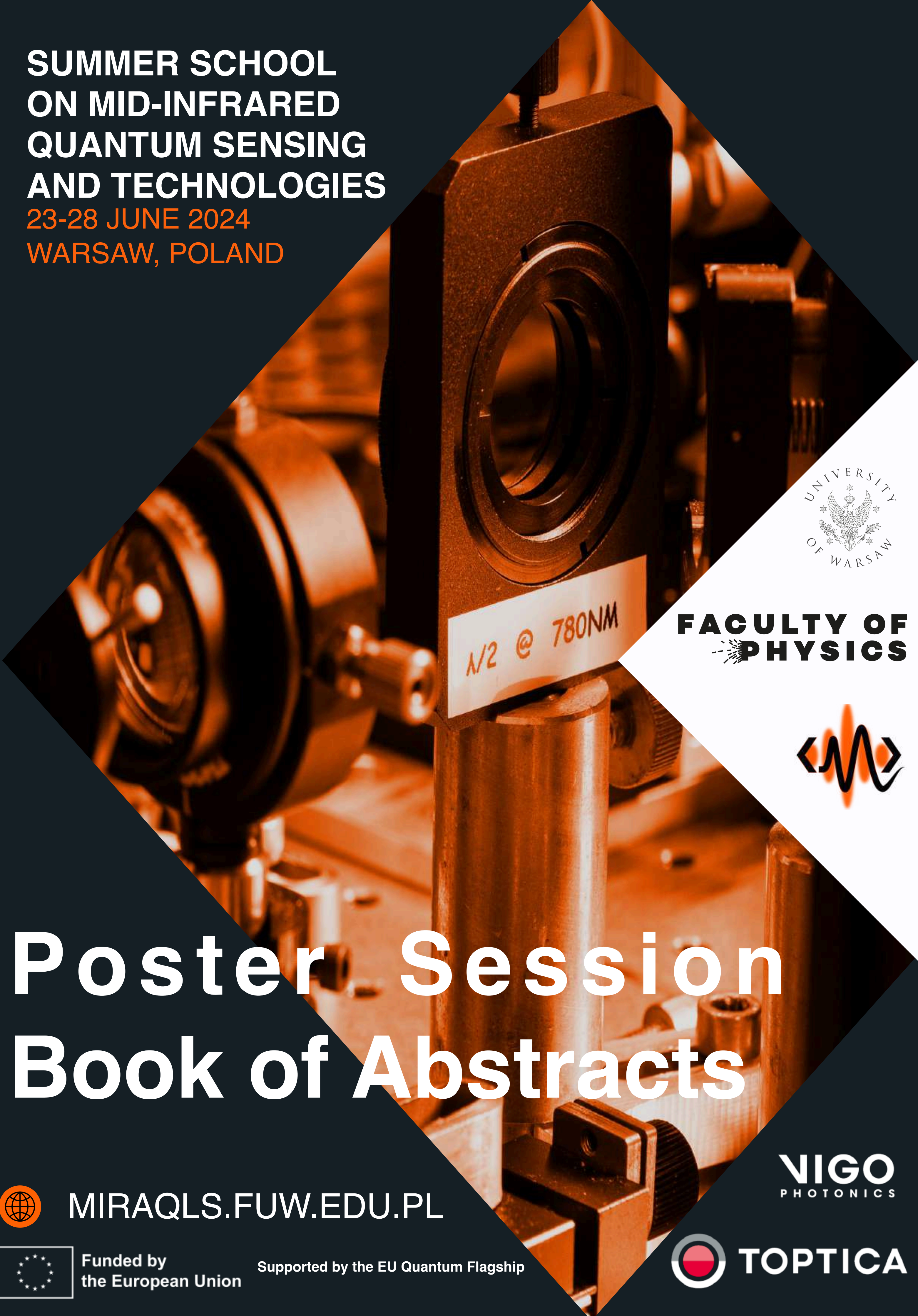
SUMMER SCHOOL ON MID-INFRARED QUANTUM SENSING AND TECHNOLOGIES

23-28 JUNE 2024
WARSAW, POLAND



UNIVERSITY OF WARSAW

FACULTY OF PHYSICS

Poster Session Book of Abstracts

MIRAQLS.FUW.EDU.PL

VIGO PHOTONICS

Funded by the European Union

Supported by the EU Quantum Flagship

TOPTICA

Poster List

No.	Presenter	Poster Title
P1	Sourav Das	Optimal single photon quantum spectroscopy
P2	Karolina Suliga	Comparison of carrier-envelope frequency offset stabilisation techniques for Cr:ZnS solid-state laser
P3	Aleksei Gaier	Direct probing of cavity-confined vacuum fields
P4	Geehyun Yang	Subcycle tomography of quantum light
P5	Riccardo Nardin	Implementation of an experimental setup for Mid-Infrared Quantum Emitters measurements
P6	Kate Fenwick	Photonic quantum walk with ultrafast time-bin encoding
P7	Amin Lakhal	Optical spectroscopy of thermal current fluctuations detected via quantum interference of absorption pathways in centrosymmetric semiconductors
P8	Krzysztof Pyrchla	Functionalization of Nanodiamonds for Stable Nitrogen-Vacancy Center Bio-Quantum Sensing
P9	Pierre-Luc Thériault	Spontaneously Oriented Evaporated Organic Semiconductor Thin Films for Second-Order Nonlinear Photonics
P10	Hubert Kołcz	Stabilization of 10-GHz micro-combs for stable soliton pulse generation
P11	Alí Angulo	Shaping the spectral correlation of bi-photon quantum frequency combs by multi-frequency excitation of an SOI integrated nonlinear resonator
P12	Diego Piciocchi	Strongly modulated broadband quantum cascade lasers for fast interleaving FTIR spectroscopy
P13	Ina Heckelmann	Quantum Walk Combs for spectroscopic applications
P14	Samuel Fontaine	Photon pair generation in III-V semiconductor microrings: modal dispersion and “built in” quasi-phase matching
P15	Jayanth Jayakumar	Quantum-enhanced joint estimation of phase and phase diffusion
P16	Gabriel Demontigny	Field-sensitive detection of femtosecond pulses in the mid-infrared using sub-cycle electron tunnelling
P17	Émile Dessureault	Characterization of an Offset-Stabilized Dual-Frequency Comb System at 1.55 μm Toward Broadband Absorption Spectroscopy
P18	Emad Rezaei Fard Boosari	Quantum data Compression
P19	Filip Sośnicki	Electro-optic spectral shaping of single-photon pulses
P20	Marcin Wajs	Spectroscopy of isotopically purified Germanium
P21	Swagata Mallik	Optimizing Third Harmonic Generation in Ge Diffraction Gratings
P22	Carlos José Sánchez Martínez	A mixed perturbative-nonperturbative treatment for strong light-matter interactions
P23	Ksawery Mielczarek	Phase-only spectro-temporal shaping of quantum light
P24	Zagbayou Bedi	Shot-noise limited terahertz detection with spintronic emitters
P25	Bohnishikha Ghosh	Towards observing quantum optical backflow
P26	Jan Krzyżanowski	Enabling two-photon interference with time lensing

No.	Presenter	Poster Title
P27	Coralie Bellemare	Silicon-Integrated Mid-Infrared Photoconductive Devices using Strain-Relaxed GeSn
P28	Patrick Del Vecchio	Light-Hole Spins Confined in Germanium
P29	Klaudia Dilcher	Atomic magnetometry with Kalman Filters
P30	Michał Siemaszko	Time series prediction with photonic quantum memristor
P31	Maryam Afsary	Advancements in Performance Enhancement for DI-QKD Protocols
P32	Alexandre Siron	Accelerating block-Toeplitz matrix vector products: Green functions approaching differential operator complexity
P33	Tripathi Om Sarveshwarpati	Modulation Free Laser Stabilization for Cold Atom Experiments
~~**P34**~~	~~Kuntal Samanta~~	~~Spatial Atomic Modulator with cold atoms~~
P35	Nicolas Rotaru	Hole EDSR in Direct Bandgap Group IV Quantum Dot
P36	Lu Luo	Ge/GeSn Nanowires for Mid-infrared Sensing and Imaging
P37	Bruno Lopez-Rodriguez	Large, deterministic and tunable thermo-optic shift for all photonic platforms
P38	Ali Abbas	Synthesis and characterization of GaSb-Ge eutectic material
P39	Krzysztof Markus	Topological insulator eutectic heterostructures
P40	Ashish Omar	Compact Diamond Microscope Utilizing Nitrogen-Vacancy Centers for Advanced Magnetic Field Vector Magnetometry
P41	İrfan Alp Gezgin	An Investigation of Layers Effects on InP/InGaAs Hole Avalanche Photodiode
P42	Mert Satilmiş	Dark Current Analysis of Extended SWIR Photodiodes
P43	Habibe Keleş	Optimization of Dry Etching Process for InAs/GaSb Superlattice Structure
~~**P44**~~	~~Betül Satılmış~~	~~Developing colloidal quantum dot flexible photodetectors operating in the non-toxic SWIR region~~
P45	Radosław Wiktor Zagajewski	Quantum Hidden Subgroup Problem
P46	Naresh Sharma	Photonic Integrated Scanning Microscope
P47	João Silva	Quantum defect fabrication in diamond for quantum sensing applications
P48	Vishal Kumar Sharma	Direct Measurement of Mode-resolved Electron-Phonon Coupling with Two-Dimensional Spectroscopy
~~**P49**~~	~~Mobin Motaharifar~~	~~Realization of Continuous Variable Quantum Key Distribution for Secure Data Transmission~~
P50	Filip Łabaj	Towards mid-infrared spectrometer systems for sensing in freshwater environments
~~**P51**~~	~~Babar Ali~~	~~PhD Electrical Engineering and Information Technology~~
P52	Kingshuk Bandopadhyay	Topological insulator-based functional heterostructures
P53	Shweta Soni	Towards Microwave- and LIF- based re-excitation of Laser Induced Plasma
P54	Johannes Feist	Taming the Bloch-Redfield equation: Recovering an accurate Lindblad equation for general open quantum systems
P55	Gisell Lorena Osorio	Design of ultrafast infrared pulsed sources based on parametric amplification in a photonic crystal fiber

