Programme

Photonics Online Meetup

#POM20Ju

25 June 2020

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@PhotonicsMeetup

Content

Program

Start/End (Zurich, CEST)	Duration	Speakers
09:00 – 09:05	0.05	**Opening**
		Biophotonics
09:05 – 09:35	0.30	**Hatice Altug**
09:35 – 09:55	0.20	Negin Zaraee
09:55 – 10:15	0.20	Mingzhou Chen
10:15 – 10:35	0.20	Filippo Pisano
10:35 – 10:50	0.15	**Break**
		Light-Matter Interactions
10:50 – 11:20	0.30	**Qihua Xiong**
11:20 – 11:40	0.20	Ileana-Cristina Benea-Chelmus
11:40 – 12:00	0.20	Chiara Trovatello
12:00 – 12:20	0.20	Marianne Aellen
12:20 – 12:40	0.20	Samuele Grandi
12:40 – 12:55	0.15	**Break**
		AI & Photonics
12:55 – 13:15	0.20	Luat Vuong
13:15 – 13:35	0.20	Yunzhe Li
13:35 – 13:55	0.20	Mario Krenn
13:55 – 14:25	0.30	**Marin Soljačić**
14:25 – 14:30	0.05	**Closing Remarks**

Time Zones			
Los Angeles	-9	Lahore	+3
Boston / Ottawa	-6	Shanghai	+6
London	-1	Sydney	+8

Abstracts

Bio-Photonics

Chair: Andrea M. Armani, University of Southern California, USA

Hatice Altug EPFL, Lausanne, Switzerland

New Frontiers in NanoPhotonics: Enabling Next-Generation BioSensors

Nanophotonics, which excels at generating enhanced light matter interactions and sub-wavelength light confinement, enables us to manipulate light in ways that are not possible achieve with diffraction limited optics and natural materials. The unique aspects are leading to numerous disruptive technologies including in sensing, imaging and spectroscopy. Our laboratory is working on the application of nanophotonics to introduce powerful biosensors that can have impact on a wide range of areas including basic research in life sciences, early disease diagnostics, safety and point-of-care testing. In particular, we exploit nanophotonics to address key challenges of current biosensors by developing technologies that can enable label-free, ultra-sensitive, multiplexed, rapid and real-time measurements on biological systems including disease biomarkers, pathogens and living systems. We employ a variety of nanophotonic techniques including dielectric metasurfaces and plasmonics. We introduce new nanofabrication procedures that can enable high-throughput manufacturing of sensing chips at low costs. We integrate optical nanobiosensors with microfluidics for efficient manipulation and handling of biosamples. We combine the use of smart data science tools with bioimaging and spectroscopy for achieving unprecedented sensor performance. In this talk, I will present some of our recent results on nanophotonic metasurfaces for sensing, bioimaging and mid-infrared spectroscopy as well as their applications in real-world settings.

Negin Zaraee Boston University, USA

Interferometric Reflectance Imaging for Label-free and Sensitive Detection of Whole Cell E. coli with Single Cell Resolution

Bacterial infectious diseases are a major threat to human health. Timely and sensitive bacteria detection is crucial in identifying the bacterial contamination and preventing the spread of infectious diseases. Due to limitations of conventional bacteria detection techniques there have been concerted research efforts towards development of new biosensors. Biosensors offering label-free, whole bacteria detection are highly desirable to those relying on label-based or bacteria molecular components detection. The major advantage is eliminating the additional time and cost required for labeling or extracting the bacterial components. Here, we demonstrate rapid, sensitive and label-free E. coli detection by interferometric reflectance imaging enhancement allowing for visualizing individual pathogens captured on the surface. Enabled by our ability to count single bacteria on a large sensor surface, we demonstrate a limit of detection of 2.2 CFU/ml from a buffer solution with no sample preparation. The simple design of our optical setup with off the shelf optical components ensures a cost-effective instrument without requiring specialized facilities. The dual imaging modality of our biosensor offers both: (i) Rapid and high throughput bacteria detection enabled by the large field of view in low-magnification imaging modality and therefore rapid scan of the entire sensor. (ii) Bacteria morphological characterization enabled by the high-magnification imaging modality which resolves down to single bacteria captured on the sensor surface.

