BOOK OF ABSTRACTS

Organized by :

LuMIn Lumière, Matière et Interfaces — CRHEA — Institut d'Optique Graduate School ParisTech — école normale supérieure paris-saclay — cnrs — université PARIS-SACLAY

INVITED TALKS

Organized by :

LuMIn Lumière, Matière et Interfaces — CRHEA — Institut d'Optique Graduate School ParisTech — école normale supérieure paris-saclay — cnrs — université PARIS-SACLAY

Emergence of quantum spin liquids from cavity QED

Darrick Chang*[1]

[1]Institut de Ciencies Fotoniques (ICFO) – Spain

Abstract

Quantum atom-light interfaces enable access to a wealth of quantum phenomena and applications within quantum information science. Despite this, a frontier that remains elusive is the realization and exploration of strongly correlated phenomena, due to two complementary problems. On one hand, such systems still suffer from significant dissipation, particularly at the level of individual quanta. On the other hand, there is a prevailing strategy to improve atom-light interaction efficiencies, by encoding processes into the collective response of many atoms. However, this strategy has the downside that collective spin or mean-field descriptions are typically good starting points to understand the physics, with paradigmatic examples being superradiance or spin squeezing. Such descriptions are incompatible with most known strongly correlated phenomena within physics.

Here, we propose a novel avenue to realize strongly correlated physics using arrays of atoms coupled to a high-finesse cavity. Notably, this approach both evades mean-field behavior despite the infinite-range photon-mediated interactions, and is partially protected from dissipation by exploiting its correlated nature, namely in the form of subradiance. We focus on the realization of topological quantum spin liquids, phases of matter (usually associated with short-range interactions) whose exotic properties include quasi-particle excitations that exhibit fractional or anyonic statistics, emergent gauge fields, and subtle long-range entanglement patterns.

In particular, we consider arrays of atoms featuring short-range and classical Ising (e.g., Rydberg mediated) interactions. We then show how long-range cavity interactions can melt the associated classical states into quantum spin liquids, by effectively projecting the state into highly correlated manifolds in which candidate spin liquid ground states are believed to live. These ground states are further shown to be perfectly dark to cavity-mediated photon emission. We anticipate that this work could open up new opportunities to realize strongly correlated and emergent phenomena with quantum atom-light interfaces, particularly by using the unique combination of long-range interactions and collective dissipation that such platforms naturally offer.

*Speaker

ERROR-DETECTED QUANTUM OPERATIONS MEDIATED BY AN OPTICAL CAVITY

B. Grinkemeyer[1]

[1] Department of Physics, Harvard University, Cambridge, MA, USA.

Neutral atoms trapped in optical tweezers are a promising platform for quantum information processing, with control over several hundred qubits already demonstrated. Further scalability can be achieved by coupling these systems to optical cavities, providing an efficient interface for light–matter interactions and quantum networking. In this talk, I will present the strong coupling of single atoms to a fiber Fabry–Perot cavity. By leveraging the collective light–matter interactions of the coupled atoms, we demonstrate novel protocols for generating entanglement mediated by the cavity. In addition to mediating interactions, the cavity biases errors to be detectable, allowing us to enhance entanglement fidelity through error detection. [1]

References

[1] Grinkemeyer, Brandon, et al. "Error-detected quantum operations with neutral atoms mediated by an optical cavity." *Science* 387.6740 (2025): 1301-1305.

Figure 1: Conference logo.

corresponding author : email@mail.com

TUNING COLLECTIVE EMISSION IN COHERENTLY COUPLED QUANTUM EMITTERS

Brahim Lounis

University of Bordeaux, Institut d'Optique & CNRS, France

The control and manipulation of quantum-entangled non-local states is essential for the development of quantum information processing. A promising route to achieve such states on a wide scale is to couple solid-state quantum emitters through their coherent dipole-dipole interactions. Entangling the electronic states of coherently interacting solid-state emitters is challenging since it requires both a coupling strength larger than the coherence decay rate, implying nanometric distances between the emitters, and quasi-degenerate optical transitions.

To address these challenges, we first focus on single aromatic molecules embedded in well-chosen solid matrices at liquid helium temperatures, which stand out as exceptional platforms for quantum optics experiments [1]. Using hyperspectral superresolution imaging in highly doped molecular crystals, we reveal pairs of coherently coupled fluorescent molecules. By tuning their optical resonances via Stark shifts, we demonstrate active control over their entanglement, reaching nearly pure subradiant and superradiant Bell states [2, 3]. Remarkably, we observe that delocalized electronic states can span distances up to 60 nm, opening promising perspectives for scalable quantum emitter networks.

We also explore lead halide perovskite nanostructures, which are emerging as versatile candidates for quantum photonic technologies. Using low-temperature magneto-optical spectroscopy, we fully resolve their band-edge exciton fine structure and identify the sublevel relaxation pathways. Furthermore, We demonstrate that engineered perovskite nanocrystals can act as efficient single-photon sources, achieving up to 60% quantum interference visibility without requiring Purcell enhancement [4].

These studies highlight complementary approaches for engineering and controlling quantum emission in solid-state systems, from molecular platforms to perovskite nanostructures.

References

[1] Deplano, P Tamarat, B Lounis, JB Trebbia. Sub-nanosecond coherent optical manipulation of a single aromatic molecule at cryogenic temperature. AVS Quantum Science 5, 041402 2023

[2] JB Trebbia, Q Deplano, P Tamarat, B Lounis. Tailoring the superradiant and subradiant nature of two coherently coupled quantum emitters. Nature communications 13, 2962 2022

[3] A Juan-Delgadoet al. Addressing the correlation of Stokes-shifted photons emitted from two quantum emitters, arXiv preprint arXiv:2501.19356 2025

[4] M. Stranstrup et al. Indistinguishable photons from single lead Halide perovskite nanorods (in prepararti on)

corresponding author : email@mail.com

Oral

NEUTRAL-ATOM WAVEGUIDE-QED

Julien Laurat

Laboratoire Kastler Brossel, Sorbonne Université, CNRS, ENS-Université PSL,
Collège de France, 4 Place Jussieu, 75005 Paris, France

The coupling of cold atoms with nanophotonic devices has recently opened a variety of novel opportunities for controlling light-matter interactions [1,2]. This combination not only promises improved scalability and figures of merit compared to free-space implementations, but also introduces new paradigms for atom-photon interactions. Dielectric waveguides offer a promising platform for such integration because they enable tight transverse confinement of the propagating light, strong photon-atom coupling in single-pass configurations and the potential for tunable long-range atom-atom interactions mediated by guided photons.

In the talk, I will present our work in this neutral-atom waveguide-QED field of research, with two distinct experimental platforms. Using atomic arrays trapped around a nanofiber, we demonstrated the capability to herald, store and read out a single collective excitation that is preferentially coupled to the guided mode [3]. In this setup, using a dynamically-controlled Bragg configuration, we also recently achieved all-optical routing and pushed the non-linearity down to the few-photon level [4,5]. I will then describe our ongoing efforts to achieve stronger coupling in single pass using photonic-crystal slow-mode waveguides. The engineering of the dispersion, and the presence of a bandgap, opens new opportunities to enhance atom-photon and atom-atom interactions. We have designed and fabricated waveguides that support a slow-mode resonant with an atomic transition and enable dipole trapping in the vicinity [6,7].

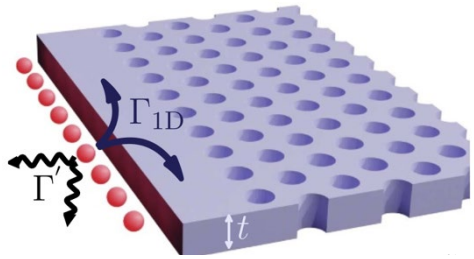


Figure 1: A novel waveguide-QED platform based on a half-W1 slow-mode waveguide [7].

References

[1] D.E. Chang, J.S. Douglas, A. González-Tudela, C.L. Hung, and H.J. Kimble.Quantum matter built from nanoscopic lattices of atoms and photons. Rev. Mod. Phys. **90**, 031002. **2018**

[2] A.S. Sheremet, M.I. Petrov, I.V. Iorsh, A.V. Poshakinskiy, and A.N. Poddubny. Waveguide quantum electrodynamics: Collective radiance and photon-photon correlations. Rev. Mod. Phys. **95**, 015002. **2023**

[3] N.V. Corzo, J. Raskop, A. Chandra, A.S. Sheremet, B. Gouraud, and J. Laurat. Waveguide-coupled single collective excitation of atomic arrays. Nature **566**, 359. **2019**

[4] N.V. Corzo, B. Gouraud, A. Chandra, A. Goban, A.S. Sheremet, D.V. Kupriyanov, and J. Laurat. Large Bragg reflection from one-dimensional chains of trapped atoms near a nanoscale waveguide. Phys. Rev. Lett. **117**, 133603. **2016**

[5] J. Berroir. Atomic arrays trapped around a nanofiber: collective non-linear quantum optics. PhD Thesis Sorbonne Université. **2022**

[6] N. Fayard et al. Asymmetric comb waveguide for strong interactions between atoms and light. Opt. Express **30**, 45093. **2022**

[7] A. Bouscal et al. Systematic design of a robust half-W1 photonic crystal waveguide for interfacing slow light and trapped cold atoms. New J. Phys. **26**, 023026. **2024**

corresponding author : julien.laurat@sorbonne-universite.fr

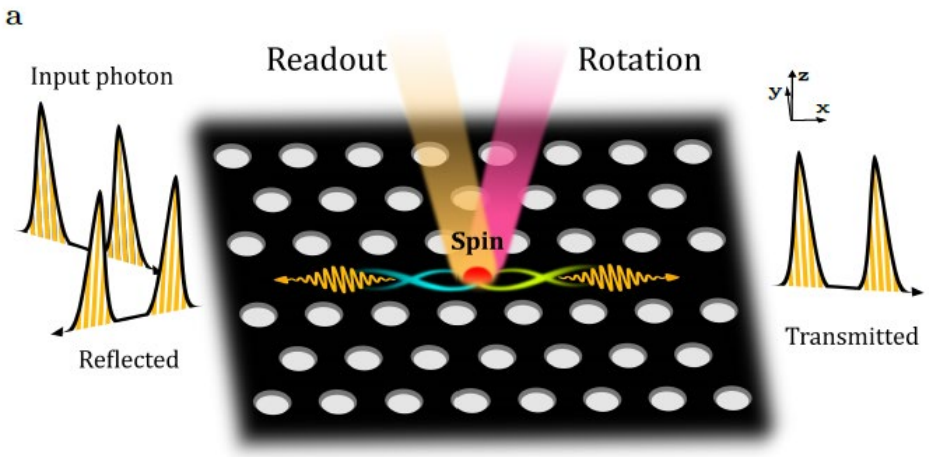
Solid-state spin-photon interfaces for quantum information processing

P. Lodahl
Sparrow Quantum and Niels Bohr Institute, University of Copenhagen, Denmark;
lodahl@nbi.ku.dk

Semiconductor quantum dots embedded in photonic nanostructures offer a highly efficient and coherent deterministic photon-emitter interface enabling on-demand single-photon sources and multi-photon entanglement sources [1,2]. We discuss the fundamental operational principles of these devices and introduce a protocol of deterministic entanglement generation by controlling a single spin in the quantum dot [3]. We will present the experimental state-of-the-art of multi-photon entanglement generation [4,5] including the realization of photon fusion [6], which is a primitive for fusion-based quantum computing. Finally, we discuss potential applications of this novel hardware for quantum communication and photonic quantum computing [7].

References

[1] Lodahl et al., Rev. Mod. Phys. 87, 347 (2015).
[2] Lodahl, Ludwig and Warburton, Phys. Today 75, 3-44 (2022).
[3] Tiurev et al., Phys. Rev. A L030601 (2022).
[4] Appel et al., Phys. Rev. Lett. 128, 233602 (2022).
[5] Meng et al., arXiv: 2310.12038
[6] Meng et al., arXiv: 2312.09070
[7] Uppu et al., Nature Nano. 16, 1308 (2021).



BNNT AS MOLECULAR TEMPLATE : FROM SINGLE MOLECULE TO SUPERRADIANT EMITTERS

J.-B. Marceau[1], J. Le Balle[1,2], D.-M. Ta[3], A. Aguilar[3], A. Loiseau[2], P. Bon[3], R. Voituriez[4], G. Recher[1], E. Gaufrès[1]

[1] Laboratoire Photonique Numérique et Nanosciences, Institut d'Optique, CNRS UMR5298, Université de Bordeaux, Talence, France
[2] Laboratoire d'Étude des Microstructures, ONERA-CNRS, UMR104, Université Paris-Saclay, France
[3] XLIM UMR CNRS 7252, Limoges, France
[4] Lab. de Physique Théorique de la Matière Condensée CNRS Sorbonne Université, Paris, France

Boron nitride nanotubes (BNNTs) have been identified as a promising dielectric host template for fluorescent molecules because of their wide-gap semiconductors of ~5.5 eV [1]. In this presentation we will focus on the different way to organize luminescent dyes inside BNNTs, from single molecules arrays to periodic J-aggregates. Especially, we will show that a local bending of BNNT induce an activated diffusion of molecules from curved to straight parts of the BNNTs [2,3]. Finally, combining ac-HRTEM and time resolved fluorescence imaging we will demonstrate that assemblies of aligned and regularly spaced dyes in BNNTs lead to superradiant light emission at room temperature with shortened lifetime by more than a decade, while keeping high brightness [4]. These multifunctional nanohybrids open a new route toward robust and low cost materials platform for quantum technologies.

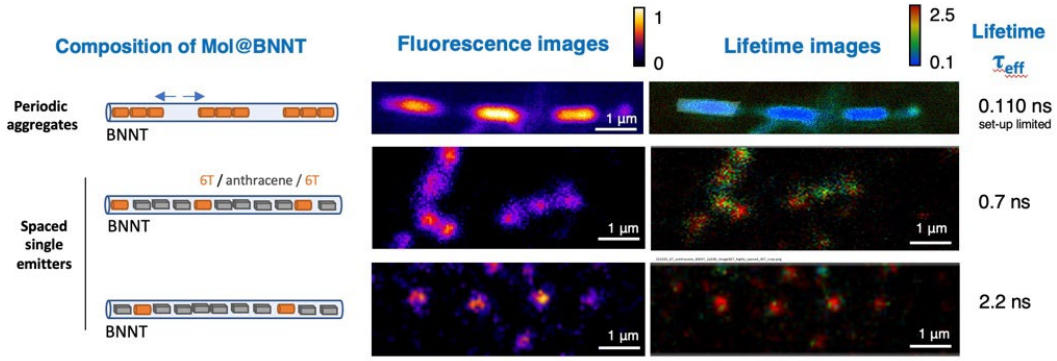


Figure 1 – Room temperature time-resolved fluorescence images at 600 nm of single molecules and superradiant 1D aggregates confined inside an individual BNNT.