Poster Abstracts

P1 Optimal single-photon quantum spectroscopy

Sourav Das (University of Warwick, United Kingdom), Aiman Khan (University of Exeter, United Kingdom), Francesco Albarelli (Università degli Studi di Milano, Italy), Animesh Datta (University of Warwick, United Kingdom)

Presented by Sourav Das (University of Warwick, United Kingdom)

Quantum spectroscopy may extract information from matter systems using quantum light more efficiently than classical light. However, achieving quantum-level precision is contingent on designing the spectroscopic set-up that generates and optimally measures quantum light that extracts maximal information from the matter system. In this work, we search for the optimal single-photon quantum light that probes single molecules in free space with maximum precision. We show, that for a set-up with no environmental and thermal noise, the perturbation in the scattered photon can be encompassed in a black-box Hamiltonian that is used to calculate Quantum Fisher Information. This approach corresponds with a typical phase estimation problem in quantum metrology and can derive tight upper bounds for the QFI. For a matter with vibrational modes and environmental noise, we calculate the full evolution of the scattered pulse to capture the effects of the environment in its modal amplitudes.

P2 Comparison of carrier-envelope frequency offset stabilisation techniques for Cr:ZnS solid-state laser

Karolina Suliga (Wroclaw University of Science and Technology, Poland), Maciej Kowalczyk (Wroclaw University of Science and Technology, Poland)

Presented by Karolina Suliga (Wroclaw University of Science and Technology, Poland)

Here, we present a comparison of two experimental techniques enabling absolute phase stabilisation in a Cr:ZnS mode-locked laser oscillator. First of them is one of the most commonly employed fCEO control techniques based on a pump laser modulation. Second one exploits linear electro-optic effect to directly control the carrier-envelope phase evolution. The laser system used in our experiments is a Kerr-lens mode-locked femtosecond (~ 30 fs) laser based on a Cr:ZnS gain crystal (central wavelength at 2.4 μm), pumped by an erbium-doped fiber amplifier.
Preliminary results has shown that the EOM-based locking is limited due to the piezoelectric effect occuring in the modulator. This is manifested by the appearance of strong resonance peaks at 1.3 MHz detuning from the locked beat-note at higher locking loop gain setting. A limitation of the pump-modulation locking originates from a finite Cr:ZnS crystal fluorescent lifetime (~ 5 μs), resulting in servo bumps located at ~ 400 kHz detuning.

P3 Direct probing of cavity-confined vacuum fields

Aleksei Gaier (École Polytechnique Fédérale de Lausanne, Switzerland), Ileana-Cristina Benea-Chelmus (École Polytechnique Fédérale de Lausanne, Switzerland)

Presented by Aleksei Gaier (EPFL, Switzerland)

Measuring short and long-range correlations of cavity-confined vacuum fields directly intra-cavity has been a longstanding goal in the terahertz frequency range, providing perspectives to directly link properties of light-matter systems with the underlying driving vacuum fields. This work discusses the experimental possibilities for measuring such correlations on the electromagnetic ground state using a hybrid design combining terahertz cavities with integrated circuits from thin-film lithium niobate platform. Using the proposed design, one benefits from the strongly enhanced amplitude of the vacuum field fluctuations ~5 V/cm, optimization of the phase-matching conditions, and maximizing the spatial overlap between terahertz and optical modes. Our calculations show that the proposed device provides detection efficiencies up to $\sim 10^{-4}$ and a signal-to-noise ratio of ~100 (for 1 second of integration time) at probe pulse energies of 1 fJ.

P4 Subcycle tomography of quantum light

Geehyun Yang (KAIST, Republic of Korea), Andrey S. Moskalenko (KAIST, Republic of Korea)

Presented by Geehyun Yang (KAIST, Republic of Korea)

Quantum light is considered to be one of the key resources of the coming second quantum revolution. If the spatio-temporal and polarization structure of modes is known, the properties of quantum light are well understood. However, thinking about quantum light on the inverse frequency of an involved photon, the corresponding picture has been missing until now. To fill this gap, we consider local quantum measurements, providing quantum statistics of the local electric field. This allows to reconstruct a quantum field at subcycle scales, even when its temporal mode structure is a priori unknown. As an example, we illustrate tomography of ultrabroadband squeezed states and photon-subtracted states derived from them, with such an extreme temporal resolution. We expect this development to elicit new spectroscopic concepts for approaching e.g. fundamental correlations and entanglement, overcoming the temporal limitation set by the oscillation cycles of both light and elementary excitations.

P5 Implementation of an experimental setup for Mid-Infrared Quantum Emitters measurements

Riccardo Nardin, Stefano Achilli, Ian Colombo, Carolina Crosta, Jacopo Pedrini, Emiliano Bonera, Matteo Campostrini, Valentino Rigato, Patrick Daoust, Oussama Moutanabbir, Fabio Pezzoli

Presented by Riccardo Nardin (Università degli Studi di Milano-Bicocca, Italy)

In this work, we present the experimental progress towards the realization of an experimental setup to conduct quantum correlation measurements, aiming to characterize single-photon emission from color centers in group IV semiconductors. The atomic defects in silicon and germanium stand out as strong contenders for single-photon emission within the mid-infrared spectrum, especially within the 1 to 2 μm range, which is crucial for telecommunications and quantum sensing. At first, we conducted preliminary macro-photoluminescence measurements at different temperatures to detect ensemble emission in the infrared region from color centers in ion-irradiated materials. Subsequently, we try to implement a micro-photoluminescence apparatus that will enable the measurement of single quantum emitters and their characterization through quantum correlation measurements by means of superconductive nanowire detectors capable of single-photon detection.

P6 Photonic quantum walk with ultrafast time-bin encoding

Kate L. Fenwick (1, 2), Frédéric Bouchard (2), Duncan England (2), Philip J. Bustard (2), Khabat Heshami (1,2), and Benjamin J. Sussman (1,2)

1. University of Ottawa, Canada
2. National Research Council of Canada, Canada

Presented by Kate Fenwick (University of Ottawa, Canada)

Quantum walks (QWs) are a valuable tool for fundamental inquiries in quantum technology, including quantum simulations, quantum search algorithms, quantum transport, and universal quantum computations. We propose and experimentally demonstrate a novel platform to perform photonic QWs using ultrafast time-bin encoding. This platform supports the scalability of QWs while retaining a significant degree of programmability and preserving excellent interferometric phase stability over extremely long periods of time.

P7 Optical spectroscopy of thermal current fluctuations detected via quantum interference of absorption pathways in centrosymmetric semiconductors

Amin Lakhal (Polytechnique Montréal, Canada), Stephane Virally (Polytechnique Montréal, Canada), Jacob B. Khurgin(ohns Hopkins University, United States), Denis Seletskiy (Polytechnique Montréal, Canada)

Presented by Amin Lakhal (femtoQ Laboratory, Polytechnique Montréal, Canada)

We propose a time-resolved optical measurement scheme for sampling transient charge currents in a bulk centrosymmetric semiconductor. The technique relies on emission of second harmonic light triggered by four-wave mixing between a pulsed below-gap optical excitation and a spontaneous intraband polarization. In the proposed scheme, weak second harmonic signal is amplified with a local oscillator field.

This all-optical technique requires neither electrical contact nor bias fields and the signal is estimated at a few percent relative to the shot noise of the probe. This proposal motivates a novel method for exploring thermal and quantum fluctuations in the solid state in a non-invasive manner.

