BOOK OF ABSTRACT – QUANTUM OPTICS AND QUANTUM MATERIALS

Lecce, May 2025

37	Luigi Frau
38	Luka Krstic
39	Manan Van Hoorebeke
40	Marco Alcibiade
41	Marina Esposito
42	Marios Matheou
43	Marko Kuveždić
44	Meetsinh Thakor
45	Meysam Saeedi
46	Mingyang Zhang
47	Nand Kumar
48	Paola Savarese
49	Paolo De Vicenzi
50	Paraskevi (Evi) Kasnetsi
51	Paula Wieteska-Bajak
52	Pavel Belov
53	Pelin Yıldırım
54	Rodrigo Sánchez-Martínez
55	Rohit Prasad
56	Sergio Balestrieri
57	Silvia Bonabello
58	Simone Di Micco
59	Stanisław Świerczewski
60	Teresa Crisci
61	Tim Wedl
62	Tom Lannon
63	Ugo Chirico
64	Uliana Diiankova
65	Victor Mitryakhin
66	Vincenzo Bruno
67	Vipin Balan
68	Yannik Brune

NUMBER 1 INDEX

Adair Campos Uscanga

Universidad Autónoma Metropolitana-Iztapalapa

Magic States in the Asymmetric Quantum Rabi Model

Magic, or nonstabilizerness, is a key property for achieving universal fault-tolerant quantum computation. It determines whether a state can be generated using Clifford operations, which are both easy to perform and have fault-tolerant implementations. This property also characterizes states that can be efficiently simulated with classical computation, as stated in Gottesman-Knill's theorem. In this work, we investigate magic states in the quantum Rabi model, which describes a hybrid system where a two-level system (or qubit) strongly interacts with light through its dipole moment. Using established magic quantifiers, we confirm the presence of magic in specific regions of the qubit-reduced and light-reduced subspaces. By exploring the parameter space of our Hamiltonian, we analyze how interactions contribute to the generation of magic and examine its relationship with entanglement.

NUMBER 2 INDEX

Alesander Sánchez Sánchez

Universitat de València

Enhanced Spectral Stability and Reduced Blinking in Single $CsPbBr_3$ Perovskite Nanocrystals Using Zwitterionic Ligands.

In 2015, Park and colleagues generated the first room temperature perovskite based single-photon source using all-inorganic CsPbI3 quantum dots (QDs). Since then, quantum light emission from a variety of perovskite nanocrystals (PNCs) has been demonstrated at both ambient and cryogenic temperatures. Despite the remarkable features of PNCs, the use of PNCs is restricted by their photostability. The research focus has moved to their challenging integration into photonics platforms. In this study, we utilized cryogenic micro-PL and micro-TRPL spectroscopy to investigate the spectral stability, blinking, and spectral color purity of single colloidal cesium lead halide PNCs with different caping ligands. The use of Zwitterionic ligands in single CsPbBr3 PNCs reduced both spectral diffusion and blinking, resulting in narrow and stable micro-PL optical transitions of ~125 µeV of FWHM. Our findings pave the way for improve the optical quality of perovskites for single photon sources as key components in quantum technology-oriented applications.

Alexandros Bampis

Ecole Polytechnique Fédérale de Lausanne (EPFL)

Depth control of room temperature single-photon emitters in gallium nitride

Bright quantum light sources are essential building blocks for quantum communication [1] and linear optical quantum computing [2]. However, most existing quantum emitters require cryogenic temperatures to operate, which constitutes a bottleneck for large scale applications. Radiative point defects in gallium nitride (GaN), a wide bandgap semiconductor, have recently been shown to emit single photons at room temperature (RT), spanning wide wavelength ranges in the visible [3] and around the telecom O-band [4]. These emitters exhibit sharp zero-phonon lines and their embedment in circular Bragg gratings has been shown, giving rise to excellent single photon purities [5]. Due to its use in the fabrication of blue light-emitting diodes, GaN is an extensively studied material which gives these single photon emitters (SPEs) another advantage for future applications. Their fundamental nature, however, is yet to be determined. This work precisely focuses on identifying these point defects. Several sample structures, grown by metalorganic vapor phase epitaxy, are investigated by scanning confocal microscopy and Hanbury Brown and Twiss experiments to study the resulting defect densities and their optical properties. SPEs are found in both doped and unintentionally doped GaN samples grown on sapphire, displaying emission wavelengths ranging from 500 nm to 950 nm and high single-photon purities, with g2(0) values as low as 0.06 at room temperature. Contrary to popular belief, naturally occurring emitters in MOVPE GaN on sapphire are shown to be interface-related defects, largely preventing high coupling efficiencies to photonic structures. Nevertheless, we demonstrate a growth sequence that produces SPEs in GaN on sapphire at any desired depth. The influence of growth conditions, impurity concentrations and strain environment on the emitter formation are discussed. This step constitutes the first milestone towards site-controlled production of SPEs in GaN. This capability would enable to deterministically position photonic structures around the created emitters and reach enhanced photon collection efficiency levels - an essential requirement to obtain a scalable photonic device.

[1] C. H. Bennett, G. Brassard, Quantum cryptography: Public key distribution and coin tossing, Theoretical Computer Science 560, 7-11 (1984)

[2] E. Knill, R. Laflamme, G. Milburn, A scheme for efficient quantum computation with linear optics, Nature 409, 46–52 (2001)

[3] A. M. Berhane et al., Bright Room-Temperature Single-Photon Emission from Defects in Gallium Nitride, Advanced Materials 29, 1605092 (2017)

[4] Y. Zhou et al., Room temperature solid-state quantum emitters in the telecom range, Science Advances 4, eaar3580 (2018)

[5] M. Meunier et al., Telecom single photon emitters in GaN operating at room temperature: Embedment into bullseye antennas, Nanophotonics 12, 1405 (2023)

NUMBER 4 INDEX

Amir Rahmani

Institute of Physics Polish Academy of Science

Quantization of dissipative modes for confined exciton-polaritons

We present a quantized fundamental framework for solving cavity electrodynamics resonators coupled to excitonic emitters. The electromagnetic field is quantized based on solutions to Maxwell's equations in a dissipative regime. The emitter is confined to a subwavelength scale, breaking the system's translational symmetry. This framework introduces a Hamiltonian in the second-quantization formalism for a lossy, confined electromagnetic field. It serves as the foundation for deriving the polaritonic Langevin and master equations, explicitly accounting for the dissipative and non-Hermitian nature of exciton-polariton systems.

Andrea Marangon

Università del Piemonte Orientale

Polysaccharides as natural, ecofriendly and low cost component for white light emission

In recent years, biopolymers have been widely used in many fields. The search for new sources of biopolymers and biomaterials has led to an increased focus on production and extraction processes, especially from natural and renewable sources. In this field, chitin is one of the most widely used biopolymers, and it consists of units of N-acetyl-2amino-2deoxy-D-glucopyranose and 2-amino-2-deoxy-D-glucose in pyranose form and linked to each other by 1-4 glycosidic bonds with an acetylation degree greater than 60%.

Chitin is known to be insoluble in all solvents, but can be dispersed in organic solvents by means of acid catalysis. In this work, three different solvents that could form stable dispersions containing chitin were selected. Through the addition of HCl, stable dispersions with optical properties could be obtained. The dispersions show very interesting emission properties due to the interactions between the dispersed chitin molecules and the molecules of the different solvents.

The obtained dispersion shows a continues emission spectra in Vis range after UV light irradiation. The emission spectra show a maximum peak in the low wavelength region of the Vis spectra. The different interaction between different solvent and chitin molecules cause a white light emission with different tonality of white light.

In conclusion, this work demonstrates the possibility to use organic and natural molecules, such as polysaccharides, as useful to produce a single component white light emitter.

NUMBER 6 INDEX

Andrea Ponticelli

Università di Napoli Federico II

Environment induced BKT transitions in Open Quantum Systems: Thermodynamic and Dynamical effects.

Using state-of-the-art numerical approaches, like World Line Quantum Monte Carlo and Density Matrix Renormalization Group with Matrix Product State ansatz, it has recently been shown that Berezinskii–Kosterlitz–Thouless (BKT) phase transitions can be observed in Open Quantum Systems induced by interaction with a thermal bath in the strong coupling regime. In particular, they have been observed in the ferromagnetic Ising chain and the Rabi model interacting with the dissipative thermal bath of harmonic oscillators. More recently it has been shown that a signature of the BKT transition can be observed in the Loschmidt echo, then in the Dynamical Quantum Phase Transitions.

Anna Grudinina

NRNU MEPhI

Bosonic effective action for the phase of the order parameter

In this work, we consider action for a quasi-one-dimensional Bose gas and derive the effective action for the condensate phase, parametrising the problem differently compared to effective low-energy action derived by Popov. In particular, instead of the hydrodynamic parametrization of the Bose field, we introduce explicitly the order parameter phase and the non-condensate part, taking into account that the phase of the condensate is a smooth function while the non-condensate part only contains large momenta. After averaging over the non-condensate fields, we obtain the effective action for the condensate phase which is non-local and includes the dissipation processes.

NUMBER 8 INDEX

Antoine Chapuis

INSP, Sorbonne University

Optical control of spin states in GaAs/AlGaAs Quantum Dot Molecules

Qubits with long coherence times make up important building blocks for quantum technologies. Together with strong light-matter coupling, it opens avenues for transferring quantum information between static, matter qubits and flying, light qubits. Semiconductor quantum dots (QD) systems are promising candidates for quantum communication protocols. Moreover, the specific transitions' optical selection rules allow for a mapping between light polarization and spin states' transitions which is a valuable tool for coherent control with light pulses. We propose to build such a spin-photon interface based either : -on a double quantum dot structure, where the thin tunnel barrier between the dots allows for coherent coupling of the electronic states -on a type-II quantum dot where the barrier material, whose gap is indirect, also allows for confinement in the X-valley. More complex level-diagrams appear giving the possibility to address and read out many different optical transitions.

NUMBER 9 INDEX

Athithyan Srikanthan

University of Southampton

Programming Photonic Quantum Chips using Phase Change Materials

Photonic integrated circuits have traditionally been application-specific, necessitating specialised design and fabrication cycles. This limitation has sparked a growing demand for programmable and tuneable devices capable of dynamically tailoring optical outputs post fabrication.[2] Programmable devices enable the arbitrary programming of Hamiltonians for quantum computation, allowing photonic quantum chips to adapt flexibly to solve various problems. This capability represents a critical milestone toward large-scale integrated quantum photonic technologies.

A major challenge in this field is the generation, control, and manipulation of single photons, which require highly indistinguishable photon sources, precise interferometers, efficient detectors, and non-volatile programming methods. [1] One viable approach to achieve indistinguishable single photon sources and efficient detectors is operating at cryogenic temperatures. [4] These conditions improve the efficiency of nonlinear processes such as spontaneous four wave mixing, which is vital for generating entangled photon pairs and other quantum states needed for large scale quantum computations.[4] Therefore, photon manipulation at cryogenic temperatures is crucial in the development of programmable and tuneable devices. Optical phase change materials (PCMs) also offer a promising solution by maintaining photon states without requiring external energy input during quantum experiments. [3] Unlike traditional methods that rely on microheaters or micro-electromechanical systems—introducing heat and noise that risk decoherence at low temperatures—PCM-based devices provide ultra-low loss, compactness, and passive programmability while remaining compatible with telecommunication wavelengths. [2]

This PhD project builds on prior work in our group that explores coupled waveguide arrays integrated with PCMs such as Sb2Se3[2]. These materials can exist in multiple non-volatile solid states and be programmed using optical or electrical pulses to switch between amorphous and crystalline phases. [2] The transitions enable robust chip modulation and the reconfiguration of devices into transmission matrices at the microscale. By programming the Hamiltonian of arbitrary unitary matrices, this approach allows photonic quantum chips to adapt dynamically to specific computational tasks. The integration of PCMs into quantum optical chips has the potential to revolutionize quantum computation by addressing key challenges in scalability, energy efficiency, and cryogenic compatibility. [3] This research aims to advance the field by developing low-loss PCM-based devices that open new avenues for programmable quantum photonic technologies.

[1] Stefano, P. (2019). LARGE-SCALE INTEGRATED QUANTUM PHOTONICS: DEVELOPMENT AND APPLICATIONS. [Thesis] Available at: https://research-information.bris.ac.uk/en/studentTheses/large-scale-integrated-quantum-photonics [Accessed 31 Jan. 2025].

