadi, H.; Fixler, D. In Extracting the reduced scattering coefficient in different optical magnifications in the blue regime: theory and experiments, Nanoscale Imaging, Sensing, and Actuation for Biomedical Applications XIX, SPIE: 2022; pp 18-25.

Single-shot field-dependent adaptive optical correction of a gradient refractive index lens

Dafei Xiao[1], Boris Fedman[1], Yoav Shechtman[1,2]

1 Russell Berrie Nanotechnology Institute

2 Department of Biomedical Engineering

Introduction and background: Gradient refractive index (GRIN) lenses, due to their miniature sizes and lightweight, have been widely applied in many fields requiring compactness and small invasiveness, like confocal and multiphoton micro-endoscopy, and miniaturized microscopy. However, their strong shift-variant aberrations distort images and decrease the effective field of view (FOV).

Objectives: simultaneously correct shift-variant aberrations at multiple field positions of a GRIN lens. Methods: Shift the correction plane away from the pupil plane and apply a new uneven segmentation scheme to address the SNR problem.

Results: We first localize each bead's correction area at the spatial light modulator (SLM), then radially segment this area, and finally correct the distorted phase of each radial sub-segment using an iterative algorithm based on an image metric. Simultaneous shift-variant multipoint correction is experimentally performed on multiple fluorescent beads serving as point-sources scattered in the FOV (figure 1). The corrected bead images exhibit improved imaging characteristics: p1 has a %118.85 higher peak intensity and %47.71 smaller FWHM. Those values for p2 are %24.29 and %12.81. For p3, they are %16.11 and %23.06.

Conclusions: Simultaneous shift-variant multipoint correction of a GRIN lens can be achieved by shifting the correction plane away from the pupil plane and using shift-variant adaptive optics, namely, applying a phase correction pattern that is field-dependent

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Miniature ultrasound detector arrays in silicon photonics using amplitude transmission monitoring

Yoav Hazan, Michael Nagli, Ahiad Levi, and Amir Rosenthal

Technion insititute

Silicon-photonics holds the promise for a new generation of ultrasound-detection technology, based on optical resonators, with unparalleled miniaturization levels, sensitivities, and bandwidths, creating new possibilities for minimally invasive medical devices. While existing fabrication technologies are capable of producing dense resonator arrays whose resonance frequency is pressure sensitive, simultaneously monitoring the ultrasound-induced frequency modulation of numerous resonators has remained a challenge. Conventional techniques, which are based on tuning a continuous-wave laser to the resonator wavelength, are not scalable due to the wavelength disparity between the resonators, requiring a separate laser for each resonator, as illustrated in Figure 1(a).

In this work, we show that also the Q-factor and transmission peak of silicon-based resonators can be pressure sensitive, exploit this phenomenon to develop a readout scheme based on monitoring the amplitude, rather than frequency, at the output of the resonators using a single pulse source. An illustration of the phenomenon is presented in Figure 1(b) and the simple system configuration used to detect the transmission modulation is presented in Figure 1(c). This phenomenon and technique, termed pulse transmission amplitude monitoring (PTAM), is demonstrated compatible with optoacoustic tomography in Figure 1(d-f).

PTAM requires a single pulse source, engineered to cover the wavelength span of the resonators, and a single photodetector per acoustic channel, making the technique scalable, potentially enabling simultaneous readout of hundreds of acoustic channels, as commonly performed with piezoelectric transducers. Using PTAM with large detection matrices, rapid three-dimensional optoacoustic and ultrasound imaging may be performed at unprecedented resolutions and rate.

Homodyne Time-of-Flight Acousto-Optic Imaging for Low-Gain Photodetector

Ahiad R. Levi[1], Yoav Hazan[1], Aner Lev[2], Bruno G. Sfez[2] and Amir Rosenthal[1]

1 *Andrew and Erna Viterbi Faculty of Electrical & Computer Engineering, Technion - Israel Institute of Technology, Technion City, Haifa, 32000, Israel*

2 *The Israel Centre for Advanced Photonics (ICAP), Soreq NRC, Yavne, Israel*

Acousto-optic imaging (AOI) is a hybrid imaging modality capable of mapping the light fluence rate in deep tissue by local ultrasound (US) modulation of the diffused photons. To capture the weak modulated light, from the reemitted speckle pattern formed on the tissue boundary, cameras are commonly used, introducing high signal-to-noise ratio (SNR) due to large number of pixels. Yet, cameras slow frame rate inflicts two major limitations as (1) it usually requires CW US operation that prevents from utilizing the US pulse time-of-flight for depth information and (2) it is slower than the US modulation and the speckle decorrelation. These limitations are solved by performing time-of flight AOI (ToF-AOI), in which US pulses are used for depth sectioning and detection of the speckle pattern temporal intensity is done with detectors owing a bandwidth higher than the ultrasound transducer.

Since the intensity of the modulated photons is relatively low, ToF-AOI systems often rely on high-gain photodetectors, e.g. photomultiplier tubes (PMTs), which limit scalability due to size and cost and may significantly increase the relative shot-noise in the detected signal due to low quantum yields or gain noise. In this work, we developed a homodyne ToF-AOI scheme in which the modulated photons are amplified by interference with a reference beam, enabling their detection with a single lowgain photodetector in reflection-mode configuration. We experimentally demonstrate our approach with a silicon photodiode, achieving over a -4fold improvement in SNR in comparison to a PMT-based setup. The increased SNR manifested in lower background noise level thus enabling deeper imaging depths. The use of a fiber-based configuration enables the integration of our scheme in a hand-held AOI probe.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Deep Imaging of Mouse Brain using Three-Photon Fluorescence Adaptive Optics

David Sinefeld[1,2*], Fei Xia[1,3,5], Mengran Wang[1], Tianyu Wang[1], Chunyan Wu[1], Hari P. Paudel[4], Dimitre G. Ouzounov[1], Thomas G. Bifano[4], and Chris Xu[1]

1 *School of Applied and Engineering Physics, Cornell University, Ithaca, NY, 14853, USA*

2 *Department of Applied Physics, Electro-optics Engineering Faculty, Jerusalem College of Technology, Jerusalem, Israel*

3 *Meinig School of Biomedical Engineering, Cornell University, Ithaca, NY, 14853, USA 4Boston University Photonics Center, Boston, MA, USA 5Present address: Laboratoire Kastler Brossel, ENS-PSL Research University, CNRS, Sorbonne Université, Collège de France, Paris, France*

Three-photon fluorescence microscopy (3PM) when combined with long wavelength excitation was shown to allow deep in-vivo mouse brain imaging. Here, we present results of a system which combines 3PM together with adaptive optics (AO) correction for in-vivo mouse brain imaging in both cortical and hippocampus layers. Our excitation source for 3PM is a 1 MHz, femto-second (fs) source @ 1300 nm, with a two-prism compressor which is used as a dispersion control, resulting in a pulse duration of ~60 fs after the objective. The output of the source is projected onto a high speed, -1020segment microelectromechanical (MEMS) spatial light modulator (SLM), which is imaged on -2axis scan mirrors and then onto the back aperture of a 1.05 NA, water immersion microscope objective. The generated signal is reflected using a dichroic beamsplitter and detected using a GaAsP Photomultiplier tube (PMT).

We use transgenic mice with YFP-labeled neurons for our demonstration. To allow imaging, the skull was removed to generate a cranial window, keeping the brain intact. The feedback mechanism is based on the nonlinearity of the -3photon signal. Since the generated fluorescence signal is a nonlinear function of the focal volume, a smaller spot size will produce a significantly higher signal, which can serve as a feedback. We used 3 point parabolic approximation with the first 55 orders of Zernike polynomials. We demonstrate AO correction on in-vivo neural imaging, for both cortical and hippocampus layers (see figure below). Hippocampus neural imaging are shown in (a-b), with a 3D volumetric reconstruction of 70×75×75 mm at depth of 1.1mm beneath the cranial window, before (a) and after (b) applying AO.

The correction in the hippocampus gives improvement factor of x7 for signal level (c,d). The resolution improvement is demonstrated for the dendritic spines (e-g), where a submicron resolution is obtained after AO correction.

Advanced Optical Analysis of Ophthalmological Nd:YAG Laser Treatments

Yaakov Slushetz[2], Ya'akov Mandelbaum[1], Rani Patal[2], Jaime Levy[2], Edward Averbukh[2], Yoel Arieli[1]

1 *Department of Applied Physics and Electro-optical Engineering, Lev Academic Center - Jerusalem College of Technology (JCT), Jerusalem, Israel*

2 *Department of Ophthalmology, Hadassah University Medical Center, Faculty of Medicine, Hebrew University, Jerusalem, Israel*

Background: The 1064 nm Nd:YAG laser that is routinely used in ophthalmology for intraocular surgery is in fact invisible. Typically, a pair of intersecting auxiliary diode-lasers with a visible wavelength of 635 nm, are used for aiming. Ideally their intersection coincides with the waist of the Nd:YAG laser. However, due to dispersion in the ocular tissue - and in the high-power diverging lens placed adjacent to the eye - the differing wavelengths result in progressive deviation between the two focal points. This problem becomes especially significant for posterior segment laser treatments, threatening the success rate and the safety.

Objectives: This work set out to calibrate the positioning system of an Nd:YAG laser eye-surgery device for use in treatments in the posterior portion of the eye. This increases clinical accuracy in such treatments, avoiding potential complications.

Methods and Results: Hospital and laboratory studies were performed to characterized the Nidek - YC1800- Nd:YAG laser apparatus together with the Volk-Goldman Goniofundus lens. A computerized ray-tracing model was then created to simulate optics in the eye and assess the difference between the focal points of the two beams. Analysis of ocular (sphero-)chromatic aberration was key. A calibration calculator was developed for the surgeons' use which computes the focal deviation in each region interior to the eye.

The aforementioned lens's high negative optical power, poses a challenge for common laboratory equipment and commercial devices. A method was found to directly measure the focal length of a negative lens; it simultaneously renders the index of refraction.

Conclusions: To our knowledge this is the first study evaluating the deviation between the target predicted by the guidance beams and the actual focus of the surgical Nd:YAG laser. The calibration calculator described can be easily used to accurately adapt the laser-surgery device to the posterior region, an achievement of great practical significance.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Imaging objects through scattering environment by combining multiview projection, Lucy-Richardson deconvolution, and outliers' removal-based metrics

Ariela Tsabary and David Abookasis

Department of Electrical and Electronics Engineering, Ariel University, Ariel, Israel

This work applied different filtering strategies including polarization, deconvolution, and image sorting processing together with multiview projections to detect hidden targets in a turbid environment. Medium was illuminated with a polarized laser beam and single-shot multiple sub-images of the object were obtained from different viewpoints using lens array. Each sub-image was deconvolved with the average PSF of the system following Lucy-Richardson deconvolution algorithm. The deconvolved sub-images were than qualitatively evaluated by contrast-to-noise ratio and entropy metrics and sorted based on those metrics. Finally, the sub-images were shifted to a common center and summed together with other sub-images to single average image. Results indicate an effective performance of the proposed method to image object embedded in scattering medium.

Elctro Optics in Industry 16:00 - 16:15

Optical Gyroscope based on Disc resonators: fabrication and packaging

Eyal Yacoby[1], Yosef London[1], Itzik Engel[2], Harel Sharabi[2], and Shauli Perel[1]
1 Applied Physics Division, Soreq NRC,Rd 4111, Yavne, Israel
2 CIELO Inertial Solutions LTD

Optical fibers have proven to be an ideal platform for gyroscopes due to their compact size and low losses. Optical Whispering Gallery Modes (WGMs) may be excited in optical resonators fabricated from low loss materials and may serve as photonic gyroscopes due to their extremely high Q factors. The penalty induced by their compact size to the angular velocity sensitivity is compensated by the effective long life of the optical mode inside the resonator.

Here we present a disc resonator with Q factors as high as ~ 108 ·7.5, fabricated from a fused silica optical-fibers preform (in the same manner as [1]). The fabrication process has been altered to accommodate the large disc diameter, improving the gyroscopes performance. A tapered fiber was used to couple light into the resonator. We describe a unique packaging scheme which offers the ability to tune and adjust the coupling efficiency of light into the WGMs.

Preliminary measurements of rotation were performed at CIELO LTD. and are presented as well. The compact monolithic device should provide better thermal stability than their fiber based counterparts while retaining their other positive attributes (long phase accumulation, polarization guiding etc).

Reference

Del'Haye, P., Diddams, S. A. and Papp, S. B., "Laser-machined ultra-high-q microrod resonators for nonlinear optics," Appl. Phys. Lett. 102(221119), 1-4 (2013).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

New Orbital Goniometer for Optical Satellite Alignment

Oren Aharon
CTO Duma Optronics

Introduction: Increased sophistication of commercial earth observation, high resolution satellites require multiple sensors to be mounted in the satellite payload. The ever-growing demand of better spatial and spectral resolution are accompanied by Interalignment between various sensors.

Background: In leu of the increasing commercial launches, the alignment process of those satellites should be fast and mechanized. We offer a revolutionary alignment measuring system for aligning various sensors deployed across the satellite perimeter. Based on a new technology of orbital transfer using a theodolite autocollimator and very accurate angular transfer method, the automatization of the process was made feasible. Moreover, this technology is adequate for measuring angle in optical prismatic elements including polygons, pentaprisms and others.

Objectives:
• Accurate measurements of angular line of sight direction of various optical or electronic sensor in respect to each other and to the satellite frame. • Mechanized measurements based on computerized sensors with minimum human involvement. • Automatic loading/unloading of measured device, preferable by robotic arms.

Methods: The device is based on transferring the accuracy of an external rotating device to the to-bemeasured device by building an orbital accuracy transfer system. In order to achieve the required rotational accuracy transfer, the measuring device is positioned on the perimeter of a rotating stage mounted around the to-be-measured part. Applicable measurements could be performed for satellites, prismatic elements, rotating stages, and many more. The system comprises of an accurately rotating stage or autocollimation theodolite, a reference rotating mirror, an optical bench, and a revolving mechanism for said electronic autocollimation theodolite. For system control, a computer with a special algorithm is implemented.

Results: The system is in the advanced stages of design and it may be introduced at the coming Oasis8 Exhibition. Recommendations and Conclusions This new technology is offered as a possible solution to automatic measurements of micro and mini satellites as they are increasingly used for commercial applications.

Optics in Medicine& Biology 16:00 - 16:15

Stray Light comparison of four different Accommodative Intra-Ocular Lens (AIOL) Designs

David Sinefeld and Eli Weinberg

Department of Applied Physics, Electro-optics Engineering Faculty, Jerusalem College of Technology, Jerusalem, Israel

Accommodative intra-ocular lenses (AIOLs), currently in clinical trial stage, are the upcoming breakthrough in the IOL industry. The main advantage that AIOLs offer is good continuous visual acuity over the entire range from far to near vision, while multi-focus IOLs (MFIOLs) offer good visual acuity at far vision and at one or two near points but degraded acuity in the intermediate ranges. Whilst the main metric of AIOL assessment is the range of accommodation, a secondary performance parameter is stray light (SL) artifacts on the retina, which can be a disadvantage in dark ambient conditions, such as night-time driving. We model and analyze 4 AIOL concepts A) Synchrony dual-optic based on inter-optic distance adjustment. B) Dynacurve based on adjustable lens curvature C) Lumina based on Alvarez principle and D) WIOL based on adjustable lens curvature with a hyperbolic surface profile. We compared the four concepts to the Brennan eye model which was used as a reference.

We show the results of the ghost analysis of the 5 models at the bottom part of the figure. While the aphakic eye model shows that the SL is uniform over the entire FOV (e), the four AIOLs models show different results: The WIOL showed the best SL performance with no AIOL-induced SL over the entire FOV range (d). The Dynacurve lens showed an SL peak intensity of similar magnitude as the background over 20-0° FOV (b), and one order of magnitude higher than the background over 55-25° FOV, spiking at 65° with %14 compared to original FOV intensity. Synchrony (a) and Lumina (c) models showed a maximum peak intensity 100 times worse than the background at 25° and 35° FOV, respectively. Fig. (f) show a comparison plot for SL peak intensity per FOV for all 4 concepts.

