ID	Abstract
1	**Advanced modelling in computational nanophotonics** Presenter: Joshua Baxter, University of Ottawa With advances in nanofabrication, modelling the optical properties of nanoscale systems is critical. The optical response of nanostructures can be simulated using the bulk permittivity of the constituent materials (1). The permittivity is generally assumed time-invariant and spatially dispersionless. While these approximations are enough for the simulations of most systems, in some cases the physics must be modelled more precisely. We present three recent projects on the modelling of complex optical properties with implications in active nanophotonics (2), ultrafast physics and nonlinear plasmonics. The algorithms we developed are unavailable in commercial or open-source software. 1.) Nonlocal models: for small nanostructures (< 10 nm) spatial dispersion cannot be neglected, and we need to account for the electron degeneracy pressure (3). 2.) Nonlinear hydrodynamics: The hydrodynamic plasma model is required to properly model conduction electron dynamics in strong optical fields (4). 3.) Time-variant permittivity: Electrodynamics combined with two-temperature modelling is required to calculate the optical response induced by nonlinearity in ITO under strong optical fields (5). Our models combined with high-performance computing allow us to achieve accurate results and significant agreement to experiments. References 1. Pernice, W. H. P. Finite-Difference Time-Domain Methods and Material Models for the Simulation of Metallic and Plasmonic Structures. J. Comput. Theor. Nanosci. 7, 1–14 (2010). 2. Shaltout, A. M. et al. Spatiotemporal light control with active metasurfaces. Science 364, eaat3100 (2019). 3. Baxter, J. et al. Parallel FDTD modelling of nonlocality in plasmonics. ArXiv200506997 Phys. (2020). 4. Bin-Alam, M. S. et al. Hyperpolarizability of plasmonic meta-atoms in metasurfaces. ArXiv200705142 Phys. (2020). 5. Alam, M. Z. et al. Large optical nonlinearity of nanoantennas coupled to an epsilon-near-zero material. Nat. Photonics 12, 79–83 (2018).
2	**Light Emission From Single Photon Avalanche Diodes** Presenter: Joseph McLaughlin, TRIUMF and Royal Holloway University of London The Silicon Photomultiplier (SiPM) is the light detection device of choice for many next-generation astroparticle physics experiments. The general design of a SiPM is a densely packed array of single photon avalanche diodes (SPADs), each acting as an individual, binary cell on a common silicon substrate. In such configurations, any radiation emitted by a single SPAD can trigger avalanches in neighbouring cells, resulting in a signal contribution that is unrelated to the physics being measured. This is a systematic effect which can negatively impact photoelectron counting and resolution, and therefore an important systematic to understand for maximizing the sensitivity of detectors in rare event searches; e.g. dark matter interactions or neutrinoless double beta decay. In this presentation, we summarize the physical processes involved in SPAD light detection and emission. We then discuss our methodology for characterizing the thermal and stimulated light emission of SPADs using our Light Emission and Injection Microscopy (LEIM) experiment.
3	**Colloidal Quantum Dot-Doped Optical Fibers Drawn from Polymer Nanocomposites** Presenter: Claudine Allen, Université Laval-COPL Colloidal quantum dots (cQDs) are now a mature nanomaterial with optical properties customizable through varying size and composition. However, their use in optical devices is limited as they are not widely available in convenient forms such as optical fibers. With the challenge of collecting dipole emission in free space, direct incorporation of cQD emitters into active plastic optical fibers is a promising avenue to increase the light throughput in all-fiber systems. Large area fibers were thus fabricated with an active core made of CdSe/CdS cQDs embedded in a polystyrene matrix volume of

	around 67%, out of a 1000 μm ± 10% outer fiber diameter including the poly(methyl methacrylate) (PMMA) cladding[1]. Thanks to a prepolymerization process reducing cQD aggregation, only transmission losses due to Rayleigh scattering are dominant at energies below the semiconductors' band gap, but are overtaken by a sharp CdS-related absorption onset around 525 nm facilitating cQD excitation. Transmission electron micrographs (TEM) confirm the polymerization process has little to no effect on cQD shape and size along with the glass transition temperature and refractive index of the nanocomposite. However, the cQD surface chemistry is affected by the radical polymerization with a ~35% drop in quantum yield shown consequent with a slight redshift and broadening of the emission spectrum. This behaviour is unaffected by the cQD concentration and further nanocomposite processing into an optical fiber. Future work will optimize the cQD shell composition and thickness to maintain the quantum yield during polymerization[2]. [1] C. Whittaker, A. Perret, C. Fortier, O.-M. Tardif, S. A Lamarre, S. Morency, D. Larivière, L. Beaulieu, Y. Messaddeq, C. N. Allen, ACS Applied Nano Materials 3(7): 6478–6488 (2020) [2] Meinardi, F., A. Colombo, K. A. Velizhanin, R. Simonutti, M. Lorenzon, L. Beverina, R. Viswanatha, V. I. Klimov, S. Brovelli, Nat. Photonics 2014, 8, 392−399.
4	Enhanced preceptor for brain-inspired intelligence over long-haul fiber-optic communications Presenter: Mahdi Naghshvarianjahromi, McMaster University The cognitive dynamic system (CDS) is inspired by the human brain neuroscience model that is built on the principles of cognition based on perception-action cycle, memory, attention, intelligence and language [1]. The proof of concept case studies in [2-4] were used single fiber optic links. However, unlike l [2-4], we proposed the enhanced CDS perceptor for posterior directly from non-Gaussian nonlinear environment. Therefore, direct posterior extraction reduces complexity and required storage. The proposed enhanced perceptor of CDS is implemented for long haul OFDM fiber optic link. It is demonstrated through simulations that this new perceptor design can provide ~7.0 dB Q-factor improvement, whereas competitive methods such as digital back propagation can provide only 1-2 dB Q-factor improvement at higher computational cost [5]. References 1. M. Naghshvarianjahromi, S. Kumar and M. J. Deen, "Brain-Inspired Intelligence for Real-Time Health Situation Understanding in Smart e-Health Home Applications," IEEE Access, vol. 7, pp. 180106-180126, 2019. 2. M. Naghshvarianjahromi, S. Kumar, M. J. Deen, "Brain Inspired Dynamic System for the Quality of Service Control Over the Long-Haul Nonlinear Fiber-Optic Link," Sensors, vol. 19, no. 9, pp. 2175-2195, 2019. 3. M. Naghshvarianjahromi, S. Kumar and M. J. Deen, "Brain-Inspired Cognitive Decision Making for Nonlinear and Non-Gaussian Environments," in IEEE Access, vol. 7, pp. 180910-180922, 2019. 4. M. Naghshvarianjahromi, S. Kumar and M. J. Deen, "Natural Brain-Inspired Intelligence for Non-Gaussian and Nonlinear Environments with Finite Memory," Appl. Sci. 10, no. 3, 1150, 2020. 5. A. Du, B. Schmidt and A. Lowery, "Efficient digital backpropagation for PDM-CO-OFDM optical transmission systems," OFC/NFOEC, OTuE2, 2010.
5	Optical actuation of coupled torsional cavity optomechanical system. Presenter: Bishnupada Behera, University of Calgary In the last few decades, it has been well established that photons have angular momentum in addition to linear momentum. Light's circular polarization gives rise to spin angular momentum (SAM), and light's helical phase structure gives rise to orbital angular momentum (OAM) [1], which is discrete and, in principle, unbounded. This spatial structure of light enables access to a large state space which we can use to encode a large amount of information per photon. This characteristic feature of light has led to a vast range of applications in technologies such as high bandwidth data transfer, optical tweezers, LIDAR, quantum communication, etc. In the last few years, there have been some developments regarding OAM detection and actuation schemes with some focusing on single-photon OAM detection as well. Some of the popular schemes that are based on interferometric methods, forked diffraction gratings, refractive elements, etc. are very challenging to scale down for chip-scale implementations. Furthermore, it is also