[2] Radford, T.W., Wiecha, P.R., Politi, A., Zeimpekis, I. and Muskens, O.L. (2024). Inverse Design of Unitary Transmission Matrices in Silicon Photonic Coupled Waveguide Arrays using a Neural Adjoint Model. [online] arXiv.org. Available at: https://arxiv.org/abs/2409.18284 [Accessed 31 Jan. 2025].

[3] Patinharekandy Prabhathan, Kandammathe Valiyaveedu Sreekanth, Teng, J., Joo Hwan Ko, Young Jin Yoo, Jeong, H.-H., Lee, Y., Zhang, S., Cao, T., Popescu, C.-C., Mills, B., Gu, T., Fang, Z., Chen, R., Tong, H., Wang, Y., He, Q., Lu, Y., Liu, Z. and Yu, H. (2023). Roadmap for phase change materials in photonics and beyond. iScience, 26(10), pp.107946–107946. doi:https://doi.org/10.1016/j.isci.2023.107946.

[4] S. Rodt, S. Reitzenstein; Integrated nanophotonics for the development of fully functional quantum circuits based on on-demand single-photon emitters. APL Photonics 1 January 2021; 6 (1): 010901. https://doi.org/10.1063/5.0031628

Bartosz Kasza

Centre for Quantum Optical Technologies, Centre of New Technologies, University of Warsaw

Atomic-optical interferometry in fractured loops: a general solution for Rydberg radio frequency receivers

Multi-level atoms, e.g. excited to Rydberg states, present many unique opportunities, but present several challenges for numerical treatment of their interaction with multiple laser fields. In hot-atom systems this is further aggravated by the necessity to include Doppler broadening. Further challenges arise if the system is time-dependent, as the system then doesn't have a strict steady-state solution. Our study presents a numerically efficient approach to solving non-equilibrium steady states, focusing on fractured atomic loops, as exemplified by Rydberg-atom microwave sensing protocols. By manipulating terms within the master equation and applying Fourier expansion of Floquet-Lindblad modes, we uncover new insights into the control and coherence of atomic states under periodic driving, resulting from fracture [1]. The results are particularly relevant for superheterodyne Rydberg sensors [2], where the main question is the efficient transfer of modulation from a weak microwave signal field to light. These findings enhance our understanding of quantum dynamics in Floquet systems and offer potential applications in modelling quantum communication, sensing and transduction protocols [3].

[1] B. Kasza et al., arXiv 2412.07632 (2024)

[2] M. Jing et al., Nature Physics 16, 911-915 (2020)

[3] S. Borówka et al., 18, 32-38 (2024)

NUMBER 11 INDEX

Beatrice Polacchi

Sapienza Università di Roma

Teleportation of genuine single-rail vacuum-one-photon qubits generated via a quantum dot source

Semiconductor quantum dot-based single-photon sources are promising not only for their quality in terms of generation rate, single-photon purity, and photon indistinguishability, but also for their capability to generate single-rail coherent superpositions of photon-number states when driven in the resonance fluorescence (RF) regime. On one hand, the investigation of quantum information protocols based on the photon-number encoding is gaining a growing interest due to the flourishing of high-efficiency single-photon detetors and sources.

On the other hand, the production of such states is challenging with linear optics. For this reason, quantum teleportation, a key protocol for quantum information tasks, could not be demonstrated with such states in a genuine way [1].

In the presented work [2], we employ a RF excited quantum dot-based single-photon source to demonstrate the quantum teleportation and the entanglement swapping of genuine single-rail vacuum--one-photon qubits. Our results pave the way for quantum information protocols based on the photon-number encoding and may suggest new applicative perspectives for quantum dot sources.

[1] E. Lombardi et al. ""Teleportation of a vacuum–one-photon qubit."" Phys. Rev. Lett. 88.7: 070402 (2002)

[2] B. Polacchi et al. ""Teleportation of a genuine single-rail vacuum-one-photon qubit generated via a quantum dot source."" npj Nanophotonics 1.1: 45 (2024)

NUMBER 12 INDEX

Daniele Nello

Polito-Department of Electronics and Communications

Study of the emission of non-classical states from quantum dot lasers

We characterize theoretically (analytically and numerically) the emission of squeezed light from quantum dot lasers, emitting in the infrared region. This emission is characterized by sub-Poissonian statistics, highlighting the quantum nature of the light. This is interesting for state-of-the-art applications in quantum communications.

NUMBER 13 INDEX

David de la Fuente Pico

Universidad Autónoma de Madrid

Rydberg excitons and polaritons in monolayer transition metal dichalcogenides in a magnetic field.

We develop a microscopic theory for excitons and cavity exciton polaritons in transition metal dichalcogenide (TMD) monolayers under a perpendicular magnetic field. We obtain numerically exact solutions for the ground and excited states, accounting for the interplay between arbitrarily large magnetic fields and light-matter coupling strengths. Our results for excitons match experimental data on diamagnetic shifts in various TMDs. For polaritons, we consider experimentally relevant system parameters and demonstrate that the diamagnetic shifts of both the ground and excited states at high magnetic fields exhibit clear signatures of the very strong coupling regime, which cannot be described by perturbative approaches. We also evaluate exciton and polariton interaction strengths within the Born approximation, finding that other approaches using variational wavefunctions overestimated the exciton interaction strength. Besides, we observe that magnetic fields weaken the interaction strength for both excitons and polaritons, with a less pronounced effect in TMDs than in quantum wells, and that light-induced modifications to the matter component in TMD polaritons can enhance interaction strengths beyond those of purely excitonic interactions.

NUMBER 14 INDEX

David Zehner

Université Paris-Saclay

Neuro-Inspired Computing in k-Space: Harnessing Spin Wave Dynamics in YIG Microdisks

We present a neuromorphic computing platform leveraging nonlinear magnon interactions in Yttrium Iron Garnet (YIG) microstructures as a foundation for energy-efficient and dynamically reconfigurable computation. Magnons, the quantized spin-wave excitations in magnetic materials, exhibit discrete mode spectra in finite-size YIG disks due to geometric constraints. These modes act as neurons in a recurrent neural network (RNN), with their nonlinear interactions representing synaptic weights. Interconnectivity is established intrinsically in the reciprocal (k-) space of the magnon spectrum, bypassing the need for physical wiring.

Parametric excitation of magnon modes is achieved in 1 μm diameter YIG disks using an in-plane static magnetic field and a coplanar waveguide to generate time-varying magnetic fields. Nonlinear magnon interactions enable mode population dynamics, which can be controlled and reconfigured via a programming signal that dynamically adjusts the thresholds and interaction strengths within the network. This reconfigurability facilitates a transition from reservoir-computing-like behavior to programmable neural network architectures.

We demonstrate the capability of this system through a speech classification task, using the Google Speech Commands dataset. Speech data, within the relevant frequency range for recognition (300 Hz – 3.5 kHz), is mapped to the excitation frequencies of the YIG setup (3.5 GHz – 4.5 GHz) via frequency scaling and shifting. Programming signals, parametrized as sinusoidal components, modulate magnon interactions to optimize classification performance. Using gradient-based optimization methods, the system successfully classifies binary speech tasks, showcasing its potential for more complex applications.

By exploiting magnonics as a computational medium, this platform combines the advantages of energy efficiency, intrinsic interconnectivity, and reconfigurability, providing a promising avenue for next-generation hardware technologies in neuromorphic computing.

NUMBER 15 INDEX

Dogyun Ko

IFPAN(institute of physics polish academy of sciences)

Second-order correlation estimation of quantum states using quantum reservoir computing

Quantum Reservoir Computing is a promising approach for quantum neural networks, with the ability to solve challenging learning tasks using both classical and quantum input data. A quantum reservoir processor can accomplish multiple tasks, such as the recognition of quantum states. We propose reservoir computing based method to predict the second order correlation of different quantum states.

Elena Fanella

Univerisity of Naples

Spectral Analysis of Dibenzoterrylen hosted in Para-terphenyl Nanocrystals

Nano-crystals doped with dye molecules have emerged as a significant resource in the field of quantum technologies. Single fluorescent molecules can be used as single-photon source and exhibit highly sensitivity to environmental conditions, which makes them ideal also as nanoscale sensors with exceptional resolution. [1-2] The nanocrystal structure, encapsulating the molecules, not only enhances long-term stability but also facilitates easy manipulation and integration of the emitters into photonic platforms. [3] We hereby investigate a recently proposed molecular crystal, based on para-terphenyl molecules, as a potential hosting matrix for a well-established emitter, dibenzoterrylene. Previous studies have demonstrated the quality of this emitter-host combination, showcasing its emission properties. [4] Building on this, we extend the research by exploring the system's spectra under lower temperature conditions and conducting additional tests, including the analysis of spectral diffusion, induced optical shifts, and dipole orientation.

[1] Toninelli, C. et al. "Single organic molecules for photonic quantum technologies." Nature materials vol. 20,12 (2021): 1615-1628. doi:10.1038/s41563-021-00987-4

[2] Duquennoy, R., et al. ""Enhanced control of single-molecule emission frequency and spectral diffusion."" ACS nano 18.47 (2024): 32508-32516.

[3] Pazzagli, S. et al. "Self-Assembled Nanocrystals of Polycyclic Aromatic Hydrocarbons Show Photostable Single-Photon Emission." ACS nano vol. 12,5 (2018): 4295-4303. doi:10.1021/acsnano.7b08810

[4] Schofield, R. C. et al. "Narrow and Stable Single Photon Emission from Dibenzoterrylene in para-Terphenyl Nanocrystals." Chemphyschem : a European journal of chemical physics and physical chemistry vol. 23,4 (2022): e202100809. doi:10.1002/cphc.202100809

NUMBER 17 INDEX

Emilia Zięba-Ostój

Wrocław University of Science and Technology

Optical characterization of InAs/InP quantum dots in the p-i-n junction emitting in the telecom C-band

E. Zięba-Ostój1, S. Fornetti2, P. Holewa1,2, C. P. Gunnarsson2,3, M. Xiong2,3, P. Mrowiński1, M. Burakowski1, K. Yvind2,3, E. Semenova2,3, M. Syperek1

1 Department of Experimental Physics, Wrocław University of Science and Technology, Poland

2 DTU Electro, Technical University of Denmark, Kongens Lyngby 2800, Denmark

3 NanoPhoton-Center for Nanophotonics, Technical University of Denmark, Kongens Lyngby 2800, Denmark

Generating single photons and entangled photon pairs in the telecom C-band is crucial for long-distance communication through fiber-based telecom infrastructure. For this purpose, self-assembled InAs/InP quantum dots (QDs) can be used as a key element of the photon state generator. However, the charge fluctuations environment can deteriorate the source performance (e.g. coherence)1,2. Here we present a single QD placed in the p-i-n junction to control over its charge environment. The presence of the junction should provide more efficient dissipation of excess charge carriers. We have employed high spatially resolved photoluminescence (PL), time- and polarization-resolved PL to examine the optical properties of this structure. We have demonstrated autocorrelation measurements for selected emission lines originating from different exciton complexes. The architecture of the presented device has the potential to modify its optical properties by manipulating the charge environment and the QD charge state through applying an external electric field.

[1] P. Holewa et al, High-throughput quantum photonic devices emitting indistinguishable photons in the telecom C-band, Nat Commun 15, 3358 (2024).

[2] D.A. Vajnert et al. On-demand Generation of Indistinguishable Photons in the Telecom C-Band using Quantum Dot Devices, ACS Photonics, 11, 2 (2024).

NUMBER 18 INDEX

Fabio Borrelli

Università degli studi di Napoli "Federico II”

Dynamics of an entangled state in TLSs coupled via a transmission line

Systems composed of lumped-element networks and transmission lines play a pivotal role in Circuit Quantum Electrodynamics (cQED). Recent experimental efforts have focused on transmon qubits interconnected by transmission lines, with the overarching goal of developing a network of quantum processors—an essential step toward distributed quantum computing. This approach holds promise for scalable quantum technologies and has also proven valuable for investigating fundamental phenomena such as the violation of Bell’s inequalities. Finite-length transmission lines are central to these setups and can operate

in multiple regimes. They may function as short-range links connecting lumped elements, serve as components in LC resonators, or provide long-range connections for remote qubit interactions. Although a substantial body of literature employs perturbative and Markovian approximations to analyze these systems, we use state-of-the-art computational techniques to investigate

their dynamics in more general settings. This allows us to uncover a broader range of behaviors and draw more comprehensive conclusions about the design and performance of cQED networks.

