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ABSTRACT BOOK

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OPTICS, PHOTONICS AND LASERS

Nov 9-11, 2022 | Virtual

Keynotes

Enhanced Interactions of Interlayer Excitons in Free-standing Hetero-bilayers

Yuerui Lu*

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Abstract:

Strong, long-range dipole-dipole interactions between interlayer excitons (IXs) can lead to novel multi-particle correlation regimes that drive the system into distinct quantum and classical phases including dipolar liquids, crystals, and superfluids. Both repulsive and attractive dipole-dipole interactions have been theoretically predicted between IXs in a semiconductor bilayer, but only repulsive interactions have been experimentally reported so far. This study [Nature 610, 478–484 (2022)] investigated free-standing, twisted (51°, 53°, 45°), tungsten diselenide/tungsten disulfide (WSe_2/WS_2) hetero-bilayers, where we observed a transition in the nature of dipolar interactions among IXs from repulsive to attractive. This was caused by quantum-exchange-correlation effects, leading to the appearance of a robust interlayer biexciton (formed by two IXs) phase that was theoretically predicted but never observed in experiments before. The reduced dielectric screening in a free-standing hetero-bilayer not only resulted in a much higher formation efficiency of IXs, but also led to strongly enhanced dipole-dipole interactions, which allowed us to observe the many-body correlations of pristine IXs at the two-dimensional (2D) quantum limit. In addition, we first observed multiple emission peaks from moiré-trapped IXs at room temperature in a well-aligned, free-standing WSe_2/WS_2 hetero-bilayer. Our findings can open avenues for exploring new quantum phases with potential for application in nonlinear optics.

Attomolar Sensing Using Microfluidic SERS Chip Fabricated by Hybrid Femtosecond Laser 3D Processing

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Abstract:

We have developed hybrid femtosecond laser processing to fabricate 3D microfluidic SERS chips enabling ultrahigh sensitivity sensing. In this process, 3D glass microfluidic channels are first fabricated by femtosecond-laser-assisted wet etching. This is followed by the space-selective formation of Ag thin films inside the microfluidic channels via femtosecond laser assisted metal plating. The deposited Ag films are subsequently nanostructured by irradiation with linearly polarized femtosecond laser to form LIPSS for SERS substrates. The resulting microfluidic SERS

chip exhibited an enhancement factor of 7.3×10^8, and then capability of the real-time detection of Cd^{2+} ions with variable concentrations from 10 ppb to 10 ppm. We have further proposed a novel strategy by taking advantage of the microfluidic configuration to achieve the detection limit down to aM. Specifically, the microfluidic chip can produce an interface of analyte solution and air on the SERS substrate in the microfluidic channel. SERS measurements at the interface (liquid-interface assisted SERS, LI-SERS) achieves the enhancement factor reaching 1.5×10^{14} with a detection limit below 10 aM [2]. The enhancement mechanism of LI-SERS is attributed to auto-collection of analyte molecules on the measurement site driving by Marangoni flows and immobilization of the collected molecules by optical trapping due to enhanced electric field on SERS substrates. We have then successfully applied LI-SERS to ultrasensitive analysis of large biomolecules for DNA discrimination and detection of biomarkers of diseases such as Alzheimer's disease.

Exploring Two-Dimensional (2D) Materials as Modulators for 2 µm Region Fiber Lasers

Harith Ahmad, Siti Aisyah Reduan, Muhamad Zharif Samion and Norazriena Yusoff

Photonics Research Centre, Universiti Malaya, 50603 Kuala Lumpur Malaysia Keynote Address at GCNT 2022

Abstract:

In this presentation, a brief introduction to the usage of 2D materials will be given. Since the discovery of graphene in 2004 by Andre Geim and Kostya Novoselov at the University of Manchester, the interest in 2D materials since then has been exponentially growing. This work provides immerse research articles in the area of graphene, graphene oxide, and other 2D materials such as topological insulators (TI), transition metal dichalcogenides (TMD), black phosphorus, and others. Although 2D materials have a very wide application that cut across many areas such as new materials for energy storage, sensors, and others, the interest in this presentation will be primarily focused on the area of photonics. Our interest will be to explore these 2D materials to act as an optical modulator for generating short pulses such as Q-switched and mode-locked pulses. A detailed aspect of the fabrication of these 2D materials will be presented as well as the fabrication of the saturable absorber devices. The current interest will be to generate these short pulses at the 2 µm region, the so-called eye-safe region, for possible application in detecting CO2 gases. Various types of gain mediums such as thulium, thulium-holmium, and holmium-doped optical fibers will be presented. The designs of an optical cavity based on 2D materials, and the various gain medium will be discussed. Measurement for the characteristics of the optical pulses and their possible usage in the detection of CO2 gases as well as for medical surgery will also be highlighted.

Bio- Inspired Artificial Eyes

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Abstract:

The diverse vision systems found in nature can provide interesting design inspiration for imaging devices, ranging from optical subcomponents to digital cameras and visual prostheses, with more desirable optical characteristics than conventional imagers. The advantages of natural vision systems include high visual acuity, wide field of view, wavelength-free imaging, improved aberration correction and depth of field, and high motion sensitivity. Recent advances in soft materials, ultrathin electronics, and deformable optoelectronics have facilitated the realization of novel processes and device designs that mimic biological vision systems. This tutorial introduces recent progress and continued efforts in researching and developing bioinspired artificial eyes. At first, the configuration of two representative eyes found in nature: a single-chambered eye and a compound eye is explained. Then, advances in bioinspired optic components and image sensors are discussed in terms of materials, optical/mechanical designs, and integration schemes.

Free Space and Fiber Optical Communications Using OAM Mode-Division Multiplexing

Yang Yue* and Haoyang Ren

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Abstract:

Optical communications, as the backbone of today's telecommunications infrastructure, supports voice, video and data transmission through global networks. One critical issue in its research is the challenge of meeting the demands of increasing the data capacity. This talk presents high-speed free-space and fiber optical communications using orbital-angular-momentum (OAM) multiplexing. OAM is a natural property of a beam with a helical phase, and theoretically has infinite topological charges. The multiplexing of OAM modes is independent of polarization and wavelength, which makes it have significant potential in improving the capacity of optical fiber communication systems.

First, the basics of OAM and its traditional applications will be introduced. As another newly explored dimension, spatial division multiplexing (SDM) has been demonstrated with the great potential to tremendously increase the data capacity. OAM modes with different topological charges are mutually orthogonal, so different OAM modes can provide a new degree of freedom for multiplexing technology, creating an additional set of data carriers in the SDM system. The building blocks of OAM-based SDM system will be discussed. Next, we will discuss the potential of using OAM modes for spatial multiplexing in a ring fiber. Several types of ring-core optical fibers for OAM modes will be presented, including multi-core ring fiber supporting thousands of OAM modes, coupled ring-core fiber with large negative dispersion, non-zero dispersion-shifted ring fiber to balance the chromatic dispersion and nonlinearity, graded-index ring-core fiber with high mode purity.

Session I - Biomedical Optics and Applications - 1

Polarisation Sensitive Optical Coherence Tomography to Unravel the Mechano-Structural Properties of Articular Cartilage

Frédérique Vanholsbeeck*[1,2], Matthew Goodwin[1,2], Marie Klufts[3], Joshua Workman[4] and Ashvin Thambyah[4]

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Abstract:

Slow degeneration and injury of articular cartilage result in degenerative and traumatic osteoarthritis (OA), respectively. OA affects more than 303 million people globally. With very few curative options, OA results in debilitating joint pain, significantly reducing the quality of life of anyone affected. Non-invasive determination of structural changes in articular cartilage is paramount for osteoarthritis researchers and clinicians alike as it allows them to identify, understand and evaluate articular cartilage damage that could lead to OA. Using polarization-sensitive optical coherence tomography (PS-OCT), we have investigated both OA types in the bovine and the equine models. While previous studies have shown that PS-OCT is a useful non-invasive tool for studying cartilage morphology and detecting osteoarthritic changes, it has limited ability to quantify the subtle changes in the early stages of joint degeneration. Our studies have shown the need for dynamic imaging to detect early-stage degeneration, with a particular emphasis on understanding the response of cartilage to mechanical stimuli. We have developed an innovative mechanical PS-OCT system to simultaneously compress and image soft tissue. The system enables changes in optical and mechanical properties of articular cartilage to be visualised as the tissue is compressed. For the first time, spatial changes in optical properties were measured *in situ*, revealing insights into the tissue ultrastructure and mechanisms of matrix function. Combined with the ability to extract the mechanical properties of the tissue, the imaging platform provides a convenient way to gain insights into the physiology and onset of degeneration of joint tissues.

Advances in Pre-Clinical Imaging using X-ray Absorption, Phase and Scatter Contrast

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Abstract:

X-ray imaging plays a vital role in industrial non-destructive testing, in border security, and in diagnostic imaging. X-rays provide high penetration depth and spatial resolution, and high-speed imaging at relatively low cost. However, X-rays only weakly interact with materials made from low-density materials such as biological soft tissues. Therefore, such materials can be difficult or even impossible to see with X-rays. Contrast in conventional X-ray imaging comes from absorption differences between materials. Although low-density materials only weakly absorb X-rays, they

can refract and scatter X-rays at ultra-small angles on the microradian scale. These effects can be used to produce additional contrast, namely phase contrast and dark field contrast. These effects cannot be observed with conventional X-ray imaging technology but, with the right equipment, they can massively boost image quality and provide more information about objects being imaged. This presentation will highlight some of our recent advances in X-ray phase contrast and dark field imaging. Examples include: i) that phase contrast can boost the contrast-to-noise ratio of high-resolution images by factors in the hundreds, which can enable X-ray exposures to be reduced by factors in the thousands [1], [2]; ii) that phase contrast enables material decomposition to be achieved with significantly higher fidelity than absorption contrast [3], [4] and; iii) that dark field imaging can provide quantitative information about unresolvable microstructural features even smaller than the resolution limit [5]. These techniques are already proving highly advantageous in pre-clinical studies.

Optical DNA Biosensing Methodologies for Clinical Diagnostic Applications

Ling Ling Tan[1]*, Nur-Fadhilah Mazlan[1], Nur Diyana Jamaluddin[1], Jeningsih[1], Nurul Huda Abd Karim[2], Nurul Yuziana Mohd. Yusof[3] and Bahariah Khalid[4,5]

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Abstract:

Nowadays, the demands for DNA detection have increased mainly for the understanding of various biological processes and developing biotechnological devices, due to their ultra-sensitivity and real-time detection regime compared to traditional hybridization assays that involved tagging the DNA probe with radioactive or fluorescent labels that are time-consuming and hazardous. Generally, the information on DNA hybridization can be acquired by utilizing small molecules such as drugs and ligands, that are able to bind to single-or double-stranded DNA through electrostatic interaction at various mechanisms including groove binding, alkylating and intercalating of DNA. There is an increasing demand for POC tests in many fields, including clinical analysis, food safety and environmental assessment, and many efforts have been made to develop biosensors that are of small-sized, portable, inexpensive and easy-to-operate. Optical DNA biosensors offer great advantages over conventional analytical techniques because they enable the direct and real-time detection of many biological and chemical substances. The transduction element of an optical sensor/biosensor can be the absorption, fluorescence, reflectance or some other optical transducers depending on the optical characteristic of the sensing reagent and physical properties of the immobilization matrix used. The optical biosensor can simply be transformed into a colorimetric sensor for semiquantitative visual inspection of chemical or biological substances of interest based on the colour change on the receptive layer of the biosensor. Visual detection is an increasingly attractive method and becoming more prevalent in many fields because both qualitative and semiquantitative assessments can be performed in real-time without any advanced or complicated instrumentation.

Shortwave Infrared (SWIR) Confocal Fluorescence Microscopy for in vivo Deeper Tissue Imaging with Single-Photon Superconducting Nanowire Detector

Fei Xia[1,2,3,*] , Monique Gevers[4], Andreas Fognini[5], Aaron T. Mok[3], Bo Li[3], Najva Akabri[3], Iman Esmaeil Zadeh[5,6] , Jessie Qin-Dregely[5], Chris Xu[3]

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Abstract:

We demonstrate one-photon fluorescence confocal microscopy of adult mouse brains using short-wave infrared wavelengths with penetration depths up to 1.7 mm in vivo through the entire cortical column and into the hippocampus region with a low-cost continuous-wave laser source and low excitation power. This is achieved by labeling quantum dots with 1300 nm excitation and 1700 nm emission and detecting with a customized single-photon superconducting nanowire detector. We further discussed the significance of the staining inhomogeneity in determining the depth limit of one-photon confocal fluorescence imaging and showed it approximately the same with two-photon microscopy.

Optical Fiber Sensors for Wheelchair Users Monitoring

Nélia Alberto[1*], Matilde Rocha[1], Cátia Tavares[1,2], Daniela Real[2], Hugo Silva[3], Paulo Antunes[1,2], M. Fátima Domingues[1]

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Abstract:

The World Health Organization estimates that 65 million people need a wheelchair in their daily lives due to impairments resulting from different health conditions, including diseases as cerebral palsy, spina bifida, spinal cord injury, multiple sclerosis, cardiovascular accident, and amputations. Due to the limitations caused by the lower movements' loss, and consequent dependence on the upper limbs and trunk muscular strength, many wheelchair users (WCUs) often complain of pain in the hands, wrists, elbows, and back. Another frequently problem reported by the WCUs is the appearance of pressure ulcers due to the permanent or even temporarily immobilization in the wheelchairs. In this presentation, two optical fiber Bragg grating (FBG) based sensing systems will be considered. One of them to monitor the muscle effort in WCUs, and the second to assess the pressure and temperature induced in the more prominent bone areas of the WCUs. For the first solution, several sensor-cells were distributed in the arms of WCU volunteers, who were asked to carry out a set of daily movements. The other system consists in the instrumentation of a wheelchair, for pressure and temperature monitoring, at the more prominent bone areas (scapulas, ischiatic, heels), while the users perform several pressure reliefs exercises. The

proposed monitoring systems provided encouraging results, with added knowledge regarding the movements of the WCUs' upper limbs and the pressure that critical body areas, prone to the development of pressure ulcers, are subjected. Hopefully, the retrieved information can contribute for improving the life quality of WCUs.

Session II - Nonlinear Optics and Photonics | Integrated Optics and Nanophotonics

Phase-Stable Multi-Terahertz Light Sources and Broadband Time-Domain Spectroscopy in a Yb-Based Regenerative Amplifier

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Abstract:

Recent developments of intense pulsed light sources in multi-terahertz region (10-50 THz), which lies between the terahertz and mid-infrared regions, have attracted tremendous attention for investigating ultrafast light-matter interactions and realizing ultrafast control of matter by light. In these applications, carrier-envelope phase stable pulses are important. We have developed optical parametric amplification (OPA) of phase-stable multi-terahertz pulses which can be tuned from 16.9 to 44.8 THz. The 255-fs laser output of the Yb:KGW regenerative amplifier is compressed to 11-fs pulses using a multi-plate broadening scheme, which can generate multi-terahertz pulses by intra-pulse difference frequency generation (DFG) in GaSe. The multi-terahertz pulses are further amplified by using a two-stage OPA in GaSe. Owing to the intra-pulse DFG, the long-term phase drift after the two-stage OPA is as small as 16 mrad during a 6-h operation without any active mechanical feedback. We also developed a broadband time-domain spectroscopy system in the multi-terahertz range. With pump-probe spectroscopy, we studied ultrafast dynamics of a photoexcited Dirac semimetal Cd_3As_2 thin film with 30-fs time resolution. We found that photoexcited carriers largely suppress the multi-terahertz refractive index due to the elevated plasma frequency. We also investigated the response function during under the formation of Floquet-Bloch state. Under 30-THz narrowband pump, the conductivity spectrum is dominated by stimulated Rayleigh scattering, which resonates between the Floquet subbands and is remarkably enhanced by the elevated plasma frequency.

