The Second Annual Optics & Photonics Student Conference

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Abstracts

Invited Speakers	
Prof. Federico Rosei, INRS *Multifunctional materials for emerging technologies*	As the age of fossil fuels is coming to an end, now more than ever there is the need for more efficient and sustainable renewable energy technologies. This presentation will give an overview on recent developments in solar technologies that aim to address the energy challenge. In particular, nanostructured materials synthesized via the bottom–up approach present an opportunity for future generation low cost manufacturing of devices. We demonstrate various multifunctional materials, namely materials that exhibit more than one functionality, and structure/property relationships in such systems, including new strategies for the synthesis of multifunctional nanoscale materials to be used for applications in photovoltaics, solar hydrogen production, luminescent solar concentrators and other emerging optoelectronic technologies.
Prof. Paul O'Brien – York University *One-dimensional Transparent Photonic Crystal Heat Mirrors for Solar Thermal Applications*	The worldwide solar thermal capacity has grown by a factor of 7.7 from 60 GWth in 2000 to 480 GWth in 2018, and these growth rates are expected to accelerate as replacing fossil fuels becomes increasingly important. Ideally, a solar thermal collector should be strongly absorbing over the incident solar spectral region, where ~0.3 µm < λ < ~2.5 µm, while preventing thermal radiation, with ~ 2.5 µm < λ < ~ 25 µm, from escaping. In practical applications solar thermal collectors are realized using solar selective surfaces with wavelength dependent absorption properties; these surfaces are highly absorbing over the solar spectral region and exhibit low emissivity values for thermal radiation with longer wavelengths. Solar selective surfaces are well-developed and have been

	commonly realized using metal oxides, metals coated with thin-films comprising dielectric/metal/dielectric sandwich structures or semiconductors and metal surfaces textured on the micron scale. While a wide range of selective surfaces that absorb solar energy are available for different applications, their transparent counterparts are underdeveloped. Transparent selective surfaces, or “transparent heat mirrors”, are technologically desirable for the advancement of concentrated solar technologies that employ volumetric receivers. This talk will present the design of transparent heat mirrors in the form of photonic structures. For example, dielectric mirrors, which are effectively one-dimensional photonic crystals, have a periodic structure in the direction normal to their surface and are comprised of alternating thin-film layers with differing indices of refraction. Wave interference phenomenon caused by interactions between incident light waves and the interfaces within the periodic structure prevents light with certain wavelengths from propagating through the structure. This presentation will discuss how transparent photonic crystal heat mirrors can be optimally designed to function as covers for volumetric solar receivers operating at different temperatures.
Prof. Claude Fabre – UPMC Sorbonne Universités *Generation of Gaussian and non-Gaussian multimode entangled states of light for applications to Quantum Information Processing*	The development of Wavelength Division Multiplexing has been at the origin of a revolution in communication that has even changed our everyday life. It is natural to investigate now whether this way of encoding and processing classical information can be extended to the domain of quantum information processing. We show that parametrically generated optical frequency combs, spanning over more than one million wavelength components, exhibit highly multipartite entanglement between the quantum fluctuations of its frequency modes. We show how to produce and characterize such highly multimode quantum states of light and discuss the ways to make use of them in Measurement Based Quantum Computing. We finally show how to produce, by mode-selective photon subtraction, the pure states exhibiting non-Gaussian statistics that are needed to provide a quantum advantage in Quantum Computing tasks.
Dr. Zachary Vernon – Xanadu *Continuous Variable Quantum Photonics*	Integrated quantum photonics has for the past decade been nearly synonymous with single photons and photon pairs. Yet many promising near term use cases of photonic quantum simulation and computation are best implemented using continuous variable (CV) encodings, which typically require squeezed light rather than single photons. In this presentation, I provide an overview of our work towards realizing scalable CV quantum simulation and computation, including the most recent progress in developing nanophotonic sources of squeezed light.