Poster Presentations

Tuesday, December 13

Spectroscopy & Optical Sensing 10:30-10:40

Optical spectroscopy based on optoelectronic chromatic dispersion in Germanium PN photodiodes: Latest advances and applications

Egor Liokumovitch, Ziv Glasser and Shmuel Sternklar
Department of Electrical and Electronic Engineering, Ariel University, Ariel 40700

Introduction: The dependence of photodiode efficiency and RF bandwidth on the wavelength is well known. However, this wavelength dependency leads to a prominent feature of photodiodes that has been largely overlooked. The wavelength-dependent pathlength of the migrating charge-carriers is the source of an extremely large effective chromatic dispersion. Based on this inherent feature, we regard this device as a source of optoelectronic chromatic dispersion (OED).

Background: Sinusoidal-modulated light with wavelengths λ1 , λ2 and power $P_0 e^{i(\Omega t)}$ illuminates a PN photodiode. Absorption, charge-pair formation, and subsequent diffusion leads to a measurable modulated current. Current contribution in each region leads to a total current at frequency Ω that is proportional to the sum of these terms:

$$F_{tot} = |F_E| e^{-i\theta_E} + |F_S| e^{-i\theta_S} = |F_{tot}| e^{-i\theta_{tot}}, \qquad (1)$$

where E, S refer to entrance and substrate, respectively. The amplitudes and phases of these terms are dependent upon several parameters, but, crucially, there is a wavelength dependence through the absorption spectrum α(λ) and a dependence on the modulation frequency $\Omega = 2\pi f$. Referring to fig. 1, if wavelength λ2 increases to λ2 + δλ the penetration depth recedes from the junction, the average diffusion time of the charge carriers increases, and so does the modulation phase-shift delay.

Objective and Method: By recording the phase of a modulated light, OED can be utilized in an FBG interrogation system for monitoring the reflected wavelength of a sensor. Furthermore, water contamination by ethanol can be determined.

Results:

A commercial PN-type germanium detector showed an OED sensitivity and OED parameter of 0.64 deg/nm and 3460 ps/nm, respectively, equivalent to 204 km of SMF28 optical fiber. Based on this, we demonstrated an application for FBG monitoring, where we achieved an interrogation spectral sensitivity of $1.25\text{pm}/\sqrt{\text{Hz}}$, equivalent to $1.08\mu\varepsilon/\sqrt{\text{Hz}}$ strain sensitivity.

Conclusions: Devices based on a Ge photodiode and OED can be utilized as special-purpose sensors and FBG interrogators, and more sophisticated on-chip solutions based on several photodiodes (e.g. Ge, Si and InGaAs) can serve as a low-cost miniature spectral sensor for a multitude of applications.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Augmenting the Sensing Performance of Entangled Photon Pairs through Asymmetry

Yoad Michael, Isaac Jonas, Leon Bello, Michael Rosenbluh & Avi Pe'er
Bar Ilan University, Institute for Nanotechnology and Advanced Materials (BINA)

Abstract: We explore experimentally the squeezing enhanced phase-sensing performance of an SU(1,1) interferometer and optimize its detection scheme under realistic conditions of loss and coherent seeding. We demonstrate improvement in the interference contrast and phase sensitivity. The sensitivity of classical measurements is fundamentally limited by shot noise. Quantum physics has been shown to enhance the measurement sensitivity beyond the shot noise limit [1] and to enable ultimate secure communication. In the context of quantum sensing, a common way to achieve sub-shot-noise sensitivity in an interferometer is to utilize squeezed light. One implementation of this concept is the SU(1,1) interferometer, where two optical parametric amplifiers (OPAs) are placed in series. The first parametric amplifier generates squeezed light in the form of correlated photon pairs, while the second amplifier annihilates this light through destructive interference, thereby forming highly sensitive detection of a phase that may be induced between the amplifiers. Previously, we used this scheme in the context of homodyne detection [2] and Raman sensing [3]. In this work, we utilize squeezed light for phase detection even in the presence of high losses. We explore the behavior of an SU(1,1) interferometer that is seeded at one of the input ports with classical light while varying the degree of internal loss between the two amplifiers. Although the SU(1,1) interferometer can spontaneously generate photon pairs with no light at the input (vacuum seed), coherent seeding of the interferometer increases the light intensity – allowing high sensitivity to be achieved by the quantum correlations that appear on top of the strong classical signal. The increased intensity provides a great advantage for real-world applications and quantum illumination schemes. In all applications of squeezed light, low photon loss must be maintained. However, it was shown that even though the entanglement itself may not survive, the residual correlation between the two initially entangled systems remains much higher than any initial classical states can provide. This implies that the usefulness of entanglement manifests itself even in entanglement-breaking scenarios [4]. Here we show that seeding the interferometer can increase the visibility of the nonlinear interference when internal loss is present (depending on whether the loss is symmetrical on the signal and idler), which is crucial for sensing physical processes that can occur between the amplifiers (such as linear phase shifts, photon loss, Raman activity, and more). We also examine asymmetrical loss on the photon pairs, and provide preliminary experimental results. This 'proof of concept' experiment provides valuable insight on the behavior of those interferometers and paves the way towards new quantum-based schemes for radar detection.

The visibility of interference at the output of OPA2, measured from the signal port, with a seeded coherent idler input $|\alpha i\ 2\ | = n$, can be written as follows:
V = 2(n + 1)t1 t2 cosh(G) (n + 1)(t1 2 + t2 2) cosh(G) + r2 2 Where t1,2 and r1,2 2 Where t1,2 and r1,2 2 Where t1,2 and r1,2 are the transmission and reflection (loss) coefficients of the signal and idler, G is the gain of the OPAs. When the losses are symmetrical, it is shown that for high values of n, $V \rightarrow 1$. This expression also shows the asymmetric effect of loss on the visibility of the interference – applying loss on the signal results in higher visibility than when applying the same amount of loss on the idler.

Conclusions We can conclude from the analysis that there is a distinguishable difference in the visibility of interference when the losses apply symmetrically and asymmetrically on the signal and the idler, and a difference is also observed for the seeded and the unseeded cases. The behavior is generally complex and depends on many different parameters, but the optimal working point of the interferometer for sensing can be found. In the future, we aim to harness these results towards the development of a quantum-enhanced radar that will detect targets that have extremely low reflection.

References
[1] C. H. Bennett and G. Brassard, "Quantum Cryptography: Public Key Distribution and Coin Tossing," Proceedings of the IEEE International Conference on Computers, Systems, and Signal Processing, Bangalore, 10-12 December 1984, pp. 175-179.
[2] Yaakov Shaked, Yoad Michael, Rafi Z. Vered, Leon Bello, Michael Rosenbluh & Avi Pe'er, "Lifting the bandwidth limit of optical homodyne measurement with broadband parametric amplification", Nature Communications 9, 609 (2018).
[3] Yoad Michael, Leon Bello, Michael Rosenbluh & Avi Pe'er, "Squeezing-enhanced Raman spectroscopy", npj Quantum Information 5, 81 (2019).
[4] S. Lloyd, "Enhanced sensitivity of photodetection via quantum illumination", Science 321, 5895 (2008).
[5] Mathieu Manceau, Gerd Leuchs, Farid Khalili, and Maria Chekhova, "Detection Loss Tolerant Supersensitive Phase Measurement with an SU(1,1) Interferometer", Phys. Rev. Lett. 119, 223604 (2017)

Chromatic Confocal Multipoint Sensors

Matthieu Desjacques
Sales Manager at STIL, MARPOSS Group

Introduction: Based on patent edited by STIL, describing the Physics of the Monopoint Chromatic Confocal Technology, ChromaPoint Sensors measure distance and transparent thicknesses from nanometer to millimeter scales of resolution, accuracy and measuring range of perfect focus. In those days, one evolution is the Multipoint Chromatic Confocal Sensor.

Background: More than 25 years of experience in optics, electronics, post-treatment software engineering, and the incremental improvements of opto-electronics components allow to design dedicated set-up to acquire several points simultaneously, distributed along a line or within several Optical Heads.

Objectives: Light Source High Density distributed via optimal coupler, optical fiber and connectors assure the confocality in the emission plan for each measured point. Retrodiffused is collected by each pinhole in the image plan and read by a spectrometer of new generation : grating and dual matrix camera are coupled to deliver high density of simultaneaous measurement points up to more than 1 million points per second. Methods : White Light LED are caracterized and optimized for the emission. Dual Matrix High Speed Camera and specific optical designs are approved to obtain the best Signal to Noise Ratio for each acquisition. Post-treatment software development to obtain in real time the barycenter of each retrodiffused peak The protocols of communication, hardware and software, are adapted to transfer high quantity of data.

Recommandations : Long life time and high performance opto-mechanical components are used to work in every kind of environments with optical heads only composed of passive components.
Conclusions: Always based on nanometer to millimeter scales, Multipoint ChromaLine Sensors and LightMaster Controller are in line with the specifications of the main applications in growth as Semi-Conductor ; Battery ; Medical ; Automotive ; Glass…

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

CMOS-compatible Si SWIR Schottky photodetectors

Dr. Lion Augel[1,2], Hanying Wen[1], Dr. Jens Knobbe[1]
1 Fraunhofer Institute for Photonic Microsystems IPMS, 01109 Dresden, Germany
2 Brandenburg University of Technology, Chair of Micro and Nano Systems, 03046 Cottbus, Germany

Background: Introducing autonomous machines and vehicles into everyday life requires safe detection of the surrounding scenery. Complex outdoor environments with changing illumination and reflections push image recognition systems in the visible to the limit. By extending the spectral detection range to the short-wavelength infrared (SWIR) the reliability of the same detection principle can be increased. Usually, these applications are addressed by detectors made from compound semiconductors. Their technological integration together with complementary metal oxide semiconductor (CMOS) read-outs is challenging and prices remain high. Schottky barrier diodes offer a meaningful path to circumvent these technological issues. While being fully CMOS compatible, the energy barrier height is adjustable regarding the desired application. Additionally, they are inherently fast and integration in focal plane arrays with high resolution seems feasible. A drawback of these devices is the low signal-to-noise ratio that arises from high dark currents, high optical reflectivity, and low internal quantum efficiency.

Objectives: Our work addresses these issues by facilitating photonic nanostructures and a metallic layer system to reduce reflections, optimize the barrier height and the energy distribution of charge carriers along the barrier. In our backside illuminated device an antireflective coating on the wafer back improves transmission into the wafer wherefore metallized pyramidal structures on the wafer front facilitate the absorption of radiation along the semiconductor metal interface. The structures are created by a double step dry etching process starting with an anisotropic and isotropic etching scheme.

Results: By using an intermediate TiN layer on the structured Si wafer before applying the AlSiCu metallization a Schottky barrier with a height of 0.6 eV could be achieved. This allows to limit dark currents through thermalized charge carriers. We present responsivity measurements and show hereby a reduction of reflection obtained through the nanostructures.

pH sensing, bioimaging, and Fluorescence lifetime imaging microscopy using polyethyleneimine coated carbon dots and gold nanoparticles

Shweta Pawar[1,2], Hamootal Duadi[1], Yafit Fleger[2] and Dror Fixler[1,2]

1 *Faculty of Engineering and the Institute of Nanotechnology and Advanced Materials, Bar Ilan University, Ramat Gan 5290002, Israel*

2 *Bar-Ilan Institute of Nanotechnology & Advanced Materials (BINA), Bar Ilan University, Ramat Gan 5290002, Israel*

The unique fluorescent nanomaterials known as carbon dots (CDs) are highly resistant to photobleaching, have low toxicity, and are well soluble in water. Polyethyleneimine (PEI) coated CDs are a novel fluorophore with good biocompatibility and pH sensing ability. Here, p-phenylenediamine (p-PD) is used as a carbon source and hyperbranched PEI is used as a surface passivation agent in a simple, one-step hydrothermal process for synthesis. The CDs optical characteristics are pH-responsive due to the presence of different amine groups on PEI, which is functional polycationic polymer. The limits of techniques based on fluorescence intensity can be overcome by fluorescent lifetime imaging microscopy (FLIM), a very sensitive method for detecting a microenvironment. In this study, FLIM was used to measure pH with pH-sensitive CDs. These molecules are nontoxic to the cells, and the positively charged CDs have the potential for nuclear targeting, allowing for electrostatic contact with DNA in the nucleus. Higher wavelengths have a larger penetration depth of electromagnetic radiation and low tissue autofluorescence, hence CDs emitting at these wavelengths are used for biolabeling applications. However, the quantum yield of these synthesized red-emissive CDs is lower. In order to enhance it, they are conjugated with gold nanoparticles for metal enhanced fluorescence (MEF). Through a potent covalent bond between them, the AuNPs are linked to CDs surfaces. These gold-CDs nanoconjugate can be used in the future for targeted imaging applications.

Keywords: Carbon dots, gold nanoparticles, pH-sensitive, Metal enhanced fluorescence, bioimaging.

MXene composite with gold nanoparticles on microfiber for enhanced sensitivity

Anastasia Novikova[1,2], Aviad Katiyi[1,2], Alina Karabchevsky[1,2]

1 *Electro-optics and Photonics Engineering Department, Ben-Gurion University of the Negev, Beer-Sheva, 8410501, Israel*

2 *Ilse Katz Institute for Nanoscale Science & Technology, Ben-Gurion University of the Negev, Beer-Sheva 8410501, Israel*

Keywords: MXene, gold nano particles, waveguides, sensing, optical microfiber

Introduction: Optical microfibers are finding new applications in various industries requiring high sensitivity and selectivity. However, in some cases microfibers are notsensitive enough and physical and chemical modifications of microfibers needs to be utilized for increasing the sensitivity.One of the promising methods is the chemical modification of surfaces with composite materials with metal nanoparticles. Here we report surface modification of SMF 28 single-mode optical fiber with a composite of gold nanoparticles and MXene.

Background: Optical fibers were discovered in 1880 by William Wheeler, who transmitted light through a glass tube and called it a "light pipe"[1]. Nearly 100 years later, in 1966, an optical fiber was proposed with a higher guiding medium than a cladding to transmit light [2]. Optical fibers were narrowed down to the size of microfibers, thereby gaining new properties and applications. One application where microfibers are important is sensors. Due to the reduction in the diameter of the fiber, the penetration depth of the evanescent field increases which enhancesits sensitivity forthe detection of substances. Furthermore, the sensitivity can increase by modifying the surface of the microfiber.

Objectives: We studied the sensitivity enhancement of microfibers by surface modification using gold nano particles and MXene composite materials.

Methods: To study various samples with different ratios of gold nanoparticles and MXene, an experimental setup was built. A broad band laser was coupled to a single-mode fiber usinga x10 objective and set to maximum power. The fiber was spliced to a commercial single-mode fiber that was tapered to a 2.5 μm diameter microfiber. The microfiber region acts as a sensitive region for sample characterization due to the large evanescent field in this region. The fiber output was spliced to a single-mode pigtail fiber that was connected to an optical spectrum analyzer.

Results: Our experimental results using a tapered fiber with composite materials show a well-defined near-infrared overtone absorption band at 560 nm which associated with surface plasmon excitation of gold nanoparticles with a diameter of 30 nm, while the absorption peak at 950 ,890 ,850 and 980 nm associated with MXene.

Conclusions: We conclude that MXene films with gold nanoparticles enhance the sensitivity of a microfiber for the detection of analytes.

References

1. Kao, K.; Hockham, G.A. Dielectric-fibre surface waveguides for optical frequencies. Proc. Inst. Electr. Eng. 1966, 113, 1151–1158.
2. Miller, S. Optical Fiber Telecommunications; Elsevier: Amsterdam, The Netherlands, 2012.