Fully Integrated Single-Chip LiDAR for Real Time Imaging

Changbum Lee*, Dongjae Shin, Kyunghyun Son, Bongyong Jang, Hyunil Byun, Jisan Lee, Changgyun Shin, Woosung Kim, Eun Kyung Lee, Dongsik Shim, Tatsuhiro Otsuka, Inoh Hwang, Hankyu Lee, Hyuck Choo, and Kyoungho Ha

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Abstract:

A light detection and ranging (LiDAR) is a technology uses a laser beam to recognize surrounding objects. LiDAR measures the distance using time-of-flight (TOF) of light by emitting laser pulses and analyzing the reflected signals corresponding to the laser pulses. LiDAR has the advantages of being able to accurately determine the distance to a target. In addition, since LiDAR uses a laser, it is more robust to weather conditions than a camera. With the advanced sensing method, LiDAR is evaluated as a core technology for realizing self-driving vehicles. LiDAR is largely divided into two types (mechanical scanning / solid state LiDAR) according to the scanning method. Currently, most LiDAR uses rotating motors or mirrors, but it is difficult to commercialize it due to high price and form factor problems. Among solid state approaches, Si-photonic optical phased array (OPA) is attracting a lot of attention due to low-cost mass production by leveraging well-established semiconductor fabrication process. However, up to now, there has a limitation in the application of LiDAR because an external light source is required, and it shows low output power. In this work, we demonstrate the solid-state LiDAR operation based on Si photonics single-chip beam scanner using III/V semiconductor optical amplifiers (SOAs) and integrated tunable laser diode (TLD), with detection range of up to 30m, 20 fps.

Temporal Dynamics of Transient Nonlinearity in Silicon Nanostructures

Guan-Jie Huang[1]***,** Hao-Yu Cheng[2], Yu-Lung Tang[1], Hotta Ikuto[3], Junichi Takahara[3,4], Kung-Hsuan Lin[2] and Shi-Wei Chu[1,5]

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Abstract:

High-index dielectric nanostructures with diverse electric and magnetic Mie resonance modes provide efficient enhancement of optical nonlinearity, leading to an emerging field of nonlinear nano-photonics. An example is our recently discovered giant optical nonlinearity in silicon nanocuboids, where the nonlinear index n_2 is five orders larger than bulk silicon (Nat. Comm. 2020, 4101). Conventionally, optical nonlinearity is examined via intensity-scan methods such as z-scan or x-scan techniques in the spatial domain, while its temporal characterization relies on pump-probe techniques. However, most studied transient signals are instantaneous and occur within the duration of the pulses. In this work, leveraging the combination of intensity x-scan and temporal pump-probe scan, we feature unconventional temporal dynamins of transient nonlinearity in silicon nanostructures, including sub-linear, super-linear, and surprisingly full saturation, at the delay of tens of picoseconds. The key underlying principle is the fluence-dependent carrier lifetime. We exemplify transient nonlinearity in silicon nanostructures through nonlinear carrier lifetime variation based on the fluence-dependent Auger recombination process. An unexpected "crossing point" across several relaxation curves with different pump intensities is unraveled, i.e., probe scattering remains constant no matter how the pump varies, leading to various nonlinear behaviors along the temporal domain. We applied these transient nonlinearities to point spreading function engineering, demonstrating the potential of sub-diffraction microscopy. We envision that our results not only offer the general scenario of transient nonlinearity generation, but the Auger-based mechanism is also applicable to other nanomaterials, shedding light on all-optical signal processing and nano-imaging.

On-Chip Integration of 2D Materials for Active Silicon Photonics Devices

Mahmoud S. Rasras

New York University Abu Dhabi, United Arab Emirates

Abstract:

Silicon Photonics (SiPh) is a disruptive technology platform that can eliminate the bottleneck in data exchange caused by the limitations of the metal interconnects for data rates beyond 10 Gbps. On-chip optical interconnect can play a major role in future massively paralleled chip multiprocessors as it offers broader bandwidth performance compared to its electrical counterpart. This talk explores the use of atomically thin two-dimensional (2D) materials, such as graphene GeP, and GaGeTe as active components for integration in the SiPh platform. These materials have shown interesting optoelectronic properties that are advantageous for both modulation and photodetection.

Reconfigurable Nonlinear Dielectric Metasurfaces

Davide Rocco[1*], Andrea Locatelli[1], Andrea Tognazzi[2], Luca Carletti[1], Costantino De Angelis[1]

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Abstract:

Dielectric nanoantennas have recently shown huge potential for nonlinear optics. High-refractive index nano-resonators have proved efficient Second-Harmonic Generation (SHG) and Third-Harmonic Generation (THG) from an optical pump beam either at visible or NIR frequencies in the static regime. In this talk, I will focus about SHG in such structures. After a brief historical introduction of SHG in AlGaAs nanostructures, I report the new promising concept of tunability. In particular, I present two innovative approaches to modulate the nonlinear emission. Firstly, I explain the possibility to modulate the SHG by using liquid crystals and lastly, I discuss the thermo-optical modulation of the second harmonic light.

Electric- Field Induced Second Harmonic Generation in SiO_2 and TiO_2

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Abstract:

Electric-field-induced second harmonic generation (EFISH) is an important nonlinear optical process. Of particular interest is EFISH in with vanishing $\chi^{(2)}$ and non-zero $\chi^{(3)}$ offers huge potential. In this work, we have investigated SiO_2 and TiO_2 as potential EFISH materials for nonlinear optoelectronic applications using DC-electric fields. We were able to observe significant second harmonic generation (SHG) in comparison to the background SHG signal. The fundamental excitation at 800 nm results in a SHG signal at 400 nm for high applied DC electric fields, which is a clear indication for EFISH. Moreover, we will present results from numerical modeling of the nonlinear response and compare the theoretical predictions with the experiments.

Nonlinear Photonics of Interband Quantum Cascade Lasers

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Abstract:

Interband cascade lasers (ICLs) constitute a new class of semiconductor lasers allowing lasing emission in the 3– 7 µm wavelength region. Their structure presents similarities and differences with respect to both standard bipolar semiconductor lasers and quantum cascade lasers (QCLs). In contrast to QCLs, the stimulated emission of ICLs relies on the interband transition of type-II quantum wells while the carrier-to-photon lifetime ratio is similar to conventional bipolar lasers. Therefore, ICLs can be classified into Class-B laser systems like common quantum well lasers, and they exhibit a multi-GHz relaxation oscillation frequency that can be related to the maximum modulation/chaos bandwidth of these lasers. Besides, ICLs take advantage of a cascading mechanism over repeated active regions, which allows us to boost the quantum efficiency and, thus, the emitted optical power. Here, we report recent results on dynamic and nonlinear properties of ICLs. In particular, we demonstrate the generation of fully developed chaos under optical feedback. We show that ICLs exhibit peculiar intensity noise features. Together, these properties are of paramount importance for developing long-reach secure free-space communication, random bit generator, and remote chaotic LiDAR systems. Lastly, we predict that ICLs are preferable devices for generation of amplitude-noise squeezing.

Dependence of the Polaritons Dispersion and Group Velocity in a 1D Lattice of Micropores with Quantum Dots on Structural Defects Concentration and Homogeneous Deformation

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[2]Mediterranean Institute of Fundamental Physics, Italy

Abstract:

The possibility of regulating the propagation of electromagnetic excitations in a polariton structure by controlled external action (elastic deformation) or the presence of structural defects is investigated. A chain of identical micropores randomly containing two types of quantum dots was considered as a model system. Moreover, the chain is in conditions of uniaxial stress (compression or stretching) directed along the axis of the chain. With homogeneous deformation (the corresponding component of the strain tensor is ε) the position of each micropore changes. At the same time, the nearest micropores-resonators are also randomly removed from each other. By diagonalizing the averaged Hamiltonian of such a system, using the virtual crystal approximation, the law of dispersion of polariton excitations $\Omega\left(k,\{C_C,C_T\},\varepsilon\right)$ and the relation for the group velocity $V\left(\vec{k}\right)=\dfrac{\partial\Omega\left(\vec{k}\right)}{\partial\vec{k}}$ of polariton excitations propagation in the desired non-ideal

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system (see Fig.1) are obtained. Here C_C, C_T are the concentrations of structural defects associated with variations in the composition and positions of the system elements, respectively.

Of particular interest is the dependency $k(C_C, C_T)$ that follows from the condition $V_3(k, C_C, C_T) = 0$. This result is important when searching for the possibility of obtaining a Bose-Einstein polariton condensate for the wave vector values $k \neq 0$.

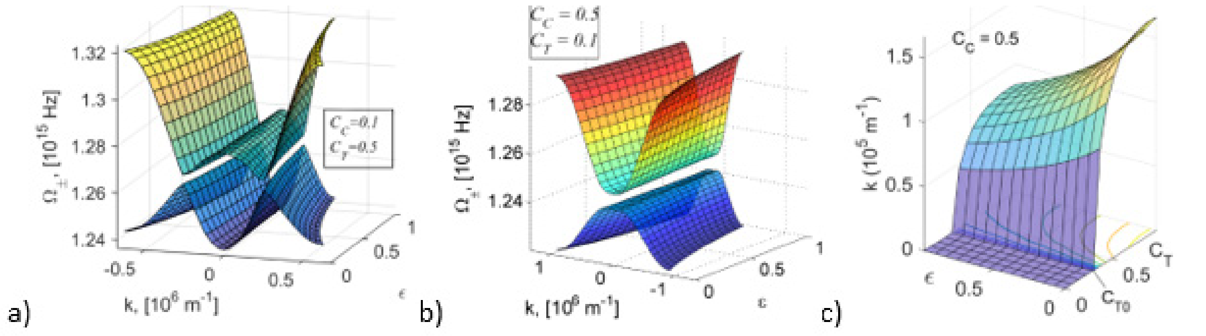

Figure 1: Dependence of the dispersion of polaritons $\Omega(k, \{C_C, C_T\}, \varepsilon)$ and $k(C_C, C_T)$ on the concentration of structural defects and the deformation parameter.

PN++ Junctions Based Plasmonic Electro-Optic Modulator

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[2]Louisiana Tech University, Department of Physics, Ruston, USA

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Abstract:

We study and present a degenerately doped $In_{0.53}Ga_{0.47}As$ PN++ junction based plasmonic electro-optic modulator, where surface plasmon polaritons (SPPs) can be exited and controlled at the metallurgical junction. For this, set of devices, are fabricated, and characterized electrically and optically. Voltage assisted optical characterization predicts far-field electron injection aided reflectivity modulation for mid-IR wavelengths. To confirm the experimental findings, numerical device characterizations using self-consistent Multiphysics electro-optic model have been performed predicting data rates up to 1Gbits/s and 3dB bandwidth as high as 2GHz. Additionally, our findings also display that decreasing the device dimensions can possibly lead to data rates more than 50Gbits/s, providing a plasmonic device architecture for high-speed control of SPPs, potentially leading to a pathway towards fast all-semiconductor based plasmotronic devices.

New Techniques for the Analysis of Complex Structured Beams

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Abstract:

General features of a structured beam can be analyzed theoretically using several approaches: geometrical optics or wave dynamics of fields at different levels of analytical or numerical approximation. Singular Optics gives relevance to local phase and intensity of a light field, and their derivatives. Caustics correspond to regions with extreme value of the intensity; on helical dislocation lines the phase is undefined, and the intensity of the field is zero. In this work, we consider complex structured beams and introduce methodologies based on those approaches. We formulate a technique that yields conditions to identify the number of waves interfering constructively/destructively at critical positions. It allows to distinguish and classify phase singularities like optical vortices and dislocations. We also study the interrelation of the morphology of caustics and the morphology of dislocation lines. An efficient methodology for identifying optical vortices, their topological charge, and the helical dislocation lines they belong to is introduced and applied. We find that non paraxial beams exhibit caustic surfaces that delimit regions with a finite volume and different intensity average. The dislocation lines play the role of an endoskeleton of the beam. The exoskeleton created in the low intensity regions shows subtle and interesting features that complement those of the endoskeleton. It is also shown that the caustics that delimit low intensity regions have a strong influence on the morphology of the exoskeleton. The techniques are exemplified for paraxial and non-paraxial Airy Symmetric 3D beams, they can be directly applied to other highly structured beams.

Large-Area Fluorescent Optical Antennas for Visible Light and Optical Wireless Communications

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[1]*European Laboratory for NonLinear Spectroscopy (LENS), University of Florence, Sesto Fiorentino, ITALY*

[2]*National Institute of Optics - CNR (CNR-INO), Sesto Fiorentino, ITALY*

Abstract:

Luminescent solar concentrators based on fluorescent materials have been extensively studied as conversion substrates for next generation solar energy harvesting devices (Wilfried et al., Opt. Express 16, 21773-21792 (2008)). Very recently, such devices have also been proposed as large-area, wide field of view optical antennas, providing a workaround to Etendue principle to realize optical receivers with GHz-class bandwidth without sacrificing the optical gain of the receiving stage (Manousiadis et al., Optica 3, 702-706 (2016)). One of the most promising avenues for exploitation of such Fluorescent Optical Antennas (FOA) is represented by the Optical wireless communication (OWC) and Visible Light Communication (VLC) sector, where ordinary LED and/

or laser sources are intensity modulated to provide for illumination along with wireless data transfer through the optical carrier. In this talk we will report on recent experimental studies exploiting novel large-area FOA substrates, based on organic (Papucci et al., J. Mater. Chem. C 9, 15608-15621 (2021)) as well as Quantum Dot fluorophores (F. Meinardi et al., Nat. Nanotechnol. 10, 878-85 (2015)), for both VLC and free-space OWC. We will report on characterization of the materials' response to external light stimuli, as well as communication tests of complete VLC/OWC systems in both indoor and realistic outdoor scenarios, for different target applications employing either colored and white LED light sources.

Twist-Optics in 1D: Moiré Effects in Silicon Photonic Nanowires

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Abstract:

Photonic moiré lattices offer an attractive platform for manipulating the flow and confinement of light from remarkably simple device geometries. This emerging field draws inspiration from the rapid research progress observed in twisted bilayer van der Waals materials or "twistronics," instead of applying moiré physics to photon propagation in wavelength-scale optical media. However, to date, only a limited number of experimental studies have been performed in this area, and there is strong interest in understanding how moiré effects can be tailored in compact and scalable optical technologies such as an integrated photonics platform. In this work, we map the moiré effects of one-dimensional (1D) photonic moiré lattices composed of width-modulated silicon nanowires, including the construction of a 1D experiment analogous to the twisting of a two-dimensional (2D) lattice. Although the twist angle $\Delta\theta$ and/or lattice mismatch $\Delta\Lambda$ are the sole defining parameters for infinite moiré crystals, we demonstrate how the crystal size, symmetry, and moiré fringe phase $\Delta\varphi$ also serve as important degrees of freedom. Through tailoring these parameters, we map a wide range of behaviors including the formation of moiré photonic crystal cavities, the onset of miniband formation and operation as a coupled resonator optical waveguide (CROW), widely tunable Q-factors and group velocities, suppression of grating sidebands, and persistent vs extinguishable tunneling. These results provide insight into the moiré physics of 1D optical systems and highlight various operating regimes relevant to the design of finite photonic moiré lattices and devices.