	known that angular momentum of light (both spin [2] & orbital) can also be measured by measuring the torque exerted by light on incident objects. In this poster, we would present the very first on-chip nanophotonic cavity optomechanical scheme [3] for optomechanical actuation/detection of light with SAM & OAM. We use an optomechanical photonic crystal cavity to measure the torque exerted by light on a nanomechanical resonator. Our scheme/device also provides a platform for interfacing free-space angular momentum carrying optical fields to nanophotonic components. [1] Allen, L., et al. PRA 1992. [2] Beth, R.A. Phys. Rev. 1936. [3] Kaviani, H., et al. Optics Express 2020.
6	**Fabrication and Optical Transduction of Diamond Photonic Crystal Nanobeams** Presenter: Elham Zohari, University of Calgary, University of Alberta Single-crystal diamond (SCD) is a promising material for both classical and hybrid quantum systems due to its outstanding optical, thermal, and mechanical properties. Optomechanical devices derived from SCD have potential for use in exquisite sensing schemes as well as quantum information mediators that couple mechanical resonances to both light and spins [1]. The highest sensitivities in optomechanical systems are achieved through the integration of the mechanical structures with resonant photonic crystal cavities which confine photons within small mode volumes with high occupancy and lifetimes [2]. Thus far, the nanofabrication of devices from bulk SCD is extremely challenging, owing to selective etching procedures necessary for preserving small photonic crystal cavities (consisting of holes on the order of 100s of nanometers) while undercutting larger (micrometre-scale) mechanical devices. As a step toward the goal of overcoming these difficulties, we demonstrate a fabrication method for SCD nanobeams integrated with one-dimensional photonic crystal cavities with high yield and optical quality factors, with the goal of such devices enabling photon-phonon interactions as well as coupling of the mechanics to nitrogen-vacancy centre spins. [1] Matthew Mitchell, Behzad Khanaliloo, David P. Lake, Tamiko Masuda, J. P. Hadden, and Paul E. Barclay, "Single-crystal diamond low-dissipation cavity optomechanics," Optica 3, 963-970 (2016) [2] Behzad Khanaliloo, Harishankar Jayakumar, Aaron C. Hryciw, David P. Lake, Hamidreza Kaviani, and Paul E. Barclay, "Single-Crystal Diamond Nanobeam Waveguide Optomechanics", Phys. Rev. X 5, 041051 (2015)
7	**Direct growth of GaAs solar cells on Si substrate via mesoporous Si buffer** Presenter: Alex Brice Poungoué Mbeunmi, 3IT-UdeS Solar energy harvested using solar cells remains a promising renewable energy but its accessibility to Society is limited nowadays by cost. The integration of high efficiency III-V GaAs-based solar cells on Si substrates is of great interest since it may path the way for lower cost solar cells and other optoelectronic devices [1], [2]. However, the ~4% lattice mismatch between GaAs and Si bulk remains a major obstacle in growing high quality GaAs films since it results with a threading dislocation density (TDD) in the order of ~1 × 109cm-2. This limits the performance of GaAs-based devices. This work presents a new approach based on the nanostructuration of the Si substrate to allow a better integration of III-V compounds on Si substrates. In fact, a TDD of ~2 × 108 cm-2 and ~4.3 × 108 cm-2 for the grown GaAs epilayers on porous silicon (PSi) and Si bulk substrates. GaAs solar cell devices have been fabricated simultaneously on PSi and crystalline Si substrates, we the same epitaxial heterostructure and fabrication process. Higher performance has been obtained for the GaAs solar cells on PSi (FF = 56% and Voc = 0.31V) compared to their counterparts on crystalline Si bulk substrate (FF = 41,73% and Voc = 0.29V). The obtained results attest the potential of the nanostructuration of Si substrates for lower cost GaAs based solar cells. REFERENCES [1] N. Jain and M. K. Hudait, "III–V Multijunction Solar Cell Integration with Silicon: Present Status, Challenges and Future Outlook," Energy Harvest. Syst., vol. 1, no. 3–4, Jan. 2014, doi: 10.1515/ehs-2014-0012. [2] J. Justice, C. Bower, M. Meitl, M. B. Mooney, M. A. Gubbins, and B. Corbett, "Wafer-scale integration of group III–V lasers on silicon using transfer printing of epitaxial layers," Nat. Photonics, vol. 6, no. 9, pp. 610–614, Sep. 2012, doi: 10.1038/nphoton.2012.204.

8	**Simultaneous Second- and Third-Harmonic Generation in Gallium Phosphide Microdisks** Presenter: Blaine McLaughlin, University of Calgary The use of circular microresonators has recently seen great results in efficient nonlinear frequency conversions [1] [2]. However, common photonic materials with both large 2nd and 3rd order optical nonlinearities present the possibility of simultaneous 2nd and 3rd order frequency conversion processes. Here we demonstrate the simultaneous generation of both second harmonic and third harmonic signals from a single pump wavelength around 1550 nm in a gallium phosphide (GaP) microdisk resonator [3] [4]. We identify the third harmonic signal as resulting from a natural QPM cascaded sum frequency generation process between the first and second harmonics. This is indicated by an observed saturating effect in the second harmonic signal at higher pump powers. This demonstrates a novel result in frequency conversion in nonlinear photonic devices which may be used to improve engineering out unwanted processes or for creating more novel frequency conversion techniques. [1] Juanjuan Lu et. al. "Periodically poled thin-film lithium niobate microring resonators with a second-harmonic generation efficiency of 250,000%/W," Optica 6, 1455-1460 (2019) [2] Alexander W. Bruch et. al. "17 000%/w second-harmonic conversion efficiency in single-crystalline aluminum nitride microresonators." Applied Physics Letters 113.13 (2018): 131102. [3] Matthew Mitchell, Aaron C. Hryciw, and Paul E. Barclay. "Cavity optomechanics in gallium phosphide microdisks." Applied Physics Letters 104.14 (2014): 141104. [4] David P. Lake et al. "Efficient telecom to visible wavelength conversion in doubly resonant gallium phosphide microdisks." Applied Physics Letters 108.3 (2016): 031109.
9	**Finite time-domain (FDTD) analysis of plasmonic properties in anisotropic gold nanoparticles.** Presenter: Sathiyamoorthy Krishnan, Ryerson University Finite time-domain (FDTD) analysis of plasmonic properties in anisotropic gold nanoparticles. Krishnan Sathiyamoorthy We study the plasmonic properties of gold nanoparticles of various shapes. The study included the synthesis of gold nanoparticles of type's that include nanosphere, nanorod, nanospheres and nanostars, and characterization using UV-Vis spectrophotometer and TEM. The finite time-domain method is used to investigate the plasmonic excitation on those nanoparticles and compared with extinction spectra measured using the spectrometer. There is an enhance in the plasmonic excitation in the nanoshells observed due to hot spots created by inter and intra-plasmonic couplings between nanospheres encapsulation polystyrene spheres. The enhancement of plasmon in the case of nanostars and nanorods were due to intra plasmonic couplings between themselves.
10	**Optomechanical driving of nitrogen-vacancy center spins in diamond** Presenter: Prasoon Kumar Shandilya, University of Calgary Quantum networks enable a broad range of practical and fundamental applications ranging from distributed quantum computing to sensing and metrology. Experimental realization of such networks is hampered by many challenges, one of them being a lack of an efficient interface between stationary and flying qubits working at room temperature. We demonstrate an interface between ensembles of the nitrogen-vacancy centers in diamond and photons with wavelengths near 1550 nm. Photons are coupled to spins via local dynamical stress produced by optomechanical driving of a diamond microdisk. Our approach does not involve intrinsic optical transitions and can be easily adapted to many other colour centers.
11	**Visible light photochromism of amorphous hydrated tungsten oxides: studies on the short-range ordering and oxidation states** Presenter: Balaji Subramanian, Trent University Tungsten oxide hydrates are of interest as they exhibit photochromic functionality. They have applications ranging from smart windows to read/write devices. In this work, two types of tungsten oxide hydrates were prepared and characterized as: WO3·2H2O (type 1) and [WO_2 (O_2)H_2 O]