Low-Frequency Raman Spectroscopy – a Versatile Technique for Characterizing Nanostructured Materials

Yaakov R. Tischler, Rena Yitzhari, Bharathi Rajeswaran, Hagit Aviv, and Vinayaka H. Damle
Department of Chemistry, Bar-Ilan University, Ramat-Gan, Israel

Raman spectroscopy is a powerful technique for identifying chemicals and characterizing materials. Raman spectra can provide insight into numerous properties, including morphology, stress/strain, crystallinity, doping level, conductivity, local temperature, and polarizability, whether in bulk, thin film, monolayer or nanostructure form. Raman spectroscopy finds applications in physical sciences, life sciences, medicine, drug discovery, and semiconductor metrology. Modern laser filters, based on volume holographic gratings amongst other approaches now make it relatively straightforward to obtain Raman spectra from 3000 cm1- down to 5 cm1-. In the low-frequency spectral range, of 5 to 200 cm1-, the Raman scattering is sensitive to the phonon dispersion relation and vibrational modes associated with the nanostructure of the material. Here we present applications of Low-Frequency Raman Spectroscopy (LFR) to characterize nanostructured and nanoscale layered materials, chiral purity of organic crystals and formulations, biomolecular assemblies, hybrid organo-metallic perovskites, and metal-organic frameworks. We show how the LFR spectrum can be related to the mechanical vibrational modes that are present at the molecular level and discuss our recent efforts to link LFR to topographic features characterized by AFM.

Locating underground objects for infrastructure mapping by analyzing thermal anomalies

Y. Bruckental[1], D. Sheffer[1], Y. Bushlin, G. Harai[2], O. Dicker[2], A. Peretz[2] and B. Milgrom[3]
1 *IARD - Sensing Solutions Ltd.*
2 *MAFAT, IMOD*
3 *Jerusalem College of Technology*

Locating objects underground is essential for infrastructure works such as construction, road construction, moving water and electricity lines, etc. Many methods are used by civil and government companies and include sensors in different spectrums. Some of the methods are invasive and require digging in the ground, which sometimes involves the destruction of cover.

In this work, we present a method based on the analysis of the soil's thermal anomalies revealed by periodic observation of the surface from a dedicated thermal camera. The anomalies are analyzed in an image processing algorithm, and allow monitoring changes in the subsoil and pointing out objects and the route of elements within it.

The method is non-invasive, allows identification with a high probability of the object in the underground, and is the basis for mapping. The image processing makes use of deep learning algorithms to extract the relevant information, and to be alerted to the routes and lines of the objects in the underground.

The work presents the results of experiments carried out for different infrastructure companies, on different land routes, which include identification and mapping through anomalies. The observation is carried out by a mounted thermal camera on top of a drone, at different times of the day and year.

Spectroscopy & Optical Sensing 10:40-10:50

The V-interferometer, a possible solution for pushbroom spectral imaging

Dario Cabib
CI Systems (Israel) Ltd.

After building two prototypes of infrared pushbroom spectral imagers using two-prism block interferometers based on the Sagnac configuration, we realized that a similar twoprism interferometer based on the Michelson configuration (taking the name from its shape) has some advantages over the previous ones, e.g. a better visibility of fringes and a lower potential source of ghosts. In order to design an interferometric spectral imager with a given spatial resolution, field of view, spectral range and spectral resolution, it is necessary to link these requirements with the physical parameters of the interferometer itself, its shape, prism material index of refraction (related to the internal unvignetted field and maximum achieved optical path difference), and with the detector array size, number of pixels and pixel pitch (related to the Nyquist requirement of fringe sampling), and optical pupil size and f-number. In this paper I present the relationship between the interferometer shape and the optical path difference function versus field in analytical form for the case of two-sided interferogram. Some considerations and results of ghosts calculations, connected to field of view and interferometer size limitations will also be shown here for this type of interferometer.

Nanostructure Array Pixels for Surface-Plasmon Material Imager

Avi Huri[1], Ya'akov Mandelbaum[1,2], Raz Mottes[2], Zeev Zalevsky[1], David Zitoun[1], Avi Karsenty[2]

1 *Bar-Ilan Institute of Nanotechnology and Advanced Materials (BINA), Bar-Ilan University, Ramat-Gan, Israel*

2 *Department of Applied Physics and Electro-optical Engineering, Lev Academic Center - Jerusalem College of Technology (JCT), Jerusalem, Israel*

Background: In addition to strong enhancement of electromagnetic fields localized surface plasmons (LSP) also display a distinct resonant peak in both the optical scattering and absorption spectra. The precise location of the peak varies depending on the material properties of the surrounding medium. This property is ideal for use as a material detector - by measuring the shift of the resonant peak the composition of the ambient solution may be extracted.

Objectives: A plasmonic nanostructure array is presented, consisting of nanoscale protrusions or cavities formed in a layer of precious metal (Ag or Au). The pattern is designed to serve as a pixel in a material imaging device intended to provide spatially resolved measurements of solvent concentration, and ultimately, real-time mapping of a chemical reaction.

Design Simulations: Using analytic studies and numeric simulations, the shape and size of the nanostructures, as well as the properties of surrounding medium are tuned to maximize scattering and absorption. The spatial density and lattice arrangement of the nanostructures is optimized to obtain maximal responsivity, while minimizing undesirable interactions such as mutual suppression and crosstalk.

Results: Fabrication by Focused Ion Beam (FIB) and structural characterization using SEM imaging is presented for initial specimens. These prototype the use of gold vs. silver, as well as cavities vs. protrusions. The plasmonic behavior of the different prototypes is compared using hyperspectral imaging obtained via dark-field optical microscopy.

A preliminary experiment is described in which silver nanocubes were coated with a nanometric layer of PDA, which was then doped with platinum at varying concentrations. The resonant peak in the absorption was determined using UV-VIS spectrometry. From this the value of the dielectric function of the PDA coating, and its dependence on the concentration of the platinum dopant was estimated based on the shift in the peak location.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Molecular Orientation Echoes via Concerted Terahertz and Near-IR excitations

R. Damari, A. Beer, D. Rosenberg, S. Fleischer

Introduction: Molecular orientation and alignment molecular ensembles is a constantly evolving field of research. Molecular alignment is commonly induced by an ultrashort near-IR pulse that exerts torque via interaction with the anisotropic polarizability of the molecules. Orientation, however, requires a resonant dipole-field interaction that is provided by a single-cycle THz field. Double pulsed schemes for echo spectroscopy in rotational dynamics, has attracted much attention in the last few years [1] and pose intriguing dynamical features owing to the multi-level nature of molecular rotors [2].

Background: Orientation echoes can be induced by a pair of THz fields [3], however this excitation scheme is severely inefficient as it requires two interactions with the 2nd THz field ('π pulse' analog). The inclusion of a near-IR interaction for echo production is much more efficient but experimental applications of THz and near-IR pulses in judiciously orchestrated excitation schemes are very scarce.

Objectives: Experimental and theoretical demonstration of an efficient scheme for inducing orientation echoes in gas phase molecular rotors. And a theoretical discussion on the coherent pathways involved in their generation.

Methods: The 2nd THz pulse is replaced by a near-IR pulse that interacts once (stimulated-Raman) with the THz-excited Methyl-iodide (CH3I) gas at the single torr pressures and ambient temperature. Detection of the orientation responses is provided by the recently developed MOISH technique [4].

Results: Orientation echoes were generated in methyl iodide (300K,10Torr) using the THz-near-IR scheme involving an efficient first order interaction with the 2nd optical pulse.

Conclusions: The THz-near-IR scheme, supported by MOISH detection, provide a practical and efficient means of experimental realization of orientation echoes. A needed tool for various research endeavors that utilize oriented molecular ensembles.

References

[1] G. Karras, E. Hertz, F. Billard, B. Lavorel, J. M. Hartmann, O. Faucher, E. Gershnabel, Y. Prior, and I. S. Averbukh, Orientation and Alignment Echoes, Phys. Rev. Lett. 114, (2015).
[2] D. Rosenberg, R. Damari, and S. Fleischer, Echo Spectroscopy in Multilevel Quantum-Mechanical Rotors, Phys. Rev. Lett. 121, 234101 (2018).
[3] J. Lu, Y. Zhang, H. Y. Hwang, B. K. Ofori-Okai, S. Fleischer, and K. A. Nelson, Nonlinear Two-Dimensional Terahertz Photon Echo and Rotational Spectroscopy in the Gas Phase, Proc. Natl. Acad. Sci. 113, 11800 (2016).
[4] A. Beer, D. Hershkovitz, and S. Fleischer, Iris-Assisted Terahertz Field-Induced Second-Harmonic Generation in Air, Opt. Lett. Vol. 44, Issue 21, Pp. 5190-5193 44, 5190 (2019).

Advanced Tip-Enhanced Nanoscopy (TEN) Using Optically Resolved Scanning Probe Tips

Jeremy Belhassen[1,4], Simha Glass[1,2], George A. Stanciu[3], Denis E. Tranca[3], Zeev Zalevsky[4,5], Stefan G. Stanciu[3] and Avi Karsenty[1,2]

1 *Lev Academic Center - Jerusalem College of Technology (JCT), Dept. of Applied Physics/Electro-Optics Eng., Advanced Lab. of Electro-Optics (ALEO), 21 Havaad Haleumi St., Jerusalem 9116001, Israel*
2 *Lev Academic Center - Jerusalem College of Technology (JCT), Nanotechnology Center for Research & Education*
3 *Center for Microscopy-Microanalysis & Information Processing, Politehnica University of Bucharest, Romania*
4 *Faculty of Engineering, Bar-Ilan University, Ramat Gan, 5290002, Israel*
5 *The Nanotechnology Center, Bar-Ilan University, Ramat Gan, 5290002, Israel*

A thorough understanding of biological species and of emerging nanomaterials requires, among others, their in-depth characterization with optical techniques capable of nano-resolution. Nanoscopy techniques based on tip-enhanced optical effects have gained over the past years tremendous interest given their potential to probe various optical properties with resolutions depending on the size of a sharp probe interacting with focused light, irrespective of the illumination wavelength. Although their popularity and number of applications is rising, tip-enhanced nanoscopy techniques (TEN) still largely rely on probes that are not specifically developed for such applications, but for Atomic Force Microscopy.

This cages their potential in many regards, e.g. in terms of signal-to-noise ratio, attainable image quality, or extent of applications. In this article we place first steps towards next-gen TEN, demonstrating the fabrication and modelling of specialized TEN probes with known optical properties. The proposed framework is highly flexible and can be easily adjusted to be of benefit to various types of TEN techniques, for which probes with known optical properties could potentially enable faster and more accurate imaging via different routes, such as direct signal enhancement or novel signal modulation strategies. We consider that the reported development can pave the way for a vast number of novel TEN imaging protocols and applications, given the many advantages that it offers.

Acknowledgment: SGS, DET and GAS acknowledge the support of UEFISCDI Grants RO-NO0601-2019-(MEDYCONAI) and PN-III-P-1.1-1TE1339-2019-(OPTIGAN)

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Miniature optical spectrometer based on optoelectronic chromatic dispersion in a PN-type germanium photodiode

Rita Abramov, Ziv Glasser and Shmuel Sternklar

Optoelectronic chromatic dispersion (OED) is a significant source of effective optical dispersion in PN-type photodiodes 1 This dominant effect can form the basis for miniature chip-size optical spectroscopy 2

In this work, we present results of highresolution spectral resolution in the C-band with the use of a Germanium PN-type photodetector. In the first stage, the photodiode is illuminated with modulated light in the C-band which consists of one or more spectral peaks and varying power levels, in order to characterize the RF response, as per a defined protocol.

The goal of this 'learning stage' is to build a 2D grid database consisting of 9 spectral resolution points in the Cband with a spectral resolution of 5nm per point, and 4 amplitude levels. Subsequently, this database is used to reconstruct an arbitrary spectrum that illuminates the photodiode. First, the least square root algorithm was tested. This method gave excellent reconstruction accuracy for up to two spectral peaks.

A second algorithm, based on the minimum distance method, gave %97 accuracy when matching 4 peaks. Using this method, we demonstrate spectral reconstruction with 1.6 nm resolution and amplitude standard deviation of %2. Furthermore, we are developing advanced AIbased algorithms which will lead to further improvements in the learning efficiency and reconstruction accuracy. In conclusion, OED-based spectroscopy in photodiodes is a new technique for developing miniature inexpensive optical spectrometers. Expanding this method to silicon and other materials will lead to chip-size spectroscopy in the visible and IR.

Imaging rotational mobility by frequency domain time-resolved fluorescence anisotropy

Gilad Yahav, Shweta Pawar, Yitzchak Weber, Hamootal Duadi, and Dror Fixler
Faculty of Engineering and Institute of Nanotechnology and Advanced Materials, Bar Ilan University, Ramat Gan, Israel

Introduction: Measurements of time-resolved fluorescence anisotropy (TR-FA) of fluorophores can reveal valuable information about the biomolecular carrier within a cell due to its sensitivity to changes in the rotational mobility of the fluorophore-biomolecule conjugate.

Objectives: Although single point TR-FA measurements are well established and routinely used for various applications, only a few reports described their extension into two-dimensional TR-FA imaging (TR-FAIM). In addition, to date, most of the reports about TR-FAIM discuss its implementation in the time domain. Nonetheless, there are earlier works, which signified the use of frequency domain (FD) measurements for the resolution of complex fluorescence intensity (FI) and FA decays. The great potential in performing TR-FAIM in the FD directly prompted the primary goal of this research, which is to undertake the extension of our FD-FLT imaging microscopy (FD-FLIM) system to include FD TR-FAIM.

Methods: We adapted an existing FD-FLIM technology for TR-FAIM by introducing a linear polarizer in the excitation path and a polarized beam splitter in the emission path. The phase delay and intensity ratios (AC and DC) between the polarized components of the fluorescence signal are recorded, leading to estimations of rotational correlation times and limiting anisotropies. The FD TRFAIM was demonstrated on seven fluorescein-glycerol samples with increasing viscosity.

Results: Although the samples exhibited a minor decrease in the FLT from 4.02ns to 3.58 ns, the correlation time increased from 0.52ns to 12.50ns.

Conclusion: The FD TR-FAIM enables the wide-field measurement of the fluorophores anisotropy decay as well as their FLT on a pixel-by-pixel basis. This investigation establishes the FD TR-FAIM as a promising tool for probing variations in both local chemical and physical environmental factors, as both affect the FLT and the rotational mobility, on a nanosecond scale, of the fluorophore-biomolecule construct across the sample under investigation.

Self-Heterodyne Detection of Tip-Enhanced Coupled Optical Near-Fields Induced in SPM by Modulation of a Bottom Piezo Actuator

Bharathi Rajeswaran, Rajashree Konar, Gilbert Daniel Nessim and Yaakov R. Tischler
Department of Chemistry and Bar-Ilan Institute for Nanotechnology and Advanced Materials, Bar-Ilan University, Ramat-Gan, Israel, 52900.

In Scanning Probe Microscopy (SPM), an optical excitation is coupled to the apex of a functionalized AFM tip that is located some nanometric distance above the surface of a sample1. SPM can provide spectroscopic information with nanoscale spatial resolution, provided that the near-field signal originating from the tip-sample junction can be extracted from the large far-field background generated by the optical excitation of the sample. Generally, the near-field signal is extracted by demodulating the scattered light signal at higher harmonics of the oscillation frequency of the SPM probe or cantilever, but this method often introduces far-field background signals and artifacts due to the mechanical actuation of the probe. Here, we present a novel experimental method for performing the crucial extraction of the nanometrically localized near-field signal. In particular, we situate an additional piezo actuator underneath the sample and drive it simultaneously at two different frequencies, f1 and f2, each in the range of 5-1 kHz. The nanometric proximity of the tip and sample causes coupling of the two optical near-fields that are separately oscillating at f1 and f2, thereby resulting in "self-heterodyne" near-field beating at the difference frequency of f-2f1. Mapping the self-heterodyne signal resulted in a higher resolution image compared to the other methods of near-field extraction that we studied which were based on higher harmonic demodulation of single frequency motions.