Session III - Biomedical Optics and Applications - 2

Three-Dimensional Quantitative OptoAcoustic Tomography for Preclinical and Clinical Applications

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Abstract:

The main clinical merit of three-dimensional (3D) optoacoustic tomography (OAT) is its potential capability to provide quantitative volumetric maps of total hemoglobin [tHb] and blood oxygen saturation [sO2]. These functional images have been the subject of extensive research for 25 years. However, only with advanced tomography system recently developed at TomoWave Laboratories we have been able to demonstrate quantitatively accurate functional optoacoustic images. The main deficiency of the past approach to quantitative OAT is the model-based computations applied to the forward problem of the optical fluence distribution through tissue without *apriori* knowledge of optical properties. The major difficulty is to learn the spatial distribution of the effective optical fluence, so that the image of absorbed optical energy can be converted into a quantitative image of the optical absorption coefficient. For the first time, we have been able to measure exponential curves of the effective optical attenuation through entire volume of interest, enabling quantitative optoacoustic tomography. However, additional signal and image processing was required to achieve quantitative accuracy: acquisition of undistorted optoacoustic signals through utilization of ultrawide band ultrasonic transducers and deconvolution of their acousto-electrical and spatial impulse responses, measurement of the 3D skin surface shell illuminated by laser pulses, acquisition of coregistered optoacoustic images at two wavelengths required to measure two unknown concentration of [Hb] and [HbO2], and calibration of coregistered images based on images of arteries with 100% blood oxygen saturation and, thus, known optical absorption coefficient at both wavelengths. While two-dimensional functional images can show improved accuracy of functional parameters using linear spectral unmixing with multiple wavelengths, only full view 3D tomographic images can accurately recover brightness of all voxels in the volume of interest. Therefore, we performed full view three-dimensional optoacoustic imaging of live animals [1] and human breast [2] to test newly developed method of quantitative OAT. In our study, we acquired *in vivo* optoacoustic signals of a live mouse at 757nm (Hb) and 1064nm (HbO2+H2O) using ultrawide-band ultrasonic transducers, and reconstructed 3D optoacoustic images incorporating transducer impulse response. Functional images of [sO2] and [tHb] were estimated from the coregistered images via the data-driven normalization of the optical fluence distribution for each wavelength. These functional images reveal high-resolution details of anatomical structures through the entire volume. Using a pair of artery and vein in close proximity to each other, we were able to perform absolute calibration of venous [sO2], which we estimated a value of 71%. Similar study was performed in a patient breast containing malignancy. The method of quantitative OAT revealed location of hypoxic cancerous tumor as well as arteries and veins in the breast. While experimental method of the optical fluence normalization through the volume of live tissues requires further refinement, the first 3D volumetric functional images of [tHB] and [sO2] shows viability of the proposed method for functional imaging in preclinical research and clinical applications.

Targeted Photodynamic Therapy for the Treatment of Metastatic Melanoma

Heidi Abrahamse

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Abstract:

Metastatic melanoma (MM) has a poor prognosis and is attributed to late diagnoses when metastases has already occurred. The standard treatments involve surgery, chemotherapy, or irradiation therapy. Photodynamic therapy (PDT) utilizes a photosensitizer (PS) that, when excited by light of a low wavelength, can be used for fluorescent non-destructive diagnosis. However, when the same PS is activated at a higher wavelength of light, it can be cytotoxic and induce tumor destruction. Metastatic Melanoma is a deadly form of skin cancer and many photodynamic therapy (PDT) studies have noted limitations in relation to effective photosensitizer (PS) drug uptake in tumors. There is a need for continued research into enhanced PS delivery via active biomarkers and passive nanoparticle systems. This should improve PS drug absorption in MM cells and increase effectiveness of combinative photodynamic methods for the enhanced diagnosis and treatment of MM can become a reality. In this study we developed a PS multicomponent nanoparticle drug conjugate carrier system which specifically targets MM cells via biomarkers to actively enhance PS delivery and so improve MM PDT. An antibody-metalated phthalocyanine-polyethylene glycol-gold nanoparticle drug conjugate, was successfully synthesized and characterized. PS active drug targeting PDT experiments at 673 nm were conducted within in vitro cultured MM. Results noted that this drug conjugate enhanced the PDT treatment of MM, through improved subcellular localization of the PS, as well as noted significantly improved cytotoxic and late apoptotic cellular death in cells. The results from this study demonstrate that through the bio-active antibody PS drug targeting of MM, the efficacy of PDT treatment for this cancer can be enhanced.

Probing Small Distances in Live Cell Imaging

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Abstract:

For probing small distances in living cells, methods of super-resolution microscopy and molecular sensing are reported. A main requirement is low light exposure to maintain cell viability and to avoid photobleaching of relevant fluorophores. From this point of view, Structured Illumination Microscopy (SIM), Axial Tomography, Total Internal Reflection Fluorescence Microscopy (TIRFM) and often a combination of these methods are used.[1,2] To show the high potential of these techniques, measurements on cell-substrate topology as well as on intracellular translocation of metabolites are described. In addition, molecular parameters can be deduced from spectral data, fluorescence lifetimes or non-radiative energy transfer (FRET) between a donor and an acceptor molecule. As an example, FRET between the epidermal growth factor receptor (EGFR) and the growth factor receptor-bound protein 2 (Grb2) is described. Since this interaction, as well as further processes of cellular signaling are sensitive to stimulation by pharmaceutical agents, methods (e.g., TIRFM) are transferred from a fluorescence microscope to a multi-well reader system for simultaneous detection of large cell populations.

Soft Optoelectronic Devices for Electrophysiology and Optophysiology

Luyao Lu

Department of Biomedical Engineering, The George Washington University, Washington, DC, USA

Abstract:

Recent advances in new materials, electronics, and assembly techniques have allowed the design and application of soft optoelectronic systems to integrate with the living organisms for a wide range of biological and biomedical applications. In this talk, I will discuss several of our recent examples of soft bioelectronic devices enabled by new concepts in materials science, micro- and nanofabrication, and electrical engineering. Those functional devices integrate transparent microelectrodes, light sources, and photodetectors in flexible or stretchable formats and allow for stable, high-fidelity, electrical, and optical mapping and modulation of cell activity (ranging from neurons to cardiomyocytes) across different spatiotemporal resolutions. We envision those materials and optoelectronic devices will open up new windows to understand important biological processes, such as studying brain/heart function, transform biology and medicine.

Photoacoustic Remote Sensing Virtual Histology

Roger James Zemp*, Nathaniel Haven, Matthew Martell, Brendon Restall, and Brendyn Cikaluk

University of Alberta, Canada

Abstract:

By accident, we recently discovered that scattered CW light is modulated when co-focused pulsed laser light is absorbed (Hajireza et al., Nature LSA, 2017). This modulation amplitude is proportional to local photoacoustic initial pressures and carries optical absorption contrast. We have been using this effect to pioneer a fundamentally new form of microscopy called photoacoustic remote sensing (PARS) microscopy, which is non-contact and reflection-mode. When using 266nm UV excitation light, strong contrast high-resolution images of cell nuclei are obtained. When combining this with UV scattering and deep learning algorithms, we have obtained images which are effectively indistinguishable from gold-standard H&E histopathology, only our approach is label-free and can be done on fresh tissue (rather than formalin-fixed paraffin-embedded tissues) in a matter of minutes. We present latest results regarding new methods for fast-scanning, cycle-consistent generative adversarial networks for realistic rendering, combination with fluorescence microscopy and optical coherence tomography, and clinical concordance testing. Our images are preferred by a panel of pathologists over frozen sections and our approach offers greater sensitivity than reported in studies performing frozen section analysis for tumor margin determination. Our approach offers great promise as a means to inspect resected tissues in cancer surgeries to inform surgeons immediately if residual tumor tissue may be remaining. This could lead to reduced numbers of repeat surgeries, improved patient prognosis and savings to the healthcare system.

The Radiation Response Measurement of a Single and Multiple Cell Ionization of Neuroblastoma Cells by Infrared Laser Trap

Mulugeta E. Goangul[1], William C. Stewart[2], Daniel Erenso[3] and **Horace T. Crogman[4]**

[1]Department of Physics2, Addis Ababa University, Addis Ababa, Ethiopia [2]Department of Biology, Middle Tennessee State University, Murfreesboro, Tennessee, 37132, USA [3]Department of Physics and Astronomy, Middle Tennessee State University, Murfreesboro, Tennessee 37132, USA [4]Department of Physics, California State University Dominguez Hills, Carson, California, 90747, USA

Abstract:

Neuroblastoma is a common type of cancer found mostly in infants and arising from the immature neural crest cells of the sympathetic nervous system. Using laser trapping technique, the present work contributes to advancing radiotherapy, a leading treatment method for cancer. A single, 2-cells, 3-cells, 4-cells, and 5-cells were trapped using the high-intensity gradient infrared laser at 1064nm and allowed to become ionized. In this work, a systematic study of Threshold Ionization Energy (TIE) and Threshold Radiation Dose (TRD) versus mass for both single and multi-cell ionization using Laser trapping techniques on neuroblastoma is presented. The results show that TIE increased as the mass of cells increased, meanwhile TRD decreased with the increase of cell mass. We observed an inverse correlation between Threshold Radiation dose and cell mass. We demonstrate how to compute the maximum radiation dosage for cell death using the laser trapping technique. Results show a possible blueprint for computing the Threshold Radiation Dose in vivo. The use of multiple cell ionization to determine radiation dosage along with better data accuracy concerning the tumor size and density will have profound implications for radiation dosimetry. The diminution in TRD becomes more significant in multiple cell ionization as we see in TRD vs. the number of cells entering the trap. This is due to the chain effect generated by radiation and the absorption by water molecules at 1064 nm. This result provides us with better insight into the optimization of the therapeutic ratio.

Plenary Session

Wave Scattering by Many Small Particles, Creating Materials with a Desired Refraction Coefficient and Other Applications

Alexander G. Ramm

Mathematics Department, Kansas State University, USA

Abstract:

The theory of wave scattering by many small impedance particles of arbitrary shapes is developed. The basic assumptions are: $a \ll d \ll \lambda$, where a is the characteristic size of particles, d is the smallest distance between the neighboring particles, λ is the wavelength. This theory allows one to give a recipe for creating materials with a desired refraction coefficient. One can create material with negative refraction: the group velocity in this material is directed opposite to the phase velocity. One can create a material with a desired wave focusing property. Quantum-mechanical scattering by many potentials with small supports is considered. The theory presented in this talk is developed in [1]-[9]. Practical realizations of this theory are discussed in [9]. In [9] the problem

of creating material with a desired refraction coefficient is discussed in the case when the material is located inside a bounded closed connected surface on which the Dirichlet boundary condition is imposed.

Polaritonic Metasurfaces

Andrea Alù

Photonics Initiative, Advanced Science Research Center, City University of New York

Physics Program, Graduate Center, City University of New York

Department of Electrical and Computer Engineering, City College of New York

85 St. Nicholas Terrace, New York, NY 10031, U.S.A.

Abstract:

In this talk, I discuss our recent efforts in the context of nano-optics and photonics, with a special emphasis on strong light-matter interactions enabled by exciton, phonon and electronic resonances in polaritonic metasurfaces. I will discuss our recent theoretical and experimental results in the context of hyperbolic polariton manipulation, valley exciton control, twisted bilayers for polariton canalization and extreme dispersion engineering and giant optical nonlinearities arising in polaritonic metasurfaces based on transition metal dichalcogenides and oxides, boron nitride, graphene and multiple quantum wells. During the talk, we will discuss the exotic light-matter interactions arising by strongly coupling material and optical resonances, stemming from the combination of material and nanophotonic engineering, and the various opportunities that these systems enable for wave physics and photonics technology.

Session IV - Holography and Fiber Devices | 2D Materials | Laser and Fiber Technologies

New Effects and Applications of the Novel Vector Optical fields Without Cylindrical Symmetry

Yue Pan[1,2,*] and Xu-Zhen Gao[1,2]

[1]*School of Physics and Physical Engineering, Qufu Normal University, Qufu 273165, China*

[2]*Shandong Provincial Key Laboratory of Laser Polarization and Information Technology, Qufu 273165, China*

Abstract:

Polarization, as an intrinsic nature of light, plays an important role in engineering the optical field and controlling the interaction of light with matter. The vector optical fields (VOFs) with inhomogeneous polarization distribution have been applied in many areas, due to the unique feature with respect to the traditional scalar optical fields. The early study of VOFs mainly focused on the VOFs with cylindrical symmetry. In recent years, novel VOFs without cylindrical symmetry have attracted significant interest. These new VOFs have not only enriched the family of the VOFs, but also provided new degrees of manipulation freedom. As a result, these VOFs have exhibited interesting properties and have been applied in many realms. In this presentation, we will present

an overview of the recently appearing VOFs without cylindrical symmetry. We mainly introduce various new VOFs we propose, including but not limited to VOFs with bipolar symmetry, VOFs with elliptic symmetry, VOFs with parabolic symmetry, VOFs with hyperbolic symmetry, fractal VOFs, uniformly elliptically-polarized VOFs, kaleidoscope-structured VOFs, ellipticity-variant VOFs, and VOFs carrying orbital angular momentum. The design scheme and experimental generation of these VOFs will be introduced, and we will present the new effects and applications of these VOFs, including tight focusing properties, propagation effects, and applications in optical micro-machining, optical manipulation, and optical information transmission.

Optical Emission and its Tunability of Two-Dimensional InSe and Related Heterostructure

Yang Li[*], Liang Zhen and Cheng-Yan Xu

School of Materials Science and Engineering, Harbin Institute of Technology, Harbin 150001, China

Abstract:

InSe possesses superior electrical and optical properties as a direct-band-gap semiconductor with high mobility from bulk to atomically thin layers, and is drastically different from transition-metal dichalcogenides, in which the direct band gap only exists at the single-layer limit. In this talk, I will introduce our results about the optical emission and its tunability of InSe and related heterostructures by geometric and heterostructure construction, strain engineering. We, for the first time, exploit strain to drastically modify the bandgap of two-dimensional (2D) InSe nanoflake. The large reversible bandgap changes of ~239 meV arises from a large bandgap change rate (bandgap strain coefficient) of fewlayer InSe in response to strain, ~154 meV/% for uniaxial tensile strain, representing the most pronounced uniaxial strain-induced bandgap strain coefficient experimentally reported in 2D materials. To overcome the disadvantage of out-of-plane dipole emission of InSe, a unique geometric ridge state of the 2D flake without compromising the sample quality was constructed, and the enhanced absorption at the ridge over a broad range of excitation frequencies from photocurrent and photoluminescence (PL) measurements. In addition, we demonstrate that the light emission of InSe can be enhanced by several times via energy funneling effect in MoS2/InSe Type-I heterostructures, which is not only significantly tuned by electrostatic gating, but also preserves efficiently upon applying a uniaxial tensile strain up to 0.52%, making it appropriate for both rigid and flexible superior optoelectronic devices.

Spatial Mode Control Based on Photonic Lantern

Lu Yao[*], Wenguang Liu, Zilun Chen, Man Jiang, Qiong Zhou, Jiangbin Zhang, Junyu Chai, Zongfu Jiang **(Invited speaker)**

College of Advanced Interdisciplinary Studies, National University of Defense Technology, China

Abstract:

We demonstrate an adaptive spatial mode control system based on photonic lantern for obtaining specific spatial modes output. Novel photonic lantern with optimized input fibers arrangements and appropriate core-to-cladding ratio with low coupling losses and low mode-dependent losses have been proposed and fabricated. Using stochastic parallel gradient descent algorithm, the phases of the inputs are actively modulated to stabilize the output of novel 5×1 photonic lantern with 30/125 µm output fiber. When the control target is the fundamental mode, the M^2 factor of output beam is below 1.2 stably, which will provide a possible technical solution to increase the mode instability threshold in large mode area fiber laser systems. Furthermore, we obtain single orbital angular momentum mode (OAM_0^1 or OAM_0^2 mode) and high order linearly polarized mode (LP_{11} or LP_{21} mode) with the purity of the corresponding modes over 0.85 by altering evaluation function, which will be of benefit in optical communication and atomic optics.