	·nH2O (0 < n < 1)(type 2)[1]. They were prepared by sol-gel methods starting from the oxidation of tungsten powder and are distinguished by the refluxing time in the synthesis. They were characterized by Raman spectroscopy, X-Ray Diffraction (XRD), and X-ray Photoelectron Spectroscopy (XPS). Irradiation of these materials with visible light of 405 nm showed that the type 1 tungsten oxide exhibits photochromism and type 2 does not. XRD showed that both samples were amorphous with short range ordering. During the coloration, the reduction of tungsten oxide from 6+ to 5+ state occurs, which can be explained by a small-polaron absorption model. XPS study of type 1 tungsten oxide for coloration times ranging from 0 to 120 secs was performed and an increase in W5+ oxidation states was evidenced with coloration time. XPS showed, upon 405 nm light irradiation, short range ordering of tungsten oxides is disrupted and becomes amorphous. This suggests structural water is being split by a photoelectrochemical process which provides protons for the coloration of type 1 tungsten oxide. This showed that the structural water in tungsten oxide [WO32H2O (type 1)] leads to coloration, answering one of the key questions regarding the photochromic mechanism of tungsten oxide hydrates. A thin film based photochromic device using type 1 tungsten oxide was prepared and it showed absorption in the infra-red region when colored using sunlight. [1] Structure of Hydrated Tungsten Peroxides [WO2(O2)H2O]·nH2O, B Pecquenard, S. Castro-Garcia, J. Livage, P. Y. Zavalij, M. S. Whittingham, R. Thouvenot, Chemistry of Materials 1998 10 (7), 1882-1888.
12	Femtosecond non-linear optical techniques and their applications in condensed matter physics Presenter: Meixin Cheng, University of Waterloo Time-resolved femtosecond (fs) nonlinear optical techniques have been developed and implemented to monitor photoinduced dynamics in a variety of condensed matter systems, which include two-dimensional (2D) transition metal dichalcogenides (TMDCs). Broadband fs transient absorption and reflectivity (bb-fs-TA/TR) have been applied to investigate carrier, phonon dynamics, and elastic properties of 1T'-MoTe2 – a TMDC that presents a first order phase transition to the Td, Weyl semimetallic phase below a critical temperature of Tc = 250 K [1]. We were able to observe the dynamics of hot carriers and low-frequency phonon modes in Td-MoTe2 under well-controlled photoexcitation conditions. Our experiments indicate that the system does not undergo a photoinduced Td-1T' phase transition; instead, ultrathin flakes develop and remains in an 'interlayer strained state'. Carefully analysis of the angular phase indicates that generation of 1A1 vibrational coherences transit from predominantly DECP (displacive excitation of coherent phonons) to ISRS (impulsive stimulated Raman-scattering) as the laser fluence increases, providing new insights into photophysical properties of MoTe2 [2]. In addition to the above, we have demonstrated a reliable and noninvasive technique to measure the elastic properties of nm-thick, micrometer-sized materials; and we applied to determine the Young's modulus of mechanically exfoliated 4 – 30-nm thick 1T'-MoTe2 flakes [3]. Current efforts in our laboratory focus on the development of polarized fs photoluminescence up-conversion (fs-PLup), which will be used to investigate dynamics of bright excitons in single-layer MoS2. [1] Vellinga, M. B., de Jonge, R. & Haas, C. Semiconductor to metal transition in MoTe2. J. Solid State Chem. 2, 299–302 (1970). [2] Cheng et al., Nat Commun. (under review). [3] Rivas et al., Generation and detection of coherent longitudinal acoustic waves in ultrathin 1T'-MoTe2. Appl. Phys. Lett. 115, 223103 (2019).
13	Photonic-enabled analog ultrahigh-speed joint time-frequency analysis and processing Presenter: Saikrishna Reddy Konatham, Institut National de recherche Scientifique Dynamic real-time spectrum analysis (RT-SA) and processing of high-speed (broadband) waveforms plays a fundamental role in broadband communications and radar technologies [1, 2], ultrafast characterization, sensing and spectroscopy [3], radio-astronomy research [4] etc. These applications require real-time computation of the Fourier transform (FT) in a continuous and gap-free manner, i.e., with no dead times in acquisition or processing, over instantaneous frequency bandwidths above the GHz range, and with temporal resolutions of a few nanoseconds or shorter. These

	specifications are beyond the reach of available RT-SA solutions, including the most advanced digital signal processing (DSP) methods [4]. Among other potential analog processing alternatives, dispersion-induced frequency-to-time mapping enables RT-SA of short isolated pulse-like signals but cannot be extended to the continuous waveforms most often found in practice [3]. Recently, we have demonstrated a universal analog signal processing architecture to achieve a direct and continuous time-mapping of a gap-free short-time Fourier transform (STFT) or spectrogram of arbitrary incoming waveforms [5]. The proposed approach, referred to as "time-mapped spectrogram (TM-SP)", is strikingly simple and it involves a suitable combination of short-pulse temporal sampling followed by dispersive delay. Using this novel concept, we have designed and demonstrated a photonics-based scheme for continuous, gap-free RT-SA of broadband microwave signals over an instantaneous frequency bandwidth approaching 5 GHz, with nanosecond resolutions, and at a computation speed of nearly 5 billion FTs per second. 1. Weiner, A. M. Ultrafast Optics (Wiley&Sons, 2009). 2. Hillerkuss, D. et al. Nat. Photon. 5, 364–371 (2011). 3. Mahjoubfar A. et al. Nat. Photon. 11, 341–351 (2017). 4. Monroe, R. M. Dissertation (Ph.D.), California Institute of Technology.(2018) 5. Konatham, S. R. et al. Nat. Commun. 11, 3309 (2020).
14	Development of a Raman spectroscopy technique for biodosimetry Presenter: Cristian Ciobanu, Carleton University Biodosimetry relates to the measurement of radiological dose deposited in biological materials. Such methods are important for the evaluation of health and risks to exposed individuals in an accidental or malicious radiological nuclear event. Current techniques however are held back by subjective and labour-intensive processes. The research described here explores the use of Raman spectroscopy (RS) for the detection of absorbed dosage in human blood plasma. A small fraction (one part per ten million) of light incident on a molecule undergoes inelastic (Raman) scattering due to the vibrations of intra-molecular chemical bonds. The resulting Raman spectra provide unique "chemical fingerprints" of biological samples that can be acquired in real-time. Blood plasma was chosen for biodosimetry because of its rich assortment of biomarkers, including over twenty thousand proteins. Using a novel flow-cell RS technique [1] developed by our team, Raman spectra of plasma samples from healthy and ex-vivo irradiated blood were obtained. Standardization methods including non-Raman background removal, instrument intensity-response correction, and normalization were applied to raw data to minimize unwanted variability across measurements and allow for reproducibility of spectra. Various statistical analysis and machine learning techniques were employed to build models capable of discriminating between control and dosed samples, using 70% of the data for training and 30% for testing. A principal component-linear discriminant analysis model yielded a detection accuracy of 85%, while a support vector machine model achieved a high accuracy of 95%. Ongoing work involves further testing, possible substitution of plasma for serum, and exploration of other discrimination models such as multivariate curve resolution in addition to extracting Raman biomarkers that are responsible for the discrimination. [1] Ben Hansson et al, Biomed. Opt. Express 10, 2275-2288 (2019).
15	Automatic Whispering Gallery Mode Biodetection Implemented on a Microfluidic Chip Presenter: Louis-Philippe Dallaire, Université Laval - COPL Over the last decades, researchers have taken a keen interest in remote microbiomes such as the picocyanobacteria colonies of arctic lakes and rivers. As a result, there has been an increasing need for fast and reliable biodetectors that are functional in the field. Previously, we developed a promising biodetection scheme based on the analysis of resonant whispering gallery modes of multiple free-floating fluorescent microspheres [1,2]. An attempt was made to implement a label-free biodetector in a custom microflow cytometer that automatically acquires the microspheres' fluorescence spectrum. An algorithm then simultaneously evaluates the microspheres' radius and their surrounding refractive index. The latter can be used to perform biodetection via a statistical test which does not require direct comparative measurements of the same microsphere. We now present a biodetector