P8 Functionalization of Nanodiamonds for Stable Nitrogen-Vacancy Center Bio-Quantum Sensing

Krzysztof Pyrchla (Gdańsk University of Technology, Poland), Mirosław Sawczak (Szewalski Institute of Fluid-Flow Machinery, Polish Academy of Sciences, Poland), Maciej J. Głowacki (Gdańsk University of Technology, Poland), Robert Bogdanowicz (Gdańsk University of Technology, Poland)

Presented by Krzysztof Pyrchla (Gdańsk University of Technology. Poland)

Nanodiamonds (NDs) with nitrogen-vacancy centres (NV) are considered to be attractive tools for quantum biosensing in vivo measurements, e.g. magnetic field, and sub-Kelvin temperature measurements. The ND core is chemically inert; however, the surface of the ND has a tendency to gather vast amounts of moieties from the biological environment, which attracts proteins from the environment. This leads to a significant degradation of the performance of the NV centre's sensing capabilities. Because of that, ND's surface functionalisation is key for the efficient application of these nanoparticles in bio-quantum sensing. In this work, we tested the novel approach for grafting the ND surface with Poly-l-Lysine to reduce the nanoparticle's aggregation in physiological media. Through both theoretical simulations and experiments, we showed that this functionalisation provides enhanced colloidal stability for NDs in a variety of environments while sustaining the possibility of optical detection.

P9 Spontaneously Oriented Evaporated Organic Semiconductor Thin Films for Second-Order Nonlinear Photonics

Pierre-Luc Thériault (Polytechnique Montréal, Canada), Alex Malinge (Polytechnique Montréal, Canada), David Bourbonnais-Sureault (Université de Montréal, Canada), Gabriel Juteau (Polytechnique Montréal, Canada), Richard Martel(Université de Montréal, Canada), Stéphane Kéna-Cohen (Polytechnique Montréal, Canada)

Presented by Pierre-Luc Thériault (Polytechnique Montréal, Canada)

Despite the large hyperpolarizabilities of small organic molecules, the investigation of evaporated organic semiconductor thin films for 2nd-order nonlinear processes without electrical poling has been limited due to the presumed centrosymmetry of the resulting film. Here, we show that the spontaneous orientation phenomenon in evaporated organic thin films can be leveraged to obtains films with substantial second order nonlinearities ($d33>10$ pm/V). We also introduce a novel codeposition approach where a molecule with a large hyperpolarizability is coevaporated with a molecule known to spontaneously align to create an environment favorable to the alignment of the nonlinear molecule. This technique can result in films with stronger nonlinear properties than a neat film, even at low concentrations. This work paves the way for the direct integration of evaporated organic semiconductor thin films for 2nd-order nonlinear processes on optical chips, without the need for electrical poling.

P10 Stabilization of 10-GHz micro-combs for stable soliton pulse generation

Prof. Jungwon Kim (KAIST - South Korea), Changmin Ahn (KAIST - South Korea), Hubert Kołcz (WUT - Poland)

Presented by Hubert Kołcz (Warsaw University of Technology, Poland)

The aim of this research was to develop and demonstrate a technique for stabilizing 10-GHz micro-combs for stable soliton pulse generation and to explore its potential applications. Having high repetition-rate and low noise characteristics, micro-combs become potential candidate for various applications including distance metrology, spectroscopy, high-speed analog-digital convertor, and quantum communication. However, the timing jitter correction through repletion rate frequency stabilization of micro-combs is required to pursue high precision in these applications. The research demonstrates the generation of optical pulse trains from the stabilized micro-combs with the experimental setup, using optical modulators, optical filters, and autocorrelators. The presented method uses a fiber-delay line-based interferometer to suppress the timing jitter and enhance the stability of the microcomb, achieving a 30 dB noise reduction in the range of 1 kHz to 100 kHz offset frequency.

P11 Shaping the spectral correlation of bi-photon quantum frequency combs by multi-frequency excitation of an SOI integrated nonlinear resonator

Alí M. Angulo (Leibniz University of Hannover, Germany), Jan Heine (Leibniz University of Hannover), J. S. S. Duran Gomez (Leibniz University of Hannover), Hatam Mahmudlu (Leibniz University of Hannover), Raktim Haldar (Leibniz University of Hannover), Charalambos Klitis (University of Glasgow), Marc Sorel (University of Glasgow, United Kingdom), and Michael Kues (Leibniz University of Hannover)

Presented by Alí Angulo (IOP-LUH, Germany)

We reveal the generation of a broadband (> 1.9 THz) bi-photon quantum frequency comb (QFC) in a silicon-on-insulator (SOI) Fabry–Pérot micro-cavity and the control of its spectral correlation properties. Correlated photon pairs are generated through three spontaneous four-wave mixing (SFWM) processes by using a co-polarized bi-chromatic coherent input with power P1 and P2 on adjacent resonances of the nonlinear cavity. Adjusting the spectral power ratio $r = P1/(P1 + P2)$ allows control over the influence of each process leading to an enhancement of the overall photon pair generation rate (PGR) $\mu(r)$ by a maximal factor of $\mu(r = 0.5)/\mu(r = 0) \approx 1.5$, compared to the overall PGR provided by a single-pump configuration with the same power budget. We demonstrate that the efficiency aND of the non-degenerate excitation SFWM process (NDP) doubles the efficiency $a1 \approx a2$ of the degenerate excitation SFWM processes (DP), showing a good agreement with the provided model.

P12 Strongly modulated broadband quantum cascade lasers for fast interleaving FTIR spectroscopy

Diego Piciocchi (ETH Zürich, Switzerland), Alessio Cargioli (ETH Zürich, Switzerland), Mathieu Bertrand (ETH Zürich, Switzerland), Sergej Markmann (ETH Zürich, Switzerland), Jérôme Faist (ETH Zürich, Switzerland), Giacomo Scalari (ETH Zürich, Switzerland)

Presented by Diego Piciocchi (ETH Zürich, Switzerland)

In this work, we employ a newly conceived type of rotational delay line (RDL) to construct a compact and stable Fourier Transform Infrared Spectrometer (FTIR). Its operation for fast spectroscopy in combination with a strongly modulated broadband Quantum Cascade Laser (QCL) is demonstrated. In this system, the RDL rotation speed provides an acquisition time of 3ms per spectrum. The continuous acquisition of spectra due to the rotation is naturally adapted for coherent averaging, which improves signal to noise ratio. The stability of the system, evaluated by means of the Allan deviation, is found to improve with the square root of the integration time until 10s, indicating a white noise component. At higher times, fluctuations are dominated by the temperature stability of the laser. An absorption measurement on water vapor is performed over a 175cm−1 range with a resolution set by the linewidth of the source laser (800MHz) and remarkable agreement is found with the HITRAN database.

P13 Quantum Walk Combs for spectroscopic applications

Ina Heckelmann, Diego Piciocchi, Alexander Dikopoltsev, Mathieu Bertrand, Mattias Beck, Giacomo Scalari, Jérôme Faist

Presented by Ina Heckelmann (ETH Zürich, Switzerland)

In this work, we present Quantum Walk Combs (QWC) as a novel mechanism for comb generation. We relate their emergence to the stabilisation of a quantum walk enabled by the fast saturable gain of the Quantum Cascade Laser gain medium. Based on both steady-state and time-resolved spectral measurements, we demonstrate the predictability, tunability and thorough theoretical understanding of such frequency combs. Considering the importance of photonic quantum walks in their proliferation, the response of QWCs to varying degrees of dynamic disorder was investigated. It was found that the Bessel-like spectra in the noiseless case can be further flattened, and tuned through a Gaussian regime to find exponentially localised spectra for high levels of disorder. This flexibility of QCWs, as well as their low noise and predictable operation, enables novel applications in spectroscopy.

P14 Photon pair generation in III-V semiconductor microrings: modal dispersion and “built in” quasi-phase matching

Samuel E. Fontaine (University of Toronto, Canada), Colin Vendromin (University of Toronto, Canada), Trevor J. Steiner (University of California, Santa Barbara, USA), Amirali Atrli (University of Toronto, Canada), Lillian Thiel (University of California, Santa Barbara, USA), Joshua Castro (University of California, Santa Barbara, USA), Galan Moody (University of California, Santa Barbara, USA), John Bowers (University of California, Santa Barbara, USA), Marco Liscidini (Universita di Pavia, Italy), J. E. Sipe (University of Toronto, Canada)

Presented by Samuel Fontaine (University of Toronto, Canada)

We show that realistic and rudimentary structures, such as III-V semiconductor microring resonators coupled to a waveguide, can efficiently generate both entangled and non-entangled photon pairs and squeezed vacuum states, by utilizing its “built in” quasi phase matching and modal dispersion. We present a quantum multi-mode calculation using asymptotic fields, arriving to the generation rate of photon pairs for continuous wave excitation and an analytical expression for the biphoton wavefunction for pulsed excitation. Expressions for the number of photons of the pulsed excitation squeezed state are also obtained. The model includes loss, having the statistics of the scattered photons. We present a sample calculation showing that, for low pump powers, conversion efficiencies of 1e-5 are attainable for our rudimentary structures, in both the continuous wave and pulsed excitation regimes. Our results suggest that prominent levels of squeezing and pump depletion are attainable.