[1] C. Allard et al, Advanced Materials (2020)
[2] A. Badon & J.-B Marceau et al, Materials Horizons (2023)
[3] J-B Marceau et al, arXiv:2402.17537 (2024)
[4] J-B Marceau et al, Encoded Dipolar Chains : from single molecule to superradiant emitters (submitted).

corresponding author : email@mail.com

Oral

GENERATION OF DEFECTS IN ULTRA-THIN HEXAGONAL BORON NITRIDE FOR QUANTUM SENSING

J. Eberle[1], I. Khanonkin[2], L. Liu[3], E. Yazici[1], T. Uto[1], A. Seiler[1], Z. Qian[1], M. Kroner[1] and A. İmamoğlu[1]

[1] Institute for Quantum Electronics, ETH Zurich, Switzerland
[2] Technion Israel Institute of Technology, Israel
[3] Nanyang Technological University, Singapore

Twisted heterostructures of van der Waals materials host a wide range of strongly correlated electronic states and exotic quantum phases. However, many quantum phenomena remain largely unexplored because conventional transport measurements are limited to conductive states. To overcome these limitations, we are developing a Quantum Optical Twist and Scan Microscope (QOTSM) that generates and detects strongly correlated states. Central to our approach is the ability to create an optically active defect that serves as a quantum sensor capable of measuring local electric fields with nano-scale resolution. We have developed a novel technique for creating the B-center in hexagonal boron nitride (hBN) films as thin as 3 nm, paving the way for high-resolution scanning and exploring the landscape of twisted heterostructures.

Figure 1: Conference logo.

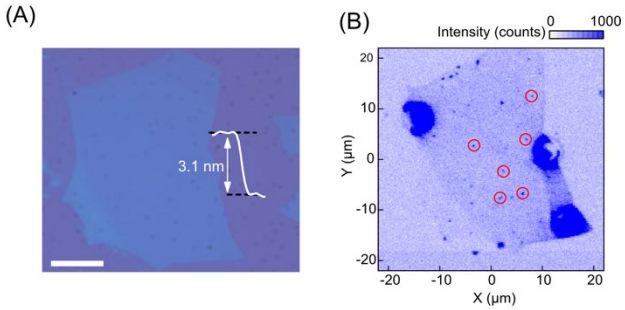


Figure 2: (A) 3nm thick hBN flake prior to irradiation with an electron beam. (C) PL measurements after electron irradiation show that emitters are created outside the irradiation spots.

corresponding author : joeberle@phys.ethz.ch

Oral

ORGANIC MOLECULES IN SOLIDS FOR PHOTONIC QUANTUM TECHNOLOGIES

Rocco Duquennoy[1], Maja Colautti[1,2],
Daniele De Bernardis[1], Elena Fanella[1], Hugo Levy-Falk[1] and Costanza Toninelli[1,2]

[1] CNR-INO c/o LENS, Via Nello Carrara 1, Sesto Fiorentino (Fi), Italy
[2] LENS, Via Nello Carrara 1, Sesto Fiorentino (Fi), Italy

In this contribution, the generation of quantum states of light from single molecules is discussed, tailored to multiple and diverse applications. We will focus on the use of polycyclic aromatic hydrocarbons (PAH), embedded in host matrices [1]. These molecules, due to their small size and well-defined properties, serve as nanoscopic sensors for pressure, strain, temperature, and various fields. The talk discusses recent advancements in coupling single PAH molecules to photonic structures to enhance and control their interaction with light [2]. Notably, two-photon interference experiments between photons emitted by different molecules on the same chip are presented, addressing a fundamental challenge in solid-state platforms for photonic quantum technologies [3]. The experiment relies on multiple milestones, including addressing several molecules simultaneously as on-demand single-photon sources [4], independently tuning their frequencies optically [5,6], and conducting real-time measurements of two-photon interference [3,7]. Additionally, the presentation explores the use of organic molecules as nanoscopic thermal sensors, enabling semi-invasive local temperature measurements in a temperature range (3 K to 30 K) unattainable by most commercial technologies [8]. These results offer insights into the local phononic environment in complex structures and an unexplored temperature regime. Finally, we will comment on the new prospects of using single molecules as interfaces between spin, optical and mechanical degrees of freedom.

References

[1] C. Toninelli et al., Nat. Mat. 20, (2021)
[2] M. Colautti et al., Ad.Q.Tech. 3, (2020)
[3] R. Duquennoy et al., Optica 9, 731-737, (2022)
[4] P. Lombardi et al., Ad.Q.Tec. 3, (2020)
[5] M. Colautti, et al., ACS Nano 14, 13584–13592 (2020)
[6] R. Duquennoy et al., ACS Nano18, 32508–32516 (2024)
[7] R. Duquennoy et al., Phys. Rev. Research 5, 023191 (2023)
[8] V. Esteso et al., Phys. Rev. X Quantum 4, 040314 (2023)

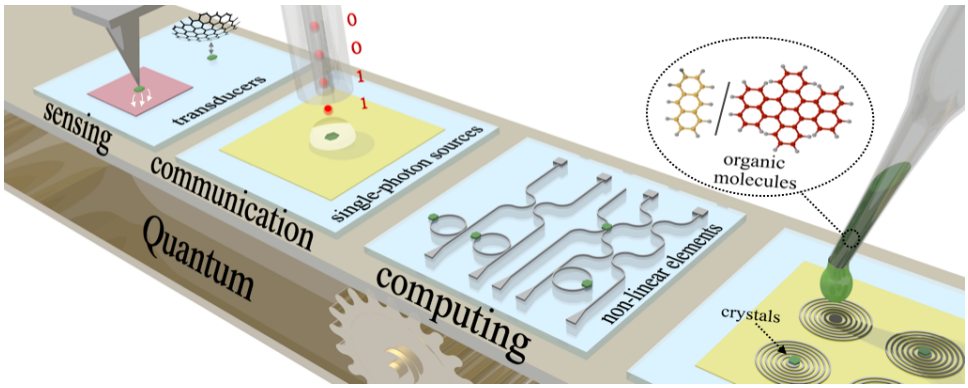


Figure 1: Artistic picture of the different experiments performed with molecules in our Lab

corresponding author : toninelli@lens.unifi.com

Oral

COLLECTIVE BEHAVIOR HALLMARKS IN DENSE RUBIDIUM VAPOR SPIN NOISE SPECTRA

J. Delpy[1], N. Fayard[1], F. Bretenaker[1] and F. Goldfarb[1]

[1] Université Paris-Saclay, CNRS, ENS Paris-Saclay, CentraleSupélec, LuMIn, Orsay, France

In magnetic systems, the spectroscopy of fundamental noise due to random spin fluctuations, called spin noise spectroscopy (SNS), can be optically performed by measuring the associated fluctuations of the Faraday-like rotation experienced by a linearly polarized probe beam propagating through the sample [1,2].
Using a thin 1 mm cell, we report anomalous features in the spin noise (SN) spectra of a dense vapor of rubidium (Rb) atoms: at high densities, we observe dramatic changes of the spin noise spectra (see Fig. 1), which we attribute to interactions arising between particles in the system [3]. Indeed, one can notice a drastic broadening of the linewidth of SN peaks and an increase of the noise at low frequencies for densities higher than 10^{14} at.cm^{-3}. Both features cannot be explained by transit decoherence and spin-exchange collisions. In the figure on the right, dashed and dash-dotted lines represent the expected values of the peaks half-widths at half maximum due to these mechanisms: the shaded area thus represent the additional broadening that cannot be explained by usual single-spin dynamics.
Using a two-body model and simulations, we can interpret the unusually large linewidths as an inhomogeneous broadening of the spin precession frequencies due to the dipole-dipole interaction and the atomic motion in the cell. We also propose a simple physical picture to explain the emergence of the unexpected low-frequency noise, based on the existence of non-zero spin steady-states for the binaries formed by the dipole-dipole interaction. This study opens the way to the characterization of many-body spin noise in strongly-correlated ensemble using SNS.

References

[1] E. B. Aleksandrov and V. S. Zapasskii, Magnetic resonance in the Faraday-rotation noise spectrum, JETP. **54**, 64 **1981**
[2] N. A. Sinitsyn and Y. V. Pershin, The theory of spin noise spectroscopy: a review, Rep. Prog. Phys. **79**, 106501 **2016**
[3] J. Delpy, N. Fayard, F. Bretenaker and F. Goldfarb, Anomalous high-density spin noise in a strongly interacting atomic vapor, Phys. Rev. Res. **7**, 013298 **2025**

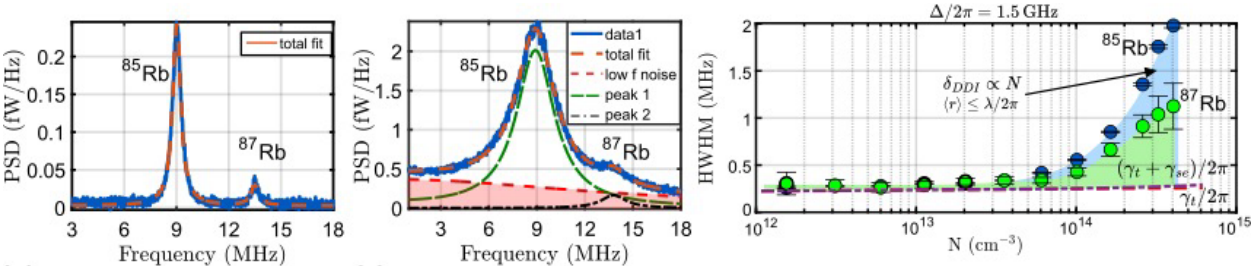


Figure 1: On the left, experimental SN spectra of rubidium obtained at a temperature T=90°C: it exhibits the usual resonances due to both isotopes ^{95}Rb and ^{97}Rb. In the center, SN spectra obtained for T=175°C, corresponding to a larger atomic density by more than 2 order of magnitude: they are much broader and a tail appears at low frequencies. On the right, evolution of SN peak half-widths at half maximum for both isotopes as a function of the Rb vapor density: shaded area represent the excess of broadening, compared to values expected from single spin dynamics simulations.

corresponding author : fabienne.goldfarb@universite-paris-saclay.fr

INVESTIGATING MULTIPLE SCATTERING FOR ANTIBUNCHING EFFECT IN A 3D COLD ATOMIC CLOUD

Mathilde Hugbart*†[1], Ana Cipris[2], Mateus Biscassi[3], Apoorav Singh Deo[1], and Stephan Asselie[1]

[1]Université Côte d'Azur, CNRS, INPHYNI, France – Université Côte d'Azur, Institut de Physique de Nice (INPHYNI) CNRS UMR 7010 – France

[2]Instituto de Física de São Carlos, Universidade de São Paulo – Brazil

[3]Université Côte d'Azur, CNRS, INPHYNI, France – Université Côte d'Azur, Institut de Physique de Nice (INPHYNI) CNRS UMR 7010, Universidade Federal de São Carlos [São Carlos] – France

Abstract

The light emitted by a quantum source, such as an atom, typically exhibits quantum correlations, which play a crucial role in numerous quantum technology applications. In particular, antibunching is a key feature of single-photon sources. While this effect naturally occurs in the emission from a single quantum emitter, it disappears when multiple emitters are involved. However, the research group led by Arno Rauschenbeutel in Germany successfully observed this phenomenon in a one-dimensional system, where cold atoms were trapped and optically interfaced with an optical nanofiber (1). This novel approach, based on the atoms' collectively enhanced nonlinear response, is of both fundamental interest and practical relevance. Nevertheless, the nanofiber setup is complex and challenging to implement in practical applications.
Our team aims to demonstrate this effect in a different setting-within a three-dimensional cloud of cold atoms confined in a magneto-optical trap (MOT). This builds upon our expertise in generating cold atomic clouds with high optical thickness, a crucial requirement for this project. However, achieving the high optical depth necessary for antibunching introduces the risk that multiple scattering could obscure the antibunching effect by randomizing the light's phase. To address this challenge, we employ two complementary methods.

The first approach involves measuring the intensity correlation functions of light scattered at small angles relative to the incident beam. The resulting signal exhibits two distinct decay times, enabling us to differentiate between contributions from single and multiple scattering (2). Through both numerical simulations and experimental verification, we demonstrate that a cigar-shaped atomic cloud can significantly suppress multiple scattering (see Fig. 1).

The second approach involves measuring the light transmission through the atomic cloud and evaluating the validity of the Beer-Lambert law. While this law holds for optically thin media, deviations are expected at higher optical depths due to multiple scattering redirecting light back into the transmitted mode. The optical thickness threshold at which this deviation

*Speaker

†Corresponding author: mathilde.hugbart@univ-cotedazur.fr

occurs depends on the cloud's geometry, making a cigar-shaped cloud a promising candidate for experimentally observing the antibunching effect.

References

(1) A. S. Prasad *et al.* Correlating photons using the collective nonlinear response of atoms weakly coupled to an optical mode. Nat. Photonics **14**, 719 (2020).
(2) A. Eloy *et al.*, Phys. Rev. A **97**, 013810 (2017). P. Lassègues, *et al.*, Phys. Rev. A **108**, 042214 (2023)

Cooperative photon emission from multiple indistinguishable quantum dots

Brian Gerardot*[1]

[1]Heriot-Watt University – United Kingdom

Abstract

Photon-mediated interactions between atoms can arise via coupling to a common electromagnetic mode or by quantum interference. Here, we engineer and probe cooperative emission arising due to path erasure from multiple distant but indistinguishable quantum dots. The primary signature of cooperative emission, the emergence of "bunching" at zero delay in an intensity correlation experiment, is used to characterize the indistinguishability of the emitters, their dephasing, and the degree of correlation in the joint system that can be coherently controlled (1, 2). To achieve cooperative emission in a scalable fashion with multiple indistinguishable quantum emitters, we introduce the use of spatial light modulators to independently control the excitation and collection of an arbitrary number of indistinguishable quantum dots, and demonstrate cooperative emission from up to 5 quantum dots. These results establish techniques to rapidly characterize indistinguishability of multiple emitters, to multiplex quantum light sources, to achieve scalable quantum light sources as inputs for programmable quantum circuits (3), and to engineer and manipulate large Dicke states (4).
References:

(1) Z. X. Koong *et al.,* Science Advances **8**, eabm8171 (2022).

(2) M. Cygorek *et al.*, Phys. Rev. A **107**, 023718 (2023).

(3) S. Goel *et al.*, Nature Physics 20, 232 (2024)
(4) R. H. Dicke, Phys. Rev. **93**, 99 (1954).