	which improves upon the algorithmic technique and works with a much simpler and robust microfluidic chip installed on a fluorescence microscope. The chip also handles the mixing of microspheres with test samples containing analytes, thus reducing the required manipulations and further paving the way towards practical field biodetectors. This new device has been tested to detect two different populations of Northern picocyanobacteria. [1] Charlebois, M., Paquet, A., Verret, L. S., Boissinot, K., Boissinot, M., Bergeron, M. G., & Allen, C. N. (2010). Toward Automatic Label-Free Whispering Gallery Modes Biodetection with a Quantum Dot-Coated Microsphere Population. Nanoscale Research Letters, 5(3), 524–532. [2] Lessard, R., Rousseau-Cyr, O., Charlebois, M., Rivière, C., Mermut, O., & Allen, C. N. (2013). Flow cytometer system for single-shot biosensing based on whispering gallery modes of fluorescent microspheres. In A. V. Kudryashov, A. H. Paxton, V. S. Ilchenko, L. Aschke, & K. Washio (Eds.), Laser Resonators, Microresonators, and Beam Control XV.
16	Direct Writing of Surface Structures and Microlens Arrays in Polymer Films with Femtosecond Pulses Presenter: Alan Godfrey, University of Ottawa When an ultrafast laser pulse is focused through a glass substrate onto a polymer film, the pulse deposits energy beneath the film. This heats and expands the film like a small balloon, creating a stable protruding 'blister' structure. In the past, the main application of blisters was using their motion during expansion to propel material from one surface to another (Laser-Induced Forward Transfer), on scales from 10 μm – 1 mm in width1,2. We use nonlinear absorption of intense femtosecond pulses to create blisters below these scales, with diameters as small as 700 nm. This could enable blister-based transfer of sensitive materials at the nanoscale. We show through calculations that high-order nonlinear absorption of intense light leads to tightly-confined energy deposition in a thin film. In experiment, we create blisters using single pulses with energies as small as 20 nJ. We demonstrate new applications of blisters beyond material transfer. Blisters can be used to pattern a film and tailor its surface adhesion without disrupting its chemical composition. We also show that individual blisters in a film act as microlenses. We create arrays of blisters and demonstrate their lensing behaviour. Within an array, where the laser spot size and pulse energy are fixed, blisters have similar focal lengths and physical dimensions (height, diameter). We characterize the surface morphology using atomic force microscopy, and the microlensing effect using a modified widefield optical microscope. Rapid fabrication of microlenses could impact the productions of concentrated solar cells, CCDs and wavefront sensors. References 1. Kattamis, N. T., Purnick, P. E., Weiss, R. & Arnold, C. B., Appl. Phys. Lett. 91, 171120 (2007). 2. Delaporte, P. & Alloncle, A.-P., Opt. Laser Technol. 78, 33–41 (2016).
17	Scalable Fabrication of Colloidal Quantum Dot-Doped Polymer Optical Fibers Presenter: Olivier-Michel Tardif, Centre d'optique, photonique et laser (COPL), Dépertement de physique, de génie physique et d'optique, Université Laval, Québec G1V 0A6, Canada Colloidal quantum dots (cQDs) are still affected by their environment, leading to poor stability of their photoluminescence (PL) across experiments. The scope of their applications has therefore hitherto been limited. Recently, our team developed a new process to incorporate cQDs inside step index polymer optical fibers [1]. Due to reduced air exposure of cQDs in the host matrix, no significant PL degradation was observed under constant illumination of a cQD-doped optical fiber over a 12-day period. Moreover, a sonication step during preform polymerization reduced cQD aggregation and ensured greater nanocomposite homogeneity, as confirmed by TEM micrographs. However, the distributions of inter-cQD distances, compared to a random Bernoulli process, still revealed small clusters. The mechanism behind such aggregation is tentatively identified as depletion attraction. Finally in waveguides, the radiative decay rate of embedded cQDs may be adjusted as optical modes supported by the fiber alter the local density of optical states (LDOS). Finite difference time domain (FDTD) simulations revealed only minimal changes in lifetime with variation of the fiber core radius: the

	Purcell factor stayed within ±2.2% of its initial value and any PL enhancement has yet to be observed [2]. Thus, step index fibers do not offer sufficient control over the radiative decay rate and other ways to modify the LDOS must be identified. References [1] C. A. Whittaker et al., Light-Generating CdSe/CdS Colloidal Quantum Dot-Doped Plastic Optical Fibers. ACS Applied Nano Materials 3(7): 6478–6488 (2020). doi:10.1021/acsanm.0c00946. [2] O.-M. Tardif, A. Perret and C. Nì. Allen, Towards optimal light-matter coupling of colloidal quantum dots in optical fibers. Low-Dimensional Materials and Devices 2020 (11465) 114651D (2020). doi:10.1117/12.2568888.

19	**Devising a Space Compressing Optic Using Inverse Design** Presenter: Jordan Pagé, University of Ottawa To make imaging systems shorter, one could use metalenses [2-4]. They allow us to replace the comparatively thick glass of lenses with a much thinner optic [1]. This, however, does not address the largest distances in the imaging system: the space between lenses. The solution we propose is to use a 'spaceplate' [5]. A spaceplate 'compresses' free space while conserving the incident path of the light. A multilayer spaceplate possesses an incredible freedom of design, including layer thicknesses and refractive indices. We first designed a multilayer spaceplate using a genetic algorithm. The result was a 25-multilayer stack, with alternating layers of silicon and silica. Although this device shows promise, the highest incident angle of light it can accept is 15º. We thus attempted to design a spaceplate using gradient ascent, optimizing each layer's thickness until they converged towards a global peak. We will also present results using gradient ascent to optimize each layer's refractive index instead of layer thickness. This optimization yields less feasible devices but provides information on the ultimate performance of spaceplates. By using gradient ascent machine learning, we will explore a more complete design space for a multilayer spaceplate, thereby establishing empirical limits to its performance. References 1. Khorasaninejad, M. et al.: Versatile multifunctional photonic components Science 358, 8100 2. Kildishev, A. V., et al., Planar photonics with metasurfaces Science 339, 1232009 3. Yu, N. et al., Flat optics with designer metasurfaces Nature Materials 13, 139–150 4. Meinzer, N., et al. Plasmonic meta-atoms and metasurfaces Nature Photonics 8, 889–898 5. Reshef, O., et al., Towards ultra-thin imaging systems: an optic that replaces space arXiv:2002.06791 6. Molesky, S. et al., Inverse design in nanophotonics Nature Photonics 12, 659–670
21	**Singlet Fission in Azulene aggregates and Azulene-derivative compounds** Presenter: Stephen Awuku, University of Saskatchewan Singlet Fission in Azulene aggregates and Azulene-derivative compounds Capturing solar energy with photovoltaic cells is a viable alternative for energy generation due to the abundance of solar radiation reaching the earth's surface. The use of p-n junction crystalline materials such as gallium arsenide