P15 Quantum-enhanced joint estimation of phase and phase diffusion

Jayanth Jayakumar (University of Warsaw, Poland), Monika E. Mycroft (University of Warsaw, Poland), Marco Barbieri (Roma Tre University, Italy), and Magdalena Stobińska (University of Warsaw, Poland)

Presented by Jayanth Jayakumar (University of Warsaw, Poland)

Accurate phase estimation in the presence of unknown phase diffusive noise is a crucial yet challenging task in noisy quantum metrology. This problem is particularly interesting due to the detrimental impact of the associated noise. In our work, we numerically investigate the joint estimation of phase and phase diffusion using generalized Holland-Burnett (gHB) states. We adopt a twofold approach by analyzing the joint information extraction through double homodyne measurement and the joint information availability across all probe states. Through our analysis, we find that the highest sensitivities are obtained by using states created by directing all input photons into one port of a balanced beam splitter. Furthermore, we infer that good levels of sensitivity persist even in the presence of moderate photon losses, demonstrating both the metrological resourcefulness and experimental feasibility of our probe states.

Link to arXiv paper: https://arxiv.org/abs/2403.04722

P16 Field-sensitive detection of femtosecond pulses in the mid-infrared using sub-cycle electron tunnelling

Gabriel Demontigny (Polytechnique Montréal, Canada), Laurent Rivard (Polytechnique Montréal, Canada), Guillaume Beaudin (Université de Sherbrooke, Canada), Paul Charette (Université de Sherbrooke, Canada), Denis Seletskiy (Polytechnique Montréal, Canada)

Presented by Gabriel Demontigny (Polytechnique Montréal, Canada)

A recent advancement in photonics is the use of electron tunneling to directly detect the electric field of an optical pulse. Since tunneling through a nano-gap is a highly nonlinear process with respect to the electric field applied, the created electron bursts emitted through the gap are shorter than the period of oscillation of the optical field applied. Thus these bursts of electron can probe the electric field of an incoming wave on a sub-cycle scale. Due to the nature of the tunneling process, the mid-infrared spectral region has an advantage for efficient electron transport. In this work, we will present our advancement in the field resolved detection of mid-infrared pulses, towards the detection of quantum states of light.

P17 Characterization of an Offset-Stabilized Dual-Frequency Comb System at 1.55 μm Toward Broadband Absorption Spectroscopy

Émile Dessureault (Polytechnique Montreal, Canada), Frédéric Lesage (Polytechnique Montreal, Canada), Denis Seletskiy (Polytechnique Montreal, Canada)

Presented by Émile Dessureault (Polytechnique Montreal, Canada)

Aiming to improve the resolution, accuracy, sensitivity or acquisition time of spectroscopic measurements of optically active gaseous samples, a new dual-frequency comb spectroscopy technique has been developed in the past two decades. Relying on the interference of two stabilized mode-locked lasers with slightly different repetition rates, a cross-correlation signal made of periodic interferograms containing the signature of the sample is generated without any moving parts. With those advantages in mind, we implement an Er:fiber dual-frequency comb system at 1.55 μm stabilized only on the repetition rate difference. We demonstrate that the setup is robust for high-resolution spectroscopy, where residual slow drifts in the carrier-envelope and repetition frequencies are corrected in post-processing of real-time radio-frequency beats.

P18 Quantum data Compression

Emad Rezaei Fard Boosari (University of Warsaw), Magdalena Stobinska (University of Warsaw)

Presented by Emad Rezaei Fard Boosari (University of Warsaw, Poland)

Quantum image processing, an emerging field in quantum technology, promises significant data reduction by converting classical images into exponentially fewer qubits for representation. Our research focuses on identifying quantum transformations that enable additional compression using orthogonal polynomials. By implementing these methods, we aim to facilitate data transfer within a potential quantum network, connecting edge servers, cloud servers, and quantum end-users

P19 Electro-optic spectral shaping of single-photon pulses

Filip Sośnicki, Michał Mikołajczyk, Ali Golestani, Michał Karpiński (University of Warsaw)

Presented by Filip Sośnicki (University of Warsaw, Poland)

One of the essential tasks in the field of quantum optics is the ability to fully control single photons, meaning controlling them in all degrees of freedom (DoF). While many experiments demonstrated control of single photons in polarization or transverse-spatial mode, one still requires methods for unitary, phase-only manipulation in the time-frequency DoF. In my presentation, I will show a technique for shaping single photons in time and spectrum by employing electro-optic phase modulation (time lenses) combined with dispersive propagation. I will show our recent results on tuning single-photon's center wavelength and spectral bandwidth by the means of electro-optic phase modulation driven with ultrawideband RF signals.

P20 Spectroscopy of isotopically purified Germanium

Marcin Wajs (Polytechnique Montréal, Canada), Simon Michel (Polytechnique Montréal, Canada), Sébastien Francoeur (Polytechnique Montréal, Canada)

Presented by Marcin Wajs (Polytechnique Montréal, Canada)

Interest in Ge and its alloys as a platform for IR photonic devices has been on the rise, as evidenced by their use in photodetection and lasing.

SNSPDs are a detector of choice for Ge PL but they require fiber coupling. For that, standard Czerny-Turner spectrometers do not offer sufficient stability of alignment while scanning over large spectral ranges. We have developed quantitative models for the origins of this misalignment and designed a new turret with sub-milliradian alignment precision to resolve this issue.

Ge is an indirect gap semiconductor and has a wide spread of stable isotopes. We have made detailed spectroscopic measurements on isotopically purified wafers to better understand the impact of isotopic disorder and atomic mass on photoluminescence and underlying mechanisms.

In my poster, I will present a model for efficiently interfacing grating-based spectrometers to SNSPDs as well as a comparative study of PL spectra of natural and isotopically purified Ge.

P21 Optimizing Third Harmonic Generation in Ge Diffraction Gratings

Swagata Mallik (Universidad Autónoma de Madrid, Spain), Megha Jain (École Polytechnique de Montréal, Canada), Johannes Feist (Universidad Autónoma de Madrid, Spain), Stéphane Kéna-Cohen (École Polytechnique de Montréal, Canada), Antonio I. Fernández-Domínguez (Universidad Autónoma de Madrid, Spain).

Presented by Swagata Mallik (Universidad Autónoma de Madrid, Spain)

Third harmonic generation (THG) in the mid-infrared (MIR) frequency region has applications in areas such as sensing and imaging of molecular species, ultrafast near-field microscopy, nonlinear spectroscopy, and direct imaging by MIR light. Germanium is an ideal candidate material for this purpose, owing to its easy fabrication, integrability, cost-effectiveness, and high third-order nonlinear coefficient in the MIR region. In this work, we aim to maximize THG in a diffraction grating made of Ge by optimizing the geometrical parameters. We computationally investigate (using the COMSOL simulation package) how the efficiency of the THG process can be maximized by tuning the grating parameters, polarization, and direction of the incident light. We furthermore calculate the mode structure of the system to analyze and interpret the results.

P22 A mixed perturbative-nonperturbative treatment for strong light-matter interactions

Carlos J. Sánchez Martínez (Universidad Autónoma de Madrid, Spain), Johannes Feist (Universidad Autónoma de Madrid, Spain) and Francisco J. García-Vidal (Universidad Autónoma de Madrid, Spain, Institute of High Performance Computing (IHPC), Singapore)

Presented by Carlos José Sánchez Martínez (Universidad Autónoma de Madrid, Spain)

The full information about the interaction between a quantum emitter and an arbitrary electromagnetic environment is encoded in the so-called spectral density. We present an approach for describing such interaction based on the splitting of the spectral density into two terms. On the one hand, a spectral density responsible for the non-Markovian and strong-coupling-based dynamics of the quantum emitter. On the other hand, a residual spectral density including the remaining weak-coupling terms. The former is treated nonperturbatively with a collection of lossy interacting discrete modes whose parameters are determined by a fit to the original spectral density in a frequency region encompassing the quantum emitter transition frequencies. The latter is treated perturbatively under a Markovian approximation. We illustrate the power and validity of our approach through numerical simulations in three different setups, including the ultra-strong coupling regime.

P23 Phase-only spectro-temporal shaping of quantum light

Ksawery Mielczarek (University of Warsaw, Poland), Michał Chrzanowski (University of Warsaw, Poland), Jerzy Szuniewicz (University of Warsaw, Poland), Filip Sośnicki (University of Warsaw, Poland), Michał Karpiński (University of Warsaw, Poland)

Presented by Ksawery Mielczarek (University of Warsaw, Poland)

Shaping spectral-temporal modes of quantum light is crucial for quantum information processing. While shaping both the phase and amplitude of light pulses is effective in classical optics, this method is unsuitable for quantum light due to the unacceptable losses it introduces, which cause decoherence. Therefore, phase-only shaping, which can be nearly lossless, presents a promising alternative. Although algorithms exist that can predict the phase needed to transform between two spectral-temporal modes, obtained phases are typically not feasible to implement experimentally.