In addition, we show that our biosensor's detection capability is unaffected by the sample complexity by testing its performance in tap water. Also, the specificity of our biosensor is validated by comparing its response to target bacteria E. coli and non-target bacteria S. aureus, K. pneumonia and P. aeruginosa. Therefore, our sensitive and label-free detection method offers new perspectives for direct bacterial detection in clinical sample.

Mingzhou Chen University of St Andrews, UK

Long term monitoring the effects of antibiotics on bacteria using acoustics-Raman microfluidics

As an infectious disease, Tuberculosis (TB) causes more than one million deaths every year worldwide. Antimicrobial resistance, which is directly related to metabolic states of the bacteria, is one major reason for the relapse and the long treatment of TB. In order to understand the details of metabolic states, it is extremely important to directly monitor them in bacteria, especially living bacteria which are exposed in the different environmental conditions. We have developed a microfluidic system combining Raman spectroscopy and acoustic trapping to monitor the reaction of living bacteria to antibiotics, e.g. isoniazid (INH) used in the current TB treatment regimen. Acoustic forces are used to confine the living bacteria in the middle of the microfluidic chamber, isolating them from the chamber surfaces, yet remaining well exposed in the surrounding medium. The medium itself may be changed at will. Under stable acoustic trapping, the cells are continuously interrogated by acquired Raman spectra over more than eight hours. By analysing the changes of those important Raman fingerprints, we can precisely monitor any subtle metabolic change in the cells, either as a result of environmental factors or the administration of antibiotics. In our experiments, we can clearly see the accumulation of lipids in cells exposed to the isoniazid while there is increasing evidence supporting that lipid rich mycobacteria can be up to forty times more resistant to first-line antibiotics compared to lipid poor ones. Our new acoustic-Raman microfluidic system will help us to develop a detailed understanding of bacteria at the molecular level and is a powerful, new a platform for testing drugs.

Filippo Pisano Istituto Italiano di Tecnologia-CBN, Italy

Towards label-free, depth-resolved nano-photonic probes for deep-brain regions

Owing to the development of light-sensitive, genetically-expressed actuators and indicators of neural activity, the advent of optics and photonics in neuroscience has enabled revolutionary experimental approaches (Yizhar et al., 2011). This has driven the growth of a related field, known as neuro-photonics. In this context, optical fibers are widely used to interface with deep brain regions that lie beyond the reach of common imaging systems. Recent work has demonstrated that harnessing modal propagation in multimode fibers opens the door to endoscopic imaging at the fiber tip (Cižmár & Dholakia, 2012) or to depth-resolved light delivery and collection using tapered optical fibers (TF) (Pisanello et al., 2017; Pisano et al., 2019).

However, the application of these methods to translational studies is hindered by the need of genetically-encoded fluorescent molecules. To circumvent this drawback, we have developed a novel class of minimally-invasive, implantable neuro-photonic probes that exploit light-matter interaction at the nanoscale to achieve label-free, optical neural interfaces using plasmonic structures fabricated on the non-planar surface of a TF. In light of the versatile optical properties of TFs, we view this strategy as a promising method towards spatially-selective, plasmonic neural interfaces with deep brain regions in vivo.

References

Cižmár, T. & Dholakia, K. (2012). Nat. Commun. 3, 1027.

Pisanello, F. et al. (2017). Nat. Neurosci. 20, 1180–1188.

Pisano, F. et al. (2019). Nat. Methods. 16, 1185–1192.

Yizhar, O. et al. (2011). Neuron. 71, 9–34.