The samples that we investigated were composed of thin film flakes of the Transition Metal Dichalcogenide WSe2 of only 5-2 layers in thickness. Such materials have been widely studied due to their unique optical properties which are highly dependent on the number of layers3-1. Here, we deposited the WSe2 flakes onto a nano-particle gold film, and also coated the AFM tip with a thin layer of gold, thereby establishing a "gap-mode" nanocavity as the tip approaches the TMDC's surface.

We used a quartz tuning fork-based AFM from Nanonics (Jerusalem, Israel)to achieve a minimal jump to contact while being in closer proximity to the sample. This study is crucial for characterizing optical properties of materials at the nanoscale and is very relevant to 2D layered materials[4-2], halide perovskites, and phase change materials, amongst others. Thus, this technique provides a platform to characterize nanometric heterogeneities and defects in nanoscale materials.

Reference

1. Yasushi Inouye and Satoshi Kawata,,Near-field scanning optical microscope with a metallic probe tip,1994, Vol. 19, No. 3 / OPTICS LETTERS
2. Lee, C. et al. Unveiling Defect-Related Raman Mode of Monolayer WS2 via Tip-Enhanced Resonance Raman Scattering. ACS Nano 12, 9982-9990 (2018).
3. Lee, H. et al. Tip-enhanced photoluminescence nano-spectroscopy and nano-imaging. 9, 3089-3110 (2020).
4. Malard, L. M. et al. Studying 2D materials with advanced Raman spectroscopy: CARS, SRS and TERS. Phys. Chem. Chem. Phys. 23, 23428-23444 (2021).

Quantum Computers 10:40-10:50

Magnetic field dependent nuclear spin polarization and its backaction on NV coherence times

Pavel Penshin, Tamara Amro, Ty Zabelotsky, Nir Bar-Gill

Hebrew University

Under the research field of defects in solid state, one key aspect is understanding the interaction of the defects we create with surrounding defects or spin bath noise. For nitrogen-vacancy (NV) centers, such interaction could be measured through the NV center's dephasing time, denoted by T2*.

The source of decay for this time scale in diamonds are the nuclear spins of the surrounding C13 and N15 as well as some electronic spin of N15. In our work, we show that by polarizing the spin bath[1], the dephasing time of the NV changes, in different trends, depending on the type of spin bath.

Micro and Nano Optics 13:20-13:30

Seeing the Light: Plasmonic Nanostructure Spectra in Bright-Field Microscopy

Ya'akov Mandelbaum[1,2], Maria Tkachev[1], Abhijit Sanjeev[1], Eugene Brozgol[1], Avi Karsenty[2], Zeev Zalevsky[1], David Zitoun[1]

1. *Bar-Ilan Institute of Nanotechnology and Advanced Materials (BINA), Bar-Ilan University, Ramat-Gan, Israel*
2. *Department of Applied Physics and Electro-optical Engineering, Lev Academic Center - Jerusalem College of Technology (JCT), Jerusalem, Israel*

When searching for plasmonic behavior in the optical scattering and absorption spectra from nanostructure patterns, fabricated on a layer of gold, microscopy with epi-illumination must be employed. However the high reflectivity of gold leads to very poor contrast between the patterns and the surrounding smooth gold surface so that the patterns are practically indiscernible. A simple image processing technique was found which facilitates segmentation of the pattern images from the surrounding gold surface. A more signficant challenge arises when attempting to extract scattering and absorption spectra from data acquired using a hyperspectral imaging device (ASI Rainbow). Inherently, the extraction of absorption spectra requires measurement of the spectrum of the incident illumination, but in epi-illumination mode measurement of this reference spectrum is nontrivial.

This was solved by 'self-renormalization' - an auto-calibration method which uniquely exploits the full spatial data available in a hyperspectral image: the region of purely specular reflection from the smooth gold immediately adjacent to a given pattern serves as a provisional reference spectrum, which is then calibrated using the known reflectivity of a smooth gold surface. The resulting absorbance spectra display a plasmonic resonance which grows significantly stronger and increasingly red-shifted at increasing heights, in perfect correspondence with the increasingly blue-grey hue observed visually.

Incoherent and coherent manipulations of valley excitons via a photonic Rashba effect

Kexiu Rong[1], Xiaoyang Duan[1], Bo Wang[1], Dror Reichenberg[1], Assael Cohen[2], Chieh-li Liu[1], Pranab K. Mohapatra[2], Avinash Patsha[2], Vladi Gorovoy[1], Subhrajit Mukherjee[1], Vladimir Kleiner[1], Ariel Ismach[2], Elad Koren[1] and Erez Hasman[1]

1 Technion - Israel Institute of Technology, Israel
2 Tel Aviv University, Israel

Recent years have witnessed a surge of interest to selectively manipulate the valley excitons in transition metal dichalcogenide monolayers, due to their potential as an alternative information carrier. Nevertheless, the short valley depolarization/decoherence time prevents the direct information transportation via valley excitons at room temperature, and an urge for a valley-photon interface emerges. Here, we show the manipulations of valley excitons both in an incoherent (by exploiting the valley polarization) and a coherent manner (by exploiting the valley coherence) via a photonic Rashba effect.

Firstly, we demonstrate a photonic Rashba effect from valley excitons in a WSe2 monolayer, which is incorporated into a photonic crystal slab with geometric phase defects [1]. This phenomenon of spin-split dispersion in momentum space arises from a coherent geometric phase pickup assisted by the Berry phase defect mode, whereby valley excitons effectively interact with the defects for site-controlled excitation, photoluminescence enhancement, and spin-dependent manipulation. Specifically, the spin-dependent branches in momentum space originate from valley excitons with opposite helicities and evidence the valley separation at room temperature. This spin-enabled manipulation of valley excitons may enable highly efficient metasurfaces for customized planar sources with spin-polarized directional emission.

Secondly, we report on a spin-optical monolayer laser by incorporating a WS_2 monolayer into a heterostructure microcavity supporting high-Q spin-valley resonances. Inspired by the creation of valley pseudospins in monolayers, the spin-valley modes are generated from a photonic Rashba-type spin splitting of a bound state in the continuum, which gives rise to opposite spin-polarized ±K valleys due to emergent photonic spin-orbit interaction under inversion symmetry breaking. The Rashba monolayer laser shows intrinsic spin polarizations, high spatial and temporal coherence, and inherent topological protection features, enabling valley coherence in the WS2 monolayer upon arbitrary pump polarizations at room temperature. Our monolayer-integrated spin-valley microcavities open avenues for further classical and non-classical coherent spin-optical light sources exploring both electron and photon spins.

Reference

[1] Rong, K. et al. Photonic Rashba effect from quantum emitters mediated by a Berry-phase defective photonic crystal. Nat. Nanotechnol. 15, 927-933 (2020).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Embedded Optical Hall Effect in Terahertz Hall-Effect Amplifier Nanoscale Device (HAND)

Raz Mottes[1,2], Avi Karsenty[1,2]

1 Lev Academic Center-Jerusalem College of Technology (JCT), Dept. of Applied Physics/Electro-Optics Eng., Advanced Lab. of Electro-Optics (ALEO), 21 Havaad Haleumi St., POB 16031, Jerusalem, 9116001, Israel
2 Lev Academic Center-Jerusalem College of Technology (JCT), Nanotechnology Center for Research & Education, Lev Academic Center, Jerusalem, 9116001, Israel

Based on the famous macro-Hall-Effect, a Hall-Amplifier-Nanoscale-Device (HAND), was analytically modelled for DC-condition. Analytical and complementary numerical results (Comsol) fully matched, enabling model's validation. While combining nano-scale, high frequencies, amplification, mixing and embedded Optical-Hall-Effect, HAND may revolutionize microelectronics circuitry. The proposed mathematical models provide greater understanding for improving HAND DC amplification for several coil geometries:

1. Single-Loop Coil (SLC) model for Infinite Wire Gain and Single-Loop coil,
2. Infinite Continuous Solenoid (ICS) and Finite Continuous Solenoid (FCS) models
3. Multi-Loop Circular Coil (MLC) model geometry, and
4. Spiral Multi-Loop Coil)SMLC(model for spiral geometry.

These analytical models developed show two regions of operation for the HAND. In the classical region, HAND works as an amplifier for DC applied voltage and as a mixer/modulator for AC applied voltage. This research also introduces new application for using the HAND in optical frequencies region using the optical Hall Effect and integrating the HAND in plasmonic circuits

3D printing-based fabrication of diffractive optical elements by liquid immersion

Reut Orange-Kedem, Elias Nehme, Lucien E. Weiss, Boris Ferdman, Onit Alalouf,
Nadav Opatovski & Yoav Shechtman
Technion - Israel Institute of Technology

Introductio: We present a method for fabricating high-quality diffractive optical element (DOE) by using standard 3D printing methods. We demonstrate how axial scaling-up of the DOE by orders of magnitude can be made possible by immersing the DOE in a nearly index-matched liquid.

Background: The standard fabrication method available today to fabricate complicated optical elements is photolithography. This method has many limitations, among them are high cost, limited design, and significant requirements in terms of infrastructure and time. 3D printing, on the other hand, enables to increase the complexity and customization of the fabricated part without increasing the cost, yet standard printing methods do not meet the precision requirement necessary to directly fabricate optical components.

Objective: Our objective is to enable the use of 3D printing to facilitate simple, fast and cheap DOE fabrication without compromising on performance.

Methods:
The relative phase accumulated in each pixel by a DOE is linearly dependent on the difference between the refractive indices of the DOE material and the surrounding media, and on the height of each pixel. Normally, the surrounding media is air so the pixel heights should be on the scale of hundreds of nanometers. In our method, by immersing the component in near index-match liquid (or using two materials with a small refractive indices difference) we can increase the dimensions of the DOE by orders of magnitudes.

Results: To demonstrate our method, we fabricate and demonstrate experimentally liquid immersed DOEs with applications in 3D super-resolution microscopy. We show the tunability of our design for wide verity of experimental conditions, and the suitability of this approach to ultrasensitive applications by localizing the 3D positions of single molecules.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Detuning Modulated Composite Segments for High Fidelity Directional Couplers in Integrated Photonic Devices

Y. Piasetzky[1], M. Katzman[2], H. Suchowski[1], A. Zadok[2]
1 Tel Aviv University, 69978 Tel Aviv, Israel
2 Bar Ilan University, 5290002 Ramat-Gan, Israel

We demonstrate a high-fidelity single-qubit gate in photonic integrated waveguides, utilizing a novel scheme of detuning modulated composite segments. We reduce the wavelength dependence of long directional couplers by an order of magnitude, indicating significantly increased robustness for fabrication errors. Integrated quantum photonics, with its intrinsic phase stability and miniature devices, gives great promise in scaling photonics devices into large numbers [1]. However, despite these advantages, the very high-fidelity requirement for quantum information processing still presents major challenges in the practical realization of integrated devices, which suffer from fabrication and other errors. With admissible errors in fault-tolerant quantum computations suggested to be smaller than 2] 4-10], more work is needed to improve such devices' fidelity and stability. Much work has been done to develop robust, error-free quantum gates [3]. Recently, a scheme that utilizes modulation of the detuning, and can be implemented in photonic integrated circuits, has been theoretically suggested [4]. This scheme allows for the fabrication of robust quantum gates even without complex control over coupling parameters. In this work, we present an experimental realization of a Detuning Modulated Composite segmented scheme for single-qubit photonic gates in a silicon photonics platform. We compare the optical power transfer functions of two ring resonators in a standard silicon-on-insulator: One comprised of a long and uniform directional coupler of 350 μm length and the other with variable-width segments according to the composite pulse scheme (Fig. 1(a-b)). The long couplers completed five cycles of power transfer. The extinction ratio and coupling ratio (Fig. 1(c-d)) in the first resonator varied strongly with wavelength, whereas the composite coupler exhibited order-of-magnitude better stability. The composite pulse design achieved critical coupling over the entire C-band [5]. The reduced spectral sensitivity suggests superior robustness to waveguide geometry fabrication errors. This scheme has the promise to help scale up the integrated-photonic quantum experiments toward a usable optical quantum computer.

References

[1] Wang, J., Sciarrino, F., Laing, A., & Thompson, M. G. (2020). Integrated photonic quantum technologies. Nature Photonics, 14(5), 273-284.
[2]Nielsen, M., & Chuang, I. (2010). Quantum Computation and Quantum Information: 10th Anniversary Edition. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511976667.
[3] Shaka, A. J. (1985). Composite pulses for ultra-broadband spin inversion. Chemical Physics Letters, 120(2), 201-205.
[4] Kyoseva, E., Greener, H., & Suchowski, H. (2019). Detuning-modulated composite pulses for high-fidelity robust quantum control. Physical Review A, 100(3), 1-6.
[5] Bogaerts, W., de Heyn, P., van Vaerenbergh, T., de Vos, K., Kumar Selvaraja, S., Claes, T., Dumon, P., Bienstman, P., van Thourhout, D., & Baets, R. (2012). Silicon microring resonators. Laser and Photonics Reviews, 6(1), 47-73.

Thickness mapping and layer number identification of exfoliated van der Waals materials by Fourier imaging micro-ellipsometry

Ralfy Kenaz[1], Saptarshi Ghosh[1], Pradheesh Ramachandran[1], Kenji Watanabe[2], Takashi Taniguchi[2], Hadar Steinberg[1], Ronen Rapaport[1*]

1 *Racah Institute of Physics, The Hebrew University of Jerusalem, Israel*
2 *National Institute for Materials Science, Japan*

Spectroscopic ellipsometry is an accurate yet non-invasive optical technique widely used in research and technology for determining the optical properties and thicknesses of thin films. Thickness estimation of exfoliated van der Waals (vdW) micro-flakes holds significant importance in the 2D-materials community and is generally performed by complex and high-cost atomic force microscopy (AFM) and Raman spectroscopy which may be invasive and produce inconclusive.

Results: The effective use of commercial spectroscopic ellipsometers on exfoliated vdW micro-structures is inhibited by their low lateral resolution (tens-of-microns at most) or slow data acquisition rates. In this work, we introduce a Fourier-imaging spectroscopic micro-ellipsometer (SME) (Figure 1(a)) [1], and its applicability in thickness mapping of graphene, hexagonal boron nitride (hBN) and transition metal dichalcogenide (MoS2, WS2, MoSe2, WSe2) flakes that are a few microns in size [2].

The SME measures spectrally resolved ellipsometric data at many angles of incidence in a single measurement within few seconds with sub5- microns lateral resolution. Our instrument demonstrates angstrom-level accurate and consistent thickness measurements and exact layer number identification on mono, bi- and trilayers of all the materials. Additionally, it addresses the pertinent issue of identifying and validating monolayer thick hBN, which is otherwise near-transparent in optical microscope and requires careful characterization in AFM or Raman spectroscopy. In addition, extracted complex refractive index from exfoliated MoS2 flakes by the SME are in excellent agreement with a commercial spectroscopic ellipsometer. Thickness mapping scans performed on mono- and bilayer MoSe2 flakes highlights the consistency and sensitivity of the SME, as seen in Figure 1(b-d). With its sub5- micron lateral resolution, fast data acquisition and the option of easy and low-cost integration into generic optical microscopes by addition of a few standard optical components, the SME offers a significant advancement over stand-alone commercial ellipsometers.