NUMBER 19 INDEX

Francesca Calloni

Università di Napoli “Federico II

Tunnel ferromagnetic Josephson junctions for hybrid superconducting qubit

F. Calloni1, R. Satariano1, H. G. Ahmad1,2, R. Ferraiuolo1,3, G. Serpico1, D. Montemurro1,2, A. Vettoliere4, G. Ausanio1,2, L. Parlato1,2, G.P. Pepe1,2, C. Granata1,2, A. Bruno3, F. Tafuri1 and D. Massarotti2,5

1Dipartimento di Fisica “Ettore Pancini,” Università di Napoli “Federico II,” Monte S. Angelo, I-80126 Napoli, Italy

2CNR-SPIN, UOS Napoli, Monte S. Angelo, via Cinthia, I-80126 Napoli, Italy

3Quantware, Elektronicaweg 10, Delft, South Holland 2628 XG, NL

4 Consiglio Nazionale delle Ricerche—ISASI, Via Campi Flegrei 34, I-80078 Pozzuoli, Italy

5Dipartimento di Ingegneria Elettrica e delle Tecnologie dell’Informazione, Università degli Studi di Napoli Federico II, via Claudio, I-80125 Napoli, Italy

Superconducting qubits are currently among the leading candidates for quantum computing [1]. To optimize qubit coherence times, two approaches are being pursued: improving materials and manufacturing or modifying the design [2][3][4]. Recently, a hybrid ferromagnetic qubit, the so-called Ferrotransmon, was proposed, where the use of tunnel magnetic Josephson junctions allows for an alternative tuning of the qubit frequency [5]. In standard transmon qubits, the frequency is tuned with a static out-of-plane field, introducing flux noise [6] [7]. The Ferrotransmon architecture features a single tunnel-ferromagnetic junction, which becomes the active element of the circuit and is tuned via a pulsed flux line, which in principle eliminates the need for static magnetic fields. In the case of a ferromagnetic junction, in-plane flux depends on the magnetization within the junction’s plane. This work outlines the key steps for implementing the hybrid ferromagnetic transmon, with a focus on optimizing tunnel magnetic Josephson junctions in terms of their transport and magnetic properties. The design, simulations, and initial experimental studies of superconducting lines generating in-plane magnetic fields are also emphasized, as these are crucial for controlling qubit frequencies on-chip in the Ferrotransmon.

[1] F. A. et al., “Quantum supremacy using a programmable superconducting processor,” Nature, vol. 574, pp. 505–510, oct 2019.

[2] M. Will et al., "High Quality Factor Graphene-Based Two Dimensional Heterostructure Mechanical Resonator", DOI:10.1021/acs.nanolett.7b01845, Nano Lett. 2017, 17, 5950-5955

[3] Wang, J.IJ., Rodan-Legrain, D., Bretheau, L. et al. Coherent control of a hybrid superconducting circuit made with graphene-based van der Waals heterostructures. Nature Nanotech 14, 120–125 (2019). https://doi.org/10.1038/s41565-018-0329-2

[4] A. K. Feofanov, V. A. Oboznov, V. V. Bol'ginov, J. Lisenfeld, S. Poletto, V. V. Ryazanov, A. N. Rossolenko, M. Khabipov, D. Balashov, A. B. Zorin, P. N. Dmitriev, V. P. Koshelets, and A. V. Ustinov, "Implementation of superconductor/ferromagnet/superconductor p-shifters in superconducting digital and quantum circuits," Nat. Phys. 6, 593–597 (2010).

[5] Halima Giovanna Ahmad et al. "Hybrid ferromagnetic transmon qubit: Circuit design, feasibility, and detection protocols for magnetic fluctuations". In: Phys. Rev. B 105 (21 2022), p. 214522.

[6] Jens Koch et al. "Charge-insensitive qubit design de rived from the Cooper pair box". In: Phys. Rev. A (2007). doi: 10.1103/PhysRevA.76.042319. https://link.aps.org/doi/10.1103/PhysRevA.76.042319.

[7] P. Krantz et al. "A quantum engineer's guide to superconducting qubits". In: Applied Physics Reviews (2019). doi:10.1063/1.5089550.

NUMBER 20 INDEX

Francesco Formicola

University of Naples Federico II

Local ergotropy dynamically witnesses many-body localized phases

Anderson localization (AL) and Many-Body localization (MBL) are dynamical phenomena in which the quantum system fails to dynamically achieve the thermodynamical equilibrium. It is known in literature that, for a quantum spin chain bipartite into two halves, entanglement entropy trend over time serves as characterization for the different phases, that is AL, MBL, and ergodic one. Previous works have shown the possibility of distinguishing the phases via thermodynamic quantities that relied on global observables. This process needs an energy price to switch-off the interactions between the subsystem and the rest, which acts as an environment. The aim of the research is to demonstrate that local ergotropy, the maximum extractable work via local unitary operations on a small subsystem, is also a dynamical signature for localization phenomena without turning off any Hamiltonian coupling. In particular, the one-dimensional disordered XXZ Heisenberg model is analysed via extended numerical simulations. Taking two spins as subsystem, it is showed that local ergotropy time behaviour clearly varies distinguishing MBL and ergodic phases. One of the fundamental consequences of our results is that an experimenter can have access to a quantum thermodynamical marker for dynamical phenomena, such as localization ones, without the need local observables, like the entanglement entropy, but only via local measures of extracted work.

NUMBER 21 INDEX

Francesco Giuseppe Capone

Università degli studi di Napoli Federico II

Dissipative Josephson junction induced by quasi-particle tunneling currents: transport and equilibrium properties.

By employing World-Line Quantum Monte Carlo (WLQMC) simulations, we demonstrate that tuning the subgap resistance associated with quasi-particle tunneling-induced dissipation in a Josephson junction leads to a Berezinskii-Kosterlitz-Thouless (BKT) quantum phase transition (QPT). This transition, occurring at zero temperature, is characterized by a change from a delocalized phase difference state to a quasi-long-range ordered state in imaginary time. Specifically, the phase difference becomes localized in either the even or odd minima of the Josephson potential, showing a spontaneous symmetry breaking. However, no signatures of the QPT are observed in the system's dynamical properties within the linear response regime, as it remains in an insulating state.

NUMBER 22 INDEX

Giuseppe Di Blasio

Politecnico di Milano

Potentialities of SiPMs in Quantum Optics: is it possible to use a single detector for coincidence measurements?

In this work we explore the unique properties of a silicon photomultiplier coupled with radiofrequency custom-designed front-end electronics to achieve simultaneous-photon counting within a single detector, which could open to potential breakthroughs in quantum optics.

NUMBER 23 INDEX

Huda Alshemmari

University of Leeds

A rate equation approach to fluorescence lifetime measurements

The interaction of a single atom with the free radiation field is normally modelled in the framework of quantum optics. However, the resulting spontaneous photon emission is a simple exponential decay process which suggests that it can be described by much simpler models. Moreover, interactions between individual atoms like atomic dipole-dipole interactions are the result of far-field interference effects of the emitted light. Motivated by this, this paper therefore introduces a classical approach to the modelling of spontaneous photon emission which is based on the idea that atomic systems are essentially tiny dipole antennae with a finite battery attached. The only quantum effect is that the detection of light at low intensity levels is coarse grained and limited to integer photon numbers. To illustrate our approach, this paper used classical electrodynamics to describe photon emission from dipole interaction atoms.

NUMBER 24 INDEX

Irene Gaiardoni

Università di Salerno

Spin-charge conversion effects in 2D materials

We investigate spin-to-charge conversion via the Edelstein effect in two-dimensional systems, focusing first on both pure Rashba electron gases and then on a more complex system—an altermagnetic interface. Using the semiclassical Boltzmann approach, we analyze the magnetization arising from the direct Edelstein effect (DEE) in a 2D anisotropic Rashba model, extracting analytical expressions in the high electronic density regime. Extending our analysis to altermagnets, where time-reversal symmetry breaking spin-polarizes electronic states while maintaining zero total magnetization, we explore the interplay between altermagnetic order and Rashba spin-orbit coupling at interfaces with broken inversion symmetry. This leads to complex chiral spin textures and unconventional spin-to-charge conversion mechanisms. We show that altermagnetic order suppresses the conventional in-plane Rashba-Edelstein response. By combining analytical modeling and ab-initio calculations for RuO$_2$ bilayers, our results offer insights into the role of Rashba spin-orbit coupling, anisotropy, and altermagnetic order in tailoring spin-charge conversion phenomena.

Ivan Solovev

University of Oldenburg

Purcell enhanced single photon emission from a quantum emitter in WSe2 monolayer embedded in a tunable cavity

Ivan Solovev[1]*, Victor Mitryakhin[1], Sven Stephan[1,2], Jens-Christian Drawer[1], L. Lackner[1], Seth Tongay[3], Kenji Watanabe[4], Takashi Taniguchi[5], Martin Esmann[1], and Christian Schneider[1]

1- Institute for Physics, Carl von Ossietzky University of Oldenburg, Germany
2 - University of Applied Sciences Emden/Leer, 26723 Emden, Germany
3 - Materials Science and Engineering, School for Engineering of Matter, Transport and Energy, Arizona State University, Tempe, Arizona, USA
4 - Research Center for Functional Materials, National Institute for Materials Science, Tsukuba 305-0044, Japan
5 - International Center for Materials Nanoarchitectonics, National Institute for Materials Science, Tsukuba 305-0044, Japan;

Secure quantum communication relies on the intrinsic quantum properties of light and requires a single-photon source that is fast, highly efficient, and easily fabricated [1]. Apart from well-established GaAs-based systems, two-dimensional semiconductors have emerged as a promising scalable platform for quantum information processing [2, 3]. Here we show, how the performance of quantum emitters in atomically thin materials can be significantly elevated by integrating them into a versatile open plano-concave Fabry-Pérot microcavity. Owing to tunability of a cavity with a high Q-factor we managed to deterministically modulate radiative decay rate of a zero-phonon line. Reached five-fold shortening of the lifetime paves the way for higher rates of quantum key distribution and generation of indistinguishable single photons in 2D semiconductors.

1. Tomm, N., et al. Nat. Nanotechnol. 16, 399–403 (2021)

2. Gao, T. et al. npj 2D Mater Appl 7, 4 (2023)

3. J.C. Drawer et al., Nano Lett. 23 (18), 8683 (2023)

NUMBER 26 INDEX

James Kwon

University of Maryland, College Park

Entanglement in Continuous Variables

Entanglement is a fundamental resource to quantum information in the sense that any protocol that is impossible classically utilizes it. Continuous variable systems have recently been studied for usage in many areas of quantum information, but the properties of entanglement in such context are yet to be fully studied. We present protocols generalizing quantum teleportation and quantum key distribution in a stronger way than what has been proposed, and prove that some restrictions present in discrete variables are not in continuous variables.

NUMBER 27 INDEX

Jonas Himmel

University of Rostock, Rostock, Germany

State transfer in latent symmetric quantum networks

The transport of quantum states is a fundamental task in information processing systems, enabling operations such as quantum key distribution and inter-component communication within quantum computers. A straightforward approach to the design of state transfer networks is to use spatial symmetries, like permutation or reflection symmetry, which strictly constraints the design space. Our work takes a novel path to designing photonic networks that lack any conventional spatial symmetries, while nevertheless supporting an efficient transfer of quantum states. Key to this approach are so-called latent symmetries, which are embodied in the spectral properties of the network, but remain hidden in the spatial domain. Furthermore, these networks can be arbitrarily extended at so-called singlet sites, without breaking the latent symmetry. An anti-symmetric excitation at the two latent-symmetric sites, will always interfere destructively at those singlet sites and hence will never leave the initial network. Latent symmetries significantly improve the flexibility in designing quantum networks and hold great potential for applications in quantum cryptography and secure state transfer.

As a proof of principle demonstration, we experimentally realize such a nine-site latent-symmetric photonic network using femtosecond laser-written waveguides and successfully observe state transfer between two sites with a measured fidelity of 75%. Furthermore, by launching an anti-symmetric two-photon state, we observe suppression of coincidences between singlet sites, as a result of destructive interference of the anti-symmetric input state and show that quantum interference is preserved by the network. This demonstrates that latent symmetries enable efficient quantum state transfer, while offering greater flexibility in designing quantum networks.