In this work, we address this problem by using neural networks to identify phases with the desired characteristics (e.g. continuity or low variance), which is achieved through the application of custom loss functions. This approach also enables enforcing of any physical constraints in the code. The presented method is wavelength independence – it can be used for the MIR photons.

P24 Shot-noise limited terahertz detection with spintronic emitters

Bédi Zagbayou (École Polytechnique de Montréal), Étienne Doiron (École Polytechnique de Montréal), Frédéric Sirois (École Polytechnique de Montréal), Tom S. Seifert (Freie Universität Berlin), Tobias Kampfrath (Freie Universität Berlin), and Denis Seletskiy (École Polytechnique de Montréal)

Presented by Zagbayou Bedi (École Polytechnique de Montréal, Canada)

Spintronic emitters are a promising new terahertz-to-infrared technology for generating radiation extending beyond 30THz. Switching the external magnetization field in which the emitters are immersed provides direct control over the amplitude and/or polarization of the emission, suitable for lock-in detection in electrooptic sampling of terahertz waveforms. We demonstrate how near radio frequency modulation of the external magnetization field ensures detection with a relative intensity noise profile at the standard quantum limit.

P25 Towards observing quantum optical backflow

Bohnishikha Ghosh, Anat Daniel, Bernard Gorzkowski, Radek Lapkiewicz (University of Warsaw)

Presented by Bohnishikha Ghosh (University of Warsaw, Poland)

A quantum particle prepared as a superposition of positive momentum states can have a negative probability current during local instances of time. The phenomenon of probability flow in the 'wrong' direction is referred to as 'backflow' and is a manifestation of wave interference. Superoscillations refer to situations where the local oscillation of a superposition is faster than its fastest Fourier component. The correspondence between backflow in quantum mechanics and superoscillations in waves has been used to demonstrate anomalous transverse local momentum components in the dark fringes of the superposition of two optical waves. The associated strong phase gradients within the dark fringes have implications for the studies of light-matter interaction. This work is also a step towards observing quantum optical backflow.

P26 Enabling two-photon interference with time lensing

Jan Krzyżanowski (University of Warsaw, Poland), Jerzy Szuniewicz (University of Warsaw, Poland), Sanjay Kapoor (University of Warsaw, Poland), Filip Sośnicki (University of Warsaw, Poland), Michał Karpiński (University of Warsaw, Poland)

Presented by Jan Krzyżanowski (University of Warsaw, Poland)

Two-photon interference is essential for many quantum communication and sensing devices. This phenomenon is quite hard to observe, because it requires the indistinguishability of the interfering photons. The photons from various quantum devices may have mismatched spectrotemporal profiles, disturbing the two-photon interference. An interface is needed to obtain the indistinguishability of the photons and enable quantum information exchange between the mismatched devices. In this work we present a proof-of-concept experiment in which we perform a two-photon interference of photons with mismatched spectral bandwidths. We correct the spectrum of one photon to match it to the other one by applying a spectral compression to one of the photons using an electro-optic time lens. We can get about 60% interference visibility by using the time lens starting from almost no visibility. The method does not require a specific wavelength of the photons, so it can be used for mid-infrared devices.

P27 Silicon-Integrated Mid-Infrared Photoconductive Devices using Strain-Relaxed GeSn

Bellemare (École Polytechnique Montréal, Canada), Atalla (École Polytechnique Montréal, Canada), Daoust (École Polytechnique Montréal, Canada), Koelling (École Polytechnique Montréal, Canada), Assali (École Polytechnique Montréal, Canada) and Moutanabbir (École Polytechnique Montréal, Canada)

Presented by Coralie Bellemare (École Polytechnique Montréal, Canada)

Nowadays, MWIR photodetector are mainly served by III-V and II-VI materials which are costly, require cooling, and face manufacturing and scalability challenges. GeSn, a Si-compatible group IV material, has the potential to circumvent these challenges with scalable, cost-effective MWIR detector fabrication, while offering a tunable bandgap controlled by Sn concentration. However, the significant lattice mismatch between Ge and Sn induces compressive strain in the material, reducing extended wavelength gain. This work investigates material and optoelectrical properties of relaxed GeSn/Ge/Si grown by chemical vapor deposition. At a low Sn content (below 5 at.%), we found that relaxed GeSn-based photoconductive devices exhibit unexpectedly low dark current and an extended room-temperature cutoff wavelength around 1.85 μm. Additionally, capacitance devices are fabricated to extract unintentional doping concentrations from CV measurements.

P28 Light-Hole Spins Confined in Germanium

Patrick Del Vecchio (École Polytechnique de Montréal, Canada), Oussama Moutanabbir (École Polytechnique de Montréal, Canada)

Presented by Patrick Del Vecchio (École Polytechnique de Montréal, Canada)

Hole spins in group IV semiconductor quantum wells (QW) are promising candidates for reliable and scalable qubits. Although Ge has recently been at the core of numerous
achievements towards scalable hole spin qubits, research in this area is primarily centered on $Si_{1-y}Ge_y$ / Ge / $Si_{1-y}Ge_y$ QWs with heavy hole (HH) spin ground states. In contrast, combining Ge with $Ge_{1-x}Sn_x$ would create a significant amount of epitaxial tensile strain in Ge, which if properly engineered, would push light holes (LH) to the ground state. This work investigates the properties of LHs confined in $Ge_{1-x}Sn_x$ / Ge / $Ge_{1-x}Sn_x$ QWs using k.p theory. Anisotropic and large (~10) in-plane g-tensor components are reported, as well as EDSR-relevant Rashba parameters being one order of magnitude larger than HH spins. These sought-for characteristics make tensile strained Ge on $Ge_{1-x}Sn_x$ a promising platform to engineer LH-based spin qubit devices.

P29 Atomic magnetometry with Kalman Filters

Klaudia Dilcher (University of Warsaw), Jan Kołodyński (University of Warsaw)

Presented by Klaudia Dilcher (University of Warsaw, Poland)

Information inference from noisy systems is a focus of interest of various research and engineering disciplines. This task for linear and Gaussian models is possible by applying so called Kalman Filter, which constitutes a way to construct an estimator that allows one to optimally extract the signal encoded in the system dynamics by minimizing the average mean-squared-error, despite the dynamics and measurement all undergoing uncontrolled independent stochastic fluctuations. In contrast to previously known algorithms, Kalman Filters do not require a full history of all previous computational steps, and so this technique is suitable for real-time data analysis.
In this work, we applied Kalman Filters for magnetic field inference from an atomic sensor with optical read-out.
Such sensors are widely used in magnetometry both within and beyond the classical limit, achieving precision comparable to cryogenic methods.

P30 Time series prediction with photonic quantum memristor

Michał Siemaszko (University of Warsaw, Poland), Mirela Selimović (University of Vienna, Austria), Iris Agresti (University of Vienna, Austria), Francesco Ceccarelli (Instituto di Fotonica e Nanotecnologie, Italy), Roberto Osellame (Instituto di Fotonica e Nanotecnologie, Italy), Philip Walther (University of Vienna, Austria), Magdalena Stobińska (University of Warsaw, Poland)

Presented by Michał Siemaszko (University of Warsaw, Poland)

Time series prediction is a crucial task for many human activities e.g. weather forecasts or predicting stock prices. One solution to this problem is to use the Reservoir Computing paradigm. The purpose of the reservoir is to map the input data into a computational space using fixed and non-linear dynamical systems. In recent years, various quantum dynamical systems have been proposed to serve as reservoirs which can potentially improve the prediction capability over the classical reservoirs.
In our work we utilize the photonic quantum memristor to build our reservoir. We show that the photonic quantum memristor is the source of a temporal memory and non-linearity in the reservoir. We evaluate the performance of the reservoir using the standard task of NARMA prediction, which contains a quadratic temporal dependance. Our findings indicate that a single memristor is sufficient for the network to effectively learn the NARMA task, maintaining an average relative error of less than 5%.

P31 Advancements in Performance Enhancement for DI-QKD Protocols

Maryam Afsary (University of Warsaw, Poland), Morteza Moradi (University of Warsaw, Poland), Magdalena Stobińska (University of Warsaw, Poland)

Presented by Maryam Afsary (University of Warsaw, Poland)

In conventional QKD protocols, the security relies on the specific implementation of the devices used by the legitimate parties. However, device independent QKD (DI-QKD) protocols offer a more robust security guarantee by eliminating the need for trusted devices.
Two important aspects of any QKD protocols are the distance and the rate at which keys can be generated. The distance is limited by attenuation of quantum signals, while the key rate depends on factors like channel noise and detector efficiency. By optimizing the post processing stage, we can improve both factors in existing protocols, making DI-QKD more practical.
This research explores different approaches to calculate a DI-QKD protocol based on photon number entanglement. We also try to combine these approaches with post-processing techniques.