References

[1] R. Kenaz, R. Rapaport, “Mapping single-shot angle-resolved spectroscopic micro-ellipsometry with sub5 microns lateral resolution,”. arXiv:2207.14161, 2022. https://doi.org/10.48550/arXiv.2207.14161.
[2] R. Kenaz, S. Ghosh, P. Ramachandran, K. Watanabe, T. Taniguchi, H. Steinberg, R. Rapaport. “Thickness mapping and layer number identification of exfoliated van der Waals materials by Fourier imaging microellipsometry”. In preparation.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

S-SNOM Imaging of Stacking Order in Few-Layer Graphene

Daniel Beitner[1,2,3], Shaked Amitay[3], Simon Sallah Atri[3], Shachar Richter[1,2], Haim Suchowski[2,3], Moshe Ben Shalom[2,3]

1 *Department of Materials Science and Engineering Faculty of Engineering Tel Aviv University Ramat Aviv, Tel Aviv 69998, Israel*
2 *University Centre for Nanoscience and Nanotechnology Tel Aviv University Ramat Aviv, Tel Aviv 69998, Israel*
3 *School of Physics and Astronomy, Faculty of Exact Sciences, Tel Aviv University, Tel Aviv 69978, Israel*

Introduction: Stacked 2D layers materials exhibit unique electronic, optical, and magnetic properties. Changes in the stacking order of these materials can create different phases with novel properties.

Background: Tetralayer graphene has three possible stacking phases, where two of them were experimentally observed: the Bernal (ABAB) and Rhombohedral (ABCD) [3-1], while the elusive third ABCB/ABAC has proven much harder to detect (Figure -1A).

Objectives: In this work, we show that single wavelength (0.63 eV) Scattering Scanning Near-field Optical Microscopy (S-SNOM), in combination with an Oscillating Spherical Dipole (OSD) model, can be used to clearly image and categorize all three phases of tetralayer graphene

Methods: Figure -1B shows a diagram of the measurement system. A 2000 nm laser diode is focused onto the tip via a parabolic mirror. The Au-coated tip scatters the near-field signal from the sample surface to the detector. A locking amplifier demodulates the signal to higher harmonics of the tip oscillation to extract the near-field. The oscillating reference signal allows extraction of the phase.

Results: A sample of graphene flake was deposited on a SiO-2coated wafer. Figure -1C shows a 2D Raman scan of the sample flake, indicating a -4layer area in the center of the sample. The scan showed two different regions which correlate to ABAB and ABCD stacking in the flake and a possible third triangular-shaped region. The AFM topography scan of the -4layer region (grey image -1C) shows no difference between the regions of the flake. The bottom images in figure -1C show the optical NSOM scan results: optical amplitude (red-yellow) and phase (blue-purple). Three different areas are clearly visible when comparing both scans. The OSD model shows that the predicted amplitude/phase values match those measured for each phase.

Conclusions: • All three possible stacking phases of Tetralayer Graphene were imaged via S-SNOM • Single wavelength imaging in combination with OSD model is sufficient to detect and categorize different phases in few layer graphene • These methods can also be applied to higher stacking numbers of graphene flakes.

References

[1] H. Li, M. I. B. Utama, S. Wang, W. Zhao, S. Zhao, X. Xiao, Y. Jiang, L. Jiang, T. Taniguchi, K. Watanabe, A. WeberBargioni, A. Zettl, F. Wang, Nano Lett. 2020, 20, 3106.
[2] D. S. Kim, H. Kwon, A. Y. Nikitin, S. Ahn, L. Martín-Moreno, F. J. García-Vidal, S. Ryu, H. Min, Z. H. Kim, ACS Nano 2015, 9, 6765.
[3] C. Bouhafs, S. Pezzini, F. R. Geisenhof, N. Mishra, V. Mišeikis, Y. Niu, C. Struzzi, R. T. Weitz, A. A. Zakharov, S. Forti, C. Coletti, Carbon N. Y. 2021, 177, 282.

Temperature Invariant Metasurfaces

Shany Zrihan Cohen, Danveer Singh, Sukanta Nandi and Tomer Lewi
The Faculty Of Engineering, Bar Ilan University

Thermal effects are well known to influence the electronic and optical properties of materials through various physical mechanisms and are the basis for many optoelectronic devices. The thermo-optic (TO) effect - the refractive index variation with temperature - is one of the common mechanisms used for tunable optical devices, including integrated optical components, metasurfaces and nano-antennas. However, when a static and fixed operation is required, i.e., temperature invariant performance - this effect becomes a drawback and may lead to undesirable behavior through drifting of the resonance frequency, amplitude or phase, as the operating temperature varies over time. This behavior can be detrimental for devices with narrow resonance linewidth such as ring and micro-resonators. In this work, we propose a systematic solution to tackle the problem of thermally induced optical fluctuations in nanophotonic devices. By using hybrid subwavelength resonators composed from two materials with opposite TO dispersions ($dn/dT<0$ and $dn/dT>0$), we compensate for TO shifts and engineer meta-atoms and metasurfaces with zero effective TO coefficient ($dn/dT\approx 0$). We demonstrate temperature invariant resonant frequency, amplitude and phase response in meta-atoms and metasurfaces operating across a large temperature range and broad spectral range. Our results highlight a path towards temperature invariant nanophotonics, which provides constant and stable optical response across a wide range of temperatures and can be applied to a plethora of optoelectronic devices. Controlling the sign and magnitude of TO dispersion extends the capabilities of light manipulation and adds another layer to the toolbox of optical engineering in nanophotonic systems.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Micro and nano Optics 13:30-13:40

A Bright Puzzle and its Dark Solution: Hyperspectral Imaging of Plasmonic Nanostructure Arrays

Ya'akov Mandelbaum[1,2], Abhijit Sanjeev[1], Eugene Brozgol[1], Avi Karsenty[2], Zeev Zalevsky[1], David Zitoun[1]

1 *Bar-Ilan Institute of Nanotechnology and Advanced Materials (BINA), Bar-Ilan University, Ramat-Gan, Israel*
2 *Department of Applied Physics and Electro-optical Engineering, Lev Academic Center - Jerusalem College of Technology (JCT), Jerusalem, Israel*

Nanostructure arrays, designed to serve as pixels in a plasmonic imaging device, were fabricated by Focused Ion Beam (FIB). To gauge plasmonic enhancement, optical scattering was measured using dark field microscopy coupled with hyperspectral imaging. The morphology observed was surprising - rather than solid rectangles, bright rectangular frames were observed around a dark interior. Several explanations for the effect were considered but none were consistent with the experimental data. In parallel a difference in surface texture between the pixels and the surrounding bulk was noted, suggesting annealing due the ion-beam. 'Control patterns' were fabricated to test this - empty squares exposed uniformly to a low-dose ion-beam. These displayed the same nonuniformity in the scattering images. Ultimately, reconsideration of dark-field mode using the methods of Fourier optics, provided the key both to understanding the phenomenon and to devising ways to overcome it. In particular a computation using an Ideal Hi-Pass Filter (IHPF) is shown to reproduce the essential characteristics. Conclusions regarding coherence are presented, and methods to obtain uniform scattering images are suggested.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Achromatic Flat Lenses: Do They Improve Imaging Performance?

Jacob Engelberg and Uriel Levy
Department of Applied Physics, The Hebrew University, Jerusalem 91904, Israel

Introduction: Flat lenses, a family including diffractive lenses and metalenses, are a hot topic of research. A critical limitation of these lenses is their strong chromatic aberration. In attempt to solve this problem, achromatic flat lenses (AFLs) have been implemented. The basic function and parameters of these two types of lenses are shown in Fig. 1

While achromatic behavior of these lenses has been experimentally demonstrated, an actual improvement in imaging performance relative to an equivalent conventional (i.e., not chromatically corrected) flat lens (CFL) has not. Such an improvement requires that the effect of the increase in resolution achieved by the achromatic behavior exceed that of the decrease in efficiency. To show an improvement in imaging performance we must devise a metric that combines resolution and efficiency into a single metric.

Methods: We propose an overall performance metric (OPM) given by:, where η is the diffraction efficiency of the flat lens, and T is its overall transmission (to all transmitted diffraction orders). Strehl is the 1D Strehl ratio, which we define here to be equal to the area under the modulation-transfer-function (MTF) graph relative to the area under the diffraction limited MTF graph. This performance metric is related to the SNR of the system, averaged over all spatial frequencies.

Results: We implemented this performance metric on several published examples and demonstrated that these AFLs do not show improved imaging performance compared to an equivalent CFL. We used the published values for the AFL Strehl ratio and efficiency. We simulated the Strehl ratio of the equivalent CFL using commercial optical design software and calculated the efficiency analytically assuming an - 8phase level diffractive structure.

Conclusions: We hope that use of our metric will allow flat lens research to focus on future solutions that can provide real benefit for imaging applications, beyond merely demonstrating achromatic behavior.

Topologically Protected Plasmonic Phases in Randomized Aperture Gratings

M. Fox[1], and Y. Gorodestki[1,2]
1 *Department of Electronics and Electric Engineering, Ariel University, Ariel 407000, Israel*
2 *Deptartment of Mechanical Engineering and Mechatronics, Ariel University, Ariel 407000, Israel*

Introduction/Background: Topological phases in optics have recently attracted much attention due to both their ability to function as a photonic model for quantum systems and their usefulness in optic and photonic devices. Among the more common methods of achieving topological phases in optics is through periodic gratings which act as serial momentum operators, as we have recently shown. This leads to overall Bloch periodicity in k-space and to subsequent multiple diffraction orders, each carrying replicas of any desired phase information. Here we demonstrate how the randomization of grating periods, which strongly diminishes the Bloch effect, diffracts all ordinary modes with uniform intensity, while still maintaining desired localization of plasmonic momenta, protected by topological phases. The results of this research shed light on polarization dependent directionality, achieved due to a combined contribution of topological and dynamic phases, and may be crucial in various fields of nanophotonics (such as optical communication, encoding, sensing etc.) where diffractionless propagation is tantamount.

Objectives: To demonstrate topological protection of plasmonic phases such that Bloch periodicity is broken but well-defined polarization dependent plasmonic scattering is present

Methods: Leakage Radiation Microscopy of right handed (RH), left handed (LH) and circular (O) nano-aperture gratings milled in gold, illuminated by NIR laser

Conclusions: We have presented a method by which the plasmonic phase of light, as it propagates through a randomized grating, can be topologically protected for circular polarizations by introducing aperture rotations which construct a desired phase front.

Ultrasoft Whispering Gallery Mode Cavities

Mark Douvidzon, Udvas Chattopadhyay, Yidong Chong, and Tal Carmon
Technion

Ultrasoft devices are expected to have giant Brownian-fluctuations with improved optical cooling [1]. However, most solids used in nanotechnology are as stiff as steel. Differently, in surface science, mixing liquids with emulsifiers permits interfacial tension with nearly zero-resistance to force. Such emulsifiers soften interfaces were never used to build devices. Assisted by optical cavities made from oil droplets submerged in water with emulsifiers adsorbed at the interface, we demonstrate here an ultrasoft device [2] where large Brownian-fluctuations are measured via their effect on an optical whispering-gallery resonance. Benefitting from mutual resonance-enhancement with capillary quality-factors Q of 37 and optical Q of 150 000, which defines it as a hybrid optocapillary-cavity [3], we measure thermal fluctuations with 6 nm amplitude at eigenfrequencies of 155 Hz. In our experiment, we observed the capillary vibrations of an n-heptane droplet submerged in water by coupling light into the whispering gallery mode of the droplet and observing the transmission fluctuations in the otherwise DC transmission signal. We trap and deform the submerged n-heptane droplet in water with optical tweezers.

We operate our laser in wavelength scanning mode and couple evanescently to the drop micro-resonator, identify a characteristic optical mode split resonance and trace it over 15 consecutive measurements. During which, the resonance shows a walk of up to 0.08 nm. We calculate the radius change and receive a peak-to-peak radius fluctuation of Δr =12 nm or a capillary amplitude of 6 nm. Comparing our results to the analytical solution [4] of a submerged drop we receive a surface tension of γ = 0.322 mN/m and a capillary amplitude of 7.7 nm, which is in the same magnitude as our measured result. In conclusion, we were operating at the ultimate softness limit where slightly adding emulsifiers results in the breakage of our device by Brownian fluctuations. Our fiber compatible technology suggests a resonantly enhanced access to giant Brownian fluctuations and might impact optical cooling of these fluctuations toward their ground state, maybe even at room temperature and pressure.

References
1. Aspelmeyer, Markus and Kippenberg, Tobias J. and Marquard, F and Marquardt, Florian, "Cavity optomechanics" Reviews of Modern Physics Vol,86 (2014).
2. A. D. Ward, M. G. Berry, C. D. Mellor, C. D. Bain, and C. D. Baine, "Optical sculpture: controlled deformation of emulsion droplets with ultralow interfacial tensions using optical tweezers.," Chem. Commun. (Camb)., Vol,16 4515–4517/43 (2006).
3. S. Maayani, L. L. Martin, S. Kaminski, and T. Carmon, "Cavity optocapillaries,"Optica, Vol,3 552/no. 5 (2016).
4. M. Strani and F. Sabetta, "Free vibrations of a drop in partial contact with a solid support," J. Fluid Mech., Vol, 141 233–247 (1984).

Modal confinement factor study in planar waveguides for sensing

Uzziel Sheintop*, Alina Karabchevsky
School of Electrical and Computer Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel

Keywords: optical waveguides, integrated photonics, spectroscopy

Introduction: Here we report the study of confinement factor dependence on wavelength and dimensions for vibrational spectroscopy with different waveguide architectures. For this, we first simulate the different designs using a finite difference eigenmode (FDE) numerical tool to find the eigenmodes and the group index and then calculate the confinement factor.

Background: Spectral fingerprints provide a reliable means of identification. That is the essential explanation for why fingerprints have replaced other methods of identification. The energy of a molecule can be divided to electronic, vibrational, rotational, and translational energy. When illuminated with infrared (IR) radiation, the atoms in the molecule start to vibrate. Optical waveguides are becoming an attractive building block in a variety of systems due to their unique features such as large evanescent field, compactness, and mostly, the ability to be configured to the required application [1]. The confinement factor is a key paramenter to characterize the waveguide efficiency for fingerprint identification.

Objectives: We have numerically investigated the ability of the planar waveguide to confine a mode and to enhance the evanescent interaction with an analyte for both TE and TM orthogonal polarizations.

Methods: By numerically solving Maxwell equations we studied different waveguide architectures to understand the dependence of the confinement factor of the waveguide's sensitivity to analytes.

Results: We have found that planar waveguides have different confinement factors which depend on the waveguide's parameters such as depth, width, materials; wavelength architecture.

Conclusions: New spectroscopic strategies can potentially be extended to detect and identify analytes and study their interaction with light in a chip-scale label-free manner and to enhance the functionality of chemical and biological monitoring.

Plasmonic Graphene-like Topological Metasurface for Modeling 2D Materials

E.D. Epstein[1] and Y. Gorodetski[1,2]
1 Department of Electrical and Electronic Engineering, Ariel University, Ariel, 40700, Israel
2 Department of Mechatronics and Mechanical Engineering, Ariel University, Ariel, 40700, Israel

Topological photonics1 is a rapidly growing field. Efficient light confinement, guiding and localization have been achieved by using photonic crystals with topological states2. Furthermore, it has been shown that optical topological phases can model complex quantum systems3. A special interest is focused on systems supporting surface plasmon (SP) modes whose properties and band structure can be manipulated by accurately designed metasurfaces4. Exciting SPs by anisotropic scatterers can lead to the topological Berry phase (BP) that further modifies the surface wave's characteristics5. We experimentally study the spin-dependent response of a plasmonic graphene-like geometric phase metasurface (GPM).

We prepared an array of rectangular grooves in a thin gold film arranged in a honeycombed lattice. The two constituent triangular sublattices are at different spatial orientations giving rise to a BP between them. Using leakage radiation microscopy, we measure the GPM's response to illumination by circularly polarized light in real and reciprocal space. We observe directional helicity dependent SP excitation. Modifying the relative angle between the sublattices gives rise to stronger spin selectivity. We confirmed these results with numerical calculations. An interesting analogy can be drawn between our structure and so-called 2D materials, such as monolayer transition metal dichalcogenides (TMDs). Many recent studies have explored these materials' properties showing a strong spin-orbit interaction6. TMDs have structures similar to ours. The plane separation in analogous to the BP accumulation. Although the fabrication of 2D materials is improving rapidly, it currently remains a complicated procedure. Our structures, by contrast, are easy to prepare and measure. We thus propose a simple way to analyze optical properties of TMDs and possibly make predictions of yet unknown features.