*Speaker

A MANY-BODY QUANTUM MEMORY USING OPTICALLY ENGINEERED NUCLEI

Mete Atatüre*[1]

[1]University of Cambridge – 19 JJ Thompson Avenue, United Kingdom

Abstract

Quantum nodes comprising multiple qubits coupled to photons can serve a range of quantum information applications including quantum repeaters and photonic cluster-state generation. An optically active solid-state spin qubit serving as broker to exchange information between a photon and several register qubits is one promising implementation. Multiple such spin-photon interfaces have demonstrated functionality including in diamond, silicon carbide and rare-earth doped YVO4 crystal. Many initial implementations involve an electronic spin in dipolar coupling to a small number of proximal nuclear spins, where their distance controls their coupling rate. III-V compound semiconductor quantum dots have superior optical properties including brightness, purity and coherence, and have efficient coupling to information-carrying single photons. However, they lack additional spins to act as register qubits for the electron spin qubit.
Quantum dots offer an opportunity for a contrasting perspective to the few proximal spin implementation, namely the nuclear spin ensemble comprising the quantum dot itself (1). The resident electron spin qubit is Fermi-contact linked to a group of roughly 100,000 nuclei, which, if not managed, serves as a source of noise detrimental to the qubit's performance. However, if these nuclei are sufficiently manipulated, they can potentially serve as an information reservoir by leveraging their collective behavior (2). This concept bears similarities to spin-wave-based photonic memories in solid states or ferromagnetic magnon modes. Advances in controlling dense nuclear spin ensembles relied on dynamic nuclear polarization and reducing their magnetic-field fluctuations (3), as well as the critical step of accessing electron-mediated collective nuclear excitations (4). The final goal is to combine a controllable electron spin with a tailored nuclear ensemble to realise a nuclear quantum register.

In this talk we will discuss the reversible quantum state transfer between an electron spin qubit and a collective excitation of 13,000 nuclear spins in a GaAs QD (5). We present a method to construct a collective nuclear state by polarizing Ga isotopes. Consequently, one of the Ga isotopes is set in our register's ground state, forming a coherent nuclear dark state with 60% polarization. Our electro-nuclear coherent control facilitate arbitrary state transfers from the electron spin qubit to the single magnon spin-wave states. We show that the register reaches a storage time of 130(16) μs, aligned with limitations from residual quadrupolar broadening.

References

(1) B. Urbaszek, et al., Rev. Mod. Phys. 85, 79. 2013

*Speaker

(2) J. M. Taylor, C. M. Marcus, and M. D. Lukin. Phys. Rev. Lett. 90, 206803. 2003

(3) A. Högele, et al., Phys. Rev. Lett. 108, 197403. 2012

(4) D. A. Gangloff, et al., Science 364, 62. 2019

(5) M. Hayhurst Appel, et al., Nat. Phys. 2024

Collective excitations in 2D and 1D molecular lattices

Stephanie Reich*[1], Sabrina Juergensen[1], José Arcos[1], and Eduardo Barros[2]

[1]Fachbereich Physik [Freie Univeristät Berlin] — Department of Physics [Freie Univeristät Berlin] – Arnimallee 14 14195 Berlin, Germany

[2]Universidade Federal de Ceará (UFC) – Brazil

Abstract

Molecules can interact through the Coulomb coupling of their transition dipole moments. This interaction gives rise to J and H aggregates for molecules in solution shifting their transition energies and giving rise to superradiance. In this talk we discuss the excited states in ordered one- and two-dimensional lattices. The Coulomb interaction leads to the formation of collective lattice states that differ remarkably from the excitations of their corresponding monomers. We show how to experimentally realize such systems through gas phase growth of molecular monolayers on two-dimensional materials such as hBN, graphene, and transition metal dichalcogenides or the filling of nanotubes with molecules leading to the formation of one-dimensional molecular chains. We discuss various building blocks for molecular lattices and their characteristics in terms of the energies and polarization characteristics of the collective states.

*Speaker

Oral

COLLECTIVE LIGHT-MATTER INTERACTIONS IN ATOMIC ENSEMBLES

I. Ferrier-Barbut[1]

[1] Laboratoire Charles Fabry, Institut d'Optique Graduate School, CNRS, Université Paris Saclay

The understanding of the cooperative emission of light by an ensemble of atoms in free space has beed an outstanding problem of atomic physics for decades. This driven-dissipative many-body system poses an outstanding challenge to theory and requires dedicated experiments. I will present experimental results from our group where we study the cooperative interaction of ensembles of cold atoms in free space with resonant radiation. First, by measuring the photons radiated by an atomic cloud that is resonantly driven by a laser, one can retrieve the existence of high-order correlations in the steady-state, due to light-induced resonant dipole-dipole interactions. Second, by using the tools of single-atom manipulation and readout, one can measure the effect of cooperative scattering by an ordered array, now at the single atom level to unravel the microscopic mechanisms behind collective effects.

corresponding author : email@mail.com

Quantum optics with ordered atomic arrays

Johannes Zeiher*[1,2]

[1]Max Planck Institute of Quantum Optics – Germany
[2]Ludwig-Maximilians-Universität München – Germany

Abstract

Ordered arrays of atoms with subwavelength spacing have emerged as a novel platform to realize efficient light-matter interfaces. In such arrays, strong cooperative coupling down to the level of single photons emerges due to the dipolar interactions between the atoms.
In our experiment, we realized an atomically thin mirror by preparing a near-unity-filled Mott insulator in an optical lattice at subwavelength distances. We confirm the cooperative nature of the system by probing the subradiant optical response both in reflection and transmission of a weak laser beam. Employing strong Rydberg interactions, we subsequently controllably switch the optical properties of the array with a locally addressed single ancilla atom. Driving coherent Rabi oscillations on the ancilla, we find evidence that the mirror can be brought in a superposition between transmission and reflection before probing. Our results pave the way towards realizing novel quantum metasurfaces and creating controlled atom-photon entanglement.
In the second part of the talk, I will report on our progress in realizing a novel experimental platform aimed at coupling an atom array to a high-finesse optical resonator, with the goal of performing fast, non-destructive state readout of individual atoms through the cavity. This platform opens new perspectives on remote entanglement generation in optical tweezer arrays, or quantum simulation of open system dynamics.

*Speaker

Oral

HYBRIDIZATION OF DISTANT MOLECULES VIA A COMMON PHOTONIC MODE

J. Nobakht[1,2] , A. Pscherer[1,2], J. Renger[1], S. Götzinger[1,2], and V. Sandoghdar [1,2]

[1]Max Planck Institute for the Science of Light, D-91058, Erlangen, Germany.
[2]Department of Physics, Friedrich-Alexander University, D-91058, Erlangen, Germany.

We have successfully established efficient Tavis-Cummings coupling of several individual organic molecules to each other via their strong coupling to a single mode of a Fabry-Perot microcavity. This achievement is marked by the collective enhancement of the vacuum Rabi splitting, accompanied by the emergence of a distinctive dark middle peak. Our investigation further unveils the formation of subradiant and superradiant states within the dispersive regime of cavity quantum electrodynamics (QED). Additionally, we report the first demonstration of two-photon excitation of two far-field coupled molecules. We discuss the potential of our experimental setting for achieving quantum cooperativitiy among a large number of solid-state emitters.

References

[1] Nobakht, J., Pscherer, A., Renger, J., Götzinger, S., & Sandoghdar, V. (2024). Cavity-mediated hybridization of several molecules in the strong coupling regime. arXiv preprint arXiv:2501.00414.

corresponding author : jahangir.nobakht@mpl.mpg.de

Controlled positioning and integration of coherent single photons emitters in hBN

Aymeric Delteil*[1]

[1]Groupe d'Etude de la Matière Condensée – Université de Versailles Saint-Quentin-en-Yvelines, Centre National de la Recherche Scientifique, Université de Versailles Saint-Quentin-en-Yvelines : UMR8635, Centre National de la Recherche Scientifique : UMR8635 – France

Abstract

Control in position and wavelength of high quality quantum emitters is crucial for implementing a top-down approach in solid-state quantum technologies. In this context, 2D materials bring new opportunities in the field, with specific integration techniques at the ultimate scale of single atomic layers. We recently demonstrated the local generation of quantum emitters ("B centers") with reproducible wavelength and high-quality photophysics in the visible range. The B centers are created by local irradiation in a scanning electron microscope. I will first present their optical properties, including coherence, indistinguishability and quantum efficiency, inferred using quantum optics techniques, such as resonant laser excitation, Hong-Ou-Mandel interference and the Purcell effect. I will also present their controlled integration into monolithic photonic devices. Altogether, the controlled generation of coherent quantum emitters in a 2D material opens appealing perspectives in quantum photonics, with applications in optical quantum technologies.

Keywords: Single photons, color centers, 2D materials, quantum photonics

*Speaker

CONTRIBUTED TALKS

Organized by :

LuMIn Lumière, Matière et Interfaces — CRHEA — Institut d'Optique Graduate School ParisTech — école normale supérieure paris-saclay — cnrs — université PARIS-SACLAY

Oral

DIPOLE DIPOLE INTERACTION IN VARIOUS SYSTEMS

Nikos Fayard [1]

[1] Université Paris-Saclay, CNRS, Ecole Normale Supérieure Paris-Saclay, CentraleSupélec, LuMIn, F-91405 Orsay, France

In this talk, I will discuss theoretically collective effects in the absorption/emission of photons by a collection of atoms or quantum dots. Those effects emerge from dipole-dipole interaction between atoms, and are strongly dependent on both the atomic and the photonic properties [1]. For instance, when the atoms are trapped on top a waveguide in which the photons propagate (Waveguide QED), the dipole-dipole interaction is infinite range [2]. On the opposite, when the atoms and the photons are in free space, the dipole-dipole interaction decays very fast as a function of the distance between the atoms. As a consequence, one has to build subwavelength atomic (or pseudo-atomic) lattices to observe strong collective effects in the free-space configuration [3].

In the first part of the talk, I will present some recent progress made by a French consortium (LKB, LCF, LuMIn, IP, C2N) to conceive and build the new generation of dispersion-engineered waveguides for WQED [4,5]. With those waveguides, we hope to reach experimentally the many-body regime of WQED where interesting phenomena can occur, such as manybody localization [6].

In the second part of the talk, I will discuss the possibility to arrange atoms, or quantum dots in subwavelength lattices. This is a very active topic both theoretically and experimentally , as people are trying to use the optical properties of superradiant and subradiant modes that emerge in thoses lattices [7,8].
To this end, the LuMIn and LPENS labs are starting a new collaboration that intend to assemble chemically perovskites quantum dots in 1D, 2D or 3D extremely subwavelength lattices (distance between QDs of 10-30 nm). This is one order of magnitude less than what can be achieved with atomic lattices. As a consequence, supperadiance can theoretically be extremely strong in those system. Unfortunately, the price to pay when using QDs instead of atoms is heavy: the different QDs can have different transition frequencies, different optical lifetime, and they suffer from pure dephasing.

References

[1] Chang, D. E., et al. *Reviews of Modern Physics* 90.3 (2018): 031002
[2] Sheremet, Alexandra S. *Reviews of Modern Physics* 95.1 (2023): 015002.
[3] Reitz, Michael, Christian Sommer, and Claudiu Genes. *Prx Quantum* 3.1 (2022): 010201.
[4] Fayard, N et al. Optics Express 30 (25), 45093-45109
[5] Bouscal, A et al. New Journal of Physics 26 (2), 023026
[6] Fayard, N et al. Physical Review Research 3 (3), 033233
[7] Rubies-Bigorda, O et al. Physical Review Research 4 (1), 013110
[8] Fayard, N et al. Physical Review A 108 (2), 023116

Figure 1: Left: atoms trapped on top of the comb waveguide [1]. Right: Quantum dots assembled in a 2D lattice.

corresponding author : nikos.fayard@ens-paris-saclay.fr

Protecting collectively-encoded qubits

Antoine Covolo[1], Valentin Magro[1], Mathieu Girard[1], Sébastien Garcia[1], and Alexei Ourjoumtsev*†[1]

[1]Jeunes Équipes de l'Institut de Physique du Collège de France (JEIP) – Collège de France, Paris Sciences et Lettres University, Paris, Centre National de la Recherche Scientifique - CNRS – 11 place Marcelin Berthelot, 75231 Paris Cedex 05, France

Abstract

Collective excitations of atomic or solid-state ensembles present many advantages for encoding qubits. Unfortunately, in presence of inhomogeneities, the qubit decays into a quasi-continuum of dark states. In most cases, this process is non-Markovian, making its description either tedious or inaccurate. We show that it can be mapped to a displacement in time-frequency phase space and accurately included in resource-efficient numerical simulations. This formalism unveils a regime where the decay is efficiently suppressed through a combination of strong driving and non-Markovianity. We experimentally reveal this "driving protection" effect using a Rydberg superatom and extend its coherent dynamics beyond the inhomogeneous-dephasing characteristic time by an order of magnitude.

Keywords: collective excitations, dynamical decoupling, non Markovian process

*Speaker

†Corresponding author: alexei.ourjoumtsev@college-de-france.fr

READOUT OF TRIPLET STATES IN SP3-FUNCTIONALIZED CARBON NANOTUBES BY OPTICALLY-DETECTED MAGNETIC RESONANCE

Alejandro De Sousa[1,2], Simon Settele[3], Timur Biktagirov[4], Uwe Gerstmann[4], Etienne Goovaerts[1], Jana Zaumseil[3], Núria Crivillers[2], and Sofie Cambré*[5]

[1]Theory and Spectroscopy of Molecules and Materials, Physics Department, University of Antwerp (TSM2) – Universiteitsplein 1, 2610 Antwerp, Belgium

[2]Institut de Ciència de Materials de Barcelona (ICMAB-CSIC) – Spain

[3]Institute for Physical Chemistry, Universität Heidelberg – Germany

[4]Lehrstuhlfür Theoretische Material physik, Universität Paderborn – Germany

[5]Theory and Spectroscopy of Molecules and Materials, Physics Department, University of Antwerp (TSM2) – Universiteitsplein 1, 2610 Antwerp, Belgium

Abstract

Molecular spin qubits offer many advantages over other qubit platforms, in particular in view of positionability, tunable energy levels and sufficiently long coherence times.(1) However, single-entity readout of such molecular spin qubits remains an issue. The remedy for this is to project the quantum state on an optical photon, as previously demonstrated for NV centers in diamond, which requires a spin system with S> 1/2.(2) Indeed, triplet sates (S=1) are commonly used to initialize, manipulate and read out electron spin MQBs.
Controlled sp3-functionalization of single-wall carbon nanotubes (SWCNTs) has become a common route to enhance their emission efficiency (3). While a lot of research focused on the effect of the functionalization on the bright singlet excitons, little information is available on how triplet excitons are affected by the creation of these sp3-defects along the CNT wall. Here we investigate such triplet excitons by optically detected magnetic resonance, a technique combining the sensitivity of emission spectroscopy with magnetic resonance transitions between the triplet sublevels in an external applied magnetic field.(2,4) We perform ODMR experiments on a series of samples with different functionalization density and functional groups, and find significant differences in zero-field splitting, ODMR intensity and triplet spin density distribution. Experimental results are corroborated by theoretical DFT calculations. While pristine SWCNTs hold triplet excitons with a purely axial symmetry and a zero-field splitting inversely proportional to the diameter of the SWCNT (4), the spin-density distribution of triplet excitons trapped in sp3-defects changes significantly. Additionally, by changing the functional group on the SWCNTs to a spin-containing group, we demonstrate strong coupling between the triplet state and the functional group, leading to enhanced intersystem crossing and strong exchange coupling between the spin states. These results show first steps towards exploiting sp3-functionalization of CNTs to create optical readout of molecular qubits.