Oral Presenters	
Ilan Tzitrin *Redoing and undoing local actions from afar: entanglement recast as an*	In a special set of quantum states, any local action on one subsystem can be replicated by an action on another. Characterizing the states for which this fundamental property holds allows us to formalize and quantify entanglement in a new way. Operational symmetries of this kind see analogy and application in

operational symmetry	quantum field theory, foundational quantum mechanics, and even classical light. Reference: I. Tzitrin, A. Z. Goldberg, and J. C. Cresswell. “Operational symmetries of entangled states,” arXiv:1906.07731 (2019).
Joshua Baxter *Deep Learning for the Prediction and Inverse Design of Plasmonic Colours*	Using pulsed laser ablation and re-deposition, nanoparticle distributions can be created on silver surfaces which result in colour due to plasmonic effects. The colour depends on the nanoparticle distribution and therefore the laser settings. We apply deep learning to solve the direct and inverse problems which link nanoparticle distributions and laser settings to the produced colour. In the direct problem, we predict plasmonic colours from nanoparticle distribution and the laser settings that would be used to generate the colours. In the inverse problem find a laser setting or nanoparticle geometry that will result in a desired colour using a novel deep-learning based method for inverse design. The resulting predictions are accurate and faster than traditional optimization.
Moein Shayegannia *Low Concentration Molecular Detection Using Multiwavelength SERS on Width-Graded Plasmonic Gratings*	Subwavelength metal gratings provide a unique means of high sensitivity molecular detection through the support of localized and propagating plasmons. Fine control at the nanometer length scale during fabrication of these metal-insulator-metal (MIM) graded gratings offer a novel and versatile paradigm for multiwavelength light localization. We have shown that fine control over the nanogroove width within a graded grating is fundamentally linked to strong coupling of surface plasmon polaritons (SPP) on the sidewalls of the nanogrooves. By appropriate utilization of this SPP coupling through groove width modulation, we have shown that rainbow light trapping is possible for wavelengths ranging from the visible into the mid-infrared, providing a platform for multiwavelength sensing. Recently we have proposed the use of width-graded MIM gratings as a substrate for surface enhanced Raman spectroscopy (SERS). We have demonstrated SERS enhancement factors of 106 to 107 for dynamic flow of aqueous phospholipid solution using 532, 638 and 785 nm laser illumination of the width-graded gratings within microfluidic devices. More recently we have been examining the detection of ultra-low concentrations of propylene glycol and glucose in aqueous solutions through Raman spectroscopy using theses width-graded nanogratings as SERS substrates. Herein we report on the viability of width-graded nanoplasmonic gratings for high sensitivity multiwavelength SERS applications. This includes examining the limit of detection of the graded gratings as a function of sample molecule concentration and various Raman parameters such as exposure time and intensity. We also discuss the influence of introducing trace concentrations of fluorescent dyes – specifically, simulating background fluorescence and as such demonstrating the performance of the width-graded gratings over fluorescent emission.
Mahdi Safari *Optically and RF Transparent*	Introduction: The concept of transparent metamaterials has been a topic of research interest over the last few years [1]. Here, with the introduction of highly conductive optically transparent silver-