Flattop Beam Shaping Using Hybrid Gratings

Zhongsheng Zhai[1*], Qingyang Li[1], Xing Yu[1], Wang Xuanze[1], Xiong Zhi[1] and Wei Feng[1]

[1]Hubei Key Laboratory of Modern Manufacturing Quantity Engineering, School of Mechanical Engineering, Hubei University of Technology, Wuhan, Hubei 430068, China

Abstract:

After a decade of research on single pixel imaging (SPI), imaging at high pixel resolution with reasonable image quality and acceptable measurement time still poses a significant challenge. This challenge results from the fundamental trade-off between the resolution and compression ratio of the image on one side, and the limits of DMD modulation frequency and time necessary for image reconstruction on the other side. Therefore, the usually reported resolution of SPI varies between 32 × 32 and 256 × 256 pixels, falling far below the standards of classical imaging techniques. To address this challenge, we have recently proposed a sampling and reconstruction strategy, which makes it possible to obtain high-quality SPI of images with reduced field of view (FOV) at the resolution of 1024 × 768 and in which the end-to-end process of the measurement and reconstruction of the image lasts only a fraction of a second. This method uses non-adaptive, binary sampling, which may be directly implemented in real-time SPI set-ups. Moreover, the sampling is designed based on multiple partitioning of the image, which allows us to determine the actual FOV and to enhance the quality of the image in the areas with relevant content. To this end, no prior knowledge of the location or shape of the FOV is required. Images with not restricted FOV are reconstructed with less details. Fast image reconstruction is possible with our previously developed closed-form method called differential Fourier-domain regularized inversion (D-FDRI), which requires only a single matrixvector product per image reconstruction.

The Primeval Optical Evolving Matter: Optical Binding Inside and Outside the Photon Beam

Roger Bresolí-Obach[1,2*], Chih-Hao Huang[3], Boris Louis[1], Tetsuhiro Kudo[4], Rafael Camacho[5], Ivan G. Scheblykin[6], Teruki Sugiyama[3], Johan Hofkens[2], Hiroshi Masuhara[3]

[1]Institut Químic de Sarrià, Spain; [2]KU Leuven, Belgium; [3]NYCU, Taiwan; [4]Toyota Technological Institute, Japan; [5]University of Gothenburg, Sweden; [6]Lund University, Sweden.

Abstract:

Optical binding has recently gained considerable attention because it enables the light-induced assembly of many-body systems. The importance of optical binding has been proven using several

materials and optical conditions; however, this phenomenon has only been described between directly irradiated particles. Here, for the first time, we report clear evidence of optically bound gold nanoparticles outside the irradiated area. By trapping at an interface, we assemble up to three nanoparticles with a linear arrangement which fully-occupies the laser focus. This linear alignment follows the rules established for optically bound systems and can efficiently scatter the trapping light, expanding the optical potential outside the irradiated area. Indeed, the scattered light interacts with particles present outside the focus area, generating several discrete arc-shape potential wells with a half-wavelength periodicity, where the diffusing nanoparticles can be stably trapped. Those external nanoparticles show a dynamic motion inside the arc and can hop between the different arcs while keeping a correlation with the linear aligned particles. Furthermore, when there are two or more external nanoparticles at the same side, the motion of these nanoparticles is also correlated, and they maintain a specific discrete separation. We propose a new model, in which the particles are optically bound outside the focal spot by the back-scattered light and multi-channel light scattering, forming a dynamic optical binding network. The reported results pave the way for understanding the light-induced colloidal assembly, crystallization, and organization of templates for biological and colloidal sciences.

High-Resolution Single Pixel Imaging with Fourier-Domain Regularization

Anna Pastuszczak[1]*, Rafał Stojek[1,2], Piotr Wróbel[1], Rafał Kotyński[1]

[1]*University of Warsaw, Faculty of Physics, Pasteura 5, 02-093 Warsaw, Poland;*

[2]*Vigo System, Poznańska 129/133, 05-850 Ożarów Mazowiecki, Poland*

Abstract:

After a decade of research on single pixel imaging (SPI), imaging at high pixel resolution with reasonable image quality and acceptable measurement time still poses a significant challenge. This challenge results from the fundamental trade-off between the resolution and compression ratio of the image on one side, and the limits of DMD modulation frequency and time necessary for image reconstruction on the other side. Therefore, the usually reported resolution of SPI varies between 32 × 32 and 256 × 256 pixels, falling far below the standards of classical imaging techniques. To address this challenge, we have recently proposed a sampling and reconstruction strategy, which makes it possible to obtain high-quality SPI of images with reduced field of view (FOV) at the resolution of 1024 × 768 and in which the end-to-end process of the measurement and reconstruction of the image lasts only a fraction of a second. This method uses non-adaptive, binary sampling, which may be directly implemented in real-time SPI set-ups. Moreover, the sampling is designed based on multiple partitioning of the image, which allows us to determine the actual FOV and to enhance the quality of the image in the areas with relevant content. To this end, no prior knowledge of the location or shape of the FOV is required. Images with not restricted FOV are reconstructed with less details. Fast image reconstruction is possible with our previously developed closed-form method called differential Fourier-domain regularized inversion (D-FDRI), which requires only a single matrixvector product per image reconstruction.

Spectral Light- Sensitive Systems of the «CORE-SHELL» Type

O.V. Tyurin, S.O. Zhukov and O.Kh. Tadeusz*

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Abstract:

A comparative study of the spectral sensitization by dyes of a homophase microsystem (HOMS) “AgBr(I) core - AgBr shell” and a heterophase microsystem (HEMS) - “CaF_2 core - AgBr shell” by dyes was carried out in this work. For spectral sensitization, we used an anionic aggregating dye: pyridine salt of 3,3’-di-γ-sulfopropyl-9-ethyl-4,5,4’,5’-dibenzothiacarbocyanine betaine. The dye was adsorbed onto the nuclei in the form of alcohol solutions. The dye not adsorbed on the surface of the nucleus; the dye was separated by centrifugation. The cores were cubic microcrystals of AgBr(I) or CaF_2 for HOMS and HEMS, respectively. The control of the linear parameters of the nuclei was carried out by electron microscopic observations. The growth of the AgBr shell onto the cores with the dye was carried out according to the two-jet ammonia method. To prevent the formation of AgBr microcrystals in the emulsion, which are not adsorbed in the form of a continuous shell on the cores with dyes, the emulsification temperature, and the feed rates of $AgNO_3$ and KBr solutions were reduced. The control of the structure of HOMS and HEMS was carried out by electron microscopic observations. As a result of spectrosensitometric and luminescence studies (T = 77 K), it was found that of the growth of the AgBr shell during the creation of HOMS, the dye is displaced onto the outer surface of the AgBr silver halide shell. When creating HEMS, the dye remains fixed on the core and AgBr, and is not displaced onto the outer surface of the silver halide shell. It has been found that the dye fixed on the inner surface of the shell, in comparison with the dye fixed on the outer surface of the shell (the case of HOMS), expands the spectral sensitivity of the emulsion with HEMS to the long-wavelength side of the spectrum. To clarify the mechanism of spectral sensitization of HOMS and HEMS, it was suggested that the specificity of the spectral sensitization of these microsystems is determined by the electrostatic interaction of the cationic component of the core with the anionic aggregating dye. If the core contains a divalent cationic component (the case of HEMS), then the anionic dye is fixed on the inner surface of the silver halide shell. If the core contains a monovalent cationic component (the case of HOMS), then the dye is displaced onto the outer surface of the silver halide shell. A feature of the spectral sensitization of HEMS is also that, in addition to the dye fixed on the inner surface of the AgBr shell, additional spectral sensitization of HEMS by another dye adsorbed on the outer surface of the AgBr shell is possible. In the case of HOMS, the combined use of these dyes leads to desensitization of the emulsion. This makes it possible to significantly expand the range of practical applications of HEMS, for example, as we have shown, for recording three-dimensional holograms with high diffraction efficiency and angular selectivity in various spectral ranges.

Session V - Novel Development-Optical Materials and Applications

Antireflective Coating of Porous Silica without Discrete Interface

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Abstract:

We aimed to strengthen AR coating of low refractive index, by using spinodal porous films based on phase separation of sodium borosilicate glass. A glass past was applied onto silica substrates, which contained powder of the glass capable of phase separation. Then, the glass powder was melted to form a film on the substrate at 900 to 1000℃ and allowed to phase separate at 600℃. Finally, the coating film was etched to a porous state. By this method, antireflection property as low as 0.5% in reflection was achieved, where a graded region formed at interface with the substrate. As to the mechanism of the optical properties, simulations based on a 3-layer model was carried out, into which the graded layer was incorporated. Furthermore, the mutual coherence degree between reflections from surface was proposed for the first time to interpret the spectra. As to the surface properties of porous structures, the coating film was investigated for the application of dust proof. In the present presentation, our approaches towards the fundamental properties of both the antireflection and the dust proof will be reviewed. In addition, we want to present how the spinodal structures could be analyzed based on SEM micrographs, which was motivated initially from the point of view of the dust proof.

Liquid Crystal Photo Aligning and Photopatterning by Nanosize Azodye Layers: Bright Future

Vladimir G. Chigrinov

Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

Department of Theoretical Physics, Moscow Region State University, 141014 Mytishi, Russia

Nanjing Jingcui Optical Technology Co., LTD, Nanjing, China

Abstract:

Photoalignment and photopatterning has been proposed and studied for a long time [1]. Light is responsible for the delivery of energy as well as phase and polarization information to materials systems. It was shown that photoalignment liquid crystals by azodye nanolayers could provide high quality alignment of molecules in a liquid crystal (LC) cell. Over the past years, a lot of improvements and variations of the photoalignment and photopatterning technology has been made for photonics applications. In particular, the application of this technology to active optical elements in optical signal processing and communications is currently a hot topic in photonics research [2]. Sensors of external electric field, pressure and water and air velocity based on liquid crystal photonics devices can be very helpful for the indicators of the climate change.

We will demonstrate a physical model of photoalignment and photopatterning based on rotational diffusion in solid azodye nanolayers. We will also highlight the new applications of

photoalignment and photopatterning in display and photonics such as: (i) fast high resolution LC display devices, such as field sequential color ferroelectric LCD; (ii) LC sensors; (iii) LC lenses; (iv) LC E-paper devices, including electrically and optically rewritable LC E-paper; (v) photo induced semiconductor quantum rods alignment for new LC display applications; (vi)100% polarizers based on photoalignment; (vii) LC smart windows based on photopatterned diffraction structures; (vii) LC antenna elements with a voltage controllable frequency.

Effects of Different Material and Morphology Coupling Elements on Rolling Fatigue Wear of 20CrMnTi Steel

Peng Zhang[1,2], Xiuyun Pang[1,2*], Siyang Wang[1,2]

[1]*Key Laboratory of Automobile Materials (Jilin University), Ministry of Education*

[2]*School of Material Science and Engineering, Jilin University, Changchun 130025, PR China*

Abstract:

20CrMnTi steel is widely used in automobile transmission parts because of its good toughness. In order to improve its wear resistance, carburization is generally used to increase its surface hardness. However, the surface after carburizing tends to form a hard coating and a soft core, and fatigue cracks are prone to occur at the junction. Combined with the bionic coupling theory, we used laser to prepare a non-uniform surface in hardness on 20CrMnTi. Five different hardness of hard units (HU) were fabricated in this study using laser remelting, laser carburizing, and laser cladding. Through the rolling fatigue wear tests and FEA, the best hard units and shape were selected. The results showed that the rolling fatigue resistance of 20CrMnTi improved in different degrees after laser. Besides, the binding and dissolution of the cladding particles should be considered. and the best HU distribution should be selected through different bionic structures including spot, strictures and net. It was found that HU with the distribution density similar to the grinding roller prepared by laser cladding SiC (Msic) performed best in wear. In this paper the distribution was reticulate pattern of 5mm*4mm.The weight loss of the bionic specimen with Msic is 10.2% of that of the blank sample, and 57.3% of that of the carburized specimen. Furthermore, this laser treatment process can to some extent substitute for the conventional carburizing heat treatment process.

Plasmonic Optical Fiber-Based Tactile Sensor for Health Monitoring and Artificial Haptic Perception

Jingjing Guo[*] and Ce Shang

School of Instrumentation and Optoelectronic Engineering, Beihang University, Beijing 100191, China

Abstract:

Tactile sensors capable of quantifying mechanical stimuli through physical contact play a pivotal role in healthcare, prosthetics, and humanoid robotics. To enable conformal contact with objects of different surface morphologies, tactile sensors with high mechanical flexibility have been extensively explored. Despite recent advances, most of the currently available flexible tactile sensors are based on electrical properties of functional materials, which often suffer from intrinsic limitations such as hysteresis, parasitic effects, signal crosstalk, and electromagnetic interference. In this work, we present a flexible optical tactile sensor by harnessing the unique optical properties of a soft and plasmonic optical fiber, which is made from composites of gold nanoparticles (GNPs) and elastomers. The tactile sensor is constructed by assembling the nanocomposite fiber in a sandwich structure, where sensitive and instantaneous sensing of contact force with high precision, low hysteresis, and tunable sensitivity is achieved by transducing mechanical stimuli into interpretable light signals. As demonstrations of its potential, the tactile sensor is utilized for real-time monitoring of blood pressure, respiration, as well as providing tactile mapping of hand motions such as tapping, shaking, and grasping. To further verify the feasibility of mimicking tactile perception of human skin, the proposed sensors integrated onto a robot hand are also demonstrated to perceive material hardness, surface roughness and shape of objects.

Optical Thermal Sensing Mechanisms in Rare Earth Activated Aurivilliu's Family Compound

Pavani Krishnapuram*, A.J. Neves, M.J. Soares, M.P.F. Graça, Suresh Kumar Jakka

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Abstract:

Optical thermal sensing is one such kind of applications with modern light-based application apart from direct display applications such as phosphors, scintillators, photocatalysis and others. Luminescence based thermometry has an enormous potential not only in in vitro and in vivo bio-imaging and medical treatment but also in the fields of temperature distribution and maintenance in vast surface areas such as electronics, aviation, space research etc., Several methods of optical temperature sensing were established in the recent years and vast research has been done on each of them. It has been proved that a single material could be used for thermal sensing through various methods. The requirements of optimized luminescent thermometers are their thermal sensitivity in the range of temperatures to be examined besides their accuracy, repeatability, and stability of the material in the ambiance of measurement. Hence, few phosphors with good sensitivities are not enough for the entire ranges and applications. Wide range of phosphors with varied physical, chemical, and even mechanical properties with excellent sensitivities in defined range of temperatures are very much needed. The presentation describes different approaches in sensing temperature via non-contact approach using diverse optical thermal sensing behaviour of $Er^{3+}/Yb^{3+}/Tm^{3+}$ co/tri-doped thermally stable compounds of Aurivillius family, bismuth lanthanum tungstate (BLW) phosphor. Three methods of thermal sensing, namely fluorescence intensity ratio (FIR) based on thermally coupled levels (TCL) and thermally non-coupled levels (NTCL) in the visible upconversion were discussed by comparing the sensitivities of each of the method based on theoretical interpretation of the results.

Two-Dimensional Perovskites with Alternating Cations in the Interlayer Space for Stable Light-Emitting Diodes

Bapi Pradhan[1]* and Yiyue Zhang[1], Elke Debroye[1], Weiming Qiu[1,2], Johan Hofkens[1,3]

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Abstract:

Lead halide perovskites have attracted tremendous attention in photovoltaics due to their impressive optoelectronic properties. However, the poor stability of perovskite-based devices remains a bottleneck for further commercial development. Two-dimensional perovskites have great potential in optoelectronic devices, as they are much more stable than their three-dimensional counterparts and rapidly catching up in performance. Herein, we demonstrate high-quality two-dimensional novel perovskite thin films with alternating cations in the interlayer space. This innovative perovskite provides highly stable semiconductor thin films for efficient near-infrared light-emitting diodes (LEDs). Highly efficient LEDs with tunable emission wavelengths from 680 to 770 nm along with excellent operational stability are demonstrated by varying the thickness of the interlayer spacer cation. Furthermore, the best-performing device exhibits an external quantum efficiency of 3.4% at a high current density (J) of 249 mA/cm2 and remains above 2.5% for a J up to 720 mA cm−2, leading to a high radiance of 77.5 W/Sr m2 when driven at 6 V. The same device also shows impressive operational stability, retaining almost 80% of its initial performance after operating at 20 mA/cm2 for 350 min. This work provides fundamental evidence that this novel alternating interlayer cation 2D perovskite can be a promising and stable photonic emitter.