P32 Accelerating block-Toeplitz matrix vector products: Green functions approaching differential operator complexity

Alexandre Siron (Polytechnique Montréal, Canada), Sean Molesky (Polytechnique Montréal, Canada)

Presented by Alexandre Siron (Polytechnique Montréal, Canada)

The presence of translational invariance in physical systems, for any choice of translationally invariant basis functions, induces a multi-dimensional block-Toeplitz structure on the corresponding Green's function matrix. Improving on the current methods for computing matrix vector products in the presence of multi-level block-Toeplitz structure, we show that the three-dimensional electromagnetic Green's function can be computed with $4(2^d - 1)n^d \log(n) + (2n)^d$ complexity, with only $2n^d$ stored elements at peak, for a system of d dimensions with n spatial cells each. Our results easily generalize to other physical contexts—such as acoustics and quantum mechanics—and appear to offer improved task scheduling and parallelization possibilities compared to the current state of the art.

P33 Modulation Free Laser Stabilization for Cold Atom Experiments

Tripathi Om Sarveshwarpati (University of Warsaw Poland), Mariusz Semczuk (University of Warsaw, Poland)

Presented by Tripathi Om Sarveshwarpati (University of Warsaw, Poland)

We present a Sagnac loop interferometer-based method for laser frequency stabilization, offering both theoretical simulation and experimental validation. By generating nearly symmetric error signals for Cesium-133 (^{133}Cs) D_2 lines, we achieve active locking of the laser frequency to the hyperfine transitions without frequency modulation around resonance. This technique shows efficient stability, enabling laser locking to a Cesium D_2 line hyperfine transition. Our measurements reveal impressive stability: $2\pi \times 1.62$ MHz(Cs) over 2 hours and $2\pi \times 320$ kHz over 60 seconds, determined via heterodyning the laser with the nearest tooth of a femtosecond optical frequency comb (FOFC). Additionally, we offer a theoretical framework utilizing Jones calculus and optical-Bloch equations to elucidate the experiment. This stabilization method proves instrumental for applications such as Magneto-optical trapping and sub-Doppler cooling of Cesium atoms.

P34 Spatial Atomic Modulator with cold atoms

Kuntal Samanta (University of Glasgow, United Kingdom), Sphinx J. Svensson(University of Glasgow, United Kingdom), Niclas Westerberg (University of Glasgow, United Kingdom), Sonja Franke-Arnold(University of Glasgow, United Kingdom)

Presented by Kuntal Samanta (University of Glasgow, United Kingdom)

Human does not have magnetoreception unlike birds or some mammals. We need magnetometer to realise it properly. Here we explore, expand and generalize the theoretical understanding of Atomic Compass demonstrated by Sonja Franke-Arnold et al. (PhysRevLett.127.233202). Here we aim to investigate the interaction of vector light with an atomic state interferometer, realized with the presence of probe and pump generated from a single beam along with a magnetic field. It offers an exploration of vectorial light-matter interaction into the regime of inner atomic processes, such as the populations of new partially dressed states which highlight connection between polarization and magnetic coupling . Our goal is also to relate the emerging absorption to the internal atomic dynamics and the vector light properties. This work helps to realize vectorial light-atom interaction in a deeper knowledge which ultimately paves the way one step closer to an atom magnetometry based on vectorial light.

P35 Hole EDSR in Direct Bandgap Group IV Quantum Dot

N. Rotaru (École Polytechnique Montréal, Canada), P. Del Vecchio (École Polytechnique Montréal, Canada), O. Moutanabbir (École Polytechnique Montréal, Canada)

Presented by Nicolas Rotaru (École Polytechnique Montréal, Canada)

Germanium (Ge) has been at the forefront of solid-state qubit development due to its numerous advantages including the quiet quantum environment of hole spins and its compatibility with silicon processing standards. However, the fact that Ge has an indirect bandgap could limit the efficiency of the optical photon-qubit coupling. Herein, we propose using Sn-alloyed Ge (GeSn) to circumvent this limitation by enabling a direct bandgap system while preserving all the desired features of Ge. We first discuss the optimal material properties to achieve simultaneously hole spin confinement and bandgap directness. We derive a theoretical model to estimate key properties in the design of electric dipole spin resonance (EDSR) quantum dot (QD) devices and discuss hole spin qubit performance under this scheme.

P36 Ge/GeSn Nanowires for Mid-infrared Sensing and Imaging

Lu Luo (École Polytechnique de Montréal, Canada), Simone Assali (École Polytechnique de Montréal, Canada), Mahmoud Atalla (École Polytechnique de Montréal, Canada), Sebastian Koelling (École Polytechnique de Montréal, Canada), Gérard Daligou (École Polytechnique de Montréal, Canada), Oussama Moutanabbir (École Polytechnique de Montréal, Canada)

Presented by Lu Luo (Polytechnique Montreal, Canada)

Germanium-tin (GeSn) semiconductors are frontrunner platforms for compact and scalable infrared technologies due to their compatibility with silicon and their tunable bandgap energy covering the entire mid-wave infrared (MWIR) range. However, the as-grown GeSn layers are typically under a significant compressive strain due to the large lattice mismatch between Ge and Sn. This compressive strain can affect the bandgap directness and induce defects to the material, thus impacting the coverage of the MWIR spectrum and the device performance. Herein, we used sub-20 nm Ge nanowires (NWs) as effective compliant substrates to grow GeSn alloys with a composition uniformity over several micrometers with a very limited build-up of the compressive strain. Ge/GeSn NWs were integrated into MWIR photodetectors and imagers operating at room temperature with Sn-content-sensitive cutoff wavelengths in the 2.0–3.9 μm range.

P37 Large, deterministic and tunable thermo-optic shift for all photonic platforms

Bruno Lopez-Rodriguez (1), Naresh Sharma (1), Zizheng Li (1) Roald van der Kolk (1), Jasper Van Der Boom (1), Thomas Scholte (1), Jin Chang (1) Silvania F. Pereira (1) and Iman Esmaeil Zadeh (1)
1. Delft Univerisity of Tecnology, Netherlands

Presented by Bruno Lopez-Rodriguez (Delft University of Technology, Netherlands)

Achieving high degree of tunability in photonic devices has been a focal point in the field of integrated photonics for several decades, enabling a wide range of applications from telecommunication and biochemical sensing to fundamental quantum photonic experiments. We introduce a novel technique to engineer the thermal response of photonic devices resulting in large and deterministic wavelength shifts across various photonic platforms, such as amorphous Silicon Carbide (a-SiC), Silicon Nitride (SiN) and Silicon-On-Insulator (SOI). In this paper, we demonstrate bi-directional thermal tuning of photonic devices fabricated on a single chip. Our method can be used to design high-sensitivity photonic temperature sensors, low-power Mach-Zehnder interferometers and more complex photonics circuits.

P38 Synthesis and characterization of GaSb-Ge eutectic material

Ali Abbas (ENSEMBLE 3 - Centre of Excellence, Poland), Piotr Piotrowski (ENSEMBLE 3 - Centre of Excellence, Poland), Dorota Anna Pawlak (ENSEMBLE 3 - Centre of Excellence, Poland)

Presented by Dorota Anna Pawlak (ENSEMBLE 3 - Centre of Excellence, Poland)

Eutectic is a physical combination of two phases by melting them at a specific temperature. Eutectic material has not only enhanced mechanical properties but also noticed new optical and electrical properties due to combination of two or more materials. GaSb is a very attractive material system for IR laser diodes, thermophotovoltaic systems, and IR detectors because its narrow band gap enables efficient operation in the long-wavelength infrared region. The binary GaSb-Ge system, investigated in this study, includes the intermetallic semiconducting compound GaSb of the III-V family and Ge, which also possess semiconducting properties.
Herein, we report high quality crystals of GaSb-Ge were grown using Vertical Bridgman (VB) technique. Usually, the size of the grains depends on the cooling rate/growth rate. In this study, the influence of different cooling rates on the microstructure and electrical properties of GaSb-Ge eutectic crystals will be presented.

P39 Topological insulator eutectic heterostructures

Krzysztof Markus (ENSEMBLE3), Kingshuk Bandopadhyay (ENSEMBLE3), Andrzej Materna (ENSEMBLE3), Dorota A. Pawlak (ENSEMBLE3, Łukasiewcz Research Network - Institute of Microelectronic and Photonics & University of Warsaw, Poland)

Presented by Krzysztof Markus (Ensemble3, Poland)

The main interest in topological insulators is due to their topologically protected gapless surface states, which have potential use in dissipationless topological electronics, quantum computation, photonics, and spintronics. However they exhibit some disadvantages, which limit their use. This includes surface degradation when exposed to the air atmosphere, low surface-to-volume ratio, and the need for various materials junctions for applications in devices. Here we propose utilizing eutectic composites as topological isolator heterostructures. Eutectics has gained recently attention as materials for metamaterials, plasmonics and other applications. While combining the benefits of eutectic composites and topological insulators we aim at overcoming their main disadvantages.