Meta-Glass	dielectric multilayer coatings [2], we present the design, fabrication and analysis of an RF transparent meta-glass where we avail the idea of using coupled metasurfaces for radomes and automobile radar applications [3]. The design achieves optical and RF transparency through the application of symmetric honeycomb metasurface patterns on both surfaces of glass. Methods: The concept of visibly transparent coupled metasurfaces is used to increase the intrinsic impedance of the meta-glass (Fig. 1 b) compared to the intrinsic impedance of bare glass, that is, from Z=166 Ohms to that of free space (377 Ohms). The metasurfaces were fabricated using photolithography, sputter deposition of silver-dielectric multilayers [2], and lift-off techniques (see Fig. 1 c). Results: The fabricated structure and its optical transmission are shown in Fig. 2. a and b, respectively. The meta-glass was designed to operate at 28 GHz (5G and automotive Radar band). The RF measurement apparatus and the RF S-parameter simulations and measurements are shown in Fig. 3. a and b, respectively. The RF transmission is enhanced by 15% and 80% compared to bare glass and low emissive glass (uniformly silver coated glass) , respectively, while the meta-glass has an average optical transparency of 76% at normal incidence. Moreover, the RF reflection is decreased drastically by 12 dB (see Fig. 3 a). [1] Hu, D., et al., 2017. Advanced Optical Materials, 5(13), p.1700109. [2] Ko, R.H., et al, 2018. APL Materials, 6(12), p.121112. [3] He, Y., et al., to be published.
Zujun Xu *Red-shifted Spectrum in Multi-Frequency Raman Generation*	Frequency resolved optics gating is applied to study the temporal structure and spectrum of the first anti-stokes. We observe a double peaked, and red-shifted spectrum. Together with phase information, we think there is two separated process in the Multi-frequency Raman generation.
Mitra Rahimian *Mapping Complex Polarization States of Light on a Solid*	We demonstrate direct visualization of complex polarization patterns by imprinting them onto a solid surface in the form of periodic nano-gratings oriented parallel to the local structure of the electric field of light. Using polarization tomography, the output polarization state can be reconstructed from the measured spatially dependent intensity profiles. However, direct visualization of the higher-order Poincaré spheres is not feasible. To visualize a polarization pattern, light has to interact with a medium that allows the pattern to be spatially resolved. In this work, vector vortex (VV) femtosecond laser beams with different states of polarization (SoP), from higher-order VV beams to complex asymmetrical SoPs arising from coherent superposition of different order vortex beams, were used on a single crystal CVD diamond to produce periodic surface structures. The diamond surface was irradiated by N = 50 and 100 pulses with various energy values. The ablated annular craters present a region characterized by ripples aligned parallel to the beam polarization.We also show while the orientation of the nano-ripples is controlled by the local electric field structure, their spacing is almost independent of laser parameters such as number of pulses and the pulse energy. The average spacing is ~170 nm.

Abdullah Rahnama *Fiber Bragg Grating Opto-fluidic Sensor*	Femtosecond laser irradiation followed by chemical etching (FLICE) was applied to standard telecommunication fiber (SMF 28), embedding an open-filament, grating array through the silica cladding and guiding core cross-section. Second order Bragg air-gratings is presented for the first time, providing Nano-fluidic channels accessible to the outer cladding surface. Various fluids were applied to the hollow-filament FBGs, generating wavelength shifts, thus providing high sensitivity to the refractive index of the immersion liquid.

Poster Presentations	
Lalitha Tripura Sundari Ghatti *Structural, optical and Raman studies of Gd doped Sodium bismuth titanate*	The effects of gadolinium (Gd) on lead free sodium bismuth titanate ($Na_{0.5}Bi_{0.5}TiO_3$, NBT) ceramics are in- vestigated. X-ray diffraction (XRD) studies indicate that perovskite phase (rhombohedral, R3c) is formed for all Gd doped NBT (Gdx:NBT) compositions (x = 0, 0.02, 0.04, 0.06, 0.08). XRD peak shifts to the higher angles for all compositions except for x = 0.08. Amphoteric nature of Gd in NBT sites are observed i.e., it occupies Bi-site up to x = 0.06 and then distributes to Ti-site. Octahedral distortion (c/a) increases in the range $0.02 \leq x \leq 0.06$ and then decreases. Raman spectra suggest that the introduction of Gd^{+3} ion induces structural changes without disturbing the long range order. The material can be readily excited using UV (360 nm) and shows emission peaks at ~592 nm and 687 nm. Optical property evaluation indicates that the lowest band gap (E_g = 2.78 eV) is observed at x = 0.08. When x > 0.04, the photoluminescence (PL) intensity decreases indicating the onset of concentration quenching. The critical energy distance (found to be 14 Å) and Dexter's theory based analysis indicate that concentration quenching is attributable to multipole-multipole (specifically dipole-dipole) inter- actions in the system. Commission International de Eclairage (CIE) chromatic color coordinates are reported for all doped systems; the observed patterns mirror PL analysis results. For instance, PL intensity shrinks beyond 4 %; this corresponds to a regression in the CIE trajectory with respect to concentration.
Shuaiwen Gao *Charge-carrier Diffusion of Semiconductor Samples with Probe and Pump Method*	To measure recombination lifetime and diffusion coefficient of semiconductor samples simultaneously, especially for silicon samples, a probe and pump method under quasi-steady state conditions is used. This technique is supported by a general mathematical model that predicts the experimental signal accounting for the 3D charge-carrier transport and recombination within the semiconductor. The predictions of the model are validated experimentally, and quantitative agreement in both amplitude and phase is found between the model and experimental results, which gives us a higher precision of lifetime and diffusion coefficient.
Carlos Miguel Garcia Rosas *Multi–cycle nonlinear carrier dynamics of n–doped semiconductor In0.57Ga0.43As*	We study the transient carrier dynamics and the nonlinear terahertz (THz) effects induced by an intense multi–cycle THz radiation in a n–doped semiconductor In0.57Ga0.43As, with the analytical–band ensemble Monte Carlo approach as a solution of the Boltzmann transport equation. For multi–cycle pulse, due to the excitation by the first half cycle, we generate a distorted current phases with the