	or silicon has proven effective. However, these materials suffer from low solar-to-electric power conversion efficiencies due to the transparency of the solar-cell absorber to photon energies below its bandgap and thermalization losses in the case of higher-energy photons. These losses have led to the Shockley–Queisser (SQ) limit for solar-to-electric power conversion efficiency, which is 33% for an ideal silicon cell (Eg = 1.1 eV) for a single-junction photovoltaic cell. We propose that singlet fission materials incorporated into solar cell applications will enhance solar cell efficiencies. Singlet fission is a spin-allowed process that involves splitting a high-energy singlet exciton into two lower-energy triplet excitons. The process can be very fast; therefore, can compete with other de-excitation pathways. Solar cells' efficiency could significantly improve if one combines a singlet fission material and ordinary material, such as silicon. The singlet fission process's energy requirement is very difficult to achieve in most molecules, however. This limits the application of singlet-fission molecules to light-harvesting technologies. To solve this problem, we are investigating azulene and azulene-derivative compounds as they fulfill the energy requirement for singlet fission from their upper-excited energy states. We will show the results of our preliminary investigations of the electronic and photophysical properties of azulene aggregates and azulene-derivative compounds using ultrafast spectroscopic techniques. Reference (1) Smith, M. B.; Michl, J. Singlet Fission. Chem. Rev. 2010, 110 (11), https://doi.org/10.1021/cr10026
22	Hyperspectral Near Infrared Spectroscopy of the brain during Breath holding using a multi-layer model of the head Presenter: Zahida Guerouah, Department of Physics. Ryerson University There are approximately 40 000 cardiac arrests (CA) in Canada each year. During CA, low cerebral perfusion can lead to the hypoxic-ischemic brain injury. Hyperspectral near-infrared spectroscopy (hNIRS) is a non-invasive technique to measure absolute and relative concentrations of chromophores in the brain such as the oxygenated hemoglobin (HbO2), deoxygenated hemoglobin (Hb) and cytochrome C oxidase (Cyt-C). Concentrations of these chromophores and their temporal variations are related to the values of the absorption coefficient (μ_a), which can be obtained from the measurements of the reflected light intensity at multiple wavelengths. The quantitative hNIRS algorithms based on the diffusion approximation for light transport in highly scattering medium will be applied to the data to measure cerebral Hb and Cyt-C in human subjects during breath-holding, which is a simple method to cause significant changes of cerebral blood parameters. In order to separate the cerebral values from the extracerebral ones, the two-layer model of the head will be used. hNIRS measurements at different source-detector distances will serve to determine fist, using an homogenous model, the properties of the top layer with a thickness close to the adult skull thickness. Then, the 2-layer model will be applied to determine the optical properties of the bottom layer (brain).
23	Plasmonic Metasurfaces with Ultra-High-Q Lattice Resonances Presenter: Md Saad-Bin-Alam, University of Ottawa The efficiency of some specific nanophotonic operations, such as subwavelength nanolasing, ultrafast all-optical switching, biosensing, and nonlinear optical processes are dependent on plasmonic resonant nanocavities [1-2]. The resonances associated with individual plasmonic metal nanostructures-based nanocavities are called the localized surface plasmon resonances (LSPRs). Recently, metasurfaces formed by periodic arrays of plasmonic nanocavities have emerged as a promising platform for such applications [1-2]. However, the practical applications of the plasmonic nanocavities are often hindered due to the intrinsic absorption and radiative losses associated with the metal nanostructures leading to very low quality-factors (Q ≈ 10). In recent years, one order of magnitude increase in the resonance Q-factors (Q ≈ 100 to 300) has been demonstrated by controlling the periodicity or lattice constant of the plasmonic metasurface arrays [2]. Such resonances are called plasmonic surface lattice resonances (SLRs). Here, we show that by properly selecting the spectral gap between LSPRs and SLRs, the metasurface array size, and maintaining the special coherency of the collimated

	incident light source (e.g. by choosing a laser instead of an incoherent thermal light source), the Q-factor of the plasmonic SLRs can be two order-of-magnitude larger (Q ≈ 1500 to 3000) than the typical Q-factor of the LSPRs.
24	An Investigation of Soliton Self-Frequency Shift in Photonic Crystal Fiber Presenter: MacAulay Harvey, Saint Mary's University A soliton is generated in optical fiber when the effects of group velocity dispersion and self phase modulation cancel allowing a pulse of light to propagate through the fiber with no change to its temporal profile or spectrum. When pulses with duration on the order of one picosecond or less are used, stimulated Raman scattering can cause the spectrum of the pulse to be continuously redshifted in an effect known as soliton self-frequency shift. This effect is of great interest because it enables the construction of a wavelength tunable laser source for use in nonlinear optical microscopy. This would allow for a larger range of samples that could be imaged and would allow investigation of the wavelength dependence of nonlinear optical phenomena in various materials. This poster will provide an explanation of the theory of soliton self-frequency shift and will give an overview of the experimental set-up used in this investigation. Experimental data showing the effect of soliton self frequency shift in optical fiber will also be presented.
25	Merging optics and electronics through optically resonant randomly addressable crossbar metamaterial architectures Presenter: Avik Mandal, University of Alberta The introduction of optical-fibre networks in the 1980's along with the ongoing merger of optics and electronics has led to light becoming the major information carrier and manufacturing tool in 21st century society. We argue here that the next evolutionary stage to combat electronic bottlenecks and ballooning energy consumption while enabling novel functionalities can be unlocked by merging nanoscale electronic and photonic architectures to create a universal mixed-mode, CMOS compatible, information processing platform. Recently, crossbar architectures consisting of 2D arrays of electronic switches, have gained significant popularity in emerging electronic data storage and computing architectures, most notably being at the heart of Intel's 3D XPoint and various memristive and phase change random access memory (e.g ReRAM and PCRAM) platforms. These arrays are implemented by sandwiching a dielectric switching medium between two arrays of plasmonic nanowire electrodes arranged perpendicular to each other, so present an architecture akin to the metal-insulator-metal (MIM) platform widely used in nanophotonics. Therefore, using finite element method simulations we show here that nanoelectronic crossbar architectures can be engineered to act as metasurfaces that exhibit multiple high quality-factor Fano-type optical resonances across visible and near infrared frequencies (λ between 400-1700nm) due to their subwavelength size and multi-layer design, while preserving their randomly addressable electronic functionality.
26	Colour tunable graded index refractory metal-oxide metamaterial coatings realized using bottom-up growth techniques Presenter: Josh Perkins, University of Alberta Photonic metamaterials research has presented a wide range of innovative devices with extraordinary functionalities. Current research in photonic metamaterials has recognized and sought solutions to the technological drawbacks of noble plasmonic metals, Such as optical losses, low-melting-points, cost and CMOS-incompatibility. The pursuit for alternative material platforms now encompasses chalcogenide semiconductors, transparent conductive oxides, nitrides, and 2D materials. In this domain, refractory metal oxides, offer a highly versatile and overlooked material platform for the realization of optoelectronic devices. These materials offer high melting points, stoichiometrically engineered optical properties across visible and infrared frequencies and CMOS compatibility, they can be deposited as discreet films or grown through controlled oxidation of nanoscale metallic templates to form metal-oxide bilayers. The metal-oxide material library also offers a multifaceted design space offering various refractive indices and extinction coefficients primed for use in optics, photonics and in metamaterial designs. Here we show that refractory metal-oxide films fabricated