*Speaker

References

(1) A. A. Fursina, A. Sinitskii, Toward Molecular Spin Qubit Devices: integration of magnetic molecules into solid-state devices, ACS Appl. Electr. Mater. **5**, 3531. **2023**

(2) E. Goovaerts, Optically Detected Magnetic Resonance, eMagRes **6**, 343. **2017**

(3) Y. Piao, B. Meany, L. R. Powell, N. Valley, H. Kwon, G. C. Schatz and Y. Wang, Brightening of carbon nanotube luminescence through the incorporation of sp3 defects, Nature Chem **5**, 840. **2013**

(4) I. Sudakov, E. Goovaerts, W. Wenseleers, J.L. Blackburn. J. G. Duque and S. Cambré, Chirality dependence of triplet excitons in (6,5) and (7,5) single-wall carbon nanotubes revealed by optically detected magnetic resonance, ACS Nano 17, 2190. **2023**

Keywords: optcial readout, triplet excitons

Driven, subwavelength arrays of quantum emitters: non-linear weak-drive limit,and correlated subradiant states

Orazio Scarlatella*†[1] and Nigel Cooper[1]

[1]University of Cambridge – United Kingdom

Abstract

Quantum emitters arrays have emerged as interesting light-matter platforms displaying strong and controllable collective effects. In subwavelength regimes, they are characterised by a manifold of subradiant eigenstates, which can host rich quantum many-body physics, and are promising for technological applications. Nevertheless, their subradiant nature prevents their controlled excitation by a weak coherent drive. While this is true at a linear level, and although the weak-drive regime has been often described using linear theories, we point out that this regime is instead strongly non-linear for regular arrays. Using a dynamical mean-field theory (DMFT), we show that by applying a simple, weak coherent drive, a steady-state with a controlled population of subradiant modes can be obtained. This constitutes a novel, driven-dissipative phase of matter, featuring a finite density of interacting subradiant excitations, and displaying strong correlations. This phase can be realized in current experiments, both with atoms and in the solid state, and it might find interesting applications in quantum technologies, owing to its multi-mode squeezing and long-range correlations.

Keywords: subwavelength arrays, driven, dissipative, strongly, correlated

*Speaker

†Corresponding author: os444@cam.ac.uk

Coherent quantum solids of dipolar excitons in sub-wavelength lattices

Camille Lagoin*[1], Corentin Morin[1], and François Dubin[1]

[1]Centre de recherche sur l'hétéroepitaxie et ses applications (CRHEA) – Université Nice Sophia Antipolis (1965 - 2019), Centre National de la Recherche Scientifique, Université Côte d'Azur – Bat. 5 Rue Bernard Grégory 06560 VALBONNE, France

Abstract

The Bose-Hubbard (BH) Hamiltonian constitutes one pillar of condensed-matter theory. It
specifically describes the collective quantum phases accessible to strongly correlated bosons confined in lattice potentials. Here, we present a semiconductor technology to emulate BH models with spatially extended correlations. By relying on semiconductor excitons, i.e. Coulomb-bound electron-hole pairs, extended Bose-Hubbard Hamiltonians are implemented in
sub-wavelength period lattices where interactions are ruled by longitudinal and transverse components of the electromagnetic radiation. These respectively yield dipolar repulsions extending to nearest neighbors, and long-range hoping in the lattice. Harnessing these two channels coherent quantum insulators are prepared dissipatively, with high purity across around
10x10 sites. At unity and half lattice fillings we thus engineer coherent Mott and checkerboard solids respectively.

*Speaker

POSTERS

Organized by :

LuMIn Lumière, Matière et Interfaces — CRHEA — Institut d'Optique Graduate School ParisTech — école normale supérieure paris-saclay — cnrs — université PARIS-SACLAY

Poster

LONG RANGE HOPPING IN A DIPOLAR BOSE HUBBARD SIMULATOR

Corentin Morin[1,2] , Camille Lagoin[1,2] , Kirk Baldwin[3], Loren Pfeiffer[3], and François Dubin[1,2]

[1]Université Côte d'Azur
[2] CNRS CRHEA, Valbonne, France
[3] PRISM, Princeton Institute for the Science and Technology of Materials, Princeton University, Princeton, USA

Indirect excitons in GaAs double quantum wells are excellent candidates to simulate the Bose Hubbard Model. By the mean of a periodic trapping and their permanent dipole, which gives rise to a quasi long range interaction, we were able to characterize quantum solids : Mott insulators and Checker board solids [1].

In the mean time excitons are the optical polarization in semiconductors. In the dipolar blockade regime, where a lattice site cannot be occupied by more than one exciton, an occupied site is equivalent to the excited state of a two level system while an empty site is equivalent to its ground state. A sub-wavelength array of dipolar excitons then allows to explore photon mediated collective effects in lattices. The dissipative part of the photon exchange leads to subradiance while the excitation exchange between sites is associated to a long range hopping [2].

We present here our recent results [3] where we observe a strong increase in the temporal coherence of spatially ordered phases. We also characterize subradiance by a decrease by 50 folds of the emission rate of the radiative recombination and decay dynamics with algebraic components. We believe this is a strong indication of the realization of a spatially ordered and coherent phase of matter : the supersolid.

References

[1] Lagoin, C., Bhattacharya, U., Grass, T., Chhajlany, R. W., Salamon, T., Baldwin, K., ... & Dubin, F. (2022). Extended Bose–Hubbard model with dipolar excitons. *Nature*, *609*(7927), 485-489

[2] Asenjo-Garcia, A., Moreno-Cardoner, M., Albrecht, A., Kimble, H. J., & Chang, D. E. (2017). Exponential improvement in photon storage fidelities using subradiance and "selective radiance" in atomic arrays. *Physical Review X*, *7*(3), 031024.

[3] Lagoin, C., Morin, C., Baldwin, K., Pfeiffer, L., & Dubin, F. (2024). Evidence for a Lattice Supersolid of Subradiant Dipolar Excitons. *arXiv preprint arXiv:2410.17162*.

Figure 1: Conference logo.

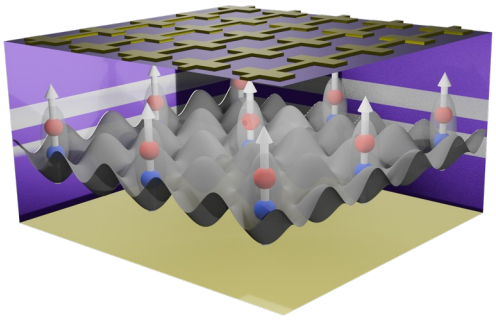


Figure 2: Artistic view of a Checker Board quantum solid of dipolar excitons in samples similar to the ones used in [1,3]

corresponding author : corentin.morin@crhea.cnrs.fr

LIGHT-MATTER INTERACTIONS ANDCOLLECTIVE EFFECTS
28-30 april 2025 Paris, France

Poster

NON-EUCLIDEAN MICROLASERS: THE PSEUDOSPHERE

H. Girin[1], C. Lafargue[2], D. Decanini[1], X. Checoury[1], and M. Lebental[1]

[1]Centre de Nanosciences et de Nanotechnologies, CNRS, Université Paris-Saclay, 10 Boulevard Thomas Gobert, Palaiseau, 91120, France.
[2]Laboratoire Lumière, Matière et Interfaces (LuMIn), CNRS, ENS Paris-Saclay, Université Paris-Saclay, CentraleSupélec, 91190 Gif-sur-Yvette, France.

Recently it became possible to fabricate three-dimensional (3D) microlasers with high optical quality by direct laser writing, in particular surface-like microlasers. First, the Möbius strip microlasers have been investigated. Mélanie Lebental's group demonstrated experiments and FDTD simulations that the modes were located on periodic geodesics [1]. In this poster, another surface-like microlaser is being investigated: the tractoid microlaser. It is a constant negative Gaussian curvature microlaser with a symmetry a revolution. Due to this symmetry, the tractoid microlaser is expected to have a behavior similar to the 2D disk microlaser in spite of its negative curvature. Thus, this poster provides experimental and numerical evidence of high Q whispering gallery modes (WGMs) in the tractoid microlaser. Similarities between the disk and the tractoid are also highlighted: marginally stable periodic geodesics, integrability, TE/TM classes of polarizations...

References

[1] Y. Song, Y. Monceaux, S. Bittner, K. Chao, H. M. Reynoso de la Cruz, C. Lafargue, D. Decanini, B. Dietz, J. Zyss, A. Grigis, X. Checoury, and M. Lebental, Möbius Strip Microlasers: A Testbed for Non-Euclidean Photonics, Phys. Rev. Lett., **127**, 203901 (2021).

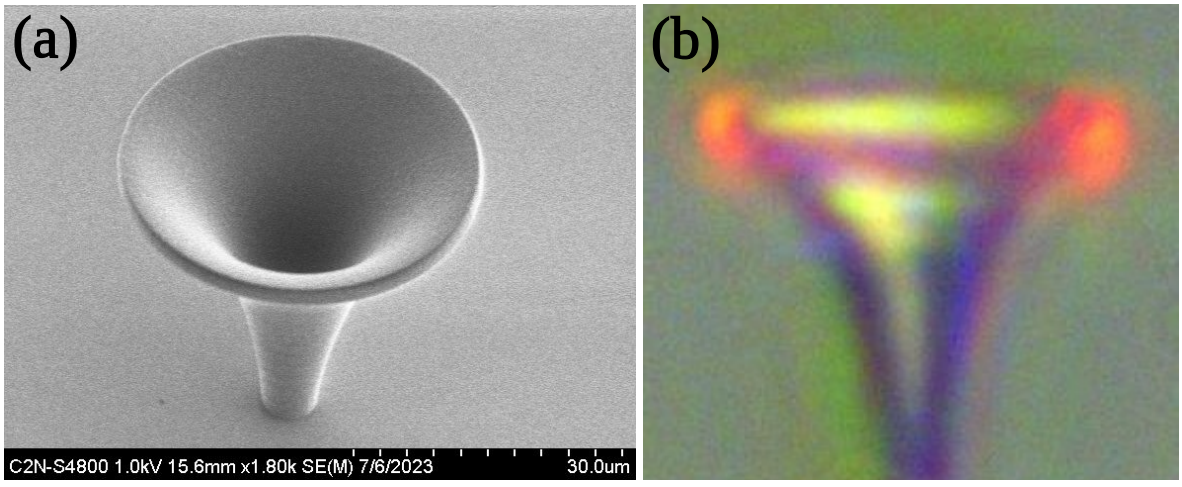


Figure 1: (a) Scanning Electron Microscope image of a tractoid microlaser. (b) Photographs of a tractoid microlaser illuminated with a low intensity white light, and under pumping. The green pump light is removed by a notch filter, while the laser emission is orange.

corresponding author : hugo.girin@cnrs.fr

Poster

Deterministic positioning and energy tunning of QEs in TMDs

A. Lamrani Alaoui[1], M. Strivastava[1], À. Moreno Abajo[2], M. Heithoff[2], V. Brandlì[1], M. Gromovyi[1], A. Courville[1], S. Vézian[1], B. Damilano[1], P. Boucaud[1], F. Koppens[2], and A. Reserbat-Plantey[1]

[1]Université Côte d'Azur, CNRS, CRHEA. Valbonne, Sophia-Antipolis, France
[2]ICFO-Institute of Photonic Science . Castelldefels,Barcelona, Spain

Control of single photon emitters in terms of energy, decay channels, and spatial position is crucial for integrated quantum nanophotonic targeting applications toward quantum communication and quantum computing. 2D semiconducting crystals (e.g. TMD) enable to deterministically create such quantum emitters using various approaches based on strain [1,2,3], defect [3], or electrostatic [4] engineering of the exciton trapping potential. Here, we have deterministically created localized excitonic states by depositing monolayer MoSe2 on nano-pillars to generate local strain. Such strain is extracted through a detailed analysis of a high-resolution AFM micrograph as in the beam limit, the second derivative of the height is proportional to the strain tensor. By correlating the strain cartography with hyperspectral photoluminescence maps measured at 3K using a confocal scanning microscope, we can demonstrate how narrow emission lines (<1meV) are linked to quantum emitters formed in strained regions in MoSe2. With super-localization techniques [5,6], we are able to determine the position of these emitters with a resolution of 100 nm and conclude that they originate predominantly from the apex of each nano-pillar.
In addition, we will present preliminary results on individual Stark tuning of such self-assembled quantum emitters.

References

[1] Palacios-Berraquero, C., Large-scale quantum-emitter arrays in atomically thin semiconductors. NatureCommunications (2017).
[2] B. D. Gerardot, Strain-Induced Spatial and Spectral Isolation of Quantum Emitters in Mono- and Bilayer WSe2. ACS publications (2015).
[3] Moody, G., Defect and strain engineering of monolayer WSe2 enables site-controlled single-photon emission up to 150 K Nature Communications, (2021)
[4] Imamoglu, A., Electrically tunable quantum confinement of neutral excitons, Nature (2022).
[5] C. Voisin, Superlocalization of Excitons in Carbon Nanotubes at Cryogenic Temperature, ACS publications (2019)
[6] B.D. Gerardot, Deterministic strain-induced arrays of quantum emitters in a two-dimensional semiconductor. Nature Communications (2017)

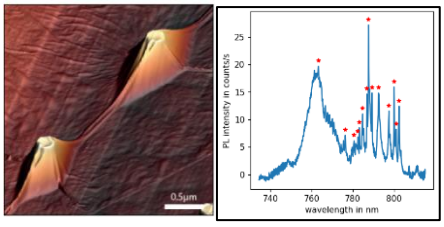


Figure 1: right panel: AFM micrograph of MoSe2 ML transferred on top of GaN pillars. left panel: PL spectrum acquired at 3K showing narrow line features.

corresponding author : Abderrahim.lamrani.alaoui@crhea.cnrs.fr/ Antoine.reserbat.plantey@crhea.cnrs.fr

Poster

MICMAC : MICROSCOPE FOR CONFOCAL IMAGING, MANIPULATION AND CHARACTERIZATION OF 2D MATERIALS.