Light Matter Interactions

Chair: Igor Aharonovich, University of Technology Sydney, Australia

Qihua Xiong, Nanyang Technological University, Singapore

Polariton Lattices in Perovsite Semiconductors

Exciton polaritons are part-light, part-matter strongly interacting Bosonic quasiparticles by dressing excitonic resonances with microcavity photons. They have extremely light effective mass and strong nonlinearity, which have shown tremendous potential in quantum fluid of light (i.e., Bose-Einstein condensate of polaritons), ultrafast polaritonic switching and topological polaritonics. Over the past several decades, this field has been largely fuelled by high quality II-VI (e.g., CdTe) or III-V (e.g., GaAs) quantum wells operating at only cryogenic temperatures constrained by the small exciton binding energy. Some organic materials show promising operation at room temperature, nonetheless they usually suffer from large threshold density and weak nonlinearity. Here in this talk, I will introduce our recent progress in realizing exciton polariton condensate and lasing in a few halide perovskite semiconductors. Then I will show that we can further optically manipulate the condensate by introducing 1D artificial polariton lattices with a large forbidden bandgap opening up to 13 meV. This work further opens a diverse possibility of 2D polariton lattices and network towards quantum simulator and topological lasing.

Ileana-Cristina Benea-Chelmus John A. Paulson School of Engineering and Applied Sciences, USA

Electro-optic interface for ultrasensitive intracavity electric field measurements at microwave and terahertz frequencies

The ability to make beams of light interact allows to connect distinct systems, with applications in communication, sensing or quantum computing. Electro-optic quantum coherent interfaces map the amplitude and phase of a quantum signal directly to the phase or intensity of a probe beam. Electro-optic interfaces that convert the complex amplitude of a THz quantum state to the near-infrared are so far limited to bulk crystals with second-order nonlinear susceptibility. In such systems, the coupling strength was extremely weak. Here, we propose an on-chip architecture[1] that concomitantly provides subcycle temporal resolution and an extreme sensitivity to sense terahertz intracavity fields below 20 V/m. We use guided femtosecond pulses in the near-infrared and a confinement of the terahertz wave to a highly subwavelength volume in combination with ultraperformant organic molecules and accomplish a record-high single-photon electro-optic coupling rate,

10,000 times higher than in recent reports of sensing vacuum field fluctuations in bulk media[2]. Via homodyne detection implemented directly on chip, the interaction results into an intensity modulation of the femtosecond pulses. We show >70 dB dynamic range in intensity at 500 ms integration under irradiation with a weak coherent terahertz field. Similar devices could be employed in future measurements of quantum states in the terahertz[3] with ultimate precision given by the standard quantum limit.

[1] Salamin, Y., et al. Compact and ultraefficient plasmonic terahertz field detector. Nature Comm. 10, 5510, 2019

[2] Benea-Chelmus, I-C., et al., Electro-optic interfaces for ultrasensitive intracavity electric field measurements at microwave and terahertz frequencies, Optica 7, 5, 2020

[3] Benea-Chelmus, I.C., et al., Electric field correlation measurements on the electromagnetic vacuum state. Nature 568, 2019

Chiara Trovatello Politecnico di Milano, Italy

Optical Parametric Amplification in 2D Semiconductor

Optical parametric amplification is a coherent physical mechanism whereby an optical signal is amplified by a pump via the generation of an idler field and it is the key ingredient of parametric oscillators-tunable sources of radiation that play an important role in several photonic applications. This mechanism is inherently related to parametric down-conversion that currently constitutes the building block for entangled photon pair generation, which has been exploited in modern quantum technologies ranging from computing to communications and cryptography. Here we demonstrate single-pass optical parametric amplification by monolayer transition-metal dichalcogenides, showing that amplification can be attained over a propagation through a single atomic layer[1]. The surface-like second-order nonlinear interaction has the advantage of bypassing phase-matching constraints thus enabling broadband collinear amplification, which generally is unattainable due to material dispersion. Moreover, the amplification process is invariant over signal and pump in-plane polarizations. By artificially stacking N monolayers with 0° interlayer twist angle, forming an AA stack, we show that the amplification gain scales with N^2. Our experimental findings pave the way for the development of atom-sized tunable sources of radiation and for innumerable applications in nanophotonics and quantum information technology.