P40 Compact Diamond Microscope Utilizing Nitrogen-Vacancy Centers for Advanced Magnetic Field Vector Magnetometry

Ashish Omar (1. CNRS, France; 2. Indian Institute of Science, India), Pralekh Dubey (Indian Institute of Science Education and Research Bhopal, India), Shashank Kumar (Indian Institute of Science Education and Research Bhopal, India), Jemish Naliyapara (Indian Institute of Science Education and Research Bhopal, Bhopal, India), Phani Peddibhotla (Indian Institute of Science Education and Research Bhopal, India)

Presented by Ashish Omar (1. CNRS, France; 2. Indian Institute of Science, India)

In this study, we have introduced the Compact Diamond Microscope (CDM), a novel magnetic field sensor based on nitrogen-vacancy (NV) defect centers in diamonds. The CDM incorporates all necessary optical components within a single compact unit, including a fiber-coupled laser source, a diamond sample with NV ensembles, and a photodetector. This integration enables both optical excitation and fluorescence signal detection, crucial for Optically Detected Magnetic Resonance (ODMR) measurements. The device's design allows for high spatial resolution and sensitivity in magnetic field imaging, making it suitable for portable applications in various sectors such as biomedicine and industry. Our experimental validations confirm the CDM's effectiveness in capturing varied ODMR spectra as a function of external magnetic field orientations. This capability extends the understanding of magnetic field interactions, offering a new approach to vector magnetometry.

P41 An Investigation of Layers Effects on InP/InGaAs Hole Avalanche Photodiode

İrfan Alp Gezgin (Bilkent University, Nanotechnology Research Center), Fikri Oğuz (Bilkent University, Nanotechnology Research Center), Ekmel Özbay (Bilkent University, Nanotechnology Research Center)

Presented by İrfan Alp Gezgin (Bilkent University, Turkey)

In the design of Hole Avalanche devices, an InP multiplication layer is used, whereas in Electron Avalanche devices, an InAlAs multiplication layer is employed. The gain mechanism of an APD device is determined by the β / α ratio of the material used in the multiplication layer. Despite InAlAs having a higher bandgap compared to InP and possessing a low tunneling mechanism and a high α / β ratio, it has not been able to compete with InP APD's in practical applications.In the study, the effects of the epitaxial layer design parameters on the I-V characteristics of APD devices were investigated with Silvaco TCAD Simulation tool. The parameters studied in the work include the Breakdown, Punch-Through Voltage, Dark Current, and Electric Field Distribution. Additionally, to enhance reliability and eliminate interface traps from standard InP/InGaAs epi designs, the effects of three different InGaAsP layers on the I-V characteristics of the device were examined.

P42 Dark Current Analysis of Extended SWIR Photodiodes

Mert SATILMIŞ (Bilkent University, Middle East Technical University), İ.Alp GEZGİN (Bilkent University, Ankara University), Çağrı TOK (Bilkent University, Ankara University), Fikri OĞUZ (Bilkent University, Middle East Technical University), Ekmel ÖZBAY (Bilkent University)

Presented by Mert Satilmiş (Bilkent University Nanotechnology Research Center (NANOTAM), Turkey)

For over three decades, research in Extended SWIR (e-SWIR) detector technologies has aimed to enhance performance while optimizing size, weight, and power (SWaP) for product deployment, with particular interest in wide spectrum detection and hyperspectral imaging. The widely adopted InGaAs material concept for e-SWIR detectors faces challenges due to lattice mismatch with the InP substrate, resulting in increased dark current levels. This poster investigates reducing surface-related dark current through SiNx:H deposition via the ICPCVD method. FTIR measurements reveal changes in bond numbers proportional to H content, affecting trap center density. Dark current modeling indicates a shift from surface to bulk-dominated current with optimized passivation. Additionally, light trapping structures, including backside reflector coatings, are explored to enhance responsivity without altering device size, aiming to improve fabrication yield.

P43 Optimization of Dry Etching Process for InAs/GaSb Superlattice Structure

Habibe Keleş (Nanotechnology Research Center, Bilkent University, Ankara Turkey), İrfan Alp Gezgin (Nanotechnology Research Center, Bilkent University, Ankara Turkey), Fikri Oğuz (Nanotechnology Research Center, Bilkent University, Ankara Turkey), Ekmel Özbay (Nanotechnology Research Center, Bilkent University, Ankara Turkey)

Presented by Habibe Keleş (Bilkent University Nanotechnology Research Center (NANOTAM), Turkey)

In recent years, superlattice structures operating in the infrared region have attracted significant attention in terms of offering easiness for both device design and microfabrication, unlike conventional structures. Superlattice structures have provided flexibility in overcoming challenges such as difficulty in production, toxicity, and high cost.

Moreover, numerous cooled and hot detectors have emerged from academic research, proving their utility in practical applications. In standard conventional micro-fabrication procedures, wet etching methods often is employed with citric acid-based solutions, as reported in the literature. However, wet etching tends to create an isotropic profile resulted in narrowing in active area on mesa type pixels after etching. This reduction in mesas causes less utilization of carriers generated in active area of each pixels in focal plane array (FPA). Furthermore, the use of wet etching complicates subsequent processing steps for the device.

P44 Developing colloidal quantum dot flexible photodetectors operating in the non-toxic SWIR region

Betul Satilmis (Gazi University, Turkey), Tugce Ataser (Gazi University, Turkey), Suleyman Ozcelik (Gazi University, Turkey)

Presented by Betül Satılmış (Gazi University Photonic Research Center, Turkey)

The high cost and complex production process of traditional photodetectors have triggered the search for alternative materials. Colloidal quantum dot structures attract attention for being environmentally friendly and cost-effective. However, concerns over toxic substances in traditional colloidal quantum dot photodetectors are rising, prompting the exploration of eco-friendly options. This project aims to develop a flexible InSb colloidal quantum dot photodetector operating in the SWIR region, utilizing environmentally friendly, low-cost, and non-toxic colloidal quantum dots. Flexible PI will be used as a substrate to expand the application area. Electrode layers will be printed as Ag nanowires using the latest technique, Aerosol Jet Printing. By aligning the energy levels between layers, it aims to effectively reduce charge collection and recombination, thereby enhancing photocurrent and quantum efficiency.

P45 Quantum Hidden Subgroup Problem

Radosław Zagajewski, Magdalena Stobińska (University of Warsaw, Poland)

Presented by Radosław Wiktor Zagajewski (University of Warsaw, Poland)

The Quantum Hidden Subgroup Problem (HSP) will be outlined from a mathematical perspective. HSP is a fundamental problem in quantum computing, underpinning many quantum algorithms that provide exponential speedups over classical methods. This poster will cover the basic concepts, mathematical foundations, and the general structure of algorithms designed to solve HSP, with a focus on the finite abelian case. The goal is to show a foundational understanding of HSP and its significance in the development of efficient quantum algorithms.

P46 Photonic Integrated Scanning Microscope

Naresh Sharma (Technical University of Delft, Netherlands), Zizheng Li (Technical University of Delft, Netherlands), Bruno Lopez-Rodriguez (Technical University of Delft, Netherlands), Roald van der Kolk (Technical University of Delft, Netherlands), and Iman Esmaeil Zadeh (Technical University of Delft, Netherlands)

Presented by Naresh Sharma (Technical University of Delft, Netherlands)

Scanning Near-Field Optical Microscopy (SNOM) revolutionized imaging by offering high-resolution images beyond the diffraction limit of traditional optical microscopy. However, its point-by-point scanning method limits rapid imaging, particularly in dynamic biological systems. We propose a novel approach utilizing Photonic Integrated Circuits (PICs) to enable parallel imaging, addressing the resolution-speed trade-off. By integrating multiple waveguides onto a single chip, PICs facilitate simultaneous scanning of different sample areas, potentially reducing acquisition time. Our configuration, featuring multiple waveguides equipped with plasmonic structures, offers a cost-effective solution for rapid, high-resolution imaging. With applications spanning visible to mid-IR wavelengths, our approach promises transformative advancements in microscopy, offering high-speed imaging capabilities previously unattainable with conventional techniques.

P47 Quantum defect fabrication in diamond for quantum sensing applications

João Paulo Silva (International Iberian Nanotechnology Laboratory, Portugal; Universidade do Porto; Portugal; INESCTEC, Portugal); João M. Maia (Universidade do Porto; Portugal; INESCTEC, Portugal); Filipe Camarneiro (International Iberian Nanotechnology Laboratory, Portugal) Paulo V. S. Marques (Universidade do Porto; Portugal; INESCTEC, Portugal); Jana B. Nieder (International Iberian Nanotechnology Laboratory, Portugal)

Presented by João Silva (INL - International Iberian Nanotechnology Institute, Portugal)

The nitrogen-vacancy (NV) center in diamond has emerged as a quantum defect with versatile applications in quantum sensing, quantum information, and cryptography. Despite its potential, current NV fabrication techniques lack spatial accuracy and the resulting NVs often fail to meet the desired optical properties.
We present advances in NV center fabrication, leveraging femtosecond (fs) lasers to create NV centers, using a 515 nm fs laser, systematically varying parameters such as energy per pulse, exposure time, depth and polarization as a way to produce NVs.
We find the optimal depth is above 10 um the diamond, with fluorescence, matching NV center in diamond spectral fluorescence emission properties, and the laser-treated areas. The study demonstrates that an increase in laser exposure time and power increase NV center creation. This study marks a step in order to create a photonic platform for quantum sensing with fluorescence both in the visible and in the infrared ranges.