NUMBER 28 INDEX

Julian Czarnecki

AGH University of Krakow

Mixed-symmetry superconducting gap at (111) LaAlO3/SrTiO3 interface

The two-dimensional electron gas (2DEG) at the LaAlO$_3$/SrTiO$_3$ (LAO/STO) interface not only exhibits a characteristic dome-like shape of the critical temperature as a function of electron concentration but also sparks a discussion about the coexistence of superconductivity and magnetic ordering in these heterostructures. The superconducting properties of LAO/STO have recently been widely studied for materials grown along the [001] crystallographic direction, but much fewer experimental and theoretical works have been dedicated to the [111] direction.

In this work, we present a theoretical study of the superconducting properties of 2DEG in LAO/STO bilayer in the [111] crystallographic direction. Starting from real-space intra- and interlayer superconducting coupling, we find that honeycomb lattice leads to non-trivial superconducting gap symmetries, including non-negligible contribution of exotic triplet \textit{p-wave} symmetry. In addition, we find that anisotropic pairing scenarios could lead to an increase of both p-wave and d-wave symmetries' contributions to the superconducting properties.

To provide a direct comparison with the experimental results, we analyze the critical temperatures as a function of the electron concentration and superconducting gap at different Fermi levels.

NUMBER 29 INDEX

Julian Trapp

LMU Munich

Electrostatic control over exciton-polaritons in a bilayer triangular lattice of electrons

Exciton-polaritons are unique hybrid quantum states that arise from the coherent superposition of elementary light and matter excitations. These bosonic quasiparticles emerge in the regime of strong light-matter coupling, with their properties determined by their excitonic and photonic components. Achieving active control over these components has been a longstanding goal in polaritonic research, as it enables the development of optical devices such as polariton lasers and tunable optical nonlinearities down to the single-photon level. In this study, we demonstrate electrostatic control of exciton-polaritons hosted in an antiparallel $MoSe_2$-WS_2 van-der-Waals heterostructure embedded in a Fabry-Pérot microcavity. The moiré potential in this solid-state platform realize a triangular bilayer version of the Fermi-Hubbard model. By controlling the doping level and electric field, we explore how the underlying bilayer Hubbard model maps onto the polaritonic properties. Field control induces a modulation of the vacuum Rabi splitting and reveals how the previously reported strong optical nonlinearity in this system depends on conduction band alignment. Doping control, in turn, uncovers a filling factor-dependent modulation of the light-matter coupling strength through Coulomb interactions between the vertically stacked electron lattices.

NUMBER 30 INDEX

Karol Sajnok

Center for Theoretical Physics, Polish Academy of Science

Modeling Nonlinear Optics with the Transfer Matrix Method

The Transfer Matrix Method (TMM) is a widely used technique for modeling linear propagation of electromagnetic waves through stratified layered media. However, since its extension to inhomogeneous and nonlinear systems is not straightforward, much more computationally demanding methods such as Finite-difference time-domain (FDTD) or Finite element method (FEM) are typically used. In this work, we extend the TMM framework to incorporate the effects of nonlinearity. We consider the case when strong coupling between excitons (electron-hole pairs) and photons leads to the formation of exciton-polaritons. This extension is crucial for accurately simulating the behavior of light in polariton microcavities, where nonlinearities arising from exciton-exciton interactions play a key role. We perform efficient simulations of light transmission and reflection in a multidimensional system using the plane wave basis. Additionally, we compare our extended TMM approach with the state-of-the-art admittance transfer method, and highlight the computational advantage of extended TMM for large-scale systems. The extended TMM not only provides a robust and computationally efficient numerical framework, but also paves the way for the development of future low-power nonlinear optical devices, polariton-based photonic circuits, and quantum photonic technologies.

NUMBER 31 INDEX

Katarina Zikic Manojlovic

Institute of Applied Physics, University of Bern, Bern, Switzerland

Spectroscopic and time-resolved study of newly synthesized molecular compounds for on-chip integrated quantum light sources

The ARTEMIS project aims to develop integrable quantum sources based on metal-organic compounds with transition metal and/or lanthanide ions. These materials exhibit tunable linear emission and nonlinear optical properties, enabling on-demand generation of single photons and entangled photon pairs or triplets. When integrated with plasmonic supernanostructured cavities, these molecular emitters achieve strong optical enhancement. Our group focuses on the quantum characterization of the light emitted by these sources to explore their potential for new metrology and sensing applications in the quantum regime. Spectroscopic and time-resolved measurements on newly synthesized compounds Tb−N(Bzlm)3 and Eu−N(Bzlm)3 dissolved in DMSO at high concentration reveal narrow emission bands and relatively long decay times.

Kerttu Aronen

Quantum Dynamics, Department of Applied Physics in Aalto University, Finland

Directional lasing at high symmetry points of plasmonic lattices with complex unit cells

Plasmonic nanoparticle lattices support plasmonic resonances and optical modes that can be used to induce lasing emission. The modes conform to the lattice symmetries, allowing for realization of vortex-like states of light that can be controlled via the array geometry. The polarization vortex states are associated with a topological charge in the reciprocal space. Lasing with a topological charge of 1 or 2 can be realized in a lattice with a six-fold rotational symmetry [1], while larger topological charges require lattices with higher rotational symmetries. Two-dimensional quasicrystal structures have been shown to host vortex modes with topological winding up to 19 [2]. We apply group theory in our design of the lattices, placing the nanoparticles in the nodes of the electromagnetic field for the enhancement of the desired nodes. These kind of controlled states of light open avenues for studying other topological phenomena in photonic lasing systems, and can have applications in sensing or information transfer.

[1] G. Salerno, Physical Review Letters 129, 173901 (2022)

[2] K. Arjas, Nature Communications 15, 9544 (2024)

NUMBER 33 INDEX

Kristina Acimovic

University of Belgrade, Faculty of Physical Chemistry

Power of Holography: Current and future Perspectives

Holography is a simple interferometric method whose strength lies in its ability to detect the smallest displacement within the system. It has proven to be particularly useful for studying natural photonic structures with complex geometries. The paper will summarize our latest research and results within the framework of natural photonics. In the end, we present the application of holography in the areas of nonlinear chemistry and non-equilibrium dynamics. Specifically, we revealed the dynamics of the Briggs Raucher reaction with minimum system disturbance, exploiting the power of holography.

Lara Couronné

Centre de Nanosciences et de nanotechnologies (C2N)/Quandela

Spin-Photon Entanglement for Generating Multiphotonic Graph States

One of the most promising approaches to scalable and universal photonic quantum computation is measurement-based quantum computing, which relies on multi-photon entangled states as a key resource. A particularly promising protocol for deterministically generating such states is the Lindner-Rudolph scheme [1]. In this scheme, a single spin confined in a semiconductor quantum dot precesses due to a small transverse magnetic field. When the spin is in a superposition between up and down is excited with a laser, an entangled state is created between the spin and the polarization of a photon. By repeating this process, the entanglement can be extended to additional photons. This protocol has been demonstrated by several research groups [2, 3, 4]. More recently, it has been further developed to generate more complex entangled states, known as "caterpillar states," through the application of optical pulses for spin phase control [5].

In this poster, I will present the work conducted by our group on implementing this scheme, including recent results on new quantum dot structures designed to extend the spin coherence time critical for this protocol. This work represents a significant step toward small-scale demonstrations of fault-tolerant quantum computing.

[1] Lindner, N. H. & Rudolph, et al. Proposal for Pulsed On-Demand Sources of Photonic Cluster State Strings. Physical Review Letters vol. 103 (2009). https://doi.org/10.1103/PhysRevLett.103.113602

[2] Su, Z.-E. et al. Continuous and deterministic all-photonic cluster state of indistinguishable photons. Reports on Progress in Physics vol. 87 077601 (2024). https://doi.org/10.1088/1361-6633/ad4c93

[3] Thomas, P., Ruscio, L., Morin, O. et al. Efficient generation of entangled multiphoton graph states from a single atom. Nature 608, 677–681 (2022). https://doi.org/10.1038/s41586-022-04987-5

[4] Coste, N., Fioretto, D.A., Belabas, N. et al. High-rate entanglement between a semiconductor spin and indistinguishable photons. Nat. Photon. 17, 582–587 (2023). https://doi.org/10.1038/s41566-023-01186-0

[5] Huet, H., Ramesh, et al. Deterministic and reconfigurable graph state generation with a single solid-state quantum emitter. arXiv. (2024)https://doi.org/10.48550/ARXIV.2410.23518

Laura Bersani

Università di Parma

Nuclear spin qudits for the implementation of quantum algorithms with unconventional NMR techniques

Molecular nanomagnets (MNMs), molecules containing one or few interacting spins, are emerging as promising building blocks for quantum technologies [1]. Since they naturally provide many accessible low-energy levels, they are particularly suitable to encode qudits, i.e. quantum digits with more than 2 levels, thus enlarging the tools of quantum logic with respect to qubit-based architectures. For instance, MNMs containing single metal ions with a non-zero nuclear spin, strongly coupled to the electronic one by a large hyperfine interaction, can provide a significant number of states for qudit-based algorithms. Their sizable hyperfine interaction on the one hand, enables thermal initialization by cooling below ∼10 mK, on the other, it makes nuclear spin manipulations by radio-frequency (RF) pulses much faster. Yb(trenpvan) and VO(TPP) [2,3] are among the more promising nuclear qudit systems, which can be rapidly and coherently manipulated with NMR pulses. Here we have designed a sequence of RF pulses to implement the Quantum Fourier Transform (QFT) on a 3-levels subspace of both these nuclear qudits. The QFT can in fact be viewed as a d-dimensional Hadamard gate, that can be decomposed a in a sequence of Planar Waves Rotations (PWRs), that are applied to the initial state to implement the transformation.To perform a 3-level QFT, two transition frequencies have to be addressed at the same time. For this reason, we built two different custom NMR probes: a broadband NMR probe (for Yb(trenpvan)) and a "Sedor" probe (for VO(TPP)), consisting in two resonant circuit coupled by an extra capacitor, so that the final circuit presented two different resonance. The tomography we performed on the final state after the implementation of the QFT yielded the expected populations. Since the experiment were performed on single crystals and thus on an ensemble of nuclear qudits, inhomogeneous broadening (T2*) effects have to be take into account with suitable refocusing sequences to recover the lost coherences. Future perspectives also include experimental upgrades for the extension of the QFT algorithm to d > 3 levels.

[1] A. Chiesa, P. Santini, E. Garlatti, F. Luis and S. Carretta, Rep. Prog. Phys. 87, 034501 (2024).

[2] S. Chicco, G. Allodi, A. Chiesa, E. Garlatti, C. D. Buch, P. Santini, R. De Renzi, S. Piligkos, S. Carretta, J. Am. Chem. Soc. 146, 1053–1061 (2024).

[3] S. Chicco, A. Chiesa, G. Allodi, E. Garlatti, M. Atzori, L. Sorace, R. De Renzi, R. Sessoli and S. Carretta, Chem. Sci. 12, 12046 (2021).

Lena Hansen

Universität Wien

Non-classical excitation of a solid-state quantum emitter

The interaction between a single emitter and a single photon is a fundamental aspect of quantum optics. This interaction allows for the study of various quantum processes, such as emitter-mediated single-photon scattering and effective photon-photon interactions. However, empirical observations of this scenario and its dynamics are rare, and in most cases, only partial approximations to the fully quantized case have been possible. We demonstrate the resonant excitation of a solid-state quantum emitter using quantized input light. For this light-matter interaction, with both entities quantized, we observe single-photon interference introduced by the emitter in a coherent scattering process, photon-number-dependent optical non-linearities, and stimulated emission processes involving only two photons. We theoretically reproduce our observations using a cascaded master equation model. Our findings demonstrate that a single photon is sufficient to change the state of a solid-state quantum emitter, and efficient emitter-mediated photon-photon interactions are feasible. These results suggest future possibilities ranging from enabling quantum information transfer in a quantum network to building deterministic entangling gates for photonic quantum computing.