Special remarks

-First evidence of light amplification in a 2D material

-The amplification is ultrabroadband and phase-matching free. This opens up the possibility to amplify any wavelength bypassing phase-matching constraints, not even defined for propagation through an atomically thin material

-The idler is entangled in energy and polarization with the signal photon and the pump photon

-In AA stacks made of N layers the gain scales like N^2

-Our findings might have innumerable applications in integrated quantum photonics.

[1] C. Trovatello et al. arXiv:1912.10466

Marianne Aellen ETH Zürich, Switzerland

Revisiting Design Principles of Two-Dimensional Metallic Lasers: Coexistence and Competition of Plasmonic and Photonic Waveguide Modes

Miniaturization and on-chip integration of photonic components bears the challenge of creating lasers with dimensions smaller than the free space wavelength. Metallic cavity lasers allow the amplification of plasmonic modes which—in contrast to photonic modes—can be confined below the diffraction limit. However, strong confinement of light comes at the cost of increased metallic losses, which must then be compensated by the laser gain material. Many designs of metallic lasers have successfully demonstrated plasmonic lasing, nevertheless, we still lack a fundamental understanding of the design requirements and limitations of metallic lasers. We experimentally demonstrate plasmonic and photonic lasing in two-dimensional silver cavities. For the gain material, we employ colloidal nanoplatelets that are deposited as gain layer with highly controlled thicknesses. Our analytical model presents design criterions and constraints imposed on the gain layer to achieve lasing in the plasmonic or the photonic mode. Additionally, we find that slightly above the thickness cutoff of the photonic waveguide mode, the plasmonic and photonic modes coexist and compete for gain. Intuitively, the plasmonic mode should exhibit a higher modal gain due to its increased overlap with the gain material compared to the photonic mode. However, our model demonstrates that the level of population inversion determines the dominant mode resulting in a previously unreported behavior that is confirmed by our experimental results. This knowledge provides guidance towards fabricating a new type of on-chip laser with controlled output of orthogonally polarized modes that can potentially be switched at unprecedented speeds.

Samuele Grandi ICFO, Spain

Long-lived entanglement between a telecom photon and a solid-state multimode quantum memory

Quantum repeaters offer the possibility to perform quantum communication over long distances. One possible repeater node can be made with a photon-pair source and an absorptive quantum memory (QM). To this end, we are developing a system which combines a solid-state QM with a source of photon pairs. The memory is based on a Praseodymium-doped crystal, where quantum information can be stored in Pr ions as a collective optical excitation using the Atomic Frequency Comb (AFC) protocol. On-demand retrieval of the information is realised by transferring the excitation to a long-lived spin state, which has already been demonstrated in this system [1]. Entangled photon pairs are generated by cavity-enhanced spontaneous parametric down conversion. This allows us to generate narrow-band pairs, where the signal is spectrally matched to the QM while the idler is in the telecom band [2].

We will present our current progress towards demonstration of energy-time entanglement between the telecom idler and the signal photon stored as a spin-wave excitation. The entanglement of the original pair is maintained by the memory's temporal multimodality. The entanglement analysis is performed using time-bin qubit analysers: a fibre-based Mach-Zehnder interferometer for the idler photon, and a solid-state equivalent based on two AFCs with different storage times for the signal photon [3]. With this setup, we have measured entanglement between the telecom photon and the signal stored in the AFC, with a fidelity high enough to violate a Bell inequality. The storage time in the QM was 10 μs, 100x longer than previous demonstrations in similar systems [3]. Ongoing improvements to the system will allow us to demonstrate entanglement with the signal photon in a spin-wave excitation, necessary to achieve longer storage times that are required for long-distance entanglement between individual nodes in a quantum network.