	driving THz fields, leading to discrete high–order harmonic generation (HHG) in the transmitted intensity spectra. For incident THz pulses with relatively high frequency, it is difficult to have current truncations faster than the original incident multi–cycle waveform and as a result, it is harder to see the harmonics. However, we observe a more favorable and clear effect of low and high frequency components generation in the spectra, where the ponderomotive potential of the THz pulse is lower for the same THz field.
Georgia Thomas *Novel signature for stromal architecture: polarized light to differentiate myxoid vs sclerotic peritumoral human breast cancer stroma*	Breast cancer is the second most commonly diagnosed form of cancer in women, with 1 in 8 women developing the disease in their lifetime. As the disease is variable in its aggressiveness, recent scientific efforts have sought to find biomarkers that correlate to patient outcomes. The host environment of the cancer, known as the tumor microenvironment (TME), has been a recent focus of this effort. The morphology of peritumoral stroma, a collagen-rich connective tissue contained in the TME, has been shown to correlate with patient outcomes. The presence of myxoid stroma (loose, unaligned collagen fibres) correlates to lower recurrence-free survival, when compared to sclerotic stroma (dense, aligned collagen similar to healthy tissue). However, studies such as this are limited with this subjective, binary classification of stroma, which does not capture the full range of possible morphologies and can lead to errors in labelling in ambiguous cases. Using polarized light microscopy, a quantitative and objective metric has been developed to assess the density and alignment of peritumoral stroma as an alternative to this binary classification scheme. Approximately 100 regions of peritumoral stroma were labelled by a pathologist and then imaged using a rotating crossed polarizer method, which generates images highlighting birefringent structures such as collagen. For each region of interest, a stromal architecture metric was calculated from these images and was able to differentiate between myxoid and sclerotic peritumoral stroma with 97% sensitivity and 84% sensitivity. Moreover, this score allows for an objective and quantitative way to classify stroma morphology, which is imperative in future studies. Future work will focus on using this methodology in more prognostic work.
Prarthana Prakasha *Analysis of Noise Performance of injection locked Optoelectronic Oscillator*	An Optoelectronic Oscillator (OEO) is a time delay oscillator that converts the optical signal from a pump laser source to stable microwave signal. The OEO consists of a RF photonic link circuit that includes the Mach-Zehnder modulator, optical delay line, photodetector, RF amplifier and RF filter. In order to improve the phase noise performance at low offset frequencies, a small RF signal is injected into the circuit causing the phase-locking phenomenon in a single loop OEO. Keeping the Yao-Maleki OEO of 1996 as the base model, we propose modelling at the base band frequency i.e, the RF carrier is considered centered at zero frequency. This requires either representing the RF signal as a complex amplitude or equivalently as two real variables: the in-phase and quadrature amplitude components. The phase shift caused by the injection locked OEO can be predicted using the quasi-linear approximation, which is obtained by adding the noise terms in the dynamic equations and by noise we refer to white Gaussian noise as well as the Flicker noise caused by the

	introduction of delayed fiber length. In this experiment we also show that the required phase noise performance for most demanding applications can be achieved with a short loop OEO as a step to further stability and compactness of the model. This short loop OEO can be achieved with fibers such as dispersion-compensating fibers for a range of 550 Mhz to 9 GHz.