	through bottom up growth of graded index oxide layers using low-cost room-temperature vapor deposition and annealing techniques enable the realization of large lateral area metamaterial coatings (meta-coatings). These meta-coatings exhibit optical resonances and light trapping behaviour across visible frequencies. The optical response and vibrant visible color observed in such meta-coatings can be tuned by controlling the thickness of the subwavelength graded index layers. Therefore, fabrication of such meta-coatings requires no lithographic nanopatterning and can be readily achieved across wafer scale and even larger lateral dimensions.
27	Nonlinear Adjoint Sensitivity Analysis of Fiber-Optic Communication Systems Presenter: Mahmoud Maghrabi, McMaster University Optical fibers play a vital role in modern telecommunication systems and networks. The light-wave propagation in an optical fiber transmission system is described by the nonlinear Schrödinger equation (NLSE). An accurate and fast sensitivity analysis of the NLSE is therefore of prime importance to achieve the optimal design of an optical fiber system using gradient-based optimization algorithms. Any gradient-based optimization algorithm requires at least one sensitivity analysis calculation with respect to all design parameters, in order to guide its search for a better design. In practice, hundreds of gradient calculations may be required to achieve the optimal design. This overhead is prohibitive and impractical for optical fiber design problems with large number of parameters, e.g., the optimal design of dispersion-managed coherent fiber-optic systems and parameter extraction of a digital backpropagation in optical fiber networks. This work presents an efficient and computationally inexpensive adjoint sensitivity analysis (ASA) approach for optical fiber communication systems. The introduced approach is based on the general time-dependent NLSE. Regardless of the number of fiber parameters, the proposed ASA approach estimates the sensitivities of the desired objective function with respect to all design parameters using only one extra adjoint system simulation. This is contrasted with the traditional finite-difference-based sensitivity analysis methods whose computational cost scales linearly with the number of design parameters. A modified split-step Fourier scheme algorithm is developed to solve the derived adjoint problem. The accuracy and efficiency of the proposed approach are demonstrated through a comparison with the accurate but computationally expensive central finite-differences (CFD) approach. Numerical simulation results show that the proposed ASA algorithm has the same accuracy as the CFD approach but with a much lower computational cost.
28	Silicon Photonics and Optical Fibre Integrated Phase Change Metamaterial Modulators for Telecommunications Presenter: Yihao Cui, University of Alberta The backbone of modern telecommunication networks consists of three main components: electronic processing modules that encode and decode information, on-chip silicon photonic waveguides for signal routing and optical fibres which serve as the connection link between individual network nodes. The electro-optical signal conversions inherent within current network architectures presents a barrier for achieving higher data rates and lower latencies. Recently, in planar platforms, phase change metamaterials (made from reconfigurable chalcogenide semiconductors) have shown great promise in the realization of all-optical switches capable of intensity modulation and beam steering functionality with built-in memory functionality at a fraction of a wavelength in size. We propose that by incorporating phase change chalcogenide metamaterials on optical fibres and silicon waveguides, signal processing capabilities can be brought to traditionally passive light guiding structures which would enable a multitude of advantages including transmission efficiency – the reduction of coupling losses between fibre and waveguide junctions, reduction in overall physical footprint of silicon photonics, lower power consumption, higher bandwidth and data rates for next-generation communication standards such as 5G, and also compatibility with future adoption of all-optical network infrastructures. Here, through multiphysics numerical simulations, we present metadevices made from reconfigurable phase change chalcogenides on side polished optical fibres and silicon nitride waveguides that exhibit large transmission contrast ratios

	of up to 5 dB between amorphous and crystalline structural phases as well as both normal and anomalous dispersion profiles across the telecommunication bands. The resonances of these metadevices can be spectrally shifted by varying the periodicity and thickness of the metasurface to tune the operational range.
29	**Optically pumped semiconductor disk laser design, emitting at 1.55 µm, based on wafer bonding technology for efficient thermal management** Presenter: Zahed Dastan, University of New Brunswick In this paper, optically pumped semiconductor disk laser which is designed based on semiconductor-dielectric-metal technique using the wafer bonding process is presented. This approach is useful in terms of reducing the number of the Distributed Bragg Reflector (DBR) layer pairs for efficient thermal management of the chip. In the design of VECSELs, emitting at telecommunication wavelength the number of DBR layer pairs is critical. Aluminum, Silver, Gold, and Copper are studied as the bonded metal layer. Moreover, the effect of the bonded metal layers on the reflectivity of the residual pump light would enhance the efficiency of pumping. Also, using a sophisticated material system for both the active region and the mirror structure enables us to study the proposed structure thoroughly. Finally, this paper proposes the possibility of enhancing the performance of the optically pumped semiconductor disk lasers for high powers, particularly at higher wavelengths. [1] M. Guina, A. Rantamäki, A. Härkönen, Optically pumped VECSELs: review of technology and progress, J. Phys. D. Appl. Phys. 50 (2017) 383001. [2] J. Paajaste, S. Suomalainen, R. Koskinen, A. Härkönen, M. Guina, M. Pessa, High-power and broadly tunable GaSb-based optically pumped VECSELs emitting near 2 µm, J. Cryst. Growth. 311 (2009) 1917–1919. [3] A. Sirbu, A. Rantamäki, E.J. Saarinen, V. Iakovlev, A. Mereuta, J. Lyytikäinen, A. Caliman, N. Volet, O.G. Okhotnikov, E. Kapon, High performance wafer-fused semiconductor disk lasers emitting in the 1300 nm waveband, Opt. Express. 22 (2014) 29398–29403. [4] A. Rantamäki, E.J. Saarinen, J. Lyytikäinen, K. Lahtonen, M. Valden, O.G. Okhotnikov, High power semiconductor disk laser with a semiconductor-dielectric-metal compound mirror, Appl. Phys. Lett. 104 (2014) 101110.
30	**Polarization entanglement from an incoherent pump** Presenter: Cheng Li, University of Ottawa Entangled photon states are usually generated from spontaneous parametric down-conversion (SPDC) pumped by a laser, a light source that is coherent in every degree of freedom [1]. Recently, there have been interests in investigating the effect of pump coherence on the down-conversion entanglement. Previous studies revealed that for position-momentum and temporal entanglement, spatial and temporal coherence of the pump is necessary for its generation [2, 3, 4]. We want to know if the spatial/temporal coherence of the pump will affect the polarization entanglement. To study this problem, We use two type-I BBO crystals rotated 90 degree from each other, when pumped by a 45 degree polarized light, we can ideally produce a maximally entangled state $\|\psi\rangle = \|HH\rangle + \|VV\rangle$[5], but since LED is a broadband and multimode light source, LED is broadband and multimode light source, the generated two photon state may contain wavelength and k vector dependent phase terms between photons from two crystals, the spatial and temporal walk-off can cause decoherence upon detection and entanglement is lost [6]. We conducted numerical simulation and showed that maximally entangled state can be generated by introducing spatial and temporal compensation. [1] Hong, C. K. and Mandel, L., Phys. Rev. A 31 (4), 2409 (1985). [2] Jha, A. K. and Boyd, R. W., Phys. Rev. A 81 (1), 227 (2010). [3] Kulkarni, G. et al., J. Opt. Soc. Am B 34 (8), 1637 (2017). [4] Zhang, W. et al. Opt. Express 27 (15), 20745-20753 (2019) . [5] Kwiat, P. G. et al., Phys. Rev. A, 60 (2), 773-776 (1999). [6] Rangarajan, R. et al., Opt. Express 17 (21), 18920 (2009).