[1] PRX 7, 021028 (2017)

[2] NJP 18, 123013 (2016)

[3] Nat. 469, 508 (2011)

AI & Photonics

Chair: Sylvain Gigan, Sorbonne Université, France

Luat Vuong UCRIVERSIDE, USA

Fast image processing with a small brain: avoiding stereotypes with vortex Fourier encoders

Optical vortices, beams with spiral phase gradients and orbital angular momentum, have unique diffractive qualities that are at the center of new approaches in optical trapping, communication, spectroscopy, and imaging. Here, I highlight insight we've recently gained on the mathematical functions available from the vortex propagation of light through a lens: when an object is illuminated with a spiral phase, the Fourier-plane image is edge-enhanced, compressed, and contains ptychographic fringes that preserve phase information. We demonstrate that with vortex spatially-encoded inputs, a dense, shallow, "small brain" neural network is capable of solving inverse problems to reconstruct both object and position at speeds 5-20 times faster than with random spatial encoders, and 2 orders of magnitude faster than convolutional neural networks. There are further advantages to vortex spatial encoding, such as robustness to noise and overfitting, which translates to the capacity to image under low-light conditions. Experimentally, we reconstruct objects (Fashion MNIST images) illuminated with 5-nJ/cm2 flux, with 3ms exposure times. With vortex Fourier encoding, we reconstruct these objects with 0.688 Structural Similarity Index Metric. The computational advantages are significant, since simple neural networks have low computational complexity and are immune to adversarial attacks. Finally, and most fundamentally, with vortex spatial encoding, we demonstrate it is possible to train a neural network to solve the inverse reconstruction problem in a manner that is transferable and generalizable. We train a small-brain neural network to first reconstruct MNIST handwritten digits, and afterwards the neural network is capable of reconstructing Arabic or Chinese. In other words, we train a small brain to avoid stereotypes. This research offers new insight for solving inverse imaging problems without deep learning.

Yunzhe Li Boston University, USA

Displacement-agnostic imaging through diffusers using an interpretable deep neural network

Coherent imaging through scatter is a challenging topic in computational imaging. Both model-based and data-driven approaches have been explored to solve the inverse scattering problem. In our previous work, we have shown that a deep learning approach for coherent imaging through scatter can make high-quality predictions through unseen diffusers. Here, we propose a new deep neural network (DNN) model that is agnostic to a broader class of perturbations including scatter change, displacements, and system defocus up to 10X depth of field. In addition, we develop a new analysis framework for interpreting the mechanism of our DNN model and visualizing its generalizability based on an unsupervised dimension reduction technique. We show that the DNN can unmix the diffuser/displacement information and distill the object-specific information to achieve generalization under different scattering conditions. Our work paves the way to a highly scalable deep learning approach to different scattering conditions and a new framework for network interpretation.

Mario Krenn University of Toronto / Vector Institute for Artificial Intelligence, Canada

Conceptual understanding through efficient inverse-design of quantum optical experiments

The design of quantum experiments can be challenging for humans. In experimental quantum optics, computational and artificial intelligence methods have therefore been introduced to solve the inverse-design problem, which aims to discover tailored quantum experiments with particular desired functionalities. While some computer-designed experiments have been successfully demonstrated in laboratories, these algorithms generally are slow, require a large amount of data or work for specific platforms that are difficult to generalize.

I will talk about Theseus, an efficient algorithm for the design of quantum experiments, which we use to solve several open questions in experimental quantum optics. The algorithm' core is a physics-inspired, graph-theoretical representation of quantum states, which makes it orders-of-magnitude faster than previous comparable approaches. The gain in speed allows for topological optimization, leading to a reduction of the experiment to its conceptual core. In each case, we can therefore interpret, understand and generalize the solutions without performing any further calculations.

We draw connections to the philosophy of science. There, pragmatic criteria have been found for "scientific understanding", in particular in de Regt's award-winning work. He describes that scientists can understand a phenomenon "if they can recognise qualitatively characteristic consequences without performing exact calculations". We argue that therefore, our algorithm contributes directly to the central aims of science.

arXiv: https://arxiv.org/abs/2005.06443

github: https://github.com/aspuru-guzik-group/Theseus

Marin Soljačić Massachusetts Institute of Technology, USA

Exciting overlaps of AI and photonics

The recent AI revolution presents a number of exciting opportunities for photonics, both to help us with photonics research, but also for photonics to help further advances in AI. Some of our recent work in these topics will be presented.

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Light-Matter Interactions

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