NUMBER 37 INDEX

Luigi Frau

CNR Nanotec

Exceptional Points and Fermi Arcs in Two-Dimensional Photonic Lattices

Hermiticity, the mathematical property that guarantees the energy conservation and the unitary evolution of a physical system, is at the basis of several physical theories. In fact, Hermitian operators are characterized by real eigenvalues, and their eigenvectors are mutually orthogonal. However, the description of a physical system is described by Hermitian operators is based on the strong assumption that it is isolated from the external environment. In general, to describe a realistic system, especially in contexts such as Optics or Photonics, a non-Hermitian formalism is necessarily required. The introduction of a non-Hermitian description not only allows dealing with dissipation channels, it also leads to novel physical phenomena that do not have a Hermitian counterpart, such as Exceptional Points (EPs). EPs are special spectral degeneracies of non-Hermitian operators: at the EP the matrix that describes such operators can no longer be diagonalized. The (complex) eigenvalues coalesce, i.e., they become degenerate in both their real and imaginary parts. Also, the eigenvectors become parallel at the EP, in a geometrical representation. Photonics and Optics are the ideal field in which these peculiar concepts can be studied. This is not only because of the ubiquity of non conservative channels (gain and losses), but also due to the simplicity with which these elements can be tailored through structural engineering. One such example are Photonic Crystals (PhCs), i.e. periodic dielectric materials. The procedure to obtain EPs in PhCs is quite straightforward: a quadratic degeneracy in the band structure can be split into a pair of Dirac points (DPs) by breaking one of the unit cell symmetries, and each DP can be further split into a pair of EPs introducing losses. Each EP of the pair is connected by an open isofrequency curve, called the bulk Fermi arc. In this work we have investigated, with both simplified analytic models and extensive numerical simulations, how EPs and the relative Fermi arc depend on the type and amount of broken symmetries in the given photonic lattice. In particular, numerical simulations have been performed by numerical codes based on the finite element method (FEM), in particular by using the commercial software COMSOL. It has been shown that it is possible to tailor the complex dispersion (i.e., real and imaginary parts) of photonic eigenmodes around the EPs, by acting on the symmetry properties of the unit cell to produce the desired dispersions in reciprocal space. These studies will be of interest to exploit EPs in PhC lattices for applications in light-emitting devices, or for fundamental physics studies.

NUMBER 38 INDEX

Luka Krstic

University of Belgrade, Faculty of Physics

POWER OF HOLOGRAPHY: CURRENT AND FUTURE PERSPECTIVES

Holography is a simple interferometric method whose strength lies in its ability to detect the smallest displacement within the system. It has proven to be particularly useful for studying natural photonic structures with complex geometries. The paper will summarize our latest research and results within the framework of natural photonics. In the end, we present the application of holography in the areas of nonlinear chemistry and non-equilibrium dynamics. Specifically, we revealed the dynamics of the Briggs Raucher reaction with minimum system disturbance, exploiting the power of holography.

NUMBER 39 INDEX

Manan Van Hoorebeke

University of Antwerp

Properties of Exciton-Polariton States Confined in a Moiré-Induced Potential

We investigate exciton-polariton states confined in a moiré-induced effective potential, focusing on the interplay between their fundamental properties and interactions. We develop an effective model to describe exciton and photon components and, through both numerical implementation and a variational approach, characterize polariton properties such as the effective Rabi splitting, Hopfield coefficients, and excitonic and photonic localization lengths. Our study specifically targets excitons in transition metal dichalcogenide (TMD) bilayers, which have emerged as a promising platform to study strongly correlated excitonic physics and hybrid light-matter systems due to their advantageous characteristics, including long exciton lifetimes, dipolar interactions, large oscillator strength, and tunable spatial confinement via twisting (moiré). We examine the effect of moiré-induced effective potentials on polariton properties, characterizing competing single-particle effects with the goal of enhancing polariton interactions. Aiming to reach the strong interactions regime, where the interaction energy exceeds the polariton linewidth, this work seeks to enable the exploration of emergent many-body phenomena in moiré polariton systems.

NUMBER 40 INDEX

Marco Alcibiade

Università degli studi di Cagliari

Synthesis and Characterization of Metal Complexes as Active Materials for On-Chip Integrated Quantum Light Sources

Materials showing nonlinear optical (NLO) properties are suitable for entangled photons generation by single parametric down-conversion (SPDC) mechanism. SPDC is an NLO process where a single photon splits into two entangled photons, a mechanism crucial for quantum optics, quantum computing, and secure communication technologies.

Molecular materials based on square-planar heteroleptic metal complexes have been proved to show high values of second-order NLO properties. These compounds are formed by a metal ion bridging two ligands: the pull one, which presents electron-withdrawing substituents that stabilize it, and the push one that has electron-donating substituents that raise its energy. Since the highest occupied molecular orbital (HOMO) is mainly formed by the pull ligand, while the lowest unoccupied molecular orbital (LUMO) is mainly formed by the push one, the HOMO-LUMO transition shows a strong charge transfer character, as required for the generation of second-order NLO properties.

This study focuses on the synthesis and characterization of heteroleptic Pt(II) complexes containing a bipyridine ligand (push) and either benzene-1,2-dithiolate or 1,3-dithiol-2-thione-4,5-dithiolate (push). The synthesized complexes were characterized using UV-Vis, IR, NMR spectroscopies, electrochemical methods and DFT calculations, to elucidate their structural and electronic properties.

The UV-Vis spectra of these materials exhibit medium to strong absorption bands extending into the visible region, attributed to metal-to-ligand charge transfer (MLCT) transitions. This transition displays solvatochromic behavior, with shifts in absorption maxima depending on the solvent polarity, highlighting their polarizable electronic structures and strong donor-acceptor interactions.

NUMBER 41 INDEX

Marina Esposito

Università degli Studi di Napoli Federico II, INFN Sezione di Napoli

ARCHIMEDES Experiment: the Weight of Quantum Vacuum

The Archimedes experiment investigates the interaction between zero-point quantum fluctuations of the electromagnetic field and gravity, contributing to one of the most longstanding discussions in modern physics: the Cosmological Constant Problem. This problem remains an open question, characterized by a significant disagreement between theoretical predictions and cosmological observations.

To understand whether vacuum fluctuations interact with the gravitational field, the first step of the Archimedes collaboration was to compute the force exerted by the gravitational field on a Casimir cavity: it resulted to be a force directed upward and equal to the weight of the vacuum EM modes that are "removed" from the Casimir cavity. To experimentally verify the interaction, the proposed approach has been to modulate the reflectivity of the Casimir cavity walls by using superconductive films: upon transition, part of the cavity modes is expelled from the cavity and if such part does weight, the cavity itself will lose (and acquire) weight at the modulation frequency that can be measured with a properly designed high sensitivity balance.

The effect of the gravitational field on a single cavity would result in an extremely small force (of the order of 10^-28 N for a cavity with a surface area of 1 dm^2 and a distance of 1 μm between surfaces), making it practically impossible to be measured. In order to enhance this effect, the Archimedes collaboration considers the use of stratified superconductors behaving like a stack of Casimir Cavities, such that the effect, for large scale crystals, is expected to be enhanced by about 12 orders of magnitude. Natural candidates for this purpose are cuprates such as YBCO, GdBCO, and BSCCO, which are high temperature superconductors with critical temperatures above 90 K. The theoretical evaluation of the contribution of the Casimir Energy at the superconducting transition has been performed by the Archimedes collaboration, proving the feasibility of the Archimedes experiment.

Currently the final setup of the experiment has been installed and thermal modulation tests on superconductive samples are ongoing.

NUMBER 42 INDEX

Marios Matheou

Politecnico di Milano

Investigating the impact of substrate on atomic defects formation in CVD-grown WS2 monolayers using Hyperspectral Imaging

Marios Matheou (1) *, Vesa Matti Juhani Hiltunen (2), Martina Riva (1), Gianluca Valentini (1), Stefano Dal Conte (1,3), Chiara Trovatello (1), Cristian Manzoni (3), Camilla Coletti (2,4), Giulio Cerullo(1,3), Armando Genco (1)

(1) Dipartimento di Fisica, Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133 Milan, Italy

(2) Center for Nanotechnology Innovation IIT@NEST, Piazza San Silvestro 12, 56127 Pisa, Italy

(3) Istituto di Fotonica e Nanotecnologie-Consiglio Nazionale delle Ricerche, Piazza Leonardo da Vinci 32, 20133 Milan, Italy

(4) Graphene Labs, Istituto Italiano di Tecnologia, Via Morego 30, 16163 Genova, Italy

*marios.matheou@polimi.it

2D materials, and in particular atomically thin Transition Metal Dichalcogenides (TMDs), exhibit properties heavily influenced by atomic defects, significantly impacting their electronic and optical performance [1], [2]. Chemical Vapour Deposition (CVD) is a leading technique for synthesizing high- quality, large area TMD monolayers. Growth substrate properties like surface energy and lattice mismatch directly impact defect density and distribution in the formed TMD crystals [3]. Hyperspectral imaging is an ideal technique to characterize such samples, since it generates a spectral hypercube of light intensity as a function of spatial (x,y) and frequency (ω) coordinates over large areas with diffraction limited resolution [4].

In our work, we used a modified fiber-compatible epifluorescence microscope with a TWINS (Translating Wedge-based Identical pulses eNcoding System) common-path interferometer [5] for a wide-field wavelength-resolved characterization of the photoluminescence (PL) produced by CVD- grown WS2 monolayers at room temperature (RT). Specifically, we characterized WS2 monolayers grown on a sapphire substrate and on an Al-rich sapphire substrate, then transferred on SiO2. In the former case, PL spectral peak position maps revealed well-defined regions of distinct spectral shifts. The redshift increases progressively from the edges towards the center of the flake, culminating in large, heavily redshifted areas at the core of the crystals. For TMDs grown on Al-rich sapphire substrate, we instead observed intense luminescence spots at the edges of the crystals. In this case, the PL peak wavelength pattern exhibits a more inhomogeneous distribution, with less pronounced redshift along the triangular crystal's bisectors.

Our study reveals significant differences in optical properties of WS2 monolayers grown on sapphire and Al-rich sapphire substrates, most probably related to different defect distributions. The Al-rich sapphire substrate might strongly influence the properties of grown materials by inducing the formation of Tungsten or Sulfur atomic defects in different positions of the crystals [6]. In combination with more advanced TEM, ARPES and XPS characterizations, these findings can be utilised for optimizing CVD growth conditions, in order to control the atomic defect density in TMD monolayers, thus tailoring their optical properties. Achieving such control on the single defect level will pave the way for their use in quantum computation and communication technologies.

[1] K. F. Mak and J. Shan, ""Photonics and optoelectronics of 2D semiconductor transition metal dichalcogenides,"" Nature Photonics, vol. 10, no. 4, pp. 216–226, 2016.

[2] D. Jariwala, T. J. Marks, and M. C. Hersam, ""Mixed-dimensional van der Waals heterostructures,"" Nature Materials, vol. 16, no. 2, pp. 170–181, 2017.

[3] Y. Gong et al., ""Vertical and in-plane heterostructures from WS_2/MoS_2 monolayers,"" Nature Materials, vol.13, no. 12, pp. 1135–1142, 2014.

[4] C. Trovatello et al., ""Hyperspectral microscopy of two-dimensional semiconductors,"" Optical Materials: X, vol. 14, no. 100145, 2022.

[5] A. Perri et al., ""Hyperspectral imaging with a TWINS birefringent interferometer,"" Optics Express, vol. 27, no. 11, pp. 15956–15967, 2019.

[6] H. Y. Jeong et al., ""Heterogeneous defect domains in single-crystalline hexagonal WS_2,"" Advanced Materials, vol. 29, no. 15, 2017.

Marko Kuveždić

Laboratoire Albert Fert, CNRS, Thales, Université Paris-Saclay, 91767 Palaiseau, France

Spin-orbit readout of spin-qubits using oxide 2DEGs

Marko Kuveždić 1, Hugo Witt 1,2, Soumyajit Mandal 2, Vladimir Pirogov 2, Nicolas Bergeal 2, Isabella Boventer1, Marco Salluzzo 3, Roberta Citro 4,5, Manuel Bibes 1

1. Laboratoire Albert Fert, CNRS, Thales, Université Paris-Saclay, 91767 Palaiseau, France

2. Laboratoire de Physique et d'Etude des Matériaux, ESPCI Paris, PSL University, CNRS, Sorbonne Université, Paris, France

3. CNR-SPIN, Complesso Univ. Monte S. Angelo, Naples, I-80126, Italy

4. Dipartimento di Fisica "E.R. Caianiello", Università di Salerno, Via Giovanni Paolo II, 132, I-84084 Fisciano (SA), Italy

5. INFN, Sezione di Napoli, Gruppo collegato di Salerno, Italy

Efficient and scalable readout of spin qubits remains a major challenge in quantum computing. This work presents a novel spin-orbit readout method that exploits the giant spin-to-charge conversion efficiency in oxide two-dimensional electron gases (2DEGs), such as those at $LaAlO_3/SrTiO_3$ interfaces [1,2]. These oxide 2DEGs provide key advantages over conventional platforms, including suppressed charge noise due to the high dielectric constant (~20,000 at low temperatures), electrically tunable spin-orbit coupling (SOC) [3], and long spin-diffusion lengths [4]. The proposed readout mechanism leverages the Edelstein effect and two-dimensional spin Hall effect to convert a qubit's spin state into a detectable voltage signal. By applying voltage pulses, electrons are extracted from single quantum dots (QDs) and transported to a T-junction, where the spin-polarized current generates a transverse non-local voltage. The polarity of this voltage directly correlates with the spin state of the QD, enabling a simple and efficient readout method.