Maxime Barreau[1]*, Vanessa Yahiaoui[1], Amandine Andrieux[2], Baptiste Fix[2], Benjamin Vest[1]
1. Université Paris-Saclay, IOGS, CNRS, Laboratoire Charles Fabry, 91127, Palaiseau, France.
2. ONERA—The French Aerospace Lab, Chemin de la Hunière, 91761 Palaiseau Cedex, France.
* maxime.barreau@universite-paris-saclay.fr

Hexagonal Boron Nitride (h-BN) is a 2D material that hosts color centers emitting single photons in the visible range. h-BN has the property of displaying remarkable brightness and great photophysical properties at ambient temperature making it a good candidate for single photon emission at these temperatures [1].

The motivation behind the project is to exploit the 2D nature of hBN to address significant challenges faced by other well-known solid state single photon emitters. For instance, NV centers of diamond are hosted in a high refractive index crystalline lattice, making extraction and collection of the photons challenging. This introduces a loss mechanism significantly degrading the sub-poissonian behavior of the source.

The 2D nature of hBN enables us to envision strategies to achieve coupling between color centers and nanostructures : a single emitter can be hosted in a monolayer, therefore being directly extracted from the host material. Also, hBN flakes and layers can be manipulated and assembled with other nanoobjects in order to address their properties. In particular, we explore designs of nanostructures to modify the angular distribution of emission, and enable the collection of the total flux emitted by the color center [2]. Another degree of freedom is the possibility to control electrically the nanostructure [3] in order to shift the emitting frequency and reduce its width so that indistinguishability is improved at low temperatures. The longer-term goal of the project is to demonstrate controlled positioning of emitters around nanostructures with advanced functionalities.

The first step we achieved was to build a confocal microscope to characterize the colored centers from hBN and measure the single photon purity by performing intensity correlation measurements. The fluorescence mapping of samples obtained is shown in Figure 1.

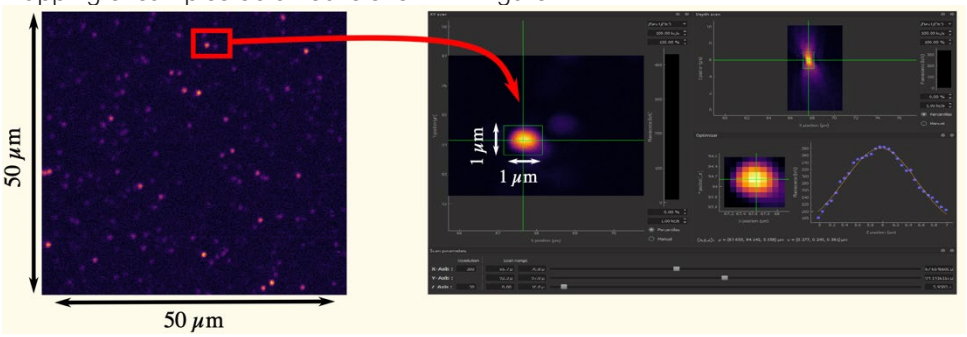


Figure 1: Fluorescence Map of NV Centers obtained thanks to the Confocal Microscopy Setup.

After designing the nanostructures through numerical simulations, we will proceed to the fabrication of the structure by first exfoliating the hBN samples, then generating defects using a SNOM and performing annealing at high temperature. A stamping method coupled to a transfer station will allow us to manipulate the activated flakes to insert them into the designed nanostructure or close to an antenna. Hence, the setup will be later upgraded to integrate these new functionalities such as manipulating and transferring 2D samples to characterize the properties of the centers more quickly.

[1] Tran, T. T., et al. (2016). Quantum emission from hexagonal boron nitride monolayers. Nature Nanotechnology, 11(1), 37-41.
[2] Mashnoon Alam Sakib et al. “Purcell-Induced Bright Single Photon Emitters in Hexagonal Boron Nitride”. In : Nano Letters 24.40 (2024), p. 12390-12397.
[3] Akbari et al.(2022), «Lifetime-Limited and Tunable Quantum Light Emission in h-BN via Electric Field

Building a neutral atoms platform for the study of collective light-matter interactions

S. Pancaldi[1], ***A. Gavalda***[1,2], ***G. Tremblier***[1], ***I. Ferrier-Barbut***[1], ***A. Browaeys***[1]

[1] *Laboratoires Charles Fabry, Institut d'Optique, Université Paris Saclay, France*
[2] *PASQAL, France*

Our set-up consisting of a cloud of laser-cooled rubidium atoms trapped in optical tweezers has allowed us to explore collective light-matter interaction phenomena predicted by Dicke [1] such as *subradiance* and *superradiance*, [2]. The key characteristic of this set-up is the capability of trapping thousands of atoms in the same optical tweezers, whose radial dimension is smaller than the excitation wavelength of rubidium. More recently, we investigated how these spontaneous atomic correlations affect the statistics of the light emitted by the cloud [3]. In particular, it was shown that this light can feature non-Gaussian correlations.
We are currently in the process of finalizing the construction of a newer version of our set-up, including a glass cell to provide more optical access to the atomic medium and flexibility to change trapping and detection paths. We hope this updated version will also be able to scale up the number of atoms we can trap, allowing us to explore denser regimes.
In the near future we aim to deepen the study of the light emitted by our cloud of atoms when excited by a classical field, write spin wave on our system [ref chinese + darrick], and also send resonant squeezed light on the system.

[1] R. H. Dicke, *Coherence in spontaneous radiation processes* Phys. Rev. **93.1** (1954) : 99.

[2] A. Glicenstein, G. Ferioli, A. Browaeys, and I. Ferrier-Barbut *From superradiance to subradiance: exploring the many-body Dicke ladder*, Optics Letters **47**, 1542 (2022).

[3] G. Ferioli, S. Pancaldi, A. Glicenstein, D. Clement, A. Browaeys, I. Ferrier-Barbut *Non-Gaussian correlations in the steady-state of driven-dissipative clouds of two-level atoms*, Phys. Rev. Lett. **132**, 133601 (2024)

LIGHT-MATTER INTERACTIONS AND COLLECTIVE EFFECTS
28-30 april 2025 Paris, France

Poster

GRAPHENE QUANTUM DOTS AS PROMISING BRICKS TO TAILOR SUPER(SUB)-RADIANCE IN COUPLED QUANTUM EMITTERS

S. Quistrebert[1], T. Huyng Thanh[1], S. Sarkar[1], H. Levy-Falk[1], S. Campidelli[2], F. Bretenaker[1], N. Fayard[1], J.-S. Lauret[1]

[1]LuMin, Université Paris-Saclay, ENS Paris-Saclay, CNRS, CentraleSupélec, 91400 Orsay, France
[2]NIMBE/LICSEN, Université Paris-Saclay, CEA, CNRS, 91191 Gif-sur-Yvette, France

Solid-state quantum emitters are a promising platform in the search for novel photon sources. In particular, Graphene Quantum Dots (GQDs) have been proven to be efficient single-photon sources with quantum yields close to unity [1]. Their bottom-up chemical synthesis provides excellent control on the size, shape and symmetry of the structure, which enables tailoring the optical properties of the GQDs for different applications [2-5].

We designed a new family of elongated GQDs with linear transition dipoles up to 16 Debye, which may be well suited to achieve super- and sub-radiant emission through dipole-dipole coupling. Super- or sub-radiant entangled states only appear when the coupling energy is greater than the detuning between emitters, which is typically on the order of a few 100s of GHz in similar emitters [6]. In the literature, control of the entanglement degree of pairs of molecules coupled by dipole-dipole interaction at low temperature has been demonstrated by actively tuning the emitters through Stark effect [7] or laser-induced tuning [8]. Here, we present some simulations showing how these new GQDs' large transition dipole help reduce the constrain on the detuning between emitters.

Coupled solid-state emitters face an additionnal challenge posed by dephasing effects. While these effects can be managed by working at low temperature (few K), this significantly increases the complexity of experiments, making them harder to scale. A more quantitative understanding of the influence of dephasing on experimental observables could help find a threshold on the acceptable amount of dephasing. For that purpose, we present simulations and analytical results on the impact of dephasing on excitation spectra and time-resolved fluorescence spectra of coupled pairs of quantum emitters.

References

[1] S. Zhao, J. Lavie, L. Rondin, L. Orcin-Chaix, C. Diederichs, P. Roussignol, Y. Chassagneux, C. Voisin, K. Müllen, A. Narita, S. Campidelli, J.-S. Lauret, "Single photon emission from graphene quantum dots at room temperature", Nat. Commun. **9**, 3470 (**2018**)
[2] M. G. Debije, "The Optical and Charge Transport Properties of Discotic Materials with Large Aromatic Hydrocarbon Cores", J. Am. Chem. Soc. **126**, 4641 (**2004**)
[3] X. Yan, X. Cui, and L.-S Li, "Synthesis of Large, Stable Colloidal Graphene Quantum Dots with Tunable Size", J. Am. Chem. Soc. **132**, 5944 (**2010**)
[4] A. Konishi et *al.,* "Synthesis and Characterization of Teranthene: A Singlet Biradical Polycyclic Aromatic Hydrocarbon Having Kekulé Structures", J. Am. Chem. Soc. **132**, 11021 (**2010**)
[5] D. Medina-Lopez, T. Liu, S. Osella, H. Levy-Falk, N. Rolland, C. Elias, G. Huber, P. Ticku, L. Rondin, B. Jousselme, D. Beljonne, J.-S. Lauret, S. Campidelli, "Interplay of structure and photophysics of individualized rod-shaped graphene quantum dots with up to 132 sp2 carbon atoms", Nat. Commun. **14**, 4728 (**2023**).
[6] C. Toninelli, I. Gerhardt, A.S. Clark et *al., '*Single organic molecules for photonic quantum technologies", Nat. Mater. **20**, 1615-1628 (**2021**)
[7] J.-B. Trebbia et *al.*, "Tailoring the superradiant and subradiant nature of two coherently coupled quantum emitters", Nat. Commun. **13**, 2962 (**2022**)

corresponding author : lauret@ens-paris-saclay.fr

Poster

[8] Lange et *al.*, "Superradiant and subradiant states in lifetime-limited organic molecules through laser-induced tuning", Nature Phys. **20**, 836-842 (**2024**)

corresponding author : lauret@ens-paris-saclay.fr

LIGHT-MATTER INTERACTIONS ANDCOLLECTIVE EFFECTS
28-30 april 2025 Paris, France

Poster

NANSOCALE ENGINEERING OF DIELECTRIC ENVIRONMENT: TOWARDS ARRAYS OF QUANTUM EMITTERS IN $MOSE_2$

M. Srivastava [1], A. Lamrani Alaoui [1], M. Gromovyi [1], B. Damilano [1], S. Chenot [1], V. Brändli [1], S. Vezian [1], P. Boucaud [1], Y. Chassagneux [2], C. Voisin [2], A. Reserbat-Plantey [1]

[1] Université Côte d'Azur, CNRS, CRHEA, 06560 Valbonne, France
[2] Laboratoire de Physique de l'Ecole Normale Supérieure (LPENS), Paris

Engineering the exciton potential landscape in 2D materials is crucial for advancing optoelectronics and nanophotonics[1]. In particular, the ability to confine excitons is key to generating quantum emitters. Various strategies have emerged to achieve this, including defect implantation[2,3], strain engineering[4,5], moiré trapping[6], and electrostatically controlled confinement potentials[7,8]. Precise control over the emitter positions is especially important for realizing ordered arrays, enabling the study of collective phenomena and the development of quantum photonic integrated circuits (PICs) based on 2D materials. Despite relatively high yields in these approaches, accurate spatial localization remains a major challenge. Defect-based methods rely on stochastic implantation, while strain and electrostatic techniques—although effective for creating self-assembled emitters—face intrinsic limitations in emitter density, as large strain gradients or doping profiles are difficult to implement at the nanoscale.

In this work, we present an alternative strategy based on tailoring the dielectric environment of excitons in $MoSe_2$. By nano-structuring surrounding materials such as GaN or TiO_2, we can modulate the excitonic potential landscape with spatial resolutions on the order of tens of nanometers. Building on recent studies[9] of how the high- and low-frequency dielectric constants influence exciton energies, we estimate the resulting confinement potentials and calculate the corresponding eigenstates as a function of nanostructure geometry. To complement this platform, we also demonstrate super-localization techniques[10] with spatial resolution below 100 nm, which provides a powerful tool to characterize and analyze arrays of quantum emitters.

References:

1. Reserbat-Plantey, A. *et al.* Quantum Nanophotonics in Two-Dimensional Materials. *ACS Photonics* **8**, 85–101 (2021).
2. Fournier, C. *et al.* Position-controlled quantum emitters with reproducible emission wavelength in hexagonal boron nitride. *Nat Commun* **12**, 3779 (2021).
3. Klein, J. *et al.* Site-selectively generated photon emitters in monolayer MoS_2 via local helium ion irradiation. *Nat Commun* **10**, 2755 (2019).
4. Palacios-Berraquero, C. *et al.* Large-scale quantum-emitter arrays in atomically thin semiconductors. *Nat Commun* **8**, 15093 (2017).
5. Branny, A., Kumar, S., Proux, R. & Gerardot, B. D. Deterministic strain-induced arrays of quantum emitters in a two-dimensional semiconductor. *Nat Commun* **8**, 15053 (2017).
6. Baek, H. *et al.* Highly energy-tunable quantum light from moiré-trapped excitons. *Sci. Adv.* **6**, eaba8526 (2020).
7. Thureja, D. *et al.* Electrically tunable quantum confinement of neutral excitons. *Nature* **606**, 298–304 (2022).
8. Heithoff, M. *et al.* Valley-Hybridized Gate-Tunable 1D Exciton Confinement in MoSe2. *ACS Nano* **18**, 30283–30292 (2024).
9. Van Tuan, D. & Dery, H. Effects of dynamical dielectric screening on the excitonic spectrum of monolayer semiconductors. *Phys. Rev. B* **110**, 125301 (2024).
10. Raynaud, C. *et al.* Superlocalization of Excitons in Carbon Nanotubes at Cryogenic Temperature. *Nano Lett.* **19**, 7210–7216 (2019).

corresponding author : mrs@crhea.cnrs.fr

LIGHT-MATTER INTERACTIONS ANDCOLLECTIVE EFFECTS
28-30 april 2025 Paris, France

Poster

METROLOGY OF MICROWAVE FIELDS WITH COLD RYDBERG ATOMS

R. Granier[1], A. El Bekai [1], R. Duverger [1] Q. Marolleau [1], A. Bonnin [1] C. Blanchard [1], N. Zahzam [1]
Y. Bidel [1], M. Cadoret [1] A. Bresson [1] and S. Schwartz [1]
[1]DPHY, ONERA, Université Paris Saclay, F-91123 Palaiseau, France

Rydberg atoms are highly promising for microwave electric field sensing owing to their large dipole matrix elements. While most experimental developments have focused on room-temperature vapors so far, utilizing cold atoms in this context could open new possibilities for applications where accuracy, long term stability and high-resolution at large integration times are required, such as calibrating blackbody shifts in state-of-the-art optical clocks or measuring the cosmic MW background.