References

[1] M. C. Rechtsman, et al. Nature, 496, 196 (2013). [2] F. D. M. Haldane & S. Raghu, Phys. Rev. Lett. 100, 013904 (2008). [3] L. Feng, R. El-Ganainy & L. Ge, Nat. Photonics, 11, 752 (2017). [4] F. Ding, Y. Yang, R.A. Deshpande, & S. I. Bozhevolnyi, Nanophotonics, 7, 1129 (2018). [5] N. Shitrit, I. Bretner, Y. Gorodetski, V. Kleiner & E. Hasman, Nano Lett., 11, 2038 (2011). [6] J. Schaibley, H. Yu, G. Clark, et al. Nat. Rev. Mater. 1, 16055 (2016).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

A 4x1 O-Band MMI Power Combiner Using Silicon Nitride Slot Waveguide Technology

Dror Malka
Faculty of Engineering Holon, Institute of Technology (HIT), Holon 5810201, Israel

Index Terms - MMI Coupler, Silicon nitride, Slot-waveguide, Optical combiner

Optical transceivers that function under a high-speed rate condition are demanded to have more optical power ability to overcome the power losses which is a cause of the need of using a larger RF line connected to the Mach-Zehnder modulator for fulfilling the high-speed condition [1]. The classic solution to this problem is to use a better power laser with a high level of 120 milliwatts. However, this solution can be complicated for a photonic chip circuit due to the high cost and nonlinear effects, which can increase the system noise. Therefore, we propose a better solution to increase the power level using a 4x1 power combiner which is based on multimode interference (MMI) using a silicon nitride slot waveguide structure. The combiner was solved using the full-vectorial beam propagation method and the key parameters were analyzed using Matlab script codes. Results show that the combiner can function well over the O-band spectrum with high combiner efficiency of at least %98.1 and after a short light coupling propagation of 28.8 μm. This new study shows how it is possible to obtain a transverse electric mode solution for four Gaussian coherent sources using silicon nitride slot waveguides technology. Furthermore, the back reflection (BR) was solved using a finite difference time domain method and the result shows a low BR of 40.1 dB. This new technology can be utilized for combining multiple coherent sources that work with a photonic chip at the O-band range. Fig. 1(a) shows the TE fundamental mode field profile inside the Si_3N_4 slot-waveguide structure of the four coherent sources for the operating wavelength of 1310 nm at the x-y plane. Fig. 1(b) shows the light propagation of four gaussian TE mode field laser sources at the x-z plane and over the O-band.

References

V. Moshaev, Y. Leibin, D. Malka, Optimizations of Si PIN diode phase-shifter for controlling MZM quadrature bias point using SOI rib waveguide technology, Optics & Laser Technology, 138, 2021 (106844).

Artificial Intelligence in Optics 13:40-13:50

Learning optimal multicolor PSF design for 3D pairwise distance estimation

Ofri Goldenberg[1], Boris Ferdman[1,3], Elias Nehme[1,2], Yael Shalev Ezra[1], Yoav Shechtman[1,3*]

1 *Department of Biomedical Engineering and Lorry I. Lokey Interdisciplinary Center for Life Sciences and Engineering, Technion - Israel Institute of Technology*
2 *Viterby Faculty of Electrical and Computer Engineering, Technion - Israel Institute of Technology*
3 *Russell Berrie Nanotechnology Institute, Technion - Israel Institute of Technology*
**Corresponding author. Email: yoavsh@bm.technion.ac.il*

Measuring the three-dimensional distance between two spots is a common task in microscopy, because it holds information on the degree of co-localization in a variety of biological systems. Often, the two spots are labeled with two different colors, as each spot represents a different labeled entity. In computational microscopy, neural networks have been employed together with point-spread-function (PSF) engineering for various imaging challenges, specifically for localization microscopy.

This combination enables "end-to-end" design of the optical system's hardware and software, that is learned simultaneously, optimizing both the image acquisition and reconstruction together. In this work, we employ such a strategy for the task of direct measurement of the 3D distance between two emitters, labeled with differently-colored fluorescent labels, in a single shot, on a single optical channel.

Specifically, we use end-to-end learning to design an optimal wavelength-dependent phase mask that yields an image that is most informative with regards to the 3D distance between the two spots, followed by an analyzing net to decode this distance. We utilize the fact that only the distance between the two spots is of interest, rather their absolute positions; importantly, the use of two colors, instead of one, inherently enables sub-diffraction distance estimation. We demonstrate our approach experimentally by distance measurement between pairs of fluorescent beads, as well as between two fluorescently tagged loci in the DNA in yeast cells. Our results represent an appealing demonstration of the usefulness of neural-nets in task-specific microscopy design, and in optical system optimization in general.

M.Sc. student under the supervision of Prof. Yoav Shechtman at the Technion, Israel Institute of Technology. Holds a B.Sc. degree at biomedical engineering from the Technion, with specialization in biomedical image and signal processing. Research work includes computational imaging and machine learning with specification to task-specific microscopy design, and optical system's hardware and software optimization.

neural-nets in task-specific microscopy design, and in optical system optimization

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Transformation and Phase Retrieval of Electromagnetic Fields between a Plane and an Arbitrary Surface Using Machine Learning

Sahar Froim, Barak Hadad, Amit Bekerman, Yakir Hadad, and Alon Bahabad

Department of Physical Electronics, School of Electrical Engineering, Fleischman Faculty of Engineering, Tel-Aviv University, Tel-Aviv 69978, Israel

The ability to tailor a specific electromagnetic field pattern along an arbitrary selected surface is interesting and of substantial importance considering its numerous immediate applications. It belongs to a class of inverse source problems, and as such it is challenging when only partial data is given. Here, we present a machine-learning approach for learning the mapping between an electromagnetic field along an arbitrarily chosen target surface to an electromagnetic field on a planar source surface. An artificial neural network (ANN) is able to find the field on a plane surface generating a measured field on a curved surface, while it can be used to design a desired field on a concave surface whose sources are on a plane. In particular, we have shown that our network is able to design the source field required to create arbitrary lines of intensity along an arbitrary concave surface. This particular ability is important for microscopy (e.g., for point-spread-function engineering and for light-sheet microscopy), for optical tweezers, where particles are subject to move along specific light patterns, for the general task of designing curved ("accelerating") beams of light, and it can also be relevant for RADAR and LIDAR systems. We also provide a method for retrieving the electromagnetic field on a planar source surface, using only the amplitude on a given target surface, demonstrating in the process phase-retrieval ability.

An advantage of our method is that, using standard Fresnel propagation integral, relating the field at the input face of the cubic volume to an arbitrary surface within the volume, requires calculating the field in the entire volume while here the ANN learns a mapping between surfaces, which is computationally much less demanding.

Research Abstract: Visual Data Detection Through Side-Scattering in a Multimode Optical Fiber

Daniel Marima*, Barak Hadad*, Sahar Froim*, Avishay Eyal, Alon Bahabad

Department of Physical Electronics, School of Electrical Engineering, Fleischman Faculty of Engineering, Tel-Aviv University, Tel-Aviv 69978, Israel

** Equally contributed*

Introduction: In recent years a lot of research was done towards performing imaging through a multi-mode fiber (MMF), aiming to use it in applications such as endoscopy. However, little research was done regarding imaging through the side of an MMF using Rayleigh side-scattered light, which can be, for example, an early step towards development of distributed optical imaging systems, or optical links interfaced via the side of an MMF.

Background: Many techniques can be used to image through a scattering system. A recent emergent technique is deep learning (DL) since it is simple, versatile, and can be applied to the intensity of the speckle pattern (as opposed to other methods that require phase information).

Objective: To obtain the pattern of the light input to an MMF based on the intensity pattern of the Rayleigh side-scattered light. Methods: Light that is either amplitude or phase modulated using images of digits and letters from the MNIST and the NotMNIST databases is projected into an MMF. A convolutional neural network (CNN) is trained to retrieve these images based on the intensity of the speckle pattern of the side-scattered light.

Results: The trained network managed to obtain a good evaluation of the images projected into the fiber, with structural similarity (SSIM) index of about %83 between the predicted and ground truth images in most datasets (see Fig.1). Additionally, an especially trained network managed to perform imaging using speckle images from either one of four locations along the fiber.

Conclusions: This work demonstrates that visual information carried by the light input to an MMF can be retrieved from side-scattered light using a CNN. Possible future research is focusing light at the side of the fiber and using it for imaging the surrounding of the fiber.

Depth Reconstruction in Gamma Camera Imaging using AI – Whole Image Regression from Hybrid UNet-Deep Networks

Avishai Haltovsky[1], Yair Yisrael Aminoff[1], Amir Shemer[2], Zeev Zalevsky[3], Ya'akov Mandelbaum[1]

1 *Department of Applied Physics and Electro-optical Engineering, Lev Academic Center - Jerusalem College of Technology (JCT), Jerusalem, Israel*

2 *Department of Electrical and Electronic Engineering, Azrieli College of Engineering, Jerusalem, Israel*

3 *Faculty of Engineering, Bar-Ilan University, Ramat-Gan, Israel*

Gamma cameras currently used for medical imaging involve a trade-off between image quality and patient safety. The latter seeks to minimize patient intake of radioactive material and exposure time. Yet in the absence of lenses for gamma rays, projection images are formed from photons propagating in a small range of angles.

This work presents a new type of gamma-ray camera, which achieves a high resolution without compromising patient safety or long acquisition time. Only a small portion of the incoming photons are blocked, and the spatial location of the light source is determined using artificial intelligence.

Using a shadow template placed on the detector, a collection of images from different locations was generated by ray-tracing simulations, to serve as a training set for artificial intelligence algorithms. These seek to reconstruct the original source locations of new images – the test set – generated from different locations in space.

This work demonstrates that it is possible to determine the location of a single light source that created the shadow pattern with good accuracy. Several methods of classical machine learning – including pseudoinverse, and Regression Support Vector Machines – were employed and compared to the performance of deep convolutional neural networks (CNN) – e.g. Resnet18. The location of the source is identified with good accuracy, even in the presence of moderate noise levels. Partial success was also achieved in identifying the location of two different sources that together contribute to a single shadow pattern.

Finally a deep neural network (DNN) was employed in regression mode to directly reconstruct the image of the source. The network was designed with a hybrid U-Net architecture, in which a pretrained DNN – Resnet50 – was embedded in the bridge. This allowed exploitation of the power of the DNN, including transfer learning, together with the capabilities demonstrated by UNet for fully two-dimensional output.

Free-electron-based interferometry for imaging of the phase and amplitude of nanoscale fields

T. Bucher, R. Ruimy, R. Dahan, S. Tsesses, G. M. Vanacore & I. Kaminer
Technion - Israel institute of technology

Ultrafast transmission electron microscopy (UTEM) enablesimaging materials with combined high spatial and temporal resolutions. One of the pioneering UTEM applications is photon-induced nearfield electron microscopy (PINEM), whereby electrons image electromagnetic fields with nanometric resolution [1-4]. The underlying PINEM interaction also shapes the free-electron wavefunction, enabling novel phenomena such as free-electron-based Ramsey interferometry [5], detection of the coherence and decoherence of quantum emitters [6], and reconstruction of the electron's quantum state [7]. Here we utilize the shaping of the electron wavefunction prior to its interaction with an electromagnetic field to propose a Mach-Zehnder-type electron interferometer scheme (see Fig. 1a) that enables phase-resolved imaging of the field and algorithmic-based imaging enhancement. We develop an optimization procedure for the extraction of the field's amplitude & phase using signal processing techniques. We exemplify these concepts by applying the electron-interferometric reconstruction in the case of a plasmonic standing wave with hexagonal geometry (see Fig. 1c-d). We compare our method with conventional PINEM using the structural similarity index measure [8] and show an improvement by almost two orders of magnitude for the minimal interaction strength necessary for the reconstruction (Fig. 1b-c). This enhancement makes it possible to image delicate specimens and ones with very weak light scattering. Additionally, we show that phase reconstruction is possible with high spatial resolution even for weak interaction strength and noisy measurements (Fig. 1d). We discuss how to implement our scheme in current UTEMs, enabling enhanced, low-dosage, amplitude, and phase imaging with deep subwavelength resolution (only limited by the electron's de Broglie wavelength, thus capable of reaching atomic resolution). The multi-knob nature of our scheme makes it especially advantageous in combination with advanced algorithms and deep-learning-based approaches, to further enhance the probing capabilities of the UTEM.

References
[1] B. Barwick, et al., "Photon-induced near-field electron microscopy". Nature 462, 902 (2009) [2] F. J. Garcia de Abajo, et al., "Multiphoton Absorption and Emission by Interaction of Swift Electrons with Evanescent Light Fields". Nano Lett. 10, 1859 (2010) [3] S. T. Park, et al., "Photon-induced near-field electron microscopy (PINEM): Theoretical and experimental". New J. Phys. 12, 123028 (2010) [4] I. Madan, et al., "Holographic imaging of electromagnetic fields via electron-light quantum interference". Sci. Adv. 5, eaav8358 (2019) [5] KE. Echternkamp, et al. "Ramsey-type phase control of free-electron beams". Nat. Phys. 12, 1000 (2016) [6] R. Ruimy, et al., "Towards atomic-resolution quantum measurements with coherently-shaped free electrons". Phys. Rev. Lett. 126, 233403 (2021) [7] KE. Priebe, et al., "Attosecond electron pulse trains and quantum state reconstruction in ultrafast transmission electron microscopy". Nat. Phot. 11, 793 (2017) [8] Z. Wang, et al., "Image quality assessment: from error visibility to structural similarity". IEEE TIP. 13, 4, 600 (2004) [9] K. Zhang, et al., "Beyond a Gaussian Denoiser: Residual Learning of Deep CNN for Image Denoising". IEEE TIP. 26, 7, 3142 (2017

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

A Lensless Polarization Camera

Shay Elmalem and Raja Giryes
Tel-Aviv University

Introduction and background: Polarization imaging is becoming widespread in recent years, as it reveals information hidden from the human eye and conventional intensity cameras. Polarization images enable various machine vision application, such as material analysis, transparent objects inspection and 3D imaging (to name a few) [1]. Almost all polarization cameras utilize either spatial multiplexing in the sensor plane (requires a dedicated sensor) or sequential polarization filtering (time consuming).

Objectives: Recently, diffuser-based lensless cameras were presented for various applications [2-4]. The principle enabling the diffuser-based imaging scheme is the caustic-like point-spread function (PSF) of the diffuser, which spreads a unique spatially pseudo-random pattern on the sensor. By designing the system to have a linear and shift-invariant PSF, the diffuser response enables compression and reconstruction of an additional modality along with the two spatial dimensions. In this work, a similar approach is utilized to achieve snapshot polarization imaging, based on a conventional sensor, diffuser, simple polarization filter and dedicated restoration algorithm.

Methods and Results: A unique property of the diffuser is that it spreads on a significant part of the sensor plane, but still enables sharp image reconstruction, thanks to its pseudo-random caustic pattern that contains many sharp features. Utilizing this pattern, image reconstruction is possible even from partial sampling of the image plane, if enough 'sharp caustics' are sampled. Exploiting this feature enables the design of a simple polarization camera, based on a conventional image sensor and simple filter, without pixel-level spatial multiplexing. Recommendations and Conclusions A diffuser-based lensless polarization camera design is presented and discussed. It is based on the unique property of the diffuser PSF that is both spatially-wide and contains narrow features, thus enabling sharp image reconstruction from spatially-partial measurements. Multiplexing of four different polarizers is performed using several patterns, and the tradeoff of different designs is discussed.