31	**Four-wave mixing, two-photon absorption and free-carrier absorption in AlGaAs waveguides of three different geometries** Presenter: Daniel Espinosa, University of Ottawa Aluminum gallium arsenide (AlGaAs) is a photonics bench-mark material among the III-V semiconductors, due to its high nonlinear refractive index, desirable for nonlinear photonics applications. It presents a direct bandgap, allowing a monolithic integration of active and passive devices on the same material platform. The four-wave mixing (FWM) process in passive AlGaAs waveguides, in particular, can be explored as a way to perform all-optical wavelength conversion. This poster presents the results of FWM studies in AlGaAs waveguides of three different geometries: strip-loaded, nanowire, and half-core [1]. The pump is a picosecond-pulsed beam, and the signal is an amplified-CW beam, both around the wavelength of 1550 nm. The FWM efficiency was measured as a function of the pump wavelength for each geometry. We also compared the experimental data with a theoretical model that considers the dispersion of the waveguides. The data deviates from theory at the wavelengths where the pump photons participate in a two-photon absorption (2PA) process. We performed the nonlinear transmission technique, using the pump beam, to measure the 2PA spectra for each of the three geometries to clarify this point. Three main characteristics were observed. First, the 2PA is not the only mechanism of nonlinear absorption. The free-carrier absorption (FCA) had to be considered in the data analyzes, and both the 2PA coefficient and the FCA cross-section were achieved. Second, the 2PA coefficient does not vanish for photon energies lower than half-bandgap, indicating a band tail similar to the linear Urbach tail. And finally, the 2PA coefficient depends on the waveguide geometry, what we attribute to the electric field modal distribution among the different layers of the waveguide. [1] D. H. G. Espinosa, K. M. Awan, M. Odungide, S. R. Harrigan, D. Sanchez, and K. Dolgaleva, Tunable four-wave mixing in AlGaAs waveguides of three different geometries. Optics Communications 479, 126450 (2021).
32	**Serum Proteins on Nanoparticles: Redefining the "hard corona"** Presenter: Sarah McColman, Ryerson University Nanoparticles in biological systems such as the bloodstream are exposed to a complex solution of biomolecules. A "hard corona" monolayer of proteins has historically been thought to form on nanoparticles upon introduction into such environments. To examine the first steps of protein binding, Fluorescence Correlation and Cross Correlation Spectroscopy were used to analyze five different nanoparticle systems. CdSe/ZnS core/shell quantum dots, 100 nm diameter polystyrene fluospheres, 200 nm diameter polystyrene fluospheres, 100 nm diameter DOPC liposomes, and 100 nm diameter PEG-grafted DOPC/DOPE liposomes were characterized and studied with respect to serum protein binding. We proposed binding mechanisms to expand general understanding about the first stages of "corona" formation, and these suggest very complex surface interactions. Heterogeneity is found to be a key factor in protein binding to nanoparticles, and as such a novel conceptualization of the preconceived corona as low-ratio, non-uniform binding rather than a monolayer arose from these studies.
33	**Patterned Nanoscale Magnetic Ferrites for Surface-Enhanced Raman Sensing** Presenter: Stephanie Gallant, Memorial University We present a new optoelectronic application for nanoscale magnetic ferrites, with our sensing surface being capable of detecting ppb levels of analytes, as well as being selective in complex matrices. As nanoscale metal oxides possess unique electronic, optical, and surface properties, they are very attractive components for use in optoelectronic sensing. Magnetic nanoparticles (NPs) have largely been employed in surface-enhanced Raman spectroscopy (SERS) as core-shell vehicles for biological detection, but little focus has been put on them as a prominent plasmonic material. We have developed a novel sensing surface with magnetic ferrite nanomaterials at the forefront of the design, with a classic plasmonic metal taking a background role, moving away from conventional SERS designs. Our NPs are patterned onto the substrate, creating a hierarchical multilayer which

	provides significant enhancement and high incidence of hotspot locations throughout the surface. Aimed at detection of polyaromatic hydrocarbons (PAHs) in waters, our surfaces can reliably detect at ppb analyte levels, and are able to distinguish PAHs within complex matrices with many other organics present. On top of impressive performance, our design is cost-effective and simple, allowing for quick analyte loading with no sample workup or extractions. In addition to linking magnetic properties and surface topography to SERS performance, we can also tune the magnetic properties and the sensitivity of the sensor through simple synthesis changes. Altering variables during synthesis results in varied crystal geometry and magnetism, which we present as correlating to surface performance. Additionally, we demonstrate how an externally applied field during spectral acquisition may affect the local enhancement of analytes on our surface.
34	Single Crystal Plasmonic Gold Metasurfaces Presenter: Sasan V. Grayli, IQC University of Waterloo Material quality and crystallinity play an important role in the activity of plasmonic nanostructures and metasurfaces. Plasmonic devices made from monocrystalline metals are expected to display much higher efficiency and stability than polycrystalline devices which are subject to many losses due to the presence of grain boundaries and defects. It has previously been demonstrated by our group that through novel epitaxial electroless deposition (EED) chemistry, ultra-smooth gold (Au) films can be grown on monocrystalline silver (Ag) surfaces. In this approach, the electrochemical incompatibility of Au and Ag that leads to galvanic replacement can be overcome in concentrated sodium hydroxide (NaOH) (1 M), where OH^- causes a decrease in the reduction potential of Au3+ cations by forming $Au(OH)4^-$ complexes (E≈0.57 V), an increase in the oxidation potential of the Ag electrode (E≈1.40 V) and acts as a reducing agent. As a result, ultra-smooth monocrystalline Au films are grown with the same crystalline orientation as the underlying Ag film. Here, we demonstrate the compatibility of this electrochemical approach in the fabrication of plasmonic metasurfaces on monocrystalline Au on flexible and rigid substrates using conventional nanofabrication techniques.
35	Measurement of the orbital-angular-momentum spectrum for high-gain parametric down-conversion Presenter: Jeremy Rioux, University of Ottawa We implement an interferometric technique which can directly encode the orbital-angular-momentum (OAM) spectrum information in the azimuthal intensity profile of an output interferogram. We use this technique to measure the OAM spectrum of a state produced by parametric down-conversion (PDC) in the high-gain regime. This technique relaxes the requirements of previous OAM detection techniques, such as interferometric stability and efficiency.
36	Quantum repeaters based on individual electron spins and nuclear-spin-ensemble memories in quantum dots Presenter: Kenneth Sharman, University of Calgary Inspired by recent developments in the control and manipulation of quantum dot nuclear spins, which allow for the possibility of transferring entanglement to the nuclear ensemble for storage, we propose a quantum repeater scheme that combines individual quantum dot electron spins and nuclear-spin ensembles, which serve as spin photon interfaces and long-term memories respectively. Distant quantum dot electron spins are entangled by heralding single photon emission after which-path information is erased using a beam splitter. The excellent light out-coupling efficiencies offered by quantum dots allow us to generate entanglement efficiently. We consider the use of quantum dots embedded in high-cooperativity optical microcavities to perform heralded entanglement swapping using cavity-assisted gates. Entangled states are transferred to the surrounding quantum dot nuclear-spin