[1] E. Lesne, et al., Nat. Mater. 15, 1261 (2016)

[2] D. C. Vaz, et al., Nat. Mater. 39, 78 (2019)

[3] A. D. Caviglia, et al., Phys. Rev. Lett. 104, 126803 (2010)

[4] F. Trier, et al., Nano Lett. 20, 395 (2019)

Meetsinh Thakor

University of Namur

Design and implementation of an experimental setup to measure complex weak values

Meetsinh Thakor, Julien Bouchat, Yves Caudano

Physics Department, naXys and NISM, University of Namur, Rue de Bruxelles 61, 5000 Namur, Belgium

The weak value was introduced in 1988 by Aharonov, Albert, and Vaidman [1] as a “New kind of value for a quantum variable” [2] that appears when averaging pre-selected and post-selected weak measurements. The weak value is a complex quantity. To determine the weak value in an optical experiment, we need to measure both the real and complex parts [3]. The setup confers precise control over the pre-selected and post-selected states, allowing for the amplification of anomalous weak values in weak measurements. Such high-precision measurements have important applications in metrology, quantum sensing, and fundamental physics.

Using a specialized filtering technique, a clear Gaussian beam is generated from the collimated laser beam. The pre-selected and post-selected states are determined using polarizers, quarter-wave plates (QWP), and half-wave plates (HWP). Additionally, the weak interaction is achieved using a birefringent material or a prism. To measure the real and complex part of a weak value, different setups of the optical lenses were used. A CCD image sensor serves as the detector.

1) Aharonov, Y., D. Z. Albert, L. Vaidman. (1988) How the result of a measurement of a component of the spin of a spin-1/2 particle can turn out to be 100. Phys. Rev. Lett. 60, 1351–1354.

2) Dressel, J., Mehul Malik, F.M. Miatto, A.N. Jordan, R.W. Boyd (2014) Colloquium: Understanding quantum weak values: Basics and applications, Reviews of Modern Physics, 86(1), pp. 307–316.

3) Dhara, R., Modak, N., Guchhait, S. and Ghosh, N. (2025) Roadmap on Weak Measurements in Optics. Adv. Phys. Res. 2400136.

Meysam Saeedi

Meysam Saeedi,a Mingyun Yuan,a Duc van Dinh,a Oliver Brandt,a Andrei Anisimov,b Georgy Astakhov,b Alberto Hernández-Míngueza a

a Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V., Hausvogteiplatz 5–7, 10117 Berlin, Germany

b Helmholtz-Zentrum Dresden – Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstr. 400, 01328 Dresden, Germany

Over the past decade, color centers (CCs) in wide-bandgap semiconductors have been widely studied due to their potential applications in quantum technologies as e.g. single-photon emitters (SPEs) and spin qubits [1,2]. In addition to high optical recombination efficiency and long-living spin states, it is also crucial to find methods for efficient manipulation of the optoelectronic properties of CCs. For this, mechanical vibrations in the form of surface acoustic waves (SAWs) offer a promising alternative to typically used microwave fields [3]. While investigations have mostly been performed in materials like diamond, 4H-SiC, and GaN [1-3], AlN has recently stood out as a host of SPEs emitting in the visible wavelength range [4], and theoretical calculations suggest it also supports optically addressable CCs with non-zero spin states [5]. In addition, due to its excellent piezoelectric properties, high acoustic velocity, and strong coupling efficiency, AlN is an ideal material for the efficient excitation of high-frequency SAWs [6].

This study aims at the controlled formation and optical characterization of CCs in high-quality AlN films, and the controlled acoustic manipulation of their emission lines and/or spin-states. Our preliminary results show that proton irradiation of a 700-nm-thick AlN film grown by molecular beam epitaxy, followed by an annealing process, lead to the appearance of emission lines in the 640–812 nm range with linewidths down to 0.14 nm. These emission lines are not observed in the as-grown sample, thus indicating that the post-growth treatments are responsible for their activation. Additional characterization techniques such as confocal photoluminescence and cathodoluminescence microscopies, as well as autocorrelation measurements, will determine their spatial density and the quantum nature of their light emission. Finally, we will use the dynamic strain of piezoelectrically excited SAWs to manipulate the optoelectronic properties of these CCs.

[1] Zhang, G., et al. (2020). Material platforms for defect qubits and single-photon emitters. Appl. Phys. Rev., 7(3).

[2] Esmann, M., Wein, S. C., & Antón-Solanas, C. (2024). Solid-state single-photon sources: Recent advances for novel quantum materials. Adv. Funct. Mater., 34(30), 2315936.

[3] Hernández-Mínguez, A., et al. (2021). Acoustically induced coherent spin trapping. Sci. Adv., 7(44), eabj5030.

[4] Xue, Y., et al. (2020). Single-photon emission from point defects in aluminum nitride films. J. Phys. Chem. Lett., 11(7), 2689-2694.

[5] Seo, H., Govoni, M., & Galli, G. (2016). Design of defect spins in piezoelectric aluminum nitride for quantum technologies. Sci. Rep., 6, 20803.

[6] Yuan, M., et al. (2024). Generation of GHz surface acoustic waves in (Sc,Al)N thin films. J. Phys. D: Appl. Phys., 57(49), 495103.

NUMBER 46 INDEX

Mingyang Zhang

CNRS-CRHEA

Exciton-Polariton Condensates in GaN-Based Microcavities for Neuromorphic Computing

Mingyang Zhang[1], Maksym Gromovyi[1], Sébastien Chenot[1], Blandine Alloing[1], and Jesús Zúñiga-Pérez[1,2]

[1]Université Côte d'Azûr, CNRS, CRHEA, Rue Bernard Gregory, 06560 Valbonne, France

[2]MajuLab, International Research Laboratory IRL 3654, CNRS, Université Côte d'Azur, Sorbonne Université, National University of Singapore, Nanyang Technological University, Singapore, Singapore

Exciton-polaritons are light-matter quasiparticles that exhibit strong nonlinearity and enable low-threshold lasing. In this context GaN, a mature semiconductor widely used in optoelectronics and electronics, is an interesting material due to its large oscillator strength and high exciton binding energy, enabling exciton-polariton condensation at room temperature. Here we report the fabrication of in-plane microcavity and waveguide structures designed for neuromorphic computing applications. A GaN layer was epitaxially grown on an $Al_{0.1}GaN$ cladding atop a GaN-on-sapphire template. Distributed Bragg reflectors (DBRs) perpendicular to the growth plane were patterned via electron-beam lithography, defining in-plane microcavities in between. In a second step, individual microcavities are interconnected through polaritonic waveguides, defining more complex polaritonic circuits intended to form an integrated polaritonic neuromorphic accelerator. This platform leverages the enhanced nonlinearity of exciton-polaritons for energy-efficient information processing, making it a promising application for exciton-polariton-based photonic circuits.

NUMBER 47 INDEX

Nand Kumar

CNR-SPIN, Naples, Italy

WAL and WL at the interface of KTO based 2DEG

Weak antilocalization (WAL) is a quantum interference phenomenon that arises from spin-orbit coupling and plays a critical role in understanding electron transport in low-dimensional systems. This study investigates WAL in KTO ($KTaO_3$) heterostructures, which have attracted significant interest due to their unique two-dimensional electron gas (2DEG) properties, strong spin-orbit interaction, and potential for novel electronic applications. By analyzing magnetoconductance data at low temperatures, the characteristic WAL behavior is observed, revealing key insights into the spin-orbit scattering mechanisms and electron dephasing in these heterostructures. The temperature and magnetic field dependence of WAL is explored, providing a comprehensive understanding of quantum coherence and spin-related transport phenomena in KTO-based systems. The findings underscore the relevance of KTO heterostructures for future spintronic devices and quantum computing applications, as they exhibit robust spin-orbit interactions coupled with tunable electronic properties.

NUMBER 48 INDEX

Paola Savarese

Università degli studi Federico II, Dipartimento di Fisica

Realizing non-Hermitian dynamics via non-unitary photonic with structured light

In recent years, non-Hermitian photonics collected significant attention as a rising field in optics due to the emergence of numerous physical concepts and novel effects. Unlike systems described by a Hermitian Hamiltonian, where the Hermitian conjugate ensures system closure to the environment and energy conservation, a non-Hermitian system characterized by complex eigenvalues enables the description of open systems and facilitates understanding of how a system can interact with the environment.

Here, we propose an innovative approach for simulating non-Hermitian dynamics by realizing a non-unitary photonic quantum walk based on a light beam propagating in free space and manipulated via step operators acting jointly on its polarization and transverse momentum. Within this framework, we use the latter degrees of freedom to encode the coin and walker systems, respectively, typically characterizing coined quantum walks. To induce spin-rotation, we utilize a uniform liquid-crystal (LC) plate and an LC dichroic polarization grating to obtain a spin-dependent non-unitary translation operation on the walker. Through the combination of liquid crystals and absorbing dyes, we can manipulate both polarization and light amplitude, effectively recreating a dispersive system. This development yields a compact and versatile platform that significantly expands the scope of photonic simulations in studying quantum dynamics. It, also, introduces a new dimension for manipulating topological states, enabling the observation of phenomena such as those related to non-Hermitian topological phases.

NUMBER 49 INDEX

Paolo De Vicenzi

Sapienza Università di Roma

Tunable GaAs x P 1–x Quantum-Dot Emission in Wurtzite GaP Nanowires

Quantum light emitters can be realized by employing semiconductor quantum dots (QD) for advanced quantum optics and nanophotonic applications. Tunable Gallium Arsenide Phosphide (GaAsxP1–x) QD in nanowires (NWs) with emission in the VIS-NIR wavelength range have a strong technological potential. Here, we synthesized crystal-pure wurtzite Gallium Phosphide (GaP) nanowires (NWs), incorporating single GaAsxP1–x QDs of various As content with a great degree of control over the shape and composition of the ternary alloy QD. A well-defined confinement of the QD and the tunability of the emission wavelength are confirmed by low-temperature micro-photoluminescence (μ-PL) spectroscopy showing that the QD NW emission is dominated by a narrow peak whose energy shifts according to the As content of the QD: from ∼650 nm (As = 70%) to ∼720 nm (As = 90%). Moreover, a localized and efficient carrier recombination mechanism is found by single-NW μ-PL mapping, confirming that this emission arises from the QD. A power and temperature-dependent μ-PL study is performed to characterize the QD excitonic properties and to identify the origins and the nature of the involved energy levels. Finally, second-order autocorrelation measurements are performed to prove the quantum nature of the emitted light. Measurements carried out as a function of excitation power in CW and pulsed regime showed a g2 value of 0.09.

NUMBER 50 INDEX

Paraskevi (Evi) Kasnetsi

A typology of quantum algorithms.

Departament d'Òptica i Optometria i Ciències de la Visió, Universitat de València, Dr. Moliner 50, 46100 Burjassot, Spain

We draw the current landscape of quantum algorithms, by classifying about 130 quantum algorithms, according to the fundamental mathematical problems they solve, their realworld applications, the main subroutines they employ, and several other relevant criteria. The primary objectives include revealing trends of algorithms, identifying promising fields for implementations in the NISQ era, and identifying the key algorithmic primitives that power quantum advantage.

Paula Wieteska-Bajak

École Centrale Méditerranée / Institut Fresnel

Rotationally invariant states for cryptography in space

In space it is often not easy to find a fixed reference frame and it is thus convenient to encrypt quantum keys in inrotationally invariant states like e.g. circular polarization [1]. Here we propose a scheme of this type with two new ingredients: (i) Fluorophores are used as single-photon sources [2,3]. (ii) A specific translater converts polarisations in time-bin encoding which ensures alignment-free quantum communication [4,5].

This work is realised in the framework of the Artemis project (“Molecular materials for on-chip integrated quantum light sources“) funded by the European Union. https://www.artemis-quantumproject.eu

[1] V. D’Ambrosio, E. Nagali, S. P. Walborn, L. Aolita, S. Slussarenko, L. Marrucci, and F. Sciarrino, “Complete experimental toolbox for alignment-free quantum communication,” Phys. Rev. Lett., vol. 108, no. 6, p. 060502, 2012.