References
[1] A. G. Andreou and Z. K. Kalayjian, "Polarization imaging: principles and integrated polarimeters," IEEE Sensors 2 (6), 566-576, (2002).
[2] N. Antipa et al.,, "DiffuserCam: lensless single-exposure 3D imaging," Optica 5, 1-9 (2018).
[3] N. Antipa et al., "Video from Stills: Lensless Imaging with Rolling Shutter," IEEE ICCP, 2019, pp. 1-8.
[4] Kristina Monakhova et al., "Spectral DiffuserCam: lensless snapshot hyperspectral imaging with a spectral filter array," Optica 7, 1298-1307 (2020).

Time-Resolved Imaging by Multiplexed Ptychography (TIMP) with Physics-Based Unsupervised Deep Learning

Omri Wengrowicz and Oren Cohen
Department of Physics and Solid State Institute, Technion, Haifa 32000, Israel
Author e-mail address: omriwen@campus.technion.ac.il

Introduction: Time-resolved Imaging by Multiplexed-Ptychography (TIMP) was demonstrated as a promising approach for ultrahigh-speed diffraction-limited imaging of complex-valued objects. However, it is accompanied by resolution deterioration. Here we propose a learning-based technique, denoted by TimpNet, that overcomes the limitations of current TIMP configurations.

Background: Ptychography is a coherent diffractive imaging scanning technique, yielding amplitude and phase information. Single-shot ptychography, where multiple diffraction patterns are recorded in a single CCD exposure, overcomes the scanning time limitation of conventional ptychography, allowing ultrafast measurements. In TIMP, the illumination is spatio-temporally engineered to produce a movie of dynamical objects from a single CCD snapshot, by using the Multi-state Ptychographic Algorithm (MsPA). In this work we replace the update step of MsPA with a neural network (NN), being optimized to invert the measurement process.

Objectives: We demonstrate TimpNet, reconstructing 9 frames of a dynamical object from an intensity pattern recorded on a single detector exposure, and compare it to MsPA. Methods: A measurement is fed into the NN we aim to train to invert the operation of the physical measuring system. An assumed physical model of the system is then applied to the output, obtaining a simulated measurement. The true and the simulated measurements are then compared, and the network is updated to minimize the loss function between the measurements. This process is repeated iteratively until convergence.

Results: We computationally produced a TIMP measurement of 9 frames, taken from CIFAR10 dataset. We reconstruct the data using TimpNet and MsPA. TimpNet reconstructions had higher image quality and resolution (see figure below). Conclusion: We present a new algorithmic method for reconstructing multiple frames from a single recorded diffraction intensity pattern image, and better reconstructed image quality and resolution compared to other iterative methods. This method will improve the performance of a TIMP-based ultra-high frame rate microscope.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Ultrafast Phenomena 15:20- 15:30

Coherent Control of Nanoparticles Nonlinear Response

Snir Nehemia[1,2], Omri Meron[1,2], Uri Arieli[1,2], Haim Suchowski[1,2]
1 *Condensed Matter Physics Department, School of Physics and Astronomy, Faculty of Exact Sciences, Tel Aviv University, Tel Aviv, 6997801, Israel*
2 *Center for Light-Matter Interaction, Tel-Aviv University, Tel-Aviv, 6779801*

Localized surface plasmon resonance (LSPR) is a collective oscillation of conduction electrons in metallic nanoparticles whose length scales are much smaller than the wavelength of the incident light. In the last two decades, enormous research efforts have been invested in exploring the LSPR's linear and nonlinear optical responses [1]. Yet, due to the LSPR's short decoherence time of a few dozen femtoseconds, it has been challenging to study their coherent dynamics. In recent years, with the advance of extreme ultrafast sources and pulse shaping methods, researchers have not only measured such dynamics but have also demonstrated control over the coherent response [3 ,2]. Most of the recent studies, however, were limited to second-order nonlinear processes and two-photon photoluminescence, which enforce some constraints on the geometry of the nanoparticles.

In our research, we utilize a sub10- femtoseconds pulse shaper to study and control the Four-wave mixing (FWM) nonlinear response of the LSPR excitations within the coherent regime. We use a spatial light modulator (SLM) to tailor the spectral phase of the incoming pulse to complement the inherent LSPR's phase. In doing so, we achieved an enhancement factor of %180 of the FWM intensity with respect to transform-limited pulse.Our results come in good agreement with the anharmonic oscillator model. We show that contrary to the second-order response, the FWM, as a third-order nonlinear process, can be measured for all nanoparticle geometries. Thus, our scheme enables the possibility to study and control a wide range of nanoparticles, and in doing so, we can both design and selectively influence nanostructures to fit our needs.

References

[1] Stoll, T., et al. (2014). Advances in femto-nano-optics: ultrafast nonlinearity of metal nanoparticles. The European Physical Journal B, 87(11), 1-19.
[2] Bahar, E., et al. (2022). Unlocking coherent control of ultrafast plasmonic interaction. Laser & Photonics Reviews, 16(7), 2100467.
[3] Accanto, N., et al. (2021). Selective excitation of individual nanoantennas by pure spectral phase control in the ultrafast coherent regime. Nanophotonics, 10(1), 597-606.

Atomic and Quantum Optics 15:20-15:30

Solid state spin photon interfaces in integrated photonics structures

Leeju Singh, Eilon Poem and Ofer Firstenberg
Department of physics of complex systems, Weizmann Institute of Science Rehovot, Israel
*Corresponding Author E-mail: leeju.leeju@weizmann.ac.il

Coherently couple electron spins and photons, both at low and high temperatures. This coupling can be increased using photonic structures embedded within the host crystal. This work is based on the combination of guided propagation of light through crystals containing transition metal ions, and the ability of the latter to coherently couple light and spin. We set out to demonstrate that these materials can sustain a coherent spin-photon link up to liquidnitrogen temperatures, that various photonic structures can be directly fabricated in them by laser writing, and that these two features can be combined in the demonstration of a hightemperature, fully integrated quantum spin-photon interface.

Scientific Background: The controlled, coherent manipulation of quantum mechanical systems is an important challenge in modern science and engineering. The quantum network architecture [1] is a canonical way to do so. In a quantum network, stationary anchored qubits become entangled by transmitting and receiving quantum information via "flying" qubits. For realization of anchored qubits the most promising are superconducting circuits [2], nuclear spins [3] and electronic spins of solid state quantum systems [4]. Photons, especially at telecom wavelengths, are the best known communication qubits. Coherent spin-photon coupling has been demonstared in solid systems only at very low temperatures, either for single-spins, or for ensembles of weakly-coupled spins. A system having both coherent spin states and strong-enough spin photon coupling to allow coherent and efficient operation above liquidhelium temperatures is still lacking. We identify transition metal (TM) ions doped into transparent crystals as a class of solid-state systems which we believe have the potential of combining these properties.

Keywords: Spin interaction, quantum spin, photonics and quantum optics.

Biography

[1] H Jeff Kimble. The quantum internet. Nature, 453(7198):1023-1030, 2008.
[2] Philip Krantz, Morten Kjaergaard, Fei Yan, Terry P Orlando, Simon Gustavsson, and William D Oliver. A quantum engineer's guide to superconducting qubits. Applied Physics Reviews, 6(2):021318, 2019.
[3] Bas Hensen, Wister Wei Huang, Chih-Hwan Yang, Kok Wai Chan, Jun Yoneda, Tuomo Tanttu, Fay E Hudson, Arne Laucht, Kohei M Itoh, Thaddeus D Ladd, et al. A silicon quantum-dot-coupled nuclear spin qubit. Nature nanotechnology, 15(1):13-17, 2020.
[4] L Childress, MV Gurudev Dutt, JM Taylor, AS Zibrov, F Jelezko, J Wrachtrup, PR Hemmer, and MD Lukin. Coherent dynamics of coupled electron and nuclear spin qubits in diamond. Science, 314(5797):281-285, 2006.

New Type of Cavity-Quantum Electrodynamics Transition in Multimode Cavities Under Strong Coupling,

May Godsi, M. Balasubrahmaniyam, Cyriaque Genet and Tal Schwartz
Physical Chemistry Department and Center for Light-Matter Interaction, Tel Aviv University, Israel

When organic molecules are embedded inside an optical cavity, their interaction with the photonic mode of the cavity may become strong enough to overcome any decay process. This strong interaction changes the wavefunctions of the molecules and creates two new quantum states known as polaritons. Until now, strong light-matter coupling has proven to be a powerful tool for enhancing energy transfer, charge transport, controlling chemical reactivity in reactions and more. In general, all previous studies have only considered strong coupling between molecules and a single cavity mode. This is correct when the cavity size is on the order of half a wavelength. But when a larger cavity is larger than this, several cavity modes might be in the vicinity of the molecular absorption. Recently, our group predicted theoretically that in such a scenario, strong coupling can occur in two very different manners, depending on the system parameters. Here we experimentally demonstrated the transition between those two regimes.

This is done by creating a series of cavities with increasing thicknesses, with all other parameters being identical. We characterized the system spectroscopically by both reflection and emission measurement. The reflection measurements showed excellent agreement with the theoretical prediction. Surprisingly, the photoluminescence measurements showed emission from high energy polaritons, which is usually not observed in molecular systems due to Kasha's rule. The dynamic of this system was revealed as well by transient absorption measurements. This observation shows that the behavior of strongly coupled systems not only depends on the coupling strength, but also on the dimensions of the system and field retardation effects, which are usually neglected in cavity quantum electrodynamics. This discovery opens up a new opportunity for engineering the photophysical properties of molecules, specifically in systems which employ strong coupling for long-range energy transfer between molecules.

Characterization of Second-Harmonic Generation in Silver Nanoparticles for Spontaneous Parametric Down-Conversion

Ariel Ashkenazy, Eliahu Cohen, Dror Fixler

Faculty of Engineering and Institute for Nanotechnology and Advanced Materials, Bar-Ilan University, Ramat-Gan 5290002, Israel

Introduction: Energy-time entangled photons (EPPs), which are at the heart of numerous quantum light applications, are commonly generated in nonlinear crystals. Some highly sensitive quantum applications require the use of ultra-broadband entangled photons that cannot be generated in nonlinear crystals due to phase-matching requirements. Here, we investigate the possibility of using metallic nanoparticles (NPs) as a source for entangled photons through spontaneous parametric down-conversion (SPDC). NPs are known for their strong light-matter coupling at their localized surface-plasmon resonance, and since the propagation length through them is negligible relative to optical wavelengths, they are excellent candidates to serve as non-phase matched sources of ultra-broadband entangled photons.

Results: We report experimental results of classical-light second-harmonic generation in silver nanotriangles and nanocubes embedded in polyvinyl alcohol. Based on the results of the experiments, performed using the reference-free hyper-Rayleigh scattering method, we present an estimation of the characteristics of SPDC in NPs.

Conclusions: Based on these experimental results, we show that, despite of the metals' centrosymmetric crystal, NPs exhibit second-order nonlinearity that is mainly of an electric dipole nature, and so they are suitable for SPDC. Moreover, we show that localized surface-plasmon resonance can play a significant role in enhancing the generated EPPs flux. Finally, we compare the SPDC capabilities of NPs to that of commonly used nonlinear crystals and show that the expected EPPs flux from NPs is weaker but the EPPs have very large bandwidth, which could be helpful for advanced quantum sensing, spectroscopy and communication applications.

References

A. Ashkenazy et al., J. Phys. B 145401, 2019.
A. Ashkenazy et al., IEEE Photonics Journal, 14(4), 2022.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Bragg-reflection from degenerate ultra-cold gases

Arnaud Courvoisier, Amruta Gadge, Nir Davidson

Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 761001, Israel

The momentum of light in a medium and the mechanisms of momentum transfer between light and dielectrics have long been the topic of controversies and confusion. The work presented in this talk discusses the problem of momentum transfers that follow the reflection of light by inhomogeneous ensembles of ultra-cold atoms. We study the reflection of light by a structured dilute cloud and measure the force that acts on the atoms as a result. We show how the resulting momentum transfer can be used to probe the dynamic of matter-wave gratings in Bose-Einstein condensates.

Single photon synchronization with a room-temperature atomic quantum memory

O. Davidson, O. Yogev, E. Poem, O. Firstenberg

Physics of Complex Systems, Weizmann Institute of Science, Israel

Future optical quantum networks will require the fast generation and synchronization of single photons. It is beneficial that these photons interact efficiently with atomic ensembles, e.g., for deterministic two-photon gates. However, on-demand generation of single photons that are compatible with atomic ensembles remains an outstanding challenge. Here we report on the generation and synchronization of heralded single photons with high indistinguishability using rubidium vapor. Using an electronic orbital ladder scheme, we achieve high bandwidth and low noise [1,2]. We obtain high storage and retrieval efficiency of single photons, as shown in Fig. 1(a), by employing the same level scheme for the photon source and the quantum memory. The fidelity of the retrieved photons is high, as demonstrated in a Hong-OuMandel interference with an un-stored photon [Fig. 1(b)], obtained by active photon synchronization.

References

[1] R. Finkelstein et al., “Fast, noise-free memory for photon synchronization at room temperature” Sci. Adv. 4, eaap8598 (2018).
[2] O. Davidson et al., “Bright multiplexed source of indistinguishable single photons with tunable GHz-bandwidth at room temperature”, New J. Phys. 23, 073050 (2021).

Quantum super-resolution in thermal light

Gal Gumpel and Erez N. Ribak

Department of Physics, Technion - Israel Institute of Technology

Introduction: The classical resolution limit is set by diffraction. Because of Heisenberg's uncertainty principle, the original angle of the light is blurred, causing the observed object, for example a binary star, to look like merged diffraction patterns. A larger aperture is required to separate these patterns, or a shorter wavelength, possible in microscopy but not in astronomy.

Objectives: Our experiment is based on amplification of photons for increased resolution. When a photon crosses the system's aperture, it reaches a light amplifier, which responds by stimulating the emission of many additional photons. These stimulated photons are correlated with the original photon, both in direction and in wavelength. These daughter photons have lesser uncertainty than their diffraction limit, and by their mere number they allow for a better measurement of the angle at which the original photon has passed the telescope aperture. This is an improvement on direct detection, which is based only on the original photon (without an amplifier).

Background: Light amplification has been disfavored because the stimulated emission is accompanied by constant spontaneous emission. The copious spontaneous photons are emitted in all directions, unlike the stimulated ones, creating a bright background, and reducing the achieved increase in resolution.

Methods: We had to separately measure the spontaneous photons to reduce its effect. In the lab experiment we blocked the light source, thus measuring only the spontaneous light half the time, while the rest of the time served to measure both stimulated and spontaneous photons. Subtraction of the background image from the combined image left only the clean image of the source.

Results: Two different solid dye amplifiers (DCM and PMN) produced %19 and %38 resolution improvements. Absolutely no use was made of prior knowledge of the object shape or other parameters. This is the first time such an experiment was performed with thermal light (~80 nm bandwidth).

Conclusions: The increased resolution comes at the price of lower sensitivity, a worthy price to pay. Moreover, the loss of sensitivity can be overcome partially by increasing the exposure time, or the observation period.

References

G Gumpel and E N Ribak, "Optical amplification for astronomical imaging at higher resolution", J. Opt. Soc. Am. B 38, A21-A26 (2021).

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Shaping spectral entanglement

Anatoly Shukhin[1], Inbar Hurvitz[2], Ady Arie[2], and Hagai Eisenberg[1]

1 The Hebrew University of Jerusalem, Givat Ram, Jerusalem, 9190401 Israel
2 Tel Aviv University, Ramat Aviv, Tel Aviv, 6997801 Israel

Introduction: Entangled photon pairs and single photons are the core of quantum optics and quantum information technologies [1,2]. The ability to efficiently create such quantum states and manipulate their properties is one of the main challenges on the way to building long-distance quantum communications, quantum computing, and quantum sensors. Regarding generation, one of the most promising approaches is the use of nonlinear optical effects, for instance, spontaneous parametric down-conversion (SPDC) [3]. However, the problem of tailoring the properties of generated states remains. It has been recently shown that domain-engineering of nonlinear crystals enables shaping the joint spectral intensity (JSI) of correlated two-photon states and thereby obtain pure heralded single photons [4], create multi-mode frequency-bin entanglement [5], and realize quantum gates [6]. In this work, we show that using domain-engineered KaTiOPO4 (KTP) crystals along with the modulation of the pump field allows to generate a variety of two-photon and single-photon states with tailorable spectral properties.