	ensembles for storage. Our scheme promises the establishment of high-fidelity entanglement over long distances with a distribution rate exceeding that of the direct transmission of photons.
37	Enhanced Nonlinear Optical Responses of Layered Epsilon-Near-Zero Metamaterials at Visible Frequencies. Presenter: Sisira Suresh, University of Ottawa In recent years, there has been a growing interest in investigating light behaviour in media with vanishing dielectric permittivity. These materials are commonly known as epsilon-near-zero (ENZ) materials. ENZ materials have been shown to possess enhanced nonlinear optical responses in their zero-permittivity region. This enhanced nonlinearity at zero-permittivity wavelength has been observed in homogeneous materials such as indium-doped tin oxide and aluminum-doped zinc oxide. The zero-permittivity wavelength of such materials is dictated by their intrinsic material properties and hence, cannot be used for applications requiring that the ENZ condition occurs at some specified wavelength. As opposed to homogeneous ENZ material, artificially engineering metamaterials allows us to have a priory defined zero-permittivity wavelength at any desired optical wavelength. This work demonstrates metamaterials composed of subwavelength, multilayer metal-dielectric stacks, designed to fulfill the ENZ condition and showed that they exhibit an enhanced nonlinear response in their zero-permittivity wavelength. Our metamaterial comprises five alternating layers of 16 nm silver and 65 nm of fused silica with a designed effective zero-permittivity wavelength of 509nm. The zero-permittivity wavelength of these metamaterials may be chosen to lie anywhere within the visible spectrum by selecting the sub-wavelength layers' right thicknesses. The ability to obtain strong nonlinearities at designated optical frequencies makes these metamaterials a flexible platform for nonlinear optics applications.
38	Unitary linear optical transformations in a reconfigurable platform. Presenter: Aldo Camilo Martinez, University of Ottawa Transformation of optical spatial modes has a wide range of applications from fundamental studies to telecommunications. Beam arrays of spatial modes are used for information transmission and information processing, the ability to transform such beam arrays enhances the capability of current optical technology. In this contribution, we experimentally demonstrate arbitrary transformations on a two-beam array. There is increasing interest in developing reconfigurable platforms to perform unitary transformations. This type of platform can unveil new application areas in photonics or improve current optical technology, next are some examples of such applications. Reconfigurable devices to perform unitaries can be concatenated and be used for matrix multiplication, adding a non-linear element to the system allows one to implement a neural network. Many information processing tasks are unitary processes and therefore they can be enhanced by the transformation of optical modes, for example by performing image compression as light propagates. From the quantum side, a reconfigurable platform can be used to execute quantum gates such as the CNOT gate. Another application is creating a sequence of different unitary operations allowing one to implement a quantum random walk, which can be used to simulate complex systems such as molecules.
39	Omnidirectional phase-matching in zero-index media Presenter: Justin Gagnon, University of Ottawa The nonlinear optical response of materials is the foundation upon which applications such as frequency conversion, all-optical signal processing, molecular spectroscopy, and nonlinear microscopy are built. However, the efficiency of all such parametric nonlinear optical processes is hampered by phase-matching requirements. Quasi-phase-matching, birefringent phase matching, and higher-order-mode phase matching have all been developed to

	address this constraint, but the methods demonstrated to date suffer from the inconvenience of only being phase-matched for a single, specific arrangement of beams, typically co-propagation, resulting in cumbersome experimental configurations and large footprints for integrated devices. Here, we experimentally demonstrate that these phase-matching requirements in a parametric nonlinear optical process may be satisfied for multiple, if not all, configurations of input and output beams when using zero-index media. Our measurement constitutes the first experimental observation of multi-directional phase matching in a medium longer than a free-space optical wavelength, allowing us to precisely determine the coherence lengths of our four-wave-mixing process. We demonstrate four-wave mixing from spectrally distinct counter-propagating pump and probe beams, the backward-generation of a nonlinear signal, and excitation by an out-of-plane probe beam. These results explicitly show that the unique properties of zero-index media relax traditional phase-matching constraints, which can be exploited to facilitate nonlinear interactions and miniaturize nonlinear devices, thus adding to the established exceptional properties of low-index materials.
40	Iridescent Cellulose Nanocrystal Films Modified with Hydroxypropyl Cellulose Presenter: Christopher Walters, University of British Columbia Cellulose nanocrystals (CNCs) are an abundant biorenewable resource that spontaneously organize into chiral nematic liquid crystals with hierarchical structure. This chiral nematic organization is retained in dried films of CNCs, giving films with brilliant iridescent colors.1 The introduction of polymers into a CNC matrix allows for the tuning of optical and mechanical properties, enabling the development of responsive photonic materials.2 Previously, researchers have investigated CNCs added to hydroxypropyl cellulose (HPC), but not the effects of small amounts of HPC on CNCs.3, 4 In this study,5 we explored the incorporation of HPC into a CNC film prepared by slow evaporation. In the composite CNC/HPC thin films, the CNCs adopt a chiral nematic structure, which can selectively reflect certain wavelengths of light to yield a colored film. The color could be tuned across the visible spectrum by changing concentration or molecular weight of the HPC. Importantly, the composite films were more flexible than pure CNC films with up to a ten-fold increase in elasticity and a decrease in stiffness and tensile strength of up to six-times and four-times, respectively. Surface modification of the films with methacrylate groups increased the hydrophobicity of the films and therefore the water stability of these materials was also improved. 1. Revol, J.-F., et al., J. Pulp Pap. Sci., 24, 5, (1998). 2. Tran, A., et al., Adv. Mater., (2020). 3. Ma, L., et al., Cellulose, 21, 6, (2014). 4. Fernandes, S. N., et al., Macromol. Chem. Phys., 214, 1, (2013). 5. Walters, C. M., et al., Biomacromolecules, (2020).
41	Sum Frequency Generation Spectroscopy: A Molecular probe for Energy Systems Presenter: Mokhtar Rashwan, University of Alberta Sum frequency generation, SFG, a surface specific spectroscopic technique, is used for probing buried surfaces and interfaces not easily accessed with conventional analytical techniques. Meanwhile, understanding the chemistry of the silica/aqueous interface is crucial since it is ubiquitous in many geochemical and industrial systems. As such, we have been using SFG to study the silica/aqueous interface under different conditions of pH and salt solutions. Further, one of the most complex silica/aqueous interfaces is oil sand tailings. Hence, understanding such a complex interface can help identify a potential oil sand tailing dewatering agent, which is an environmental challenge for oil sand exploration. Using SFG, we could observe silica-kaolinite surfaces dewatering with saturated aqueous lime (pH 12.4), which puts lime a potential candidate as an oil sand tailing dewatering agent. We have also studied the effect of solution pH and surface morphology on the photocatalytic activity of titania surfaces, used in energy related photocatalytic reactions, such as carbon dioxide reduction.

42	**Electric Field Measurements from THz to mid-IR** Presenter: Étienne Doiron, femto Q lab, Polytechnique Montreal Traditional spectroscopy involving square-law detectors does not allow the recuperation of complete information on the state of light, with the phase information generally lost. This information is however crucial not only for full characterisation of the light field itself but also for sensing the response function of various materials, especially in the out-of-equilibrium scenarios[see e.g. 1]. In this context, electro-optic sampling (EOS) is a great tool allowing direct measurement of the optical field in the time domain, gated through hthe three-wave mixing process of non-linear optics[2-4]. By using few-cycle gating pulses, one can achieve direct amplitude and phase measurement for frequencies in the range from the THz to the near-IR bands. The time resolution of this oscilloscope for light is set by the length of the gating pulses, also determining the frequency bandwidth of the measurement. In our implementation, pulses from a homebuilt mode-locked Ti:Sapphire laser have been compressed down to 13 fsby chirped mirrors, as characterized via the frequency-resolved optical gating (FROG, [5])and two-dimensional spectral shearing interferometry(2DSI, [6])setups. These allowed the generation and EO sampling of broadband THz to mid-IR pulses, spanning from 0.5THz to 55 THz. These results are compared with expected performance using response function calculations allowing exploration of new and effective non-linear detector crystals.This performance paves the way toward an ultrabroad characterization platform of quantum light-matter coupling in condensed matter, mediated through low-energy collective excitations in the THz to mid-IR frequency range[7-9]. [1] R. Huber et al., Nature 414, 286-289 (2001)[2] Q. Wu and X.-C. Zhang, APL 71, 1285 (1997)[3] A. Leitenstorfer et al., APL 74, 1516 (1999)[4] J. Faure et al., Opt. Quantum Electron. 36, 681-697(2004)[5] D. J. Kane and R. Trebino, IEEE J. Quantum Electron. 29, 571 (1993)[6] J. R. Birge et al., Opt. Lett. 31, 2063-2065 (2006)[7] C. Rieket al., Science 350, 420-423 (2015); Nature 541, 376-379 (2017)[8]I.-C. Benea-Chelmus et al., Nature 568, 202-206 (2019)[9] M. Kizmannet al., Nat. Phys. 15, 960-966 (2019)