Here, we report a novel approach [1] for the metrology of microwave fields with cold 87 Rubidium Rydberg atoms based on trap-loss-spectroscopy in a magneto-optical trap (MOT). This technique stands out for its simplicity, relying solely on fluorescence measurements. By using a two-photon transition highly-detuned from the intermediate state, we realize a situation where the frequencies of the spectral lines are well-described by a coupled two-level system (quasi-ideal Autler-Townes configuration), which is particularly favorable for the linearity of the sensor in the resonant case. With a scale factor linearity of a few percent and a long-term frequency stability equivalent to a resolution of $5\ \mu V/cm$ at $2500\ s$ and no noticeable drift over this time period, this new measurement technique appears to be particularly well-suited for metrology experiments. This method will allow in principle to reconstruct the amplitude and the frequency of the microwave field simultaneously without the need for an external reference field. A mid-term perspective of this project is the implementation of an experimental setup for trapping and manipulating cold atoms in optical tweezers. Then, we will be able to characterize the properties of the resulting sensor in different operating regimes: single atoms vs atom ensembles, utilizing trap position control for spatial or frequency resolution, leveraging atom-atom interactions to generate and investigate metrologically useful quantum states.

References

[1] Romain Duverger, Alexis Bonnin, Romain Granier, Quentin Marolleau, Cédric Blanchard, Nassim Zahzam, Yannick Bidel, Malo Cadoret, Alexandre Bresson, and Sylvain Schwartz. Metrology of microwave fields based on trap-loss spectroscopy with cold rydberg atoms. Phys. Rev. Appl., 22:044039, Oct 2024.

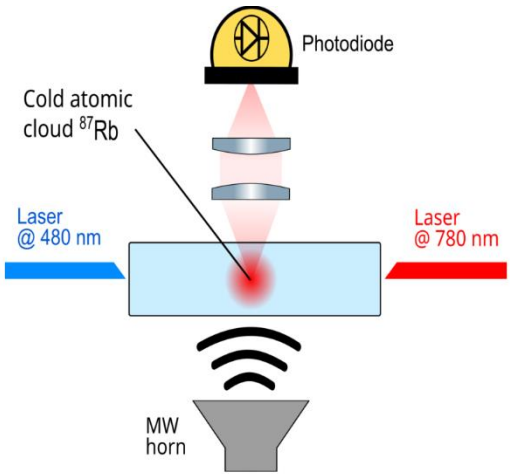


Figure 1: Schematic view of the experimental setup.

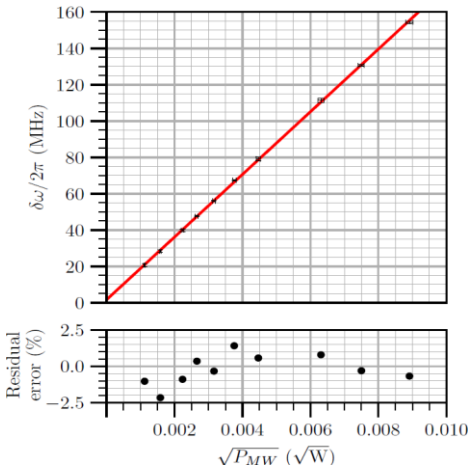


Figure 2: Measured Autler-Townes splitting as a function of the square root of the MW power at 15.973 GHz

corresponding author : romain.granier@onera.fr, anthony.el_bekai@onera.fr

QUANTUM ELECTRODYNAMICS OF GRAPHENE LANDAU LEVELS IN A DEEP SUB-WAVELENGTH HYPERBOLIC PHONON POLARITON CAVITY

Gian Marcello Andolina*[1], Matteo Ceccanti[2], Bianca Turini[2], Riccardo Riolo[3], Marco Polini[3], Marco Schiro[1], and Frank Koppens[2]

[1]Collège de France – Collège de France, EHESS, CNRS – France
[2]ICFO – Spain
[3]UNIPI – Italy

Abstract

The confinement of electromagnetic radiation within extremely small volumes offers an effective means to significantly enhance light-matter interactions, to the extent that zero-point quantum vacuum fluctuations can influence and control the properties of materials. Here, we develop a theoretical framework for the quantum electrodynamics of graphene Landau levels embedded in a deep sub-wavelength hyperbolic cavity, where light is confined into ultrasmall mode volumes. By studying the spectrum, we discuss the emergence of polaritons, and disentangle the contributions of resonant quantum vacuum effects from those of purely electrostatic interactions. Finally, we study the hybridization between magnetoplasmons and the cavity modes.

*Speaker

Probing the exciton spin-valley depolarization with spin-momentum-valley locked unbound states using tr-ARPES

Mehdi Arfaoui*†[1,2,3], Sihem Jaziri[4], and Robson Ferreira[5]

[1]Université Paris-Saclay, ONERA, CNRS, Laboratoire d´tude des microstructures (LEM) – ONERA, Université Paris-Saclay, Centre National de la Recherche Scientifique – 92322 Châtillon, France
[2]Laboratoire de physique de l'ENS - ENS Paris (LPENS) – Sorbonne Universite, Centre National de la Recherche Scientifique, Université Paris Cité, Département de Physique de l'ENS-PSL – 24, rue Lhomond75005 Paris, France
[3]Laboratoire de Physique de la matière Condensée [Tunis] (LPMC) – Faculté des Sciences de Tunis, 2092 Tunis El Manar, Tunisia
[4]Laboratoire de Physique des Matériaux, Faculté des Sciences de Bizerte – Tunisia
[5]Laboratoire de physique de l'ENS - ENS Paris (LPENS (UMR_8023)) – $-Écolenormalesupérieure-Paris, UniversitéParissciencesetlettres, SorbonneUniversite, CentreNationaldelaRechercheScientifique$: $UMR8023, UniversitédeParis--24, rueLhomond75005Paris, France$

Abstract

Time-resolved angle-resolved photoemission spectroscopy (tr-ARPES) is a powerful technique to access the ultrafast dynamics of intervalley couplings and population exchanges. In monolayer transition metal dichalcogenides, excitons have high binding energy, enabling resonant excitation without generating many free electron-hole pairs. They remain localized in momentum space, allowing clear distinction of valley-specific currents in tr-ARPES signals. In our work, we present a detailed theoretical description of the high-energy states that form the escape continuum for photoejected electrons in a tr-ARPES experiment, paying particular attention to their momentum dispersions, time-reversal symmetries, and spin characteristics. We analyse the robustness of valley-spin polarization against intervalley processes, focusing on Coulomb-exchange-driven coupling. This quantifies the dependence of tr-ARPES measurements on setup parameters like incident angle and light helicity. Our findings have broad implications and are anticipated to be applicable to other two-dimensional structures and intervalley scattering events.

Keywords: tr, ARPES, exciton, 2D, materials

*Speaker
†Corresponding author: mehdi.arfaoui@onera.fr

LIGHT-MATTER INTERACTIONS ANDCOLLECTIVE EFFECTS
28-30 april 2025 Paris, France

Poster

COLLECTIVE LIGHT SCATTERING IN ORDERED 1D CHAINS OF DYSPROSIUM ATOMS

G. Biagioni[1], B. Hofer[1], D. Bloch[1], N. Bonvalet[1], A. Browaeys[1] and I. Ferrier-Barbut[1]

[1] Université Paris-Saclay, Institut d'Optique Graduate School, CNRS, Laboratoire Charles Fabry, 91127, Palaiseau, France

Understanding and controlling the light-matter interaction is crucial for many applications ranging from quantum metrology to quantum computing. While the interaction of light with a single quantum emitter is well understood, an ensemble of many emitters coupled by a resonant probe is a complex open quantum system. Programmable arrays of atoms in optical tweezers are particularly appealing for these kinds of problems, since the geometrical ordering offers the possibility to enhance the collective behavior exploiting the constructive and destructive interference between the emitters.

Here, we present a novel experimental apparatus of single dysprosium atoms trapped in one-dimensional tweezer arrays [1,2]. We employ a magic wavelength for the 626 nm intercombination transition, allowing for high-fidelity imaging. We then build defect-free atomic arrays with variable interparticle distances, reaching spacings of the order of a few transition wavelengths. In this regime, we report recent measurements of collective light scattering, manifesting in frequency shifts of the 626 nm transition [3]. Thanks to the flexibility of the tweezers setup, we measure the shift as a function of the interatomic distance. Relying on the interplay between the narrow intercombination transition and a broader transition at 421 nm, we develop an imaging scheme capable of resolving the internal state of the atoms trap by trap. We measure the propagation of the excitations along the array, highlighting the interference effect between the drive field and the field radiated by the atoms, at the origin of the observed frequency shifts. We also perform measurements in the strong excitation regime with Ramsey spectroscopy, and we observe a dependence on the waiting time between the two Ramsey pulses due to the finite lifetime of the excitations. This measurement allows us to draw a connection between the linear optics regime and the strong excitation limit typical of optical atomic clocks.
Finally, we will discuss the implementation of a narrowline cooling scheme in non-magic trap conditions, with which we reach a 75 % occupation of the motional ground state in the radial direction of the tweezers. The increased control on the motional degree of freedom will find application in future light scattering experiments, in which suppressing the thermal disorder is important so as not to hinder many-body interference effects [4].

References

[1] D. Bloch, B. Hofer, S. R. Cohen, A. Browaeys and I. Ferrier-Barbut, PRL **131**, 203401 (2023).
[2] D. Bloch, B. Hofer, S. R. Cohen, M. Lepers, A. Browaeys and I. Ferrier-Barbut, PRA **110**, 033103 (2024).
[3] B. Hofer, D. Bloch, G. Biagioni, N. Bonvalet, A. Browaeys and I. Ferrier-Barbut, https://arxiv.org/abs/2412.02541 (2024)
[4] R.T. Sutherland and F. Robicheaux, PRA **94**, 013847 (2016)

corresponding author : giulio.biagioni@institutoptique.fr

READOUT OF TRIPLET STATES IN SP3-FUNCTIONALIZED CARBON NANOTUBES BY OPTICALLY-DETECTED MAGNETIC RESONANCE

Alejandro De Sousa[1,2], Simon Settele[3], Timur Biktagirov[4], Uwe Gerstmann[4], Etienne Goovaerts[1], Jana Zaumseil[3], Núria Crivillers[2], and Sofie Cambré*[5]

[1]Theory and Spectroscopy of Molecules and Materials, Physics Department, University of Antwerp (TSM2) – Universiteitsplein 1, 2610 Antwerp, Belgium

[2]Institut de Ciència de Materials de Barcelona (ICMAB-CSIC) – Spain

[3]Institute for Physical Chemistry, Universität Heidelberg – Germany

[4]Lehrstuhlfür Theoretische Material physik, Universität Paderborn – Germany

[5]Theory and Spectroscopy of Molecules and Materials, Physics Department, University of Antwerp (TSM2) – Universiteitsplein 1, 2610 Antwerp, Belgium

Abstract

Molecular spin qubits offer many advantages over other qubit platforms, in particular in view of positionability, tunable energy levels and sufficiently long coherence times.(1) However, single-entity readout of such molecular spin qubits remains an issue. The remedy for this is to project the quantum state on an optical photon, as previously demonstrated for NV centers in diamond, which requires a spin system with S> 1/2.(2) Indeed, triplet sates (S=1) are commonly used to initialize, manipulate and read out electron spin MQBs.
Controlled sp3-functionalization of single-wall carbon nanotubes (SWCNTs) has become a common route to enhance their emission efficiency (3). While a lot of research focused on the effect of the functionalization on the bright singlet excitons, little information is available on how triplet excitons are affected by the creation of these sp3-defects along the CNT wall. Here we investigate such triplet excitons by optically detected magnetic resonance, a technique combining the sensitivity of emission spectroscopy with magnetic resonance transitions between the triplet sublevels in an external applied magnetic field.(2,4) We perform ODMR experiments on a series of samples with different functionalization density and functional groups, and find significant differences in zero-field splitting, ODMR intensity and triplet spin density distribution. Experimental results are corroborated by theoretical DFT calculations. While pristine SWCNTs hold triplet excitons with a purely axial symmetry and a zero-field splitting inversely proportional to the diameter of the SWCNT (4), the spin-density distribution of triplet excitons trapped in sp3-defects changes significantly. Additionally, by changing the functional group on the SWCNTs to a spin-containing group, we demonstrate strong coupling between the triplet state and the functional group, leading to enhanced intersystem crossing and strong exchange coupling between the spin states. These results show first steps towards exploiting sp3-functionalization of CNTs to create optical readout of molecular qubits.

*Speaker

References

(1) A. A. Fursina, A. Sinitskii, Toward Molecular Spin Qubit Devices: integration of magnetic molecules into solid-state devices, ACS Appl. Electr. Mater. **5**, 3531. **2023**

(2) E. Goovaerts, Optically Detected Magnetic Resonance, eMagRes **6**, 343. **2017**

(3) Y. Piao, B. Meany, L. R. Powell, N. Valley, H. Kwon, G. C. Schatz and Y. Wang, Brightening of carbon nanotube luminescence through the incorporation of sp3 defects, Nature Chem **5**, 840. **2013**

(4) I. Sudakov, E. Goovaerts, W. Wenseleers, J.L. Blackburn. J. G. Duque and S. Cambré, Chirality dependence of triplet excitons in (6,5) and (7,5) single-wall carbon nanotubes revealed by optically detected magnetic resonance, ACS Nano 17, 2190. **2023**

Keywords: optcial readout, triplet excitons

SYNTHESIS AND OPTICAL PROPERTIES OF A NEW FAMILY OF GRAPHENE QUANTUM DOTS

Stéphane Campidelli*[1], Cynthia Banga-Kpako[1], Daniel Medina-Lopez[1], Thanh Trung Huynh[2], Suman Sarkar[2], Océane Capelle[2], Mateusz Wlazło[3], Silvio Osella[4], and Jean-sébastien Lauret[2]

[1]Université Paris-Saclay, CEA, CNRS, NIMBE, LICSEN, 91191 Gif-sur-Yvette, France – CEA – France
[2]Laboratoire Lumière, Matière et Interfaces (LuMIn) – ENS Paris-Saclay – France
[3]Faculty of Physics, University of Warsaw (FUW) – Pasteura 5, 02-093 Warsaw, Poland, Poland
[4]Chemical and Biological Systems Simulation Lab, Centre of New Technologies, University of Warsaw – 2c Banacha Street, 02-097, Warszawa, Poland, Poland

Abstract

For the last decade, a great attention has been paid to the size reduction of graphene using conventional "top-down" approaches (lithography and etching, thermal treatments and oxidation of bulk materials) to fabricate graphene quantum dots (GQDs) or graphene nanoribbons (GNRs). However, the "top-down" approaches do not allow a sufficient control of the structure of the material and of the oxidation state of the edges, which drastically affect the properties. In order to truly control, with the required level of precision, the morphology and the composition of the materials and of its edges, the bottom-up approach is the relevant way to proceed.1,2
Here, I'll present the "bottom-up" synthesis of graphene quantum dots and the first investigation of the photoluminescence (PL) properties of at the single molecular-scale. The GQDs exhibited emission of single photons at room temperature with high brightness and purity.3,4 Beyond this first demonstration, our interest deals with the study of the structure-property relationship in GQDs and how the size, the symmetry of the particles will permit to tune the emission properties and finally be able to perform reverse engineering to design GQD with tailor-made properties.5,6

References

(1) A. Narita, X. Y.Wang, X. Feng, K. Müllen, Chem. Soc. Rev. **44**, 6616, **2015**.