Session VI - Multidimensional Applications of Photonics, Optics and Lasers | Optical Design and Instrumentation

Detection of Low-Frequency Underwater Sound by Self-Interference of a Reflection Laser Beam

Yang Miao

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Abstract:

A simple and non-invasive optical technique, based on laser beam self-interference, to detect low frequency underwater acoustic signal was demonstrated. Clear self-interference fringes of a laser beam reflected from the surface capillary wave transformed from low frequency underwater acoustic signal by a cylinder were observed. The fringe distribution is in contrary with the usual and the farther the interference fringe is from the center, the stronger its intensity. By analyzing the fringe region and the fringe interval, the frequency of underwater acoustic signal and its relative amplitude were measured. A model based on physical optics modified the fringe distribution function and the theoretical fit with modified function is in good agreement with experimental observation.

Research and Application of Digital Image Correlation Measurement Method in Complex Thermo-Mechanical Coupling Deformation Measurement

Xiang Guo

School of Aeronautics, Northwestern Polytechnical University, China

Abstract:

Complex thermal-mechanical coupling deformation is inevitable in the operation of materials and structures. This presentation presents some novel methods of measuring thermal-mechanical coupling deformation. For the mechanical performance of ablation materials across the ablation process, an acquirement method was designed to require the speckle feature image during the ablation process. A corresponding matching and parameter model was proposed between the feature changed speckle feature and the initial speckle feature. Furthermore, a calibration method was designed to be utilized in the synchronous calibration of both the infrared and visible cameras, and a matching method of the infrared image and the visible image was proposed. The proposed method can provide technical support for studying the thermal-mechanical coupling deformation of materials and structures.

Snapshot Imaging Spectropolarimetry based on RGB Polarization Imaging

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Abstract:

Imaging spectropolarimetry (ISP) is an emerging sensing method that acquire both the spectral and polarization information of an object. Most of the existing ISP imaging systems require devices for spectral and polarization modulation, making the system complex and expensive, and sacrifice spatial or temporal resolution. Here, a snapshot ISP is developed based on deep learning and polarization camera. The spectral and polarization images are reconstructed from an RGB polarization demosaicked image taken by the RGB polarization camera by a hybrid network which is composed by polarization demosaicking and hyperspectral recovery. The feasibility is verified by the simulation and experiment result. The proposed snapshot imaging system is low cost and suitable for both the static and dynamic object detection.

Near Field Magneto-Optical Binding

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Abstract:

In this work we show analytically and numerically the formation of a near-field stable optical binding between two identical plasmonic particles, induced by an incident plane wave. The equilibrium binding distance is controlled by the angle between the polarization plane of the incoming field and the dimer axis, for which we have calculated an explicit formula. We have found that the condition to achieve stable binding depends on the particle's dielectric function and happens near the frequency of the dipole plasmonic resonance. The binding stiffness of this stable attaching interaction is four orders of magnitude larger than the usual far-field optical binding and is formed orthogonally to the propagation direction of the incident beam (transverse binding). The binding distance can be further manipulated considering the magneto-optical effect and an equation relating the desired equilibrium distance with the required external magnetic field is obtained. Finally, the effect induced by the proposed binding method is tested using molecular dynamics simulations. Our study paves the way to achieve complete control of near-field binding forces between plasmonic nanoparticles.

Physical Nature of the Abraham forces

Vladimir Torchigin

Institute of Informatics Problems, Federal Research Center "Computer Science and Control" of the Russian Academy of Sciences, Russia

Abstract:

Currently, there is no generally accepted idea of the forces that arise in a homogeneous optical medium where a light wave propagates. At the beginning of the century, Abraham put forward the idea that the momentum of light in an optical medium decrease by a factor of n, where n is the refractive index of the optical medium, but the propagating of light is accompanied by an appearance of forces, which now are called the forces of Abraham. On the contrary, Minkowski believed that the refractive index increases by a factor of n. At present, there is no generally accepted idea of the magnitude of the momentum of light in an optical medium. On the basis of the thought experiments carried out in 2014-2021, we have shown that from the generally accepted laws of physics and optics it unequivocally follows that the momentum of light in an optical medium increase by a factor of n. At the same time, we showed that the Abraham forces also exist. Thus, in the dispute between Abraham and Minkowski neither one nor the other is right. The magnitude and physical nature of the Abraham forces in the field of an electromagnetic wave were clarified. Moreover, it turned out that the Abraham forces are also excited during the propagation of waves of a different physical nature, in particular, ultrasonic waves in air. For this case, there is experimental confirmation of the existence of Abraham forces.

Experimental Evidence of the Quasi- Universality in the Forward Light Scattering Lobe for the Micrometric Objects

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Abstract:

A quasi-universality property of Mie scattering was evidenced in recent publications by C.M. Sorensen [1], where the authors represent the forward scattered intensity normalized by the differential Rayleigh cross section, as a function of the coupling parameter. Here we provide the first clear experimental evidence of this result thanks to the recently introduced Single Particle and Scattering method. It allows a multiparametric characterization of single scatterers [3] through a self-referenced interferometric measurement of the field amplitude rigorously at zero angle, that is in the forward scattering lobe. Thus, the Sorensen plots are produced without any free parameter for pure water droplets suspended in air and oil-in-water emulsions [4]. Furthermore, we find that the same plots realized with the experimental results obtained from non-spherical objects appreciably deviate from the quasi-universality behavior observed for spheres, as inferred by Sorensen and coworkers [5]. Notably, the larger discrepancies occur in the wavelength-scale size range. The use of these plots can widen the field of particle diagnostics in the critical micrometric size range.

Experimental Wavefront Reconstruction of a Gaussian Beam Propagating Through Optical Turbulence

Eduardo Fabián Peters Rodríguez*, Marco Sepúlveda[2], Pablo Scherz[2], Leandro Nuñez[2], and Darío G. Pérez[2]

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Abstract:

Atmospheric turbulence induces distortions in an optical beam propagating through it, resulting in beam spreading, beam wandering and irradiance fluctuations (among other effects). Due to the dynamic nature of these effects, the experimental wavefront reconstruction of a perturbed beam presents a great challenge. Interferometric wavefront reconstruction techniques require very sophisticated assemblies that make them prone to alignment errors due to their high sensitivity to environmental disturbances. This hinders its experimental implementation. New phase retrieval methods overcome most of the limitations of the interferometry-based ones; are suitable for amplitude or phase objects (or both) and their reconstruction algorithm based on propagation equations does not require a priori knowledge of the beam to be reconstructed. We propose an experimental implementation of a phase retrieval technique for the characterization of Gaussian optical beams through turbulence. This technique is based on binary amplitude modulation that has proven to be suitable for dynamic applications using a digital micromirror device (DMD). To our knowledge, this is the first experimental high-speed complex wavefront reconstruction of optical beams—by binary amplitude modulation—through controlled real turbulence. This experiment represents the first step in our research focused on understanding optical turbulence from an experimental point of view.

Estimating Uncertainty for the Instrument Transfer Function Measurement of 3D Scanners

Swati Jain[1]* and Angela D. Allen[2]

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Abstract:

Spatial resolution is an important aspect of many optical instruments. It is defined as the ability of surface-topography measuring instruments to distinguish closely spaced surface features. Following convention, spatial resolution can be defined as the spatial frequency response of the instrument, known as the instrument transfer function (ITF). In this paper, we describe the step-artifact approach for estimating the ITF for 3D scanners, discuss step-artifact characterization and validation approaches, and present a method to estimate the combined uncertainty of the ITF measurement. The approach is demonstrated using the EinScan-Pro 3D scanner. A step artifact is used for the measurement that takes advantage of the cleaving properties of a single-side polished silicon wafer. The uncertainty analysis includes simulations to estimate the contribution due to influencing factors such as the alignment of the step artifact to the measurement axis, the diffuse vs. specular scattering properties of the step edge, and various processing parameter choices.

Near and Mid-Infrared Optical Anisotropy of $ZnGeP_2$ Crystals

Gennady Medvedkin*

General Molded Glass, USA

Abstract:

Polarized optical spectroscopy has been applied in the range of 0.65–3.0 µm to probe undoped $ZnGeP_2$ crystals for intrinsic point defects that affect the crystal perfection. An increased linear optical dichroism up to 70% is achieved due to rearrangement of deep levels after low-temperature annealing (LTA). Zinc vacancies among other defects (phosphorus vacancies, cationic antisites) make the main contribution to the local structure transformation. Optical dichroism was compared in two modes: linear and nonlinear using the available data previously published. A surprising fact is that the amplitude of optical dichroism at the deep acceptor V_{Zn} exceeds the maximum photopleochroism ~55% for direct optical transitions in $ZnGeP_2$. Structural improvement based on the distorted tetrahedron model is discussed.

Multi-Image Generation Via Aperture Stop Exploitation

Aaron J. Pung[1]*

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Abstract:

Conventional digital cameras utilize an optical lens column to capture, transport, and focus light from a scene onto a CMOS or CCD sensor. In color detectors, the pixels are often arranged

in a three-color Bayer pattern; light absorbed by the red, green, and blue pixels undergoes a demosaicing process to produce the final image. In turn, objects and materials within the image can be identified and separated during post-processing. In an effort to enhance the camera's capabilities, spectral and polarimetric filters can placed within the optical system as a divided aperture or divided focal plane. After properly calibrating and demosaicing the data, the user is able to reconstruct multiple monochromatic and polarimetric snapshots of the scene. Since any filter placed along the optical axis imposes its functionality on the resulting image, however, this approach is not ideal. Alternatively, other image splitting techniques such as prisms, X-cubes, compound optics, and beam splitters also accomplish scene division, but ultimately result in images with reduced information (spectral, polarimetric, or intensity content) or resolution. In this study, a novel image-splitting technique is explored. Numerically validated with Zemax, the approach places a reflective component along the optical axis such that properties of the aperture stop may be exploited. In doing so, the incident scene is split into three independent spatially separated images wherein each image contains the full scene with all of its spectral, polarimetric, and relative intensity information. In turn, each of the multiple images can be independently filtered, processed, and recorded.

35-W Highly Effective Ytterbium-Erbium-Thulium Tandem All-Fiber 1.94-µm Laser System at 975-nm Diode Pumping

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Abstract:

Here we report one of a promising in this sense solution, viz. a compact and easily implementable laser system based on Ytterbium-Erbium doped fiber (YEDF) and TDF, used in tandem. The system is pumped by a set of four 30-W laser diodes (LD) operating at 975 nm (common at the market and so easily repairable), in-stack controlled by a single current driver. Pump power is launched into the YEDF pieces through commercial fibered pump combiners. The YEDF / TDF laser system is itself composed of two parts: the first comprising a master oscillator and amplifier at 1567 nm, both based on YEDF and pumped by the LDs, and the second being a TDF laser at 1947 nm; the latter is directly in-core pumped by the former. The YEDF and TDF employed are both home-made fibers, having core diameter of 10 µm and NA=0.17. The laser wavelengths of the two parts of the system (1567 nm / 1947 nm) are established by couples of suitable fiber Bragg gratings (FBGs) – highly-reflective (HR, >25 dB) and lowly-reflective (LR, ~1 dB) – which form the corresponding Fabry-Perot cavities. The laser scheme was implemented as the result of optimization, including fine adjustment of the FBGs' reflection coefficients and the lengths of the active fibers; particularly, it was found that the optimal length of YEDF-stages for both the master oscillator and amplifier is ~7 m while that for the TDF laser is ~5 m. The basic results obtained using this scheme are listed as follows. At maximal 975-nm launched pump power, output powers at 1567 nm are respectively ~20 W (the master oscillator's stage, two LDs used) and ~43 W (the amplifier's stage, four LDs used), which corresponds to overall efficiency of 35% in both circumstances. Accordingly, maximal output power at 1947 nm (the TDF laser stage) is ~35 W, corresponding to ~80% efficiency with respect to the launched (by the YEDF amplifier) power at 1567 nm and overall (vs. total power delivered from four 975-nm LDs) efficiency of ~30%. The

laser regime established in the YEDF / TDF scheme is purely continuous-wave oscillation without any trend to self-pulsation. Optical bandwidth of 1.94-µm laser generation does not exceed 1.5 nm (at maximal power). The realized laser system is extremely simple in assembling and lacks any additional intra- or inter-cavity elements, which is advantageous in the sense of robustness and potential commercialization.

Assessment of the Exposure to VIS and IR Incoherent Optical Radiation According to ICNIRP 2013

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Central Institute for Labour Protection – National Research Institute, Warsaw Poland

Abstract:

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has revised its risk assessment criteria concerning exposure to optical incoherent radiation in visible (VIS) and infrared (IR) spectral range (Health Physics 105(1): 74-96, 2013). Differences between the new criteria and the current criteria of EU Directive 2006/25/WE (following 1997 Guideline of ICNIRP) concern photochemical and thermal hazards of the eye. The aim of this study is to present measurement results and relevant assessment analysis performed for several artificial light sources by using both systems, and to show practical effects of using the revised ICNIRP requirements. The analysis was carried out on such devices as AR glasses handling station Epson BT35E, VR goggles service station Oculus Rift (in both cases with one screen tested), and an electric arc of a manual metal arc welding station. The time of exposure to the optical radiation was assumed to be in line with the real usage time of each of the tested devices. The measurement methods used in the study involve revised values of the limit angles that specify small and large sources of optical radiation. On the basis of the measurement results, it has been shown that the Exposure Limit values for VIS and IR optical radiation determined by using the current and revised ICNIRP criteria may differ significantly. This includes photochemical and thermal hazard of the retina, where multifold differences can be observed. The study confirms a suggestion that the Directive 2006/25/WE should be updated according to the new ICNIRP guidelines.

Keynotes Session

Photovoltaics as Key Pillar of our Future Energy System: Technology, Manufacturing, and Markets

Eicke R. Weber

European Solar Manufacturing Council ESMC

Former Director, Fraunhofer Institute for Solar Energy Systems, Freiburg

Abstract:

The urgency to transform our global energy system as soon as possible towards 100% renewable

energy (RE) is getting more and more attention, especially in view of the yearly increasing weather phenomena ascribed to global climate change, and the recent war in Ukraine that demonstrated the need for secure renewable energy supply. Numerous studies of a world supplied with 100% RE show that harvesting solar energy, together with wind power, will be the main pillars of our future, sustainable energy system. For a world of near-100% RE we will need about 50-70 Terawatt of installed PV power, up from 1 TW that we achieved just recently. Fortunately, PV technology is still undergoing rapid progress towards higher efficiencies at lower cost. We will discuss the current and emerging PV technology generations, that are today 95% based on crystalline-Si technologies, and the growing markets for PV cells and modules. An important issue will be our efforts to re-start photovoltaic manufacturing in Europe along the full value chain.

3D Nanophotonic-electronic Integrated Circuits for Future Computing, Networking, and Imaging Systems with Self-Learning Capabilities

S. J. Ben Yoo*, David Mansom[1]*, John Smith[2], Fred Cox[3]

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Abstract:

We discuss a new neuromorphic computing paradigm enabled by embedded attojoule silicon-photonic nanophotonics. We will discuss attojoule nanophotonic spiking neurons designed based on bioderived principle and following Izhikevich's formalism to create an artificial optoelectronic neuron that imitates the behaviors of biological neurons. We theoretically design, prototype an artificial neuron, and experimentally demonstrate a prototype. Furthermore, we design 45 nm foundry-realizable optoelectronic neurons, and persue nanoscale neurons with extreme energy efficiency. We will then construct a scalable photonic neural network consisting of nanophotonic synapses and nanoscale optoelectronic neurons. Scalability of the proposed neural network is accomplished by photonic tensor core decomposition and by realizing 3D nanophotonic-nanoelectronic integrated circuits. Benchmarking of the brain-derived neuromorphic computing examining energy-efficiency, throughput, and accuracy will also be discussed.