P48 Direct Measurement of Mode-resolved Electron-Phonon Coupling with Two-Dimensional Spectroscopy

Vishal Kumar Sharma (Goethe University, Frankfurt, Germany)

Presented by Vishal Kumar Sharma (Goethe university, Frankfurt, Germany)

Electron-phonon coupling (EPC) is foundational in condensed matter physics, determining intriguing phenomena and properties in both conventional and quan- tum materials. In this manuscript, we propose and demonstrate a novel two dimensional (2D) EPC spectroscopy which allows for direct extraction of EPC matrix elements. We find that two pronounced phonon modes of methylammo- nium lead iodide (MAPI) at room temperature exhibit highly distinctive EPC behaviors, both in strength, geometry, and temperature dependence across the phase transition. This demonstration indicates the potential of our novel 2D spectroscopy for studying the evolution of mode-resolved EPC at various exter- nal conditions and phonon-mediated light induced ultrafast control of condensed materials.

P49 Realization of Continuous Variable Quantum Key Distribution for Secure Data Transmission

Mobin Motaharifar (Amirkabir University of Technology, Tehran, Iran), Mahmood Hasani (Amirkabir University of Technology, Tehran, Iran)

Presented by Mobin Motaharifar (Amirkabir University of Technology (Tehran Polytechnic), Iran)

Quantum technologies are promising new horizons in different areas. One of those areas is communication, which requires the use of quantum key distribution (Q.K.D) protocols. Although discrete variable QKD protocols were devised earlier, continuous variable QKD seems to be more promising as it can be implemented more easily by employing current communication infrastructure. The reason is that CV-QKD utilizes coherent and squeezed states of light whereas the DV-QKD requires qubits, mostly in the form of single photons. The exchange of entangled states between Alice and Bob is one way of realizing CV-QKD and it could be done by quantum teleportation. We introduce the idea of using squeezed states of light in photonic integrated circuits for the sake of teleportation. After reviewing this idea in detail, some of the practical challenges and obstacles in the way of CV-QKD are also evaluated. Such a setup could be beneficial in improving CV-QKD processes which is further discussed.

P50 Towards mid-infrared spectrometer systems for sensing in freshwater environments

Filip Łabaj, Rafał Stojek, Marta Łowcewicz, Jerzy Kalwas, Ryszard Piramidowicz (Warsaw University of Technology)

Presented by Filip Łabaj (Warsaw University of Technology, Poland)

Monitoring of phosphate, nitrite and nitrate concentration in water resources is critical for predicting and preventing mass mortality events caused by algae blooms in aquatic environments. Commonly used measurement techniques that can evaluate the concentration of phosphates, nitrites, and nitrates are mainly limited to the use of analytical reagents or ion-selective membranes and specialized laboratory equipment. The application of in-situ, mid-infrared absorption spectrometry promises a drastic improvement in response time and sensitivity, as well as a reduction of the system's footprint in comparison to classical methods. We present the results of ongoing research focused on creating a mid-infrared spectrometric system capable of measuring the concentration of phosphates, nitrites, nitriates and ammonia ions in freshwater reservoirs, using a compact Fabry-Perot cavity filter and type 2 superlattice (T2SL) photodiodes, optimized for the long-wave infrared spectral region.

P51 PhD Electrical Engineering and Information Technology

Babar Ali (University of Naples Federico II, Italy)

Presented by Babar Ali (University of Naples Federico II, Italy)

The development of an innovative platform based on nanoantenna (Simple and Cost-Effective Nanostructured Substrate) for bio sensing applications. Development of suitable substrate for surface enhanced infrared absorption spectroscopy (SEIRA) platform.

P52 Topological insulator-based functional heterostructures

Kingshuk Bandopadhyay (ENSEMBLE3 Centre of Excellence, Poland), Krzysztof Markus (ENSEMBLE3 Centre of Excellence, Poland), Andrzej Materna (ENSEMBLE3 Centre of Excellence, Poland), Marta Buza (Łukasiewicz – IMiF, Poland), Cheng Chen (University of Oxford, United Kingdom), Federico Mazzola (Elettra-Sincrotrone Trieste, Italy), Alexei Barinov (Elettra-Sincrotrone Trieste, Italy), Masayoshi Tonouchi (Osaka University, Japan), Yulin Chen (University of Oxford, United Kingdom), and Dorota A. Pawlak (ENSEMBLE3 Centre of Excellence, Poland)

Presented by Kingshuk Bandopadhyay (ENSEMBLE3 CoE, Poland)

Three-dimensional topological insulators (TI) attract great deal of interest due to their potential use of the topologically protected surface states (SS) in spintronics, magneto-electronics and quantum computation. However, challenges such as the high sensitivity of the SS to the atmosphere, the low surface-to-volume ratio, and the need for various material heterojunctions currently limit the application of these materials. Here, we successfully fabricated the TI heterostructures by an easy, fast and single-step process, which could meet all those challenges and pave the way for exploring other exotic phenomena in the near future. Utilizing directional solidification different TI-based eutectic composites were produced, where two crystalline phases are combined in a structured form with joined interfaces. Existence of the metallic surface states and the formation of electrical junction have been confirmed throughout specific characterization methods.

P53 Towards Microwave- and LIF- based re-excitation of Laser Induced Plasma

Shweta Soni (Comenius University, Slovakia), Pavel Veis (Comenius University, Slovakia)

Presented by Shweta Soni (Comenius University, Slovakia)

A significant tradeoff exists between acquisition time and plasma decay, impacting the acquisition sensitivity of atoms, ions, and molecules individually, in laser induced plasma (LIP). Our experimental approach allows us to re-excite LIP either through direct dressing of atoms with a resonant UV laser or by microwave interaction. The former method excites species in the plasma to highly excited atomic states corresponding to temperatures around 10^4 K, with lower states populated by cascade from the excited state. In contrast, microwave dressing enhances plasma oscillations, increasing temperature through collisional energy transfer of oscillating electrons. We conducted Laser Induced Fluorescence (LIF) excitation of phosphorus (31P) atoms at 213.56 nm using a 253.6 nm laser, resulting in a 40-fold enhancement in intensity. Additionally, we developed microwave excitation of LIP, which extends plasma lifetime and volume, enabling improved molecular analysis.

P54 Taming the Bloch-Redfield equation: Recovering an accurate Lindblad equation for general open quantum systems

D. Fernández de la Pradilla (Universidad Autónoma de Madrid, Spain), E. Moreno (Universidad Autónoma de Madrid, Spain), J. Feist (Universidad Autónoma de Madrid, Spain)

Presented by Johannes Feist (Universidad Autónoma de Madrid, Spain)

Master equations play a pivotal role in investigating open quantum systems. In particular, the Bloch-Redfield equation stands out due to its relation to a concrete physical environment. However, it does not provide a Lindblad form that guarantees that the density matrix stays completely positive, which has raised some concerns regarding its use. This study builds on previous efforts to transform the Bloch-Redfield framework into a mathematically robust Lindblad equation, while fully preserving the effects that are lost within the secular approximation that is commonly used to guarantee positivity. We propose and evaluate straightforward solutions to two potential problems in these previous approaches: non-Hermitian energy shifts and negative decay rates. Our approach offers an effective and general procedure for obtaining a Lindblad equation, derived from a concrete physical environment, while mitigating the unphysical dynamics present in the Bloch-Redfield equation.

P55 Design of ultrafast infrared pulsed sources based on parametric amplification in a photonic crystal fiber

G. L. Osorio (Polytechnique Montreal), F. A. Domínguez-Serna (Conahcyt - Centro de Investigación Científica y de Educación Superior de Ensenada, Mexico), K. Garay-Palmett (Centro de Investigación Científica y de Educación Superior de Ensenada, Mexico)

Presented by Gisell Lorena Osorio (Polytechnique Montreal, Canada)

Applications of nonlinear optical phenomena in photonic crystal fibers (PCF) attract interest due to their versatility, speed, and high-power compatibility. A key application is generating ultrafast pulsed light via parametric amplification, especially in spectral bands lacking suitable sources, such as the infrared region, where current ultrafast laser technologies are not easily tunable. This work presents the design, simulation, and implementation of ultrafast sources in PCFs in the infrared. We report on the theoretical and numerical analysis of the parametric amplification process in a PCF based on the classic vectorial theory of stimulated four-wave mixing (FWM). Additionally, we experimentally demonstrated the generation of signal-idler photon pairs through spontaneous FWM in a PCF. These results will aid in designing new pulsed sources across a wide range of frequencies using parametric amplification in fibers.

Partners

Quantum Flagship

Funded by the European Union

Supported by the EU Quantum Flagship MIRAQLS project no. 101070700

University of Warsaw

Faculty of Physics, University of Warsaw

Candela Foundation

Toptica

Vigo Photonics