[2] D. Mara, Z. Cai, S. Bonabello, S. Penna, R. Van Deun, L. Marchiò, L. Pilia, and F. Artizzu, “Spectral tuning and emission enhancement through lanthanide coordination in a dual Vis-NIR emissive cyanide-bridged heterometallic Ru(II)-Er(III) complex,” Cryst. Growth Des., vol. 24, pp. 3798–3808, 2024.

[3] C. Yang, D. Mara, J. Goura, F. Artizzu, and R. Van Deun, “Photophysical and primary self-referencing thermometric properties of europium hydrogen-bonded triazine frameworks,” Molecules, vol. 27, p. 6687, 2022.

[4] J. Brendel, N. Gisin, W. Tittel, and H. Zbinden, “Pulsed energy-time entangled twin-photon source for quantum communication,” Phys. Rev. Lett., vol. 82, no. 12, pp. 2594–2597, 1999.

[5] T. Durt and B. Nagler, “Quantum cryptographic encryption in three complementary bases through a Mach-Zehnder setup,” in Probing the Structure of Quantum Mechanics: Nonlinearity, Nonlocality, Computation and Axiomatics, D. Aerts, M. Czachor, and T. Durt, Eds., World Scientific, Singapore, pp. 259–286, 2002.

NUMBER 52 INDEX

Pavel Belov

Universität Rostock

Bound states in the continuum in cuprous oxide quantum wells.

Bound states in the continuum (BICs) [1] are remarkable quantum states whose hallmark is the absence of the linewidth broadening and which therefore exhibit giant nonradiative lifetimes. Bound states embedded in the continuum have been first suggested to exist by von Neumann and Wigner in the context of an open quantum system with rapidly oscillating potential [2]. One century later, they became of practical relevance in photonics as particular solutions of the wave equation [3,4] and opened up important applications [5]. BICs are extensively studied in quantum optics due to their unique properties, including the ability to achieve the enhanced light-matter interactions, sharp Fano resonances, and extremely long-lived and confined single-photon excitations [6]. However, the proposed quantum-mechanical systems with BICs still fall into the category of speculative theoretical work, rather than practical realization. The designed theoretical setups [3,7] are hard to implement in atomic systems as they require rather challenging conditions.

In this report, we propose a realistic semiconductor system containing BICs which allows for a practical realization [8]. By varying the confinement strength of excitons in cuprous oxide quantum wells [9], we show that the long-lived Rydberg states of the confined electron-hole pairs appear in the continuum background. The trivial symmetry-protected BICs in this system are formed due to a different parity of the charge-carrier subbands, while the proper nontrivial BICs appear as a result of the Friedrich-Wintgen destructive interference between adjacent exciton resonances [7]. The calculations of the linewidths based on the coupled-channel Schroedinger equation with three channels and only few basis states are confirmed by a numerically exact solution employing a B-spline basis and the complex coordinate-rotation method [10]. We argue that finite-sized cuprous oxide crystals, due to their large exciton binding energies, are a convenient platform for experimental identification of BICs.

[1] C. W. Hsu et al., Nat. Rev. Mat. 1, 16048 (2016).

[2] J. von Neumann and E. Wigner, Phys. Z. 30, 467 (1929).

[3] D. C. Marinica et al., Phys. Rev. Lett. 100, 183902 (2008).

[4] Y. Plotnik et al., Phys. Rev. Lett. 107, 183901 (2011).

[5] M. Kang et al., Nat. Rev. Phys. 5, 659 (2023).

[6] G. Calajó et al., Phys. Rev. Lett. 122 073601 (2019).

[7] H. Friedrich and D. Wintgen, Phys. Rev. A 32, 3231 (1985).

[8] A. Aslanidis et al. ""Bound states in the continuum in cuprous oxide quantum wells"", submitted to Phys. Rev. Lett., (2024).

[9] P. A. Belov et al., Phys. Rev. B 109, 235404 (2024).

[10] P. A. Belov, Phys. Rev. B 105, 155417 (2022).

NUMBER 53 INDEX

Pelin Yıldırım

Quantum Dynamics Group (Prof. Päivi Törmä), Department of Applied Physics, Aalto University, Finland

Effective Interactions and Density of States in Plasmonic Bose-Einstein Condensation

Bose-Einstein condensates (BEC) are typically formed by atomic gases cooled to ultracold temperatures to ensure that the particles are lowered to the ground state. One way to overcome the low-temperature condition is to use metallic nanoparticle arrays that are coupled to dye molecules either in weak [1] or strong [2] coupling regimes. The electromagnetic modes called surface lattice resonances (SLRs) created in plasmonic lattices act as bosonic particles to form the condensate at room temperature. Strong coupling BEC experiences a blue-shift in the condensate energy as an indicator of the effective interactions present in the lattice.

The objective of this work is to observe the effective interactions by monitoring the condensate energy of lattices with different density of states (DOS) values. The change in DOS is achieved by altering the nanoparticle geometry, namely by changing the length of the gold rectangular nanoparticle. Transmission experiments are conducted to calculate the DOS of the array, and condensation experiments are conducted to observe the condensate energy. The findings of the work indicate a positive relation between DOS and effective interactions in plasmonic BEC.

[1] Hakala, T.K., Moilanen, A.J., Väkeväinen, A.I. et al. Bose–Einstein condensation in a plasmonic lattice. Nature Phys 14, 739–744 (2018)

[2] Väkeväinen, A.I., Moilanen, A.J., Nečada, M. et al. Sub-picosecond thermalization dynamics in condensation of strongly coupled lattice plasmons. Nat Commun 11, 3139 (2020)

NUMBER 54 INDEX

Rodrigo Sánchez-Martínez

Institute of Physics, Universidad Nacional Autónoma de México

Protecting Intercavity Polaritons in Strongly Coupled Cavities.

Multicomponents and many-body systems constitute a powerful route to achieve complexity and novel states that are unattainable to their single-particle counterparts. Arrays of strongly coupled cavities enable the emergence of exotic mixed light-matter states, such as intercavity exciton-polaritons—a unique class of excitations distributed across the extended coupled system. In this work, we demonstrate that the spatial segregation of their photonic and matter components endows intercavity polaritons with remarkable robustness and a tunable heavy mass. Furthermore, we unveil the connection between the transparency window commonly observed in slow-light experiments and the protection of the intercavity nature of these polaritons, both arising from the intentional design of an energy-level landscape that mimics the Λ scheme.

Rohit Prasad

Julius-Maximilians-Universität Würzburg

Predictive Modeling, Detection, and Fidelity Optimization of Linear Cluster States for Photonic Quantum Computing: Towards Optimal Experimental Parameters

The use of photons as flying qubits for quantum computation and information processing has been a subject of extensive research. One prominent approach for utilizing photons in quantum computation is measurement-based quantum computing (MBQC), which employs cluster states as a computational resource. In MBQC, the desired quantum circuit is implemented through a sequence of measurements on a pre-prepared cluster state. However, the experimental realization of high-fidelity linear cluster states remains challenging due to various sources of errors that degrade the purity of the emitted states from quantum dots.

In this work, we present an analytical formulation for the fidelity of generated linear cluster states, focusing on the predominant errors that affect their purity when emitted from a quantum dot. Our goal is to provide a predictive framework that allows researchers to estimate the achievable fidelity of linear cluster states from a given quantum dot sample prior to conducting experiments. This framework also offers insights into the cost-to-improvement ratios for various experimental parameters, enabling researchers to prioritize efforts that yield the most significant benefits with minimal time and resource expenditure.

By understanding the cluster state generation protocol and the impact of different error sources on the polarization-encoded information in photons, we develop an algorithm to generate the density matrix of the linear cluster state. The algorithm maintains a fixed number of total coincidence counts of 10^3 for an N-qubit linear cluster state, thereby circumventing the exponential time complexity, O(c^n), typically required for partial or full tomography of the system.

Future work will aim to incorporate additional error parameters to further refine our fidelity predictions and enhance our understanding of the factors influencing the quality of linear cluster states generated from quantum dots. This comprehensive approach will facilitate the optimization of quantum dot sample properties for improved cluster state generation, advancing the practical implementation of photonic quantum computing.

NUMBER 56 INDEX

Sergio Balestrieri

CNR-ISASI

Spin-Orbit Coupling-Induced Optical Manipulation of Plasmonic Nanoparticles

In nanophotonic systems, the spin-orbit coupling effect, a quantum phenomenon linking the spin of the photon to its spatial degrees of freedom, gives rise to extraordinary optical properties and novel technological applications. This effect is evident in fundamental optical phenomena such as light propagation in anisotropic media, nonparaxial optics, and reflection/transmission at dielectric interfaces.

A key consequence of spin-orbit coupling is the emergence of a transverse spin angular momentum (tSAM) component, which remains locked to the propagation direction of light. This enables spin-directive coupling in photonic systems that support evanescent-wave interactions. In particular, evanescent waves—such as transverse-magnetic surface-plasmon polaritons (SPPs)—play a crucial role in inducing spin-momentum locking, exerting forces and torques on nanoparticles. These interactions facilitate applications ranging from active particle selection to chiral manipulation via metasurfaces and biological structure analysis. In gold nanoparticles, localized surface plasmon resonance (LSPR) generates a nonzero tSAM along the sphere surface, affecting electromagnetic field-induced forces and torques. In this work, we demonstrate that spin-orbit interactions in gold monomers lead to polarization-dependent trajectory shifts due to self-induced spin momentum from LSPR. Furthermore, in gold dimers, field hybridization effects within the gap result in nontrivial spin momentum distributions, giving rise to vortex-antivortex pairs. The interaction of these vortices creates spin singularities whose position and strength can be dynamically controlled via incident polarization and nanoparticle separation. These findings provide fundamental insights into nanoscale optical manipulation and open new avenues for advanced applications in spin-optics, biophotonics, and nanomanipulation technologies.

NUMBER 57 INDEX

Silvia Bonabello

Università degli Studi del Piemonte Orientale

Color-tunable emissive lanthanide-based films for photonic applications

In view of their several unique properties, including their long luminescence lifetimes and narrow emission in the Visible and near-infrared (NIR) ranges, lanthanide complexes have been the focus of many years of study. These properties have led to a wide range of applications in various fields such as electronics, biomedical imaging and telecommunications. (Bünzli et al., 2010) More recently, lanthanide-based luminescent materials are attracting interest as potential single-photon emitters. In particular, single-molecule lanthanide complexes with organic ligands offer the opportunity to control the emission spectral characteristics through the tunability of the chemical environment and significantly enhanced processing flexibility with respect to traditional bulk quantum emitting materials. These aspects are key to the development of alternative solid-state single-photon sources (Toninelli et al. 2021).

In this study, we investigate suitably-designed Europium and Terbium single-molecule emitters and their incorporation into transparent and flexible hybrid films. These complexes have been synthesized using a benzimidazole derivative ligand which was selected on the basis of its energy levels that make it a suitable sensitizer for the lanthanide emitters and furthermore, it is a symmetrical ligand that leads to a decrease in crystal field splitting and, consequently, more coherent and intense emission. Following the successful synthesis of the complexes, their optical, spectroscopic and structural characterisation was performed, revealing an unusual crystal field splitting of the emission lines reflecting the high crystallinity and symmetry of the complexes. Subsequently, the doping of polyurethane-based films, synthesised by a sol-gel procedure, was undertaken. (Damasio de Freitas et al., 2023)

The characterisation of the films, doped with different weight percentages of complex, via spectroscopic and optical investigation, demonstrated their capacity to achieve color-tunability depending on the excitation wavelength. Specifically, for terbium doped film, an intense emission peak in the green (544 nm) is observed when the ligand is excited at 280 nm, and a white emission band is observed simultaneously exciting the ligand and the metal at 333 nm. A similar situation is observed for europium, with an intense emission in the red region (613 nm) by exciting the ligand at 280 nm and a white emission band as a combination of the emission of the film in the blue (around 450 nm) and europium (613 nm). To summarise, the effective synthesis of films with intense tunable emissions in the visible was achieved and in view of the simplicity of the synthesis, it is reasonable to expect the system to be optimised for different applications, including quantum photonic applications.