Nanoscale 3D Printing of Functional Structures

Yong Feng Lu[*,1], Ying Liu[1], Wei Xiong[1], Peixun Fan[1], Aofei Mao[1] and Jean-François Silvain[2]

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Abstract:

Three-dimensional (3D) electrically conductive micro/nanostructures are now a key component in a broad range of research and industry fields. Direct laser writing by two-photon polymerization (TPP) has been established as one of the most promising methods for achieving 3D fabrication

in micro/nanoscales, due to its ability to produce arbitrary and complex 3D structures with sub wavelength resolution. However, the lack of TPP-compatible and functional materials represents a significant barrier to realizing the functionality of the fabricated devices, such as high electrical conductivity, high environmental sensitivity, and high mechanical strength, etc. In this work, a novel method was developed to realize metallic 3D micro/nanostructures with silver-thiol-acrylate composites via TPP followed by femtosecond laser nanojoining. Complex 3D micro/nanoscale conductive structures have been successfully fabricated with ~200 nm resolution. The loading of silver nanowires (AgNWs) and joining of junctions successfully enhanced the electrical conductivity of the composites from insulating to 92.9 S m-1 at room temperature. Moreover, for the first time, a reversible switching to a higher conductivity was observed, up to ~103-105 S m-1 at 523 K. The temperature-dependent conductivity of the composite was analyzed using the variable range hopping and thermal activation models. The as-developed nanomaterial assembly and joining method in this study paves a way toward a wide range of device applications, including 3D electronics, sensors, memristors, micro/nanoelectromechanical systems (MEMS/NEMS), and biomedical devices, etc.

Photonics ASICs for Machine Intelligence

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Abstract:

With an ongoing trend in computing hardware towards increased heterogeneity, domain-specific coprocessors are emerging as alternatives to centralized paradigms. The tensor core unit has shown to outperform graphic processing units by almost 3-orders of magnitude enabled by higher signal throughout and energy efficiency. In this context, photons bear several synergistic physical properties while phasechange materials allow for local nonvolatile mnemonic functionality in these emerging distributed non vonNeumann architectures. While several photonic neural network designs have been explored, a photonic tensor core to perform matrix vector multiplication and summation is yet to be implemented. In this talk I will introduce an integrated photonics-based tensor core unit by strategically utilizing i) photonic parallelism via wavelength division multiplexing, ii) high 2 Peta-operations-per second throughputs enabled by 10's of picosecond-short delays from optoelectronics and compact photonic integrated circuitry, and iii) near-zero static power-consuming novel photonic multi-state memories based on phase-change materials featuring vanishing losses in the amorphous state [Sorger Group, Appl. Phys. Rev. 2020]. Combining these physical synergies of material, function, and system, we show, supported by numerical simulations, that the performance of this 4-bit photonic tensor core unit can be one order of magnitude higher for electrical data, whilst the full potential of this photonic tensor processor is delivered for optical data being processed, where we find a 2-3 orders higher performance (operations per joule) as compared to an electrical tensor core unit whilst featuring similar chip areas. This work shows that photonic specialized processors have the potential to augment electronic systems and may perform exceptionally well in network-edge devices in the looming 5G networks and beyond.

Session VII - Photonics for Energy and Green Technologies | Metamaterials and Metasurfaces | Optical Fibers and Sensing Technologies

Response of Natural Mineral Muscovite to fs Laser Pulse

Deb Kane[1*], Saurabh Awasthi[1,2], Alex Fuerbach[1] and Doug Little[1]

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[2]Dept. of Mechanical Engineering, University of Connecticut (UCONN), Storrs, USA

Abstract:

We initiated fs laser pulse processing studies on natural mineral mica (muscovite) substrates to research making fiducial marks for sample registration in nanotechnology and nanoscience applications. Further to this, laser processing of muscovite can be enabling for new and improved use in its many roles in capacitors, resistors, insulators, high-voltage and lithium batteries, sensors, displays, LEDs, and other consumer and specialist photonic and electronic systems and devices. We anticipated muscovite would be, largely, similar to glasses and transparent crystalline materials such as quartz in fs laser processing. It is not. Novel laser processing outcomes are found (Appl. Surf. Sci. 513, 145702 (2020); Opt. Laser Technol. 135, 1-5, 106641 (2021)). Key differences of muscovite compared to standard optical materials that lead to this are: (i) its nanolayered structure; (ii) the impact of mineral water; and (iii) natural variations in the standard chemical composition (KAl2(Si3Al)O10(OH)2). In characterizing the muscovite/ fs-laser-pulse interaction we have demonstrated the use of optical surface profiling to complete micro-volumetric analysis of the topography of the fs laser pulse processed sites (Opt. Laser Technol. 140 (6), 106997 (2021)) to give insight into viscoelastic deformation and ejection that can be frozen when resolidifiication occurs. Also, time of flight secondary ion mass spectroscopy (ToF-SIMS) has been explored for its suitability to show changes in chemical composition (Appl. Surf. Sci. 581, 151746 (2022)). An overview of muscovite fs laser processing to date will be presented.

Metalens Enabled High-Resolution Terahertz Holographic Images

Ruoxing Wang[1] and **Li Li**[2*]

[1]Department of Mathematics and Physics, North China Electric Power University, Baoding, 071003, China; [2]Key Laboratory of In-Fiber Integrated Optics of Ministry of Education, College of Physics and Optoelectronic Engineering, Harbin Engineering University, Harbin, 150001, China

Abstract:

Terahertz (THz) holography can enable a THz wavefront to be recorded and reconstructed. It is of great significance in the application of THz communication and information storage. Metasurfaces have shown much promise in the arbitrary manipulation of amplitude, phase, and polarization of electromagnetic waves, making them suitable for the development of THz holograms. However, most metasurface-based THz holograms are limited by optimization algorithms and sample

size, suffering from low resolution and no grayscale information. Here, we will report our recent progress on the metalenses and THz holograms and introduce a new method for reconstructing high-resolution THz holograms with full grayscale information using metalenses. By designing a THz metalens to generate high density foci with customized polarization profile as the pixels of target image, a high-resolution THz hologram with full grayscale information can be reconstructed on the focal plane of metalens, which has potential application prospects in THz communication, information security and anti-counterfeiting.

Active Phase-Change Metagrating for Amplitude-Only Modulation Based on VO_2

Sun-Je Kim*

Myongji University, South Korea

Abstract:

In this talk, our recent studies on the active optical metasurfaces operating in the visible and near-infrared bands are introduced and summarized thoroughly. As the main ingredients as the active optical material, in our works, thermal phase-change material, vanadium dioxide is chosen and studied at the optical wavelengths. The key idea and novelty of the studies lie in the fine understanding on the optical properties of the materials, and design & application of the proper optical resonances, such as thin film, plasmonic, Mie, hybrid Mie-plasmonic, waveguiding, and Fano type resonances, for the certain multi-objective modulation goals. Our work is mainly focused on the development of practical active modulation methods of amplitude of light propagating in the free space using the active metasurfaces with the subwavelength and near wavelength period.

Nanostructures and Metasurfaces for Light Management in Solar Cells

Braulio Garcia-Camara*, Lorena Escandell, Eduardo Lopez-Fraguas, Ricardo Vergaz, Jose Manuel Sanchez-Pena

Groups of Displays and Photonic Applications. Carlos III University of Madrid, Spain.

Abstract:

Photovoltaics is considered one of the most promising renewable sources. Consequently, researchers are trying to improve the solar cell performance, and in particular their efficiency, during years. Material engineering, optics or electrical engineering are only a few of the disciplines involved in this multidisciplinary challenge. The recent results obtained using perovskites as active materials are quite promising to obtain a new step forward the final target, even surpassing the Shockley-Quessier limit. Besides this, we are still far from the final step and further efforts are still required. In this sense, optics and photonics are proposing novel light management techniques to improve the absorption in the active layer by manipulating the optical path, reducing reflectance or guiding the light through the solar device. Among others.

Resonant dielectric nanostructures and/or resonant metasurfaces are promising alternative because of their capabilities to confine, direct or guide light and also their relatively easy integration in these devices. This talk will summarize some of our last proposals to improve

the optical performance of solar cells, either silicon, perovskite or III-V devices. We numerically design different kind of ordered nanostructures with the aim of efficiently controlling the light distribution along the different layers of the solar cell, increasing its absorption of the active material and reducing the total reflection.

Broadband High-Efficiency Achromatic Meta-Device Based on Phase and Dispersion Independently Controlled Metasurface

Wenye Ji* and Paul Urbach

Faculty of Applied Science, Delft University of Technology, Delft, The Netherlands

Abstract:

Achromatic devices have wide application prospect in radar or fields. However, chromatic aberration and limited bandwidth restrict their development. In this paper, we achieve broadband high-efficiency transmission achromatism based on metasurface. In order to verify the theory and design method, we design an achromatic anomalous deflector and fabricate the sample. The experimental results are in good agreement with theory. Our findings provide valuable theory and strategy for achromatic device design.

3D Printed Metaparticle Scatterers Based on the Platonic Solids

Alexander W Powell*, James R Capers, Simon A.R. Horsley, J. Roy Sambles, Alastair P. Hibbins

University of Exeter, United Kingdom

Abstract:

Here we demonstrate powerful, broadband, scatterers in the form of textured spheres with symmetries based around the platonic solids. These can mimic the optical scattering behaviour of metal nanoparticles at microwave frequencies. They show powerful isotropic scattering, with negligible dependence on incident angle or polarization for multiple resonant modes. Controlling the geometry of grooves in a sphere of a given radius can define parameters such as scattering intensity, directivity, and bandwidth. Groups of the scatterers can be used to define custom emission patterns for antennas or control the backscattering profile of various objects. These scatterers have applications in enhancing the radar signature of small objects such as drones and satellites, and in controlling the radiation pattern of antennas.

Fiber-Membrane Composite Devices for Acoustic Sensing

Wenjun Ni* and Chunyong Yang

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Abstract:

Fiber optic broadband acoustic sensors have great potential applications in many civil and military fields, such as oil and gas pipeline leakage monitoring, high-precision photoacoustic spectrum detection, seismic wave monitoring and anti-submarine monitoring. Compared with the traditional electronic acoustic sensor, optical fiber acoustic sensor has the advantages of high sensitivity, resistant to strong electromagnetic interference, light weight, small size, resistant to corrosion and other irreplaceable advantages. The research of broadband acoustic sensor based on fiber-membrane composite devices structure has been conducted to achieve the goal of high sensitivity, high precision, fast response, ultra-wideband and small size of the acoustic sensor. Four different broadband acoustic sensors based on fiber-membrane composite devices have been designed. It can be divided into two categories: the one broadband acoustic sensor is based on the transmission-type special optical fiber device combined with membrane, and the other ultra-wideband acoustic sensor is based on the reflective EFPI structure combined with the membrane.

Calibration of Interferometric Optical Path Length Using the Non-Uniform Fourier Transform

Muqian Wen[1*], Kieran O'Mahoney[2], John Houlihan[3], Ken Thomas[3]

South East Technological University, Ireland

Abstract:

Interferometric Optical Path length changes have been used across a range of disciplines for metrology purposes. Methods of scanning optical path lengths can range from temporal scanning to spatial scanning, etc. Both typically require calibration to compensate for non-uniform delay scanning in the interferometer using a reference laser. Non-uniform scanning velocity of translation stages in temporally scanned interferometers introduces significant additional spectral content which can greatly affect measurement accuracy without calibration. This additional spectral content is primarily due to irregular sampling of the input signal due to variations in scanning velocity. Calibration has conventionally been based on the construction of zero-crossing detection circuits, phase locked loop control or Hilbert transform based calibration of optical path length, methods which rely on resampling data based on known delay values derived from the reference laser. The non-uniform Fourier transform deals directly with non-uniformly sampled data. It has in the past been used to facilitate linear processing on irregularly sampled data, numerical solution of partial differential equations, etc. This work investigates the application of the non-uniform Fourier transform for the recalibration of optical delay in temporally scanned interferometers using a reference laser and the recalibration of measurement sources co-propagating in the interferometer. The technique is applied to Optical path lengths scans up to 4.8m.

Session VIII - Atomic Physics | Laser Science and Technology | Optical and Photonic Communications and Signaling | Quantum Science, Communications and Applications | Solar Energy & Photovoltaics

Complete Characterization of Ultrafast Optical Fields by Phase-Preserving Nonlinear Autocorrelation

Dong Eon Kim[1,2*], Alexander Gliserin[2,3], Soo Hoon Chew[2,3] and Seungchul Kim[3]

[1]Pohang University of Science and Technology, South Korea, [2]Max Planck Center for Attosecond Science, Max Planck POSTECH/Korea Research Initiative, South Korea, [3] Pusan National University, South Korea.

Abstract:

Nonlinear autocorrelation was one of the earliest and simplest tools for obtaining partial temporal information about an ultrashort optical pulse by gating it with itself. However, since the spectral phase is lost in a conventional autocorrelation measurement, it is insufficient for a full characterization of an ultrafast electric field, requiring additional spectral information for phase retrieval. Here, we show that introducing an intensity asymmetry into a conventional nonlinear interferometric autocorrelation preserves some spectral phase information within the autocorrelation signal, which enables the full reconstruction of the original electric field, including the direction of time, using only a spectrally integrating detector. We call this technique Phase-Enabled Nonlinear Gating with Unbalanced Intensity (PENGUIN). It can be applied to almost any existing nonlinear interferometric autocorrelator, making it capable of complete optical field characterization and thus providing an inexpensive and less complex alternative to methods relying on spectral measurements, such as frequency-resolved optical gating (FROG) or spectral phase interferometry for direct electric-field reconstruction (SPIDER). More importantly, PENGUIN allows the precise characterization of ultrafast fields in non-radiative (e.g., plasmonic) nonlinear optical interactions where spectral information is inaccessible. We demonstrate this novel technique through simulations and experimentally by measuring the electric field of ~6-fs laser pulses from a Ti:sapphire oscillator. The results are validated by comparison with the well-established FROG method.

Mitigation of Amplified Spontaneous Emission Noise for an All-Fiber Coaxial Aerosol Lidar with Different Single-Photon Detectors

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Abstract:

For a coaxial single photon lidar system, amplified spontaneous emission (ASE) noise from the fiber amplifier is inevitable. The ASE backscattering from specular reflection annihilates the far-

field weak signal, resulting in low signal-to-noise ratio, short measurement distance, and even misidentification. We propose a method for calibrating and mitigating ASE noise in all-fiber coaxial aerosol lidar and demonstrate the method for a lidar system with different single-photon detectors (SPDs). The accuracy of the coaxial aerosol lidar is comparable to that of the biaxial one. We conducted an experiment using three different detectors, namely, InGaAs/InP SPD, up-conversion SPD, and superconducting nanowire SPD in the same coaxial lidar system. Compared with the biaxial system, the three different detectors we used have achieved more than 90% ASE noise suppression, the measured visibility percent errors of InGaAs/InP SPD data, up-conversion SPD data, and superconducting nanowire SPD data all within 20%, and the percent error within 10% are 99.47%, 100%, and 95.12%, respectively. Moreover, time-sharing optical switching allowed to obtain background noise with high accuracy.

Analyses and Evaluation of Environmental Parameters Impact to Underwater Optical Wireless Communication

Shien-Kuei Liaw[1*], Shofuro Afifah[1], Amirullah Wijayanto[1] and Chien-Hung Yeh[2]

Graduate Institute of Electro-Optical Engineering, National Taiwan University of Science and Technology (NTUST), Taiwan

Department of Photonics, Feng Chia University, Taiwan

Abstract:

We demonstrated an underwater optical wireless communication (UOWC) system by using green laser at 450 nm. For system performance evaluation, the green laser was modulated by a 1.25 Gbps NRZ-OOK format with PRBS of 24 and 31, respectively. The bit error rate (BER) performance were measured in 1.5, 3.0 and 6 m, individually, for performance study. The best BER value can reach 5 x 10e-7 for 1.25Gbps date rate in 6 m transmission. Next, the UOWC transmission system was carried out by changing various parameters such as temperature, turbulence, artificial seawater which by adding salt into the experimental water. When a submerged motor has an output of 1200 L/h is used to simulate the water turbulence, the impact to BER and transmission quality is little. For temperature variation measurement, the experiment shows that at an original temperature of 25°C, it has the best BER as compared to lower temperature or higher temperature. We found that water flow disturbance has little impact to both BER and eye diagram quality. Then, artificial seawater is made to simulate the seawater environment. Under such condition, the UOWC transmission system can only transmit 3 m instead of 6 m due to generated impure particles and water disturbance. Both factors degrade the BER quality in the seawater.