(2) Y. Gu, Z. Qiu, K. Müllen, J. Am. Chem. Soc. **144**, 11499, **2022**.

(3) S. Zhao, J. Lavie, L. Rondin, L. Orcin-Chaix, C. Diederichs, P. Roussignol, Y. Chassagneux, C. Voisin, K. Müllen, A. Narita, S. Campidelli, J.-S. Lauret, Nat. Commun. **9**, 3470, **2018**.

(4) T. Liu, C. Tonnelé, S. Zhao, L. Rondin, C. Elias, D. Medina-Lopez, H. Okuno, A. Narita, Y. Chassagneux, C. Voisin, S. Campidelli, D. Beljonne, J.-S. Lauret, Nanoscale, **14**,

*Speaker

3826, **2022**.

(5) D. Medina-Lopez, T. Liu, S. Osella, H. Levy-Falk, N. Rolland, C. Elias, G. Huber, P.; Ticku, L. Rondin, D. Beljonne, J.-S.; Lauret, S. Campidelli, Nat. Commun. **14**, 4728, **2023**.
(6) H. Levy-Falk, O. Capelle, T.; Liu, D. Medina-Lopez, E. Deleporte, S. Campidelli, L. Rondin, J.-S. Lauret, Phys. Status Solidi B, **260**, 2300310, **2023**.

Keywords: Graphene Quantum Dots, Photophysics

Uniting Quantum Processing Nodes of Cavity-coupled Ions with Rare-earth Quantum Repeaters Using Single-photon Pulse Shaping Based on Atomic Frequency Comb

Pierre Cussenot*†[1,2], Bastien Grivet[1], Ben P. Lanyon[3], Tracy E. Northup[3], Hugues De Riedmatten[4,5], Anders S. Sørensen[6], and Nicolas Sangouard[7]

[1]Université Paris–Saclay, CEA, CNRS, Institut de physique théorique – CEA-DRF – France
[2]DGA – Direction générale de l'Armement (DGA) – France
[3]Institut für Experimentalphysik, Universität Innsbruck – Austria
[4]Institució Catalana de Recerca i Estudis Avançats [Barcelona] (ICREA) – Passeig Lluís Companys, 23 08010 Barcelona - Espanya, Spain
[5]Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology (ICFO) – 08860 Castelldefels (Barcelona), Spain
[6]Niels Bohr Institute [Copenhagen] (NBI) – Blegdamsvej 17, DK-2100 Copenhagen, Denmark
[7]Institut de Physique Théorique - UMR CNRS 3681 – Institut de physique theorique, CEA, CNRS, Université Paris-Saclay, CEA Saclay 91191 Gif sur Yvette France – France

Abstract

Connecting quantum processing nodes at a distance is an important challenge in the context of distributed quantum computing. Here (1), we propose an efficient method that enables custom temporal reshaping of single-photon pulses emitted by a cavity-assisted Atomic Frequency Comb (AFC) (2) quantum memory, whilst preserving purity. The shaping technique can be used to interface two physical platforms that otherwise produce photons with a typical temporal mismatch of one or two orders of magnitude (cavity-coupled trapped ions and rare-earth-doped crystals). Once this interfacing challenge is overcome, a new quantum network architecture that we introduce shows how to remotely connect processing nodes (ions) via a quantum repeater backbone (based on crystals).
Our approach to reshaping is to modify the commonly used AFC memory protocol for systems exhibiting inhomogeneous broadening like rare-earth-doped crystals. Using a custom sequential readout technique synchronised with the collective rephasing of the emitters, it is possible in the impedance-matching regime to achieve an arbitrary temporal shaping at the quantum level.

In a feasibility study based on recent experiments, it is shown that the photon waveform from a Pr3+:Y2SiO5 memory (3) can be made almost indistinguishable from a pure component of the photon mixed state emitted by a single 40Ca+ ion embedded in a high finesse cavity (4) (99 % overlap instead of 32 %).

*Speaker
†Corresponding author: pierre.cussenot@ipht.fr

Addressing the general problem of how to interface two physical platforms that interact with light on very different timescales, we thus offer a viable and tangible solution for uniting quantum processing nodes with a quantum repeater backbone.

References

(1) Preprint related to this presentation: https://arxiv.org/abs/2501.18704

(2) Afzelius, M. and Simon, C. Impedance-matched cavity quantum memory. Phys. Rev. **A** 82, 022310 (**2010**).

(3) Duranti, S. et al. Efficient cavity-assisted storage of photonic qubits in a solid-state quantum memory. Opt. Express **32**, 26884 (**2024**).

(4) Krutyanskiy, V. et al. Entanglement of Trapped-Ion Qubits Separated by 230 Meters. Phys. Rev. Lett. 130, 050803 (**2023**).

Rydberg Superatoms Interacting via Cavity Photons

Sébastien Garcia*[1], Antoine Covolo[1], Mathieu Girard[1], Valentin Magro[1], and Alexei Ourjoumtsev[1]

[1]JEIP, UAR 3573 CNRS, Collège de France, PSL University – JEIP, USR 3573 CNRS – France

Abstract

One major road towards the development of efficient photonic quantum technologies would be to rely on unitary deterministic photon-photon interactions. However, optical photons do not interact naturally. One thus has to use light-matter interactions to find ways towards effective photon-photon interactions. In the last decades, two approaches have been developed to achieve strong photon-photon interactions with cold atoms. On one side, experiments featuring a single atom strongly coupled to a cavity have a strong nonlinearity enabling the realization of quantum logic gates between two photons. On another side, experiments mapping photons onto Rydberg excitations in a cold atomic gas can also achieve strong photon-photon interactions. Nevertheless, both approaches are bounded by either technical or physical limits, keeping them far from ideal unitary deterministic photonic interactions.

Our system combines these two approaches to overcome their limitations. We use a small atomic cloud, placed inside a medium-finesse optical cavity and driven to a highly-excited Rydberg state. The number of atoms enhances the coupling between the cloud and the cavity, while Rydberg interactions prevent double excitation within the cloud. Consequently, the atomic assembly acts as a single two-level collective superatom. We coherently control its state and optically detect it in a single shot (1). With this setup, we achieved the first deterministic preparation of non-Gaussian Wigner-negative free-propagating optical quantum states (2).

Building on these achievements, we recently expanded our experimental setup by incorporating an additional atomic cloud within the cavity (see Fig. 1). To illustrate the coupling between the two superatom via the cavity, we introduce one excitation into a superatom and transfer it through a cavity photon into the other one. We detect the population in each atomic cloud by probing the Rydberg blockade, while employing electromagnetically induced transparency in a configuration on the other superatom to render it transparent. We demonstrate the coherence of the process by mapping the transferred excitation in the second superatom to a photon leaving the cavity and by measuring its phase via homodyne detection.

These results pave the way towards efficient implementations of more complex operations, such as entanglement protocols (3), or applications in quantum optics (4)

Keywords: Cold atoms, Rydberg, Cavity QED

*Speaker

FLUIDS OF LIGHT, FROM SUPERFLUIDITY TO SINGLE PHOTON SOURCE

Quentin Glorieux*[1]

[1]Laboratoire Kastler Brossel (LKB) – Université Pierre et Marie Curie (UPMC) - Paris VI, Ecole Normale Supérieure de Paris - ENS Paris, Collège de France, EHESS, CNRS, CNRS : UMR8552 – 4 Place Jussieu, 75231 Paris Cedex 05, France

Abstract

We present recent advances in the study of quantum fluids of light in rubidium vapor. Utilizing a hot atomic vapor platform, we achieve all-optical control of photonic quantum fluids, enabling the modeling of two-dimensional Hamiltonians similar to the Gross-Pitaevskii equation. Thanks to quantum optics techniques, we implement full-field retrieval to measure momentum distributions and hydrodynamical observables, probing the superfluid transition dynamically (1). We also explore quantized vortices and quantum turbulence, extending insights into nonlinear phenomena (2). Moreover, engineering strong photon-photon interactions via giant Kerr non-linearities, we target the observation of quantum phase transitions, specifically from superfluid to Mott insulator states. This research is bringing together the fields of ultracold gases, quantum optics and nanophotonics to invent new optical systems (3). @font-face {font-family:"Cambria Math"; panose-1:2 4 5 3 5 4 6 3 2 4; mso-font-charset:0; mso-generic-font-family:roman; mso-font-pitch:variable; mso-font-signature:-536870145 1107305727 0 0 415 0;}@font-face {font-family:"Liberation Serif"; panose-1:2 11 6 4 2 2 2 2 2 4; mso-font-alt:"Times New Roman"; mso-font-charset:0; mso-generic-font-family:roman; mso-font-pitch:variable; mso-font-signature:-536868097 1342208255 33 0 447 0;}@font-face {font-family:"Noto Sans CJK SC Regular"; panose-1:2 11 6 4 2 2 2 2 2 4; mso-font-charset:0; mso-generic-font-family:auto; mso-font-pitch:variable; mso-font-signature:0 0 0 0 0 0;}@font-face {font-family:FreeSans; panose-1:2 11 5 4 2 2 2 2 2 4; mso-font-alt:Calibri; mso-font-charset:0; mso-generic-font-family:swiss; mso-font-format:other; mso-font-pitch:variable; mso-font-signature:-469627137 1073799551 4128 0 447 0;}@font-face {font-family:Times; panose-1:2 11 6 4 2 2 2 2 2 4; mso-font-alt:"Times New Roman"; mso-font-charset:0; mso-generic-font-family:auto; mso-font-pitch:variable; mso-font-signature:-536870145 1342185562 0 0 415 0;}@font-face {font-family:"Helvetica Neue Light"; panose-1:2 0 4 3 0 0 0 2 0 4; mso-font-alt:"HELVETICA NEUE LIGHT"; mso-font-charset:0; mso-generic-font-family:auto; mso-font-pitch:variable; mso-font-signature:-1610611969 1342185563 2 0 7 0;}p.MsoNormal, li.MsoNormal, div.MsoNormal {mso-style-unhide:no; mso-style-qformat:yes; mso-style-parent:""; margin:0cm; mso-pagination:widow-orphan; font-size:12.0pt; mso-bidi-font-size:10.0pt; font-family:Times; mso-fareast-font-family:Times; mso-bidi-font-family:"Times New Roman"; mso-ansi-language:EN-US; mso-fareast-language:ZH-CN;}.MsoChpDefault {mso-style-type:export-only; mso-default-props:yes; font-size:10.0pt; mso-ansi-font-size:10.0pt; font-family:"Liberation Serif",serif; mso-ascii-font-family:"Liberation Serif"; mso-fareast-font-family:"Noto Sans CJK SC Regular"; mso-hansi-font-family:"Liberation Serif"; mso-bidi-font-family:FreeSans; mso-font-kerning:0pt; mso-ligatures:none; mso-ansi-language:FR; mso-fareast-language:ZH-CN; mso-bidi-language:HI;}div.WordSection1 {page:WordSection1;}

*Speaker

Keywords: superfluidity, quantum optics, fluids of light

Laughlin-like states of few atomic excitations in small subwavelength atom arrays

Blazej Jaworowski*†[1] and Darrick Chang[2]

[1]Institut de Ciencies Fotoniques [Castelldefels] (ICFO) – Parc Mediterrani de la Tecnologi, E-08860 Castelldefels (Barcelona), Spain

[2]Institut de Ciencies Fotoniques (ICFO) – Spain

Abstract

Remarkable collective quantum-optical phenomena were demonstrated in atom arrays within the single-excitation picture. On the other hand, the many-excitation physics of these systems is much less studied. One way to gain insight into such physics is to look for analogies with strongly-correlated systems in condensed matter, for example the fractional quantum Hall effect.

It was shown that, on the single-excitation level, subwavelength honeycomb arrays of three-level atoms have topological band structure. In this work, we demonstrate that finite "flakes" of such an array, even as small as a "nanoring" of six sites, are capable of hosting Laughlin-like states of few excitations. The finite-size effects in these systems smear out the divergence of dispersion relation near the light cone, and the native hard-core interaction creates the Laughlin-like correlations. We propose how to drive the two-excitation Laughlin-like states using uniform light, and show how the their existence shows up in the angular momentum distribution of photons emitted by the system.

Keywords: atom arrays, fractional quantum Hall effect, topological order

*Speaker

†Corresponding author: blazej.jaworowski@icfo.eu

Poster

ENDOHEDRAL FILLING OF NANOTUBES FOR PHOTOCATALYSIS

Y. Midiladji Bakary[1], Laurence Blois[1], C. Marichy[1], F. Toche[1], R. Chiriac[1], F. Vialla[2], D. Bouyssi[3], N. Monteiro[3], A. Amgoune[3], C. Desroches[1], and S. Forel[1]

[1]LMI, Laboratoire des Multimatériaux et Interfaces, UMR 5615, Université Claude Bernard Lyon 1, CNRS
[2]ILM, Institut Lumière Matière UMR 5306, Université Claude Bernard Lyon 1, CNRS
[3]ICBMS, Institut de Chimie et Biochimie Moléculaires et Supramoléculaires UMR 5246, Université Claude Bernard Lyon 1, CNRS

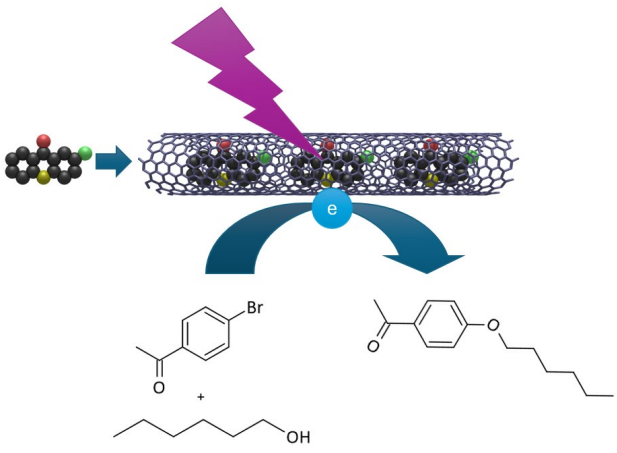
The development of photocatalysts offers a promising approach to driving chemical reactions under milder conditions by using light as an energy source. This strategy has significant potential for advancing green chemistry, providing sustainable alternatives to traditional catalysis, which urgently require improvement. Current research in photocatalysis predominantly focuses on two main material types: transition metal-based catalysts and organic dye photocatalysts. Transition metals, such as platinum and ruthenium, are highly effective under visible or UV light; however, their high costs, limited availability, and the environmental impact of their extraction pose significant barriers to large-scale, sustainable use. Organic dyes, on the other hand, are cost-effective and can operate under low-energy light but suffer from photobleaching, which compromises their stability and long-term functionality.