NUMBER 58 INDEX

Simone Di Micco

University of Rome "Sapienza"

Quantum machine learning and quantum computing with the photon-number encoding

Excitonic-based quantum dot sources are one of the best near-deterministic single-photon sources available at the moment. Recent progress in the development of such sources has significantly reduced decoherence processes in the two-level system emitting the single-photons. Furthermore, these kind of sources have been proved to transmit the coherence of the excited/ground state of the two-level system to the emitted photon. The possibility of having coherent superposition of photonic states in the photon-number basis opens new possibilities in the field of quantum communication and large-scale quantum networks. In this work we investigate the characteristics of states generated by two different excitonic-based sources in a superposition of vacuum- and one-photon components in order to exploit such states for quantum machine learning and quantum computing tasks.

Stanisław Świerczewski

University of Warsaw

Hybrid Quantum-Classical Approach to Reservoir Computing for Efficient Quantum State Classification and Tomography

Stanisław Świerczewski, Piotr Deuar, Michał Matuszewski, Timothy C.H. Liew, Barbara Piętka, Andrzej Opala

Quantum reservoir computing is a modern paradigm in quantum information processing inspired by artificial neural networks [1]. The Quantum Reservoir Neural Network (QRNN) can solve tasks such as regression or classification in both classical and quantum domains. An integral part of the QRNN is a reservoir created by randomly coupled quantum nodes that process quantum input data and reveal hidden correlations in a way that classical algorithms can interpret. Nevertheless, due to the exponential scaling of computational complexity, simulating large-scale bosonic reservoirs by solving the Lindblad Master Equation is inefficient. In this study, we employ the Positive-P method [2] to simulate the dynamics of large (here with more than 15 bosonic nodes), high-density reservoirs. This study demonstrates that using a quantum reservoir coupled to a classical artificial neural network we can perform quantum tomography by predicting the Wigner quasi-probability distribution function of quantum states including coherent states, squeezed vacuum states, and Schrödinger's cat states, across a broad range of parameters. Furthermore, we have shown that by utilizing the quantum-classical approach to reservoir computing an accuracy of over 96% in distinguishing between thermal, squeezed vacuum, and Schrödinger's cat states can be achieved despite the comparable density of these states.

[1] S. Ghosh, A. Opala, et al., npj Quantum Inf 5 , 35 (2019).

[2] P. Deuar, A. Ferrier, et al., Phys. Rev. X Quantum 2, 010319 (2021).

NUMBER 60 INDEX

Teresa Crisci

Università degli Studi di Napoli Federico II

Integrated Graphene Photodetector for Low-Power and Quantum-Ready Applications

In this work a graphene-based integrated photodetector optimized for operation around 1550 nm, designed with a composite waveguide structure comprising hydrogenated amorphous silicon, graphene, and crystalline silicon has been investigated. By embedding graphene within the waveguide, we enhance light-matter interaction, leveraging charge carrier trapping at the graphene/amorphous silicon interface to modulate the thermionic current at the graphene/crystalline silicon Schottky junction. Our CMOS-compatible fabrication process preserves graphene integrity, as confirmed by Raman spectroscopy, and achieves a responsivity of 1.9 A/W at 1535 nm, with an external quantum efficiency of 153% and a noise equivalent power of 9.6 pW/√HzHz. The responsivity increases at lower optical power, making the device highly suitable for low-power photodetection.

Furthermore, operating the detector at cryogenic temperatures could significantly suppress thermal noise and reduce the thermionic dark current at the Schottky junction, improving signal stability and enhancing the device sensitivity. These improvements could make the photodetector a promising candidate for quantum applications, including single-photon detection and quantum key distribution (QKD). The combination of high responsivity, CMOS compatibility, and the potential for ultra-low-noise operation suggests that this device could be integrated into next-generation quantum photonic circuits. Further investigation at cryogenic temperatures is needed to assess its viability for quantum applications.

NUMBER 61

INDEX

Tim Wedl

LMU Munich

Tuning Quadrupolar Excitons in Trilayer WSe2

Multilayer WSe_2 hosts various excitonic species, including dipolar excitons with large dipole moments (alternating layers) and quadrupolar excitons, which exhibit a nonlinear response to external electric fields. By integrating the material into a dual-gated device and exciting these excitons, we investigate quadrupolar excitons and their interactions. For the dipolar excitons present, it was observed how charge injection effectively tunes the dipole moments. Our findings demonstrate that WSe_2 homotrilayers offer a field-tunable platform for engineering light–matter interactions and exploring diverse exciton–exciton interactions.

NUMBER 62 INDEX

Tom Lannon

Queen's University Belfast

Testing the effects of decoherence on the performance quantum thermometry using the nitrogen-vacancy centre in diamond.

Understanding the interaction of a quantum system with its surroundings is vital for advancing quantum technologies and defining the limits of quantum mechanics. Quantum sensing offers an effective strategy for probing the dynamics of these interactions. Using the tools of quantum metrology and open quantum systems, we have theoretically investigated the performance of quantum thermometry in the presence of damping and dephasing channels. The Fisher information corresponding to population and phase measurements is used as a figure of merit in this respect. Room temperature experimental results will be obtained using the nitrogen-vacancy centre in diamond, allowing for a direct comparison of experiment with theory. These findings enable us to gain deeper insights into these decoherence mechanisms and inform the development of more robust quantum technologies.

NUMBER 63 INDEX

Ugo Chirico

University of Naples Federico II

Cryptography in the Post-Quantum Era

The advent of quantum computers threatens current cryptographic protocols, rendering traditional security schemes based on factorization and discrete logarithms obsolete. To address this challenge, post-quantum cryptography (PQC) aims to develop cryptographic algorithms resistant to quantum attacks, while quantum cryptography (QC) introduces new paradigms based on the principles of quantum mechanics.

In this study, we analyze the post-quantum algorithms standardized by NIST, focusing on Kyber for public-key encryption and Dilithium for digital signatures. We discuss their mathematical foundations, implementation challenges, and impact on cybersecurity.

Additionally, we explore the role of Quantum Key Distribution (QKD), a cryptographic protocol that leverages the principles of quantum mechanics to ensure secure communications, making interception physically detectable. While QKD cannot fully replace classical cryptographic techniques, it represents a promising solution for high-security scenarios.

Finally, we examine the practical implications of PQC and QC adoption in critical sectors such as digital identity, blockchain, and secure communications, outlining strategies for a secure transition to the post-quantum era.

NUMBER 64 INDEX

Uliana Diiankova

Ruhr University Bochum, Germany

Birefringence-Induced Polarization Dynamics in Multimode Spin-VCSEL

Vertical-cavity surface-emitting lasers (VCSELs) are appealing devices for short-reach optical networks but face fundamental modulation bandwidth limitations due to carrier-photon resonance [1]. Spin-VCSELs offer broader bandwidth by manipulating carrier spin polarization. Our previous investigations focused only on VCSELs operating in a single mode [1, 2]. Here, we extend these studies by exploring the dynamics and characteristics of higher-order modes under spin injection. In our work, 850 nm VCSEL [3] was continuously biased and optically pumped with circularly polarized pulses from a 750 nm Ti:Sa laser. Optical selection rules [4] link carrier spin polarization changes to emitted light polarization, producing oscillations in circular polarization, which we recorded with a streak camera.

We observed resonance frequencies of f_R=34 GHz in the fundamental mode and f_R=29 GHz in the higher-order mode. Polarization oscillation frequency f_R is directly proportional to the frequency difference Δf between the linearly polarized orthogonal modes induced by birefringence [1]. The emission spectrum, measured with an optical spectrum analyzer, confirms that the observed oscillations correspond to Δf in both the fundamental and higher order modes.

The interplay between modes could introduce additional resonances in the frequency response, potentially providing a pathway to expand the modulation bandwidth of spin-VCSELs and paving the way for the next generation of high-speed, short-reach optical communications.

[1] M. Lindemann, G. Xu, T. Pusch, et al, "Ultrafast spin-lasers," Nature 568, 212-215 (2019).

[2] M. Lindemann, T. Pusch, R. Michalzik, N. C. Gerhardt, M. R. Hofmann, "Frequency tuning of polarization oscillations: Toward high-speed spin-lasers," Appl. Phys. Lett. 108, 042404 (2016).

[3] T. Pusch, M. Lindemann, N.C. Gerhardt, M.R. Hofmann, and R. Michalzik, "Vertical-cavity surface-emitting lasers with birefringence splitting above 250 GHz," Electron. Lett. 51, 1600-1602 (2015).

[4] N. C. Gerhardt, M. R. Hofmann, "Spin-controlled vertical-cavity surface-emitting lasers," Advances in Optical Technologies 2012, Article ID 268949, 15 pages (2012).

NUMBER 65 INDEX

Victor Mitryakhin

Carl von Ossietzky Universität Oldenburg

Emerging Rabi-Oscillations in a monolayer single photon emitter driven through its excited state

Single photon sources (SPS) based on transition metal dichalcogenides (TMD) are considered promising candidates for a number of quantum applications due to relatively cheap production and flexibility in terms of tuning methods. However, the performance of such sources has not yet reached the level of the state-of-the-art solid-state SPSs. One of the main problems severely limiting the capabilities of TMD SPSs is the fast dephasing rate of the outgoing photon wavepackets, which is believed to be mostly caused by the charge environment and the coupling to vibrations of crystal lattice. In this regard, to eliminate or significantly decrease the influence of these effects on the coherence of the emitter, the most straightforward way would be to establish resonant excitation. To this date, the implementation of such excitation of TMD SPSs remains a challenging task. However, there exists a numerous alternative ways of quasi-resonant excitation. In the work, we study the photoluminescence excitation spectra of several quantum dots in tungsten diselenide monolayer and show quasi-resonant excitation through excited states of the dots manifesting itself in appearance of Rabi oscillations.

NUMBER 66

INDEX

Vincenzo Bruno

University of Salerno

Quantum Transport through Periodically driven Impurities: interplay of Fano resonance and cavity effect.

This work explores the transport properties of a one-dimensional continuum system with two periodically driven impurities. By applying Floquet theory, we transform the time-dependent Hamiltonian into an effective time-independent one, resulting in a multichannel scattering problem.

Our analysis highlights the interplay between Fano interference and the cavity-like behavior of the Floquet channels, which generates a complex transmission spectrum. As observed in systems with a single driven impurity, a Fano resonance emerges in the weak coupling regime. We identify a critical distance between the impurities at which this resonance is eliminated. These findings suggest that the coupling between Floquet channels and cavity modes plays a crucial role in shaping the system's transport properties.

NUMBER 67 INDEX

Vipin Balan

Politecnico di Milano

Dual colour rapid volumetric scan Full Aperture Extended Depth Oblique Plane Microscope

Oblique Plane Microscopy (OPM) is a special variant of light-sheet microscopy. In OPM, 3D images of the sample are acquired one plane at a time, by illuminating through a two-dimensional sheet of light propagating in an oblique direction. The illuminated plane is then imaged on a camera through off-axis optics. Conventional OPM is limited in resolution and flexibility due to the presence of tilted geometry in the detection path. In the poster, I will present a new variant of microscope named Full Aperture Extended Depth OPM, which addresses these problems. In this microscope the oblique plane is imaged on a camera through dynamic remote focusing instead of the conventional reprojection using multiple objectives. The remote focusing is done using an electrically tuneable lens. This enables this microscope to scan a larger FoV axially in the sample, up to millimetre scale dimensions. Being a single objective microscope two-dimensional samples like optical slides can be imaged apart from conventional lightsheet microscopes.

 INDEX

Yannik Brune

Technische Universität Dortmund

Thermally contaminated Coherent States in Light-Matter Interactions

Many applications in modern quantum optics and quantum information science, such as state preparation, rely on well-defined and well-known coherent states. Even small thermal contributions can significantly impact the usability of these states. However, the precise estimation of such thermal residuals remains challenging as standard quantifier like g(2) lose precision for small thermal contributions since they are affected by the relative thermal fraction. To improve this aspect, we focus instead on the light-field quantum coherence, mixedness and purity of its incoherent counterpart, while describing the light field by a displaced thermal state. These quantifiers, which depend on the absolute thermal contribution, not only offer higher sensitivity to small thermal residuals compared g(2), but also give deeper insights into the light field's offdiagonal elements. We prove our approach experimentally by performing quantum state tomography on prepared states to measure the three quantifiers. As a proof of concept, we finally investigate how the thermal residuals impact light-matter interactions using the Jaynes-Cummings Hamiltonian as a toymodel. Our results reveal how an atomic system responds to thermal residuals in the input light field and how it depends on the chosen quantifiers. This work not only allows a finer characterization of real light field but also offers deeper insights into the effects caused by their thermal residuals.