Self-Mixing Displacement Reconstruction Based on Improved Fringe Scaling

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Abstract:

Obstacles in self-mixing (SM) based displacement sensing are the time consuming estimation of parameters such as optical feedback factor and linewidth enhancement factor and the complex

algorithm of displacement retrieval. There have been presented fringe counting (FM) method and consecutive samples based unwrapping method (CSU) method as methods capable of avoiding such complexities. However, the FC method has very low resolution and the CSU method requires the normalization of SM signals (SMSs), which is very complicated and is even impossible when the SMSs are affected by a speckle noise. We have proposed a new method of displacement reconstruction with high resolution, which does not need complex processes such as parameter estimation or normalization. In addition, the method proposed can be applied to all feedback regimes and work well even when SMSs are subject to a speckle noise.

Environment-Assisted Strong Coupling Regime and Entanglement

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Abstract:

In recent years, much attention has been paid to the study of optical and quantum systems with the regime of strong coupling. It is realized when the interaction constant between subsystems exceeds their relaxation rates [1]. Here, we consider a system of two coupled subsystems, each of which interacts with its own environment. We show that the coupling between subsystems leads to a change in the interaction of the system with the environment. Such a change leads to the appearance of an additional interaction between the subsystems, which is proportional to the derivative of the environmental density of states over frequency and the interaction constant between subsystems [2]. The appearance of an additional interaction contributes to the preservation of the strong coupling regime with an increase in the relaxation rates in the system [2]. We also show that in the case when the coupling constant exceeds the dephasing rate, separate dephasing reservoirs can create a long-lived entangled state [3]. The lifetime of this state is proportional to the exponent of the ratio of coupling constant to environmental temperature and can be, by orders of magnitude, larger than the system's characteristic dephasing and dissipation times [3].

Curved novel grating structure for DLA electron Accelerators

Salar Ghaderi1*

[1]*Middle East Technical University (METU), Turkey*

Abstract:

In daily life, we are experiencing a shift of technology from computers at a scale range of great buildings to nano-scale processing chips. We focus on one of the most groundbreaking research fields, the Nanoscale particle accelerators which use optical and laser technologies. Dielectric Laser Accelerators (DLA), are electron accelerators that use commercial laser (here semiconductor Laser)pulses in dielectric nano-scale cavities to build extreme forces on particles. Silica-made gratings are designed to match the laser phase with the electron particles. These gratings, impart a pi phase shift on the penetrating laser fields. This phase matching enables electrons to continually become accelerated by the laser field. Here we suggest a new model of a curved grating for the first time that enables to build a curved laser phase match on electrons resulting in a curved path electron accelerator chip. Here we address the key features of a complete synchrotron accelerator system on a chip by designing focusing fields, and optical solutions to keep

accelerating electrons in the cycle. This new finding is essential in building future compact accelerators as curved paths are essential for further compacting the electron accelerators. As can be demonstrated, this accelerator can be a micro-scale alternative to today's large-scale accelerators. Many current technologies including LHC particle colliders and cancer x-ray therapy systems and many more rely on large-scale conventional particle accelerators. This technology is a bridge to the next level of technology that enables many current large-scale technologies to fit in the palm of your hand.

The Cesium D_2 Hyperfine Structure

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Abstract:

The Cesium D_2 hyperfine interaction splits the ground state J_g=1/2 in two levels, F_g = 3, 4. The four excited states with J_e=3/2 are split in the levels F_e = 2, 3, 4, 5. The energy level correction is due to magnetic interaction of the electron angular momentum with the nuclear spin I=7/2. The multitude of energy levels are resolved in an external magnetic field. In the S ground state, the electron orbital angular momentum is zero, L=0. The electron spin couples with the nuclear spin. Energy level splitting in an external magnetic field can be determined exactly with the Breit-Rabi formula. In the P excited state, where L=1, no exact solution exists. Splitting of the energy levels is the result of coupling of three angular momenta: nuclear spin, electron spin and electron orbital angular momentum. The numeric calculation is of interest as it can be applied to other alkaline atoms as well. The matrix representation of the uncoupled basis $|m_I m_J\rangle$ is suitable. It has dimension 32x32. The size is equal to the dimension of the product space of **I** and **J**, i.e., 32 = (2*7/2+1) * (2*3/2+1). In the coupled representation **F** = **I** + **J**, the size is equal to the sum of the states of the F multiplets, 32 = 2*2+1 + 2*3+1 + 2*4+1 + 2*5+1. The excited state hyperfine correction is the sum of magnetic dipole interaction energy and three terms of the electric quadrupole interaction energy: a term proportional $(\mathbf{IJ})^2$, a term proportional **IJ** and a term proportional $\mathbf{I}^2\mathbf{J}^2$. The Zeeman interaction energy resolves the degeneracy of the states. It describes the energy correction due to the magnetic moments in the presence of an external magnetic field. The hyperfine structure is directly involved in optical double resonance spectra. As electric double resonances appear in the low field region, the energy levels may be calculated with a linear approximation. While the energy level diagram provides the positions of the double resonances, a dedicated calculation is necessary to provide the line strengths of the double resonances.

High-power, Frequency-Quadrupled UV Laser Source Resonant with the 1S0–3P1 Narrow Intercombination Transition of Cadmium at 326.2 nm

Shamaila Manzoor[1]*, Jonathan N. Tinsley[1], Satvika Bandarupally[1], Mauro Chiarotti[1], Nicola Poli[1]

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Abstract:

We present a novel high-power, frequency-stabilized, tunable, single-mode UV laser source operating at 326.2 nm, resonant with the Cd narrow intercombination transition ($^1S_0$–$^3P_1$). A maximum produced power of 1 W at 326.2 nm is achieved by two successive frequency doubling stages of a narrow-linewidth (<1 kHz) seed laser at 1304.8 nm. At 652.4 nm, approximately, 3.4 W of optical power is produced by a visible Raman fiber amplifier (VRFA) that amplifies and generates the second harmonic of the infrared radiation. The 652.4 nm light is subsequently frequency-doubled down to 326.2 nm in a nonlinear bow-tie cavity using a Brewster-cut beta-barium-borate (BBO) crystal for 2.5 W of coupled red power, achieving a maximum conversion efficiency of approximately 40 %. Full characterization of the laser source, together with spectroscopy signals of all Cd isotopes, spanning more than 4 GHz in the UV, will be presented. Further implementation of the laser on cooling and trapping Cd atoms will also be presented. This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (Grant Agreement No. 772126- TICTOCGRAV).

Data-Driven Machine Learning Prediction for Emerging Photovoltaic Materials

Lei Zhang[1]*

[1]Nanjign University of Information Science and Technology, China

Abstract:

Emerging solar cell materials such as the lead halide perovskites offer interesting optoelectronic properties yet suffering from several notorious issues. Then what's next? In this talk, I will discuss the recent data-driven and machine learning studies for optimizing the halide perovskite materials and predicting new photovoltaic materials in our group. Various data-driven efforts for molecularly modifying the halide perovskite surfaces will be explained, including the high-throughput calculations and experiments, data mining, machine learning and symbolic regression methods. In the second half of the talk, I will discuss the pros and cons of the natural language processing approaches to help inversely predicting new solar cell materials by automating the literature reading process.

Regulation of Ultrafast Laser Transfer for Flexible GaN-Based Device

Lingfei Ji*

Beijing University of Technology, China

Abstract:

Study on one-step low-energy ultrafast laser transfer for ultra-smooth, low-stress patterned gallium nitride (GaN) film and GaN-based light-emitting diode (LED) device without affecting electroluminescence performance is presented. The spatiotemporal evolution of the plasma behavior during laser transfer is revealed.

Linear and Nonlinear Dynamics in a Two-Membrane Optomechanical System

Paolo Piergentili[1 2*], Riccardo Natali[1 2], David Vitali[1 2 3] and Giovanni Di Giuseppe[1 2]

[1]University of Camerino, Italy; 2INFN Sezione di Perugia, Italy; 3CNR-INO, Italy

Abstract:

The linear and non-linear dynamics of an optomechanical system made of a two-membrane ethalon in a high-finesse Fabry-Pérot cavity is discussed. The presence of the second membrane inside the optical cavity might enhance the optomechanical coupling making this system interesting to reach the strong-coupling regime. The first experimental characterization of the optical, mechanical, and especially optomechanical properties of a sandwich constituted of two parallel membranes within an optical cavity will be presented. We find that the optomechanical coupling strength is enhanced by constructive interference when the two membranes are positioned to form an inner cavity which is resonant with the driving field. In the linear regime we prove the capability to tune on demand the single photon optomechanical couplings and the optomechanical interaction allows the simultaneous optical cooling of the fundamental modes of the two distinct membranes. Furthermore, the behavior of the non-linear dynamics of such a system in a pre-synchronization regime will be discussed. In the non-linear regime, a truthful detection of membrane displacements much above the usual linear sensing limited by the cavity linewidth is presented. The non-linear dynamics of the mechanical oscillator provides a novel procedure for the determination of the optomechanical interaction strength of the system: the slope with which the temporal dynamics of the mechanical oscillator reaches a limit cycle, allows us to determine, in a simple and consistent way, the single photon optomechanical rate, without the need of knowing the bath temperature, providing a novel procedure for the full characterization of an optomechanical system.

Dynamic Magnetic Field Entanglement Stabilization

Jin Wang*

University of Michigan-Dearborn, USA

Abstract:

A method for stabilizing oscillations and maximizing entanglement in a decoherence free Heisenberg spin dimer using a time varying magnetic field is presented. Unentangled and fully entangled initial states are investigated. A stabilizing magnetic field intensity function was found for both initial states. These time varying magnetic field intensity functions are different from each other, implying that the magnetic intensity variation needed to stabilize the system depends on the initial state. The time varying magnetic field functions were found using simulated annealing optimization. This work proves that it is possible to remove the oscillatory nature of entanglement and maximize entanglement in decoherence free systems.

Plenary Session

Higher Harmonic Generation and Ultra Supercontinuum from Electronic and Molecular Kerr Effects From Various States of Matter Under Intense Femtosecond Laser Pulses

Robert Alfano

The City College of New York, New York, NY

Abstract:

An electromagnetic model is used to explain the higher harmonic generation and ultra-supercontinuum generation at extreme femtosecond laser intensity depending on the response times on nonlinear Kerr index of refraction. The Kerr index mechanism depends upon response of electronic clouds and different molecular motions. The electronic cloud index of refraction n(t) can be instantaneous while the molecular motion is average over many cycles < n(t)>. The electronic cloud distortion model is used based on the carrier-envelope phase at the optical cycle response and envelope of pulse to explain the experimental Higher Harmonic Generation (HHG) and Supercontinuum Generation from the interaction of high-intensity ultrafast pulses for gases and solids. The index of refraction electronic cloud model responses on about 50 attosecond time scale. The theory reveals the salient experimental features observed from the HHG in the form of the three characteristic regimes for different states of matter. The electronic self-phase modulation model from nonlinear Kerr index n2 reveals three salient features of the HHG: decreasing Harmonics generation followed by a plateau to descending HHG signals to the cutoff frequency using the method of the stationary phase on electronic self-phase modulation (ESPM). This ESPM model is fundamental and a better alternative model to the quantum mechanical interpretation of HHG. In addition, the ESPM model gives additional features of spectral broadening about the N odd harmonics supporting the theoretical ansatz presented. The outcome from the ESPM model is a supercontinuum background superimposed with the sharp odd HHG peaks which was experimentally observed before in various forms of matter. The Ultra Supercontinuum is theoretically simulated for extreme spectral broadening from the index of refraction changes from the envelope response to the fifth- and third-order susceptibilities from self-phase modulation (SPM) under the influence of an extremely high-intensity femtosecond laser pulse from Kerr <n(t)>. We show the potentially produce spectral broadening changes extending from extreme X-rays, UV, visible, THz down to DC. The theoretical results show that an extremely high-intensity pulse as high as on the order of 10^{14} - 10^{16} W/m^2 can influence the fourth-order refractive index arising from fifth order susceptibility large enough that the nonlinear $n_4 I_0^{\,2}$ term to overtakes the $n_2 I_0$ term from the third-order susceptibility to produce the ultra-supercontinuum broadening in the rare gases, liquids, solids and plasma. The spectra can extend to most of Maxwell spectra using various states of matter; it can even show negative frequencies. This presentation provides an opportunity to extend the SPM model from X-rays to DC to form Ultra Supercontinuum Generation and HHG depending on the response time of media using extreme intensity fs pulses in the four states of matter.

Programming Complex Systems for Quantum Information & Machine Learning

Dirk R Englund

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Abstract:

After several decades of intensive theoretical and experimental efforts, the field of quantum information processing is at a critical moment: special-purpose quantum information processors are at or past the “quantum complexity frontier” where classical computers can no longer predict their outputs: we can “program complexity”, unable to predict the outcome. Meanwhile, new technologies to connect quantum processors by photons give rise to quantum networks with functions impossible on today’s “classical-physics” internet. But to harness the power of quantum complexity in “noisy intermediate-scale” quantum computers and networks, we need new methods to control and understand them -- and perhaps to manage noise sufficiently to reach fault tolerance. This talk discusses one approach: large-scale programmable photonic integrated circuits[1] (PICs) designed to control photons and atomic or atom-like quantum memories[2–7]. The second part of the talk considers another “complexity frontier” requiring large-scale control: that encountered in machine learning and signal processing. These problems present new opportunities at the intersection with quantum information technologies -- specifically, we will consider new directions for processing classical and quantum information in deep learning neural networks architectures, with a particular focus on hardware error correction[8–11].

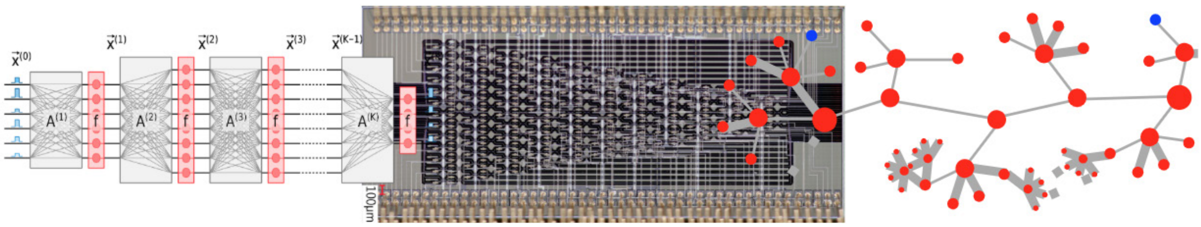

Figure: A programmable photonic integrated circuit (center) for machine learning acceleration (left) or quantum repeater networks (right).