Results: Some of the measured JSIs are shown in fig. 1. Without the pump modulation, the JSI looks like an ellipse rotated at a certain angle with respect to the wavelength axes (fig. 1a). When the pump is modulated, the JSI is no longer a single ellipse but rather two ellipses separated by the gap (fig. 1b). In the case of degenerate SPDC this state can be treated as a frequency-bin analog of the |Φ +> Bell state. Rotating the polarization of one field at 90 degrees, the state can be turned into the frequency-bin NOON state |ψ> = |2ω0 1 ω0|+<2 ω12 ω2>

When the modulation frequency is further increased, initial single-ellipse JSI splits into many lobes each of which can be round shaped (fig. 1c). Such a state can be seen as a frequency-bin qudit, where different lobes correspond to the different terms in a qudit state [7,8]. We also used crystals with different poling patterns (apodization functions) to get modulation in the phase-matching function in addition to that in the pump. In general, by combining modulation in the phase-matching function and in the pump, it is possible to get JSI with the desired number of peaks, their shape, and phases.

References

[1] O'brien, Jeremy L., Akira Furusawa, and Jelena Vučković. "Photonic quantum technologies." Nature Photonics 3.12 (2009): 687-695.
[2] Flamini, Fulvio, Nicolo Spagnolo, and Fabio Sciarrino. "Photonic quantum information processing: a review." Reports on Progress in Physics 82.1 (2018): 016001.
[3] Eisaman, Matthew D., et al. "Invited review article: Single-photon sources and detectors." Review of scientific instruments 82.7 (2011): 071101.
[4] Alexander Pickston, Francesco Graffitti, Peter Barrow, Christopher L. Morrison, Joseph Ho, Agata M. Brańczyk, and Alessandro Fedrizzi, "Optimised domain-engineered crystals for pure telecom photon sources," Opt. Express 29, 6991-7002 (2021)
[5] Morrison, Christopher L., et al. "Frequency-bin entanglement from domain-engineered down-conversion." arXiv preprint arXiv:2201.07259 (2022)
[6] Graffitti, Francesco, et al. "Direct generation of tailored pulse-mode entanglement." Physical Review Letters 124.5 (2020): 053603.
[7] Bernhard, Christof, et al. "Shaping frequency-entangled qudits." Physical Review A 88.3 (2013): 032322.
[8] Lu, Hsuan-Hao, et al. "Quantum information processing with frequency-comb qudits." IEEE Photonics Technology Letters 31.23 (2019): 1858-1861

Atomic and Quantum Optics 15:30-15:40

Direct generation of spatially entangled qudits using quantum nonlinear holograms

O. Yesharim[1], S. Pearl[1], J. Foley-Comer[1], I. Juwiler[2] and A. Arie[1]

1 Tel Aviv University, School of Electrical Engineering, Ramat Aviv 69978, Tel Aviv, Israel
2 Department of Electrical and Electronics Engineering, Sami Shamoon College of Engineering, Ashdod 77245, Israel

Introduction: A nonlinear hologram can record the amplitude and phase of a desired optical waveform by spatially modulating the second order nonlinear coefficient. When the hologram is illuminated by a pump beam, this waveform is reconstructed at the second harmonic frequency. Here we extend the application of nonlinear holography to the quantum optical regime for the first time; thus enabling compact engineering of high dimensional entangled quantum states that may be beneficial for quantum information protocols. Methods. We shape the spatial quantum correlations of entangled photon pairs generated in a type- 2 spontaneous parametric down conversion (SPDC) pumped by a continuous wave laser, with a Gaussian profile, at 532.25 nm by imprinting Hermite-Gauss (HG) patterns in a nonlinear photonic crystal (NPC). We have designed and fabricated (using electric field poling) quantum nonlinear holograms in KTiOPO4 (KTP), for generating either a bi-photon Bell state in the HG basis, $|\psi >\approx (1/\sqrt{2})(|HG00a , HG01b > +e\, i\phi|HG01a , HG00b >)$, or a state with 3 dominant pairs of coincidences, approximating a bi-photon qutrit.

Results: The measured coincidence rates between the signal and idler photons, for a regular periodically poled KTP crystal (a) and for two nonlinear holograms (b) and (c) in the HG basis are shown in Fig. 1. It is clearly seen that the engineered crystal can alter the coincidence pattern. For the Bell state (case b), we have determined a violation of the Clause-Horne-Shimony-Holt inequality with S = 2.379 ± 0.118 and a fidelity of 0.89 with respect to the ideal Bell state.

Conclusions: Quantum nonlinear holography enables all optical controlled, on-chip generation of spatially entangled qudits and constitutes a platform for generating desired quantum states by using unconventional crystal patterns.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Sensing strong-coupling with quantum free-electrons

Aviv Karnieli[1], Shai Tsesses[2], Renwen Yu[3], Nicholas Rivera[4], Zhexin Zhao[3], Ady Arie[5], Ido Kaminer[2] and Shanhui Fan[3]

1 Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Ramat Aviv 69978, Tel Aviv, Israel
2 Andrew and Erna Viterbi department of Electrical and Computer Engineering, Technion - Israel Institute of Technology, Haifa 32000, Israel
3 Department of Electrical Engineering, Stanford University, Stanford, California 94305, USA
4 Department of Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA
5 School of Electrical Engineering, Fleischman Faculty of Engineering, Tel Aviv University 69978, Tel Aviv, Israel
Author e-mail address: avivkarnieli@tauex.tau.ac.il

Strong coupling in light-matter systems [1] is essential for many quantum technologies, and in the optical domain, such systems currently lack quantum coherent probes with nanometric spatial resolution. Motivated by recent advances in free-electron quantum optics [2,3], we propose the use of free electrons as high-resolution quantum sensors for strongly-coupled light-matter systems.

Using a unified quantum model of free-electron-atom—photon interaction, we show how quantum interference manifested in the free-electron wavefunction can be used for an enhanced sensing protocol of the position and dipole orientation of a sub-nm atom inside a cavity. Further, by shaping the free-electron wavefunction, measurement of the quantum state of the hybrid light-matter system is made possible. This can prove beneficial for readout of quantum information encoded in cavity polaritons and its subsequent transmission using free electrons, as well as to resolve the temporal dynamics of ultrafast Rabi oscillations using ultrafast electron microscopy.

Oasis 8th International Conference and Exhibition on Optics & Electro-Optics

Light-matter interface based on dense, ordered atomic lattices

I. Shani, Y. Solomons, E. Reches, A. Behera, E. Shahmoon, O. Firstenberg, N. Davidson
Weizmann Institute of Science

Arrays of trapped neutral atoms have recently entered the spotlight and are considered a promising platform for quantum computing [1]. The quantum features in these platforms are mainly based on short-range atomic interactions [2] hindering their scaling up, especially in low dimensional geometries. Here, we introduce a novel scale-up route by coherently coupling these arrays to propagating photons. Strong coupling between a single propagating mode of light and defect-free atomic 2D arrays was recently demonstrated with subwavelength ('microscopic') inter-atomic separation [3-5]. To benefit from the simplicity, flexibility, and scalability of optical tweezers arrays, we propose to extend this scheme to atomic arrays with 'mesoscopic' separations, slightly above the optical wavelength. We will develop and construct such mesoscopic atomic arrays and, by exploiting either several atomic layers or an additional moderatefinesse cavity, suppress their coupling to high-order diffraction modes and maximize the coupling (cooperativity) to a single optical mode, such that quantum state transfer from light to the collective excitation of the atomic array can be realized

References

[1] M. Morgado and S. Whitlock, Quantum simulation and computing with rydberg qubits, 2020, arXiv:2011.03031.
[2] D. Hayes, P. S. Julienne, and I. H. Deutsch, "Quantum logic via the exchange blockade in ultracold collisions", Phys. Rev. Lett. 98, 070501 (2007).
[3] E. Shahmoon, D. S. Wild, M. D. Lukin, and S. F. Yelin, "Cooperative resonances in light scattering from two-dimensional atomic arrays", Phys. Rev. Lett. 118, 113601 (2017).
[4] A. Asenjo-Garcia, M. Moreno-Cardoner, A. Albrecht, H. J. Kimble, and D. E. Chang, "Exponential improvement in photon storage fidelities using subradiance and "selective radiance" in atomic arrays", Phys. Rev. X 7, 031024 (2017).
[5] J. Rui, D. Wei, A. Rubio-Abadal, S. Hollerith, J. Zeiher, D. M. Stamper-Kurn, C. Gross, and I. Bloch, "A subradiant optical mirror formed by a single structured atomic layer", Nature 583, 369-374 (2020).

Remote All Optical Chip-Scale Magnetometery

Kfir Levi, Avital Giat, Eliran Talker, Liran Golan, Liron Stern
Department of Applied Physics, The Center for Nanoscience and Nanotechnology, The Hebrew University of Jerusalem, Jerusalem, 91904, Israel

Optical magnetometry has been the subject of numerous seminal studies and applications in the recent years. Specifically, atomic magnetometry allows the interaction between atoms, resonant light and magnetic fields, to modulate light properties that could be used to determine the magnetic field, with sensitives as lower than 1 fT/√Hz. More recently, such spectacular levels of sensitivity have been demonstrated in micromachined mm-scale cells allowing the significant reduction of magnetometers size, weight and power (SWaP). Here, we propose and demonstrate chip-scale based all-optical remote magnetic sensing. Specifically, we remotely interrogate mm-scale micromachined vapor cells, and measure the ambient magnetic field with at a standoff distance of distance of ~10 meters and a sensitivity of ~1 pT/√Hz (fig 1). Micromachined cells, are highly appealing for such task, due to their small dimensions and the ability to remotely control their atomic density with relatively low powers. Indeed, controlling the atomic density is achieved using visible laser which is absorbed in the silicon frame of the cell, whilst magnetic resonances are archived by means of a modulated 795 nm laser (operating in the Bell-Bloom configuration). Simultaneously we are able measure the distance between micro-cell and the interrogating system by means of time-of-flight measurements, thus correlating between position and magnetic field. Consequently, we provide a novel toolset to remotely map arbitrary, remote and hard to access magnetic field in an unshielded environment with high sensitivity and spatial resolution.

Moreover, such apparatus can be scaled by utilizing a myriad of micro-cells interrogated remotely, and thus enable the exciting prospect of remote spatial mapping of magnetic fields, paving the way to a myriad of novel and diverse applications.

Room-temperature ultrabright single photon sources for free space and fiber-based applications

Alexander Nazarov[1,2], Hamza Abudayyeh[1], Ronen Rapaport[1,2], Boaz Lubotzky[1]

1 Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 9190401, Israel
2 The Center for Nanoscience and Nanotechnology, The Hebrew University of Jerusalem, Jerusalem 9190401, Israel

Introduction: For many quantum applications, deterministic GHz-rate single photon sources at ambient temperature would be necessary. However, achieving such a goal simultaneously is difficult due to both the slow intrinsic decay rate and the omnidirectional emission of most quantum emitters.

Objectives: Our vision is to create on-chip single-photon sources with a high photon rate, high purity, the ability to work with different sources, and the possibility to work in compact systems as well as in fiber applications (high directionality).

Results: We solve these challenges by a novel hybrid approach, using a complex monolithic photonic resonator constructed of a gold nanocone responsible for the rate enhancement, enclosed by a circular Bragg antenna for emission directionality [1,2]. A repeatable process accurately binds colloidal quantum dots to the tip of the antenna-embedded nanocone. As a result, we achieve simultaneous >20-fold emission rate enhancement and record-high directionality leading to an increase in the observed brightness by a factor as large as 450 (80) into an NA = 0.22 (0.5)[3]. We project that these miniaturized on-chip devices can reach photon rates approaching 1.4´108 single photons/second thus enabling ultrafast light-matter interfaces for quantum technologies at ambient conditions.

We also demonstrate a single-photon source for an on-chip device at ambient conditions. The device consists of a single QD coupled to a bullseye nanoantenna with a hole at the center and paves the way to direct coupling of the emission into an optical fiber.

Conclusions: In summary, we were able to reproducibly show record-high directionalities of single photons at room temperature compared to other state-of-the-art platforms. We demonstrated as well a promising solution for an on-chip device with back pumping with high directionality and the ability to be coupled to a fiber.

Keywords: Single-photon sources, quantum dots, quantum optics, quantum information, plasmonics, colloidal nanocrystals

References

[1] Hamza Abudayyeh and Ronen Rapaport, Quantum Sci. Technol. 2 034004 (2017)
[2] Abudayyeh et al., ACS Nano 15, 11, 17384 (2021)
[3] Abudayyeh et al., APL Photonics 6, 036109 (2021)

Quantum Computers

Phase Retrieval of Vortices in Bose-Einstein Condensates

Ron Ziv[1], Anatoly Patsyk[2], Yaakov Lumer[2], Yoav Sagi[2], Yonina C. Eldar[3] and Mordechai Segev[1,2]

1 Department of Electrical Engineering, Technion, Israel
2 Department of Physics, Technion, Israel
3 Department of Mathematics and Computer Science, Weizmann Institute of Science, Israel

Bose-Einstein condensation (BEC) is a quantum state of matter where particles are trapped and cooled until they form a macroscopic population in a single quantum wavefunction. Measurements of such states are performed by imaging the particles in-situ or in the “far-field” by opening the trap and recording time-of-flight (TOF) images. In these measurements, one records the atoms’ density (similar to the intensity of optical beams). Alas, as this is a pure quantum state, it also has a well-defined phase structure, which cannot be resolved by these measurements alone. Thus, to recover the phase structure of the BEC wavefunction, interference measurements have been suggested, which poses a major experimental challenge. This raises a natural question: Can the phase structure be recovered without atomic interference? As we explain below, this question is related to the well-known phase retrieval problem from optics, but with some important differences. Here, we propose and demonstrate in numerical simulations a simple scheme for the complete characterization of the quantum wavefunction of a Bose-Einstein condensation from TOF measurements, including wavefunctions containing vortices.

Our proposed measurement scheme is based on a simple variation to TOF measurements and does not require any kind of interference. Moreover, we show that traditional measurements contain ambiguities in the measurements of vortices due to the radial symmetry in propagation, preventing the reconstruction of their phase, regardless of algorithm used. The variation we propose breaks the radial symmetry in the propagation allowing our measurement scheme to resolve these ambiguities and facilitates the recovery of single vortices and of vortex arrays, including their directionality. Additionally, since the evolution of BECs is nonlinear, described by the Gross-Pitaevskii equation (GPE), our algorithm is based on nonlinear dynamical evolution rather than on the simple Fourier transform used in linear phase-retrieval problems.

Atomic and Quantum Optics 15:40-15:50

Universal approach for quantum interface and memory with atomic arrays

Yakov Solomons, Roni Ben-Maimon, Dr. Ephraim Shahmoon,
Weizmann Institute of Science

Spatially ordered arrays of atoms have attracted much attention recently and was recognized as an effective quantum-interface. It has been shown that the collective response of the atoms to light combined with the spatial order, results in strong light-matter coupling and a reduction in the emission of light into unwanted directions. In this work, we developed a full analytical and unified approach for the analysis and characterization of atomic arrays platforms, focusing on the application of quantum memory in the atomic array. We show that various systems can be mapped to a generic 1D model of light interacting with an atomic dipole. Each system will be characterized by a cooperativity parameter C, which is the ratio between the emission to the desired mode, to the emission to undesired modes. The optimal quantum memory efficiency of such a system is then given by $C+1C$, which is equal to its maximum reflectivity. We discuss in detail the cases of 2D subwavelength and superwavelength atomic arrays, as well as 3D phase matched atomic array, and correction due to small disorder in atoms positions and the finiteness of the array are included.