Poster Presentations

Spectral Light- Sensitive Systems of the «CORE-SHELL» Type

O.V. Tyurin, S.O. Zhukov and O.Kh. Tadeusz*

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Abstract:

A comparative study of the spectral sensitization by dyes of a homophase microsystem (HOMS) “AgBr(I) core - AgBr shell” and a heterophase microsystem (HEMS) - “CaF_2 core - AgBr shell” by dyes was carried out in this work. For spectral sensitization, we used an anionic aggregating dye: pyridine salt of 3,3’-di-γ-sulfopropyl-9-ethyl-4,5,4’,5’-dibenzothiacarbocyanine betaine. The dye was adsorbed onto the nuclei in the form of alcohol solutions. The dye not adsorbed on the surface of the nucleus; the dye was separated by centrifugation. The cores were cubic microcrystals of AgBr(I) or CaF_2 for HOMS and HEMS, respectively. The control of the linear parameters of the nuclei was carried out by electron microscopic observations. The growth of the AgBr shell onto the cores with the dye was carried out according to the two-jet ammonia method. To prevent the formation of AgBr microcrystals in the emulsion, which are not adsorbed in the form of a continuous shell on the cores with dyes, the emulsification temperature, and the feed rates of $AgNO_3$ and KBr solutions were reduced. The control of the structure of HOMS and HEMS was carried out by electron microscopic observations. As a result of spectrosensitometric and luminescence studies (T = 77 K), it was found that of the growth of the AgBr shell during the creation of HOMS, the dye is displaced onto the outer surface of the AgBr silver halide shell. When creating HEMS, the dye remains fixed on the core and AgBr, and is not displaced onto the outer surface of the silver halide shell. It has been found that the dye fixed on the inner surface of the shell, in comparison with the dye fixed on the outer surface of the shell (the case of HOMS), expands the spectral sensitivity of the emulsion with HEMS to the long-wavelength side of the spectrum. To clarify the mechanism of spectral sensitization of HOMS and HEMS, it was suggested that the specificity of the spectral sensitization of these microsystems is determined by the electrostatic interaction of the cationic component of the core with the anionic aggregating dye. If the core contains a divalent cationic component (the case of HEMS), then the anionic dye is fixed on the inner surface of the silver halide shell. If the core contains a monovalent cationic component (the case of HOMS), then the dye is displaced onto the outer surface of the silver halide shell. A feature of the spectral sensitization of HEMS is also that, in addition to the dye fixed on the inner surface of the AgBr shell, additional spectral sensitization of HEMS by another dye adsorbed on the outer surface of the AgBr shell is possible. In the case of HOMS, the combined use of these dyes leads to desensitization of the emulsion. This makes it possible to significantly expand the range of practical applications of HEMS, for example, as we have shown, for recording three-dimensional holograms with high diffraction efficiency and angular selectivity in various spectral ranges.

Study of the Stability in Rows of Plasmonic Nanoparticles

Alicia Fresno-Hernández[1*], Manuel I. Marqués-Ponce[2] and Carmen Vázquez[1]

1Carlos III University of Madrid (UC3M), Displays and Photonic Applications Group (GDAF), 28911, Leganés (Madrid), Spain; 2Autonomous University of Madrid (UAM), Materials Physics Department, IFIMAC, Nicolás Cabrera Institute, 28049, Madrid, Spain.

Abstract:

Currently, the field of optical forces is focusing on the development of systems of biological interest, such as new forms of fiber optic-based trapping. In the framework of these studies, it is essential to know the structural stability of the systems.

This work analyzes the stability of a row of plasmonic nanoparticles subjected to an optical force field. For this purpose, a row of 51 silver particles is designed with the possibility of rotating

with respect to an axis passing through its center. Silver has the particularity that the real part of the polarizability is negative in a range of wavelengths, and we want to see if this property can affect the stability of the chain. Using the coupled dipole method (CDA), we calculate the fields, forces and torques [1-3] to see, given a wavelength, for which configurations the system becomes stable.

We will then add a second row of particles at a fixed position at a certain distance from the previous one, and analyze whether, thanks to the addition of this new row, the stability angles change or whether the system becomes unstable.

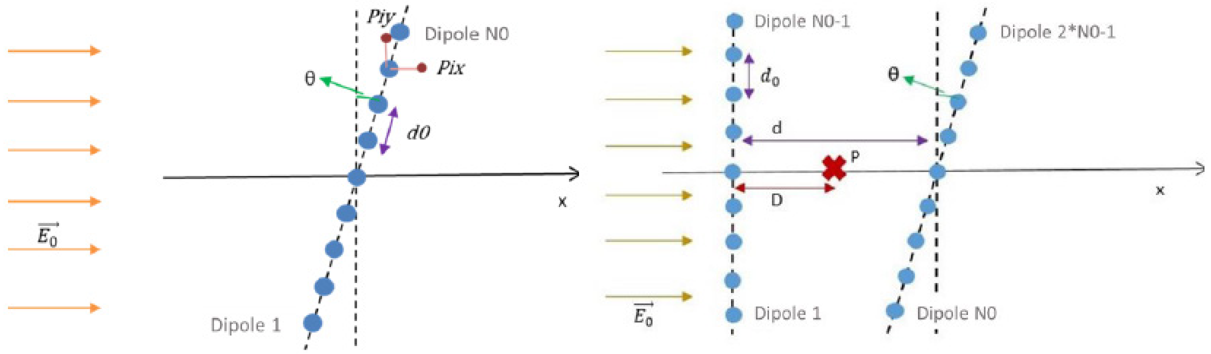

Figure 1. Proposed nanoparticle systems. a) Single-row system. b) Two-row system. In both cases the nanoparticles are illuminated with a plane wave propagating in the +x direction.

Laser Assisted Barbed Suture for Wound Closure during Plastic Surgery

Karuna Nambi Gowri[1*], Roger J. Narayan[2], Phillip McClellan[3], Gregory L. Ruff[4], Martin W. King[1,5]

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Abstract:

Based on the American Society for Plastic Surgery 2020 annual report, there are about 23 million plastic surgical procedures performed in the USA each year. Conventional monofilament and braided sutures are being replaced by barbed sutures. Barbed sutures are sutures with barbs projecting from the main suture monofilament which, when used during wound closure, will interact and self-anchor with the surrounding tissues, thereby reducing slippage and wound dehiscence. The purpose of this research is to use a laser source, together with a mechanical cutting technique to create barbs on collagen and catgut monofilaments in order to maximize the production and availability of barbed sutures and understand variations in their anchoring performance. Barbing was performed with a cutting blade and the tensile strength and elongation at break were evaluated. In order to have supporting evidence for these mechanical results, cross-sectional analysis of the catgut monofilaments was also performed. Preliminary data indicated that there is a reduction in local tensile stress due to a reduction in the cross-sectional area of

the catgut filaments after barbing. The observed increase in initial modulus suggested that the cross-section of catgut is not homogeneous, and the core is stiffer than the outer sheath. Future work will include evaluation of the mechanical properties of barbed sutures produced through a laser irradiation technique along with analysis to understand the anchoring performance of the sutures in different types of tissue.

Incoherent laser radiation

Sergey Kobtsev*

Novosibirsk State University, Russia

Abstract:

From the advent of laser radiation, it was radically different from the radiation of then conventional incandescent light bulbs in its high directivity and intensity, as well as its coherent properties. The phrase 'coherent radiation' became standard in reference to laser output and all radiation sources were divided into two classes with respect to radiation coherence: lasers and non-laser radiation sources (light bulbs, light-emitting diodes, and so forth). This report presents the concept of an incoherent laser, which may be implemented on the basis of noise-like pulse generation regime with its typically chaotic distribution of the optical field within the pulse. Noise-like pulses are composed of many (over 100) sub-pulses with random (or quasi-random) amplitude and duration chaotically (or quasi-chaotically) situated inside the pulse envelope. One of the attractive features of these pulses is their ability to carry relatively high per-pulse energy and average radiation power. Additionally, noise-like pulses demonstrate fairly high efficiency of nonlinear conversion. This combination of advantages offered by noise-like pulses allows them to be considered as the basis for implementation of a low-coherence laser. The present report discusses specific cavity configurations of a low-coherence fibre laser and the methods of control over its output radiation. The most promising configurations are shown. The possibilities and limitations of a low-coherence fibre lasers are considered, as are their possible application areas.

Laser Fabrication of Composite Subwavelength Gratings

Yaroslava Andreeva[1]* and Alexander Suvorov[1], Dmitry Sinev[1]

[1]ITMO University, Russian Federation

Abstract:

In this work we present the result of laser fabrication of highly regular nanocomposite gratings with the period of about 330 and 180 nm. The mechanisms of laser-induced formation of periodical structures of different orientations on thin TiO_2 film with silver nanocrystals are discussed. We than show that such nanocomposite gratings exhibit several interesting properties including optical anisotropy and second-harmonic generation. The proposed method allows fabrication of prolongated large-scale nanogratings with a very high performance. The study is supported by RSF (Grant No 21-79-10241)

Quantum Imaging of Biological Tissue Samples

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Abstract:

Quantum techniques are used to image healthy and cancerous human lung tissues. Qubits are used to characterize birefringence in a histological melanoma lung sample by means of polarization sensitive measurement using density matrices of two-level quantum entangled photons. Coincidence rates of entangled photons are measured for a set of sixteen polarization states. Tomographic, inverse numerical optimization technique is used to reconstruct the density matrix and the degree of entanglement for each pixel of the investigated sample. The changes in the entanglement between two qubits are used to characterize birefringence of the sample. Well-defined entanglement images show the presence of birefringence in lung tissues with melanoma and no birefringence is detected in healthy samples.

Engineered Core-Shell Nanoparticles-Based Absorber for the Visible-Near Infrared Regime

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Abstract:

Engineering the nanoparticles embedded in the solar cells leads to excellent scattering and absorption properties of incident light that can be exploited for more energy to be trapped and absorbed with an overall improvement in optical efficiency. This work provides a detailed investigation of the optical properties of gold (Au) and silver (Ag) based nano-shell and nano-matryoshka (NM) across the entire visible and near-infrared (NIR) regime. Using the Mie theory of scattering, subsequent simulations are performed via GUI based MATLAB tool. After a comparison analysis with other dielectric core materials (HfN, ZrN, and TiN), Silica (SiO_2) is found to provide maximum absorptivity as the dielectric core material coated with Au and Ag as the outer shell. Thereafter, tunability across a broader spectrum is achieved by varying the geometrical parameters of both the nano-shell and NM. From the subsequent series of optimization, it is observed that the lower range of wavelengths (visible region) accounts for enhanced absorption, and the longer wavelengths (NIR region) witness a wider spectral coverage. Finally, after observing the absorption characteristics for the proposed NM-based configurations, Au-SiO_2-Au with 55nm-65nm-75nm feature sizes are found to be the engineered parameters. In the case of nano-shells, the maximum absorption for SiO_2 (core) -Au (shell) and SiO_2 (core) -Ag (shell), is observed for radius dimensions of 70nm (core) -80nm (shell) respectively. The proposed nanoparticle-based absorbers can be a potential application for solar cells that require maximum absorption with broad spectral coverage.

The Effects of Multiple Internal Reflections: Newton's Prism Never Ceases to Amaze

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Abstract:

Everyone knows the spectacle of rainbow in nature when, following a thunderstorm, the light of Sun is spectrally dispersed by water droplets suspended in the atmosphere. The rainbow phenomenon, with its various orders (up to five observed in nature, more than eleven in laboratory), occurs as a consequence of the multiple reflections of light inside the water droplets. The most beautiful experiments in optics on spectral dispersion of white light remain those performed by Newton with prisms, described in the classical work Opticks, and frequently replicated in schools and universities. What happens in a water droplet suggests to study what happens inside an equilateral prism, when it is suitably illuminated with white parallel light. Due to its triangular geometry compared to the spherical one of the water droplets, however, the light refracted externally to the prism will not be simply a series of spectrally dispersed beams, instead will be a succession of white and spectrally dispersed alternating beams. In essence, the light will be internally reflected an indefinite number of times and will produces, in correspondence with each reflection, an externally refracted beam that will be white or spectrally dispersed depending on the parity of the number of reflections previously undergone. In this work, I analyze, both theoretically and experimentally, the properties of the most intense light beams refracted out of the faces of the equilateral prism, made of dense flint glass, when it is illuminated with white or laser light (532 nm wavelength), polarized "p", "s" or unpolarized.

Laser Paintbrush: From Fundamentals of Laser Oxidation to Modern Art

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Abstract:

What is a laser paintbrush: myth or reality? In this talk we will show not only laser coloration results but also possibility of color change and erasing by subsequent laser treatment. The broad palette of basic colors on titanium is shown and the fundamentals of laser oxidation process for metal coloration are revealed. The importance of cooling rate after laser exposure are discussed with the reference to our numerical modelling. Moreover, the developed device called "Laser paintbrush" based on fiber laser will be presented as a tool for manual painting colorful pictures on metallic surfaces. The results are highly promising for modern art and design.

Second Harmonic Generation on Germanium Telluride (GeTe) Thin Films

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Abstract:

Germanium telluride (GeTe) is both polar and semiconducting in nature. While the intrinsic, large concentration of free carriers in GeTe might suggest the impossibility to switch its ferroelectric polarization, the reliable control of the ferroelectric reversal through gating has been recently demonstrated [1]. Such a compound has been theoretically proposed prototype of a new class of materials, namely ferroelectric Rashba semiconductors. They display bulk bands with giant Rashba-like splitting due to the inversion symmetry breaking arising from the ferroelectric polarization, thus allowing for the ferroelectric control of the spin texture. Having nonzero second-order nonlinear susceptibility, ferroelectrics have broken inversion symmetry and accordingly giving rise to optical SHG signal. Thus, we used SHG to investigate the critical temperature of the GeTe and doped GeTe thin films. We found that the doping of GeTe with Sn (tin) drastically decreases the critical temperature, allowing for the chemical tunability of the ferroelectric properties of GeTe. Measurements of the ferroelectric hysteresis loop of Ge_xSn_yTe by electro-resistance measurements on micrometric gates confirmed the tunability of the coercive field with the composition. Furthermore, SHG imaging also allowed to confirm the nanometric distribution of ferroelectric domains in GeTe (111) epitaxial thin films.

Generation of Vortex Beams Superposition by Multisector Binary Phase Plates Fabricated by Laser-Induced Microplasma

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Abstract:

Generation of optical vortex beams (OVBs) superposition and transformation of cylindrical vector beams of the first order (radially or azimuthally polarized beams) into hybrid high order beams are intensively developing scientific areas. The application of multisector binary phase plates in these areas is firstly stimulated by the simplicity of their design, manufacturing, and application reliability in comparison with other optical elements. OVBs superposition is used in focusing and beam shaping for laser micro- and nanoprocessing, optical manipulation, communications. MBPPs are phase optical elements which consist of sequence of etched and unetched sectors. Intensity distribution generated by MBPPs with two phase levels of 0 and π in the far field becomes OVBs superposition with opposite topological charges $+l/2$ and $-l/2$ in the paraxial approximation, when $\cos(\varphi) = 1$ and $\sin(\varphi) = 0$. We purpose to use carbon laser-induced microplasma (LIMP) for fabrication of MBPPs on fused silica plates. Fabricated MBPPs testing was performed based on registration of intensity distributions generated in the far field by CCD camera and in a scheme with a nanosecond fiber laser (wavelength $\lambda = 1.06$ μm) for simultaneous processing of steel plates.

A Satellite-based ICESat-2 Adaptive Elliptical DBSCAN Reference Bathymetric Point Dataset Extraction Method

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Abstract:

Most of the existing passive remote sensing bathymetry techniques are based on in-situ bathymetric points combined with optical mathematical models for bathymetric inversion, which greatly limits their application in areas where in-situ data are not available. The ICESat-2 observation satellite with the Advanced Topographic Laser Altimeter System (ATLAS) offers great advantages in collecting bathymetric point datasets. The Density-Based Spatial Clustering applied with Noise (DBSCAN) has been proven to be an effective method for detecting ATLAS photon signals. However, determining the key parameters of DBSACN is a challenge due to the large number of LiDAR raw photons and complex topographic variations. Here, we propose a new method to extract the high-precision ICESat-2 reference bathymetry point datasets using the adaptive elliptical DBSCAN algorithm: shallow water feature photon (SWFP) extraction is performed based on ICESat-2 ATLAS data and an innovative adaptive elliptical DBSCAN (AE-DEBSCAN) algorithm is applied for reference bathymetric photon point detection. The results show that the AE-DEBSCAN method could achieve higher accuracy in the bathymetric signal detection compared to the standard DBSCAN method. The reference bathymetric points of ICESat-2 were consistent well with the in-situ data over St. Thomas Island. In addition, a total dataset of about 159,400 reference bathymetric points in the nearshore area of five islands in the Virgin Islands was obtained based on our method. Furthermore, a neural network approach was applied to obtain bathymetric maps by combining the reference bathymetric point datasets and Sentinel-2 passive remote sensing images of five islands in the Virgin Islands.

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