In this work, we propose a new strategy to fill single-walled carbon nanotubes (SWCNTs) using vapor-phase infiltration to create hybrid structures that combine SWCNTs with photocatalysts. This approach aims to improve the efficiency, stability, and recyclability of the photocatalyst [1]. Indeed, SWCNTs are known for their exceptional charge mobility [2], high chemical stability, and unique nanoscale tubular structure, making them excellent protective layers [3] that can simultaneously enhance photocatalyst properties.

Recently, Andrew and co-authors [4] demonstrated that thioxanthone can participate in dual photoredox/nickel-catalyzed coupling reactions of aryl bromides and alcohols, providing a sustainable alternative to precious metal-based catalysts. As a proof of concept, we successfully encapsulated a derivative of thioxanthone within SWCNTs. The new SWCNT-thioxanthone hybrid materials were successfully used to catalyze the coupling of aryl bromides and alcohols, demonstrating their potential for advancing green and sustainable catalysis.

References

[1] González-Muñoz, D. et al. *ACS Appl Mater Interfaces* 13, 24877–24886 (2021)
[2] Javey, A. et al. *Nature* 424, 654–657 (2003)
[3] Gaufrès, E. et al. *ACS Nano* 10, 10220–10226 (2016)
[4] Andrews, I. C. et al. *ChemPhotoChem* 8, 272 (2024)



corresponding author : salome.forel@univ-lyon1.fr

Poster

Figure 1: illustration of the photocatalysis enabled by a SWCNT-thioxanthone complex

corresponding author : salome.forel@univ-lyon1.fr

WHISPERING GALLERY MODES POLARITONIC LASER RELYING ON SEMICONDUCTOR QUANTUM SHELLS MONO-EXCITONIC GAIN

Charlie Kersuzan[1,2], Sergei Celaj[1], Celine Roux Byl[2], Justine Laurent[3], Willy Daney De Marcillac[4], Thomas Pons[2], and Agnès Maître*†[5]

[1]Institut des Nanosciences de Paris (INSP) – Sorbonne Université UPMC Paris VI – France

[2]Laboratoire de physique et d'étude des matériaux (LPEM) – ESPCI Paris, PSL Research University – France

[3]Gulliver – ESPCI Paris, PSL Research University – France

[4]Institut des NanoSciences de Paris (INSP) – CNRS : UMRSorbonneuniversité, CNRS : UMR7588, CNRS – France

[5]Institut des NanoSciences de Paris (INSP) – Sorbonne Université UPMC Paris VI – France

Abstract

Semiconductor colloidal nanocrystals are very attractive quantum nano-objects for single photons nanosource and optoelectronics, thanks to their brightness, their photostability, their operation at room temperature and their easy processability in solutions (1). We demonstrate here that the coupling of collections of colloidal CdS/CdSe/CdS quantum shells (a spherical core of CdS and two concentric shells of CdSe and CdS, see figure 1) to highly resonant microcavity modes leads to in phase emission of emitters. Thanks to whispering gallery modes, large collection of quantum shells serve as optical gain material for efficient lasing

By photolithography, we fabricate either parabolic micro-cavity (fig1) (2), whose bottom is smaller than the top or circular disks above pillars . Thanks to these geometries, the excited whispering gallery modes do not leak into the substrate, assuring a high confinement of the resonant gallery modes at the circumference of the cavity. We spin coat a high concentrated solution of quantum shells on the sample, serving as the gain material. The quantum shells on the micro-cavity are excited by a 532nm pulsed laser, whose intensity is gradually increased. Over pump intensity threshold, we observe lasing modes at a wavelength equal to 680nm, and whose intensity grows linearly with the pumping laser intensity (fig 1) (3).

On the contrary to former studies for which lasing was associated to biexcitonic gain, we demonstrate here that lasing in such highly resonant cavity is associated to mono excitonic gain, with a lasing line on the red side of the mono-excitonic fluorescence peak. Our model evidences the role of the stoke shift in such monoexcitonic, red shift lasing.

Moreover, quantum shell excitonic emission experiences high confinement within the micro-cavity thanks to its highly resoannt whispering gallery modes. We study the influence of this

*Speaker

†Corresponding author: agnes.maitre@insp.jussieu.fr

confinement to the emission.

References

(1) S. Jana, X. Xu, A. Klymchenko, A. Reisch, T. Pons, *Microcavity-Enhanced Fluorescence Energy Transfer from Quantum Dot Excited Whispering Gallery Modes to Acceptor Dye Nanoparticles*, *ACS Nano* **2021** *15* (1), 1445-1453

(2) C. Kersuzan, S. Celaj, W. Daney de Marcillac, T. Pons, A. Maître, *Photolithographed Whispering Gallery Mode Microdisk Cavities Coupled to Semiconductor Quantum Dots, ACS Photonics* **2024** *11*(4), 1715-1723
(3) C. Kersuzan et al, *Monoexcitonic lasing of semi-conductor nanocrystals in polymeric parabolic microcavities*, submitted

Robustness of super-radiance to decoherence

Laszlo Rassaert*[1] and Tommaso Roscilde[1]

[1]Laboratoire de Physique de l'ENS Lyon (Phys-ENS) – Ecole Normale Supérieure de Lyon, Université de Lyon, Centre National de la Recherche Scientifique – 46 allée d'Italie 69007 Lyon, France

Abstract

Solid-state emitters collectively coupled to light - such as nano-spheres or nano-platelets - are inevitably immersed in a finite-temperature environment, introducing dephasing. This destroys correlations between the dipoles of the emitters, and therefore it is detrimental for collective emission phenomena such as super-radiance (1). This raises the question whether super-radiance can survive the presence of individual dephasing; and whether it can be observed at all in the solid state without engineering the environment of the emitters.
By exploiting the existence of an efficient numerical solution for systems with permutational invariance (2), in this work we study the collective emission property of large ensembles of emitters, both in the case of an excitation pulse, as well as under continuous incoherent pumping. In both situations, we observe that super-radiance survives up to a sizeable critical dephasing rate, comparable with the collective emission rate. The critical dephasing marks a sharp dynamical transition in the pulsed case; and a steady-state dissipative phase transition under continuous pumping. In both cases the critical point is characterized by a well-defined scaling of the emission intensity, respectively I_~N^4/3 and I_~N^3/2, intermediate between the normal one I_~N and the super-radiant one I_~N^2.
References :
(1) Dicke, R.H. (1954) 'Coherence in Spontaneous Radiation Processes', Physical Review, 93(1)
(2) Shammah, N. et al. (2018) 'Open quantum systems with local and collective incoherent processes: Efficient numerical simulations using permutational invariance', PRA, 98(6)

Keywords: Superradiance, Open Systems, Solid, state emitters, Decoherence, Dephasing, Phase transition, Critical exponent

*Speaker

Two-photon correlations and HOM visibility from an imperfect single-photon source

Eva Gonzalez Ruiz*[1,2], Johannes Bjerlin[2], Oliver August Dall'alba Sandberg[2], and Anders S. Sørensen[2]

[1]Institut de Physique Théorique - UMR CNRS 3681 – CEA, CNRS, Université Paris-Saclay, CEA Saclay 91191 Gif sur Yvette France – France

[2]Center for Hybrid Quantum Networks (Hy-Q), Niels Bohr Institute – Denmark

Abstract

We study the two-photon correlations of an emitter based single-photon source in the realistic scenario where the drive field may leak into the detection path. We find that the pulse length of the input field strongly influences the impurity of the single-photon source. In particular, the second-order correlation function $g^{(2)}$ reaches a minimum for a certain pulse length, which represents a compromise between minimizing the re-excitation error of the emitter and minimizing the number of photons from the leaked field. As a consequence, the optimal pulse strongly depends on the amount of laser leakage from the input field. Importantly, the phase of the leaked field matters as there will be interference with the field emitted from the emitter and one cannot simply add the two contributions. Moreover, we show how the leakage fraction is reduced by means of a low-pass filter, which thus strongly reduces $g^{(2)}$. We also study the relation between the second order correlation function and the HOM visibility V. Contrary to the common assumption in the literature of $F = (1 - V)/g^{(2)} = 2$, the factor F can attain values anywhere in the interval between $F=1$ and $F=3$ for a good single photon source ($g^{2}\ll 1$)*depending on the precise nature of the multiphoton component.*

*Speaker

Juggling with stackings and angles in twisted boron nitride bilayers

Lorenzo Sponza*[1], Van Binh Vu[2], Elisa Serrano Richaud[1], Hakim Amara[1,3], and Sylvain Latil[2]

[1]Université Paris-Saclay, ONERA, CNRS, LEM, 92322 Châtillon, France – LEM ONERA-CNRS, LEM, ONERA- CNRS – France

[2]Service de physique de l'état condensé (SPEC - UMR3680) – Institut Rayonnement Matière de Saclay (DRF), Université Paris-Saclay, Centre National de la Recherche Scientifique – SPEC - UMR3680 CEA-CNRS(ex-URA 2464), CEA/Saclay, Orme des Merisiers, F-91191 GIF SUR YVETTE CEDEX, France

[3]Laboratoire Matériaux et Phénomènes Quantiques (MPQ ($UMR_7$162))−−$CentreNationaldelaRechercheScientifique, UniversitéParisCité$−−$UniversitéParisDiderot, Bât.Condorcet$, 10$rueAliceDomonetLeonieDuquet, Case$7021, 75205$Pariscedex$13, $France$

Abstract

When a 2D lattice is rotated on top of another, a periodic moiré pattern arises and low-dispersing states, or flat bands, are formed as a consequence of local stacking modulations. They often endow the system with novel phenomena, the most spectacular of which is the emergence of sperconductivity in twisted bilayer graphene (1). In this context, twisted bilayers of hexagonal boron nitride (hBN) differ from graphene ones because of two characteristics: hBN has a gap, so flat bands are expected to influence optical properties rather than transport ones and it hosts two atomic species, so many more stacking configurations are possible. Indeed, I will demonstrate that five hexagonal stacking sequences are compatible with any given moiré periodicity. I will then focus on their impact on the electronic structure by addressing two twisting limits: the small-angle limit (far from twists of 30∘) (2) and the large-angle limit (approaching 30∘) (3). I will discuss the emergence of intriguing band structure features that may be specific to each stacking (2) or common to all of them (3), and investigate their role on optical properties and their origin.

References

(1) Y. Cao, V. Fatemi, S. Fang, et al., Unconventional superconductivity in magic-angle graphene superlattices. Nature **556**, 43. **2018**

(2) S. Latil, H. Amara, and L. Sponza. Structural classification of boron nitride twisted bilayers and ab-initio investigation of their stacking-dependent electronic structure. SciPost Phys. **14**, 053. **2023**

(3) L. Sponza, B. V. Vu, E. Serrano Richaud, H. Amara, and S. Latil. Emergence of flat bands in the quasicrystal limit of boron nitride twisted bilayers. Phys. Rev. B **109**, L161403. **2024**

*Speaker

Keywords: moiré, boron nitride, simulation, electronic structure, optics, stacking

Polarization texture and sensing application of ferroelectric nanocrystals

Athulya Muraleedharan Bindu[1], Kevin Co[2], Jingye Zou[2], Maxime Vallet[3,4], Abdelali Zaki[3], Christine Bogicevic[3], Fabienne Karolak[3], Charles Paillard[3,5], Karen Perronet[1], Céline Fiorini-Debuisschert[6], and François Treussart*[7]

[1]Laboratoire Lumière, Matière et Interfaces (LuMIn) – Université Paris-Saclay, ENS Paris-Saclay, CNRS, CentraleSupélec – France

[2]Laboratoire Structures, Propriétés et Modélisation des solides (SPMS) – Université Paris-Sud - Université Paris-Saclay, Centrale Supélec, CNRS – France

[3]Laboratoire Structures, Propriétés et Modélisation des solides (SPMS) – Institut de Chimie - CNRS Chimie, CentraleSupélec, Université Paris-Saclay, Centre National de la Recherche Scientifique – CentraleSupélec - Bâtiment Eiffel - 3 rue Joliot-Curie 91190 GIF-SUR-YVETTE, France

[4]Laboratoire de Mécanique Paris-Saclay (LMPS) – CentraleSupélec, Université Paris-Saclay, Centre National de la Recherche Scientifique, Ecole Normale Supérieure Paris-Saclay, Centre National de la Recherche Scientifique : UMR9026 – 4 avenue des sciences / 8-10 rue Joliot Curie, 91190 Gif-sur-Yvette, France

[5]University of Arkansas [Fayetteville] – 1 University of Arkansas, Fayetteville, AR 72701, United States

[6]Service de physique de l'état condensé (SPEC - UMR3680) – Institut Rayonnement Matière de Saclay (DRF), Université Paris-Saclay, Centre National de la Recherche Scientifique – SPEC - UMR3680 CEA-CNRS(ex-URA 2464), CEA/Saclay, Orme des Merisiers, F-91191 GIF SUR YVETTE CEDEX, France

[7]Laboratoire Lumière, Matière et Interfaces – Université Paris-Saclay, ENS Paris-Saclay, CNRS, CentraleSupélec – France

Abstract

Ferroelectric materials offer unique polarization textures at the nanoscale, with potential applications in improving energy efficiency and enabling advanced sensing technologies. In this work, we explore the polarization properties and electric field sensing capabilities of barium titanate (BaTiO) nanocrystals (NCs), emphasizing their intrinsic ferroelectric properties and functional potential.
First, we investigated the polarization textures of BaTiO NCs using piezoresponse force microscopy (PFM). Experimental results, complemented by theoretical simulations, revealed a core structure composed of 180◦ up-and-down domains, surrounded by surface layers exhibiting 90◦ domain rotations (1). These findings establish PFM as a valuable tool to assess the potential of ferroelectric nanostructures in advanced sensors.

Building on this, we developed a nanosensor for detecting electric fields with submillisecond response times. Using rare-earth-doped BaTiO NCs capable of upconversion (UC) luminescence, we demonstrated optical detection of rapid changes in electric potential. Surface

*Speaker

charge variations induced by external fields alter the polarization via the converse piezoelectric effect, modulating the UC spectrum. These NCs exhibit a response time of 100 μs and a sensitivity of 4.8 kV/cm/$\sqrt{}$Hz, enabling detection of fields comparable to the one of neuronal action potentials (2).

Together, these studies highlight the dual promise of BaTiO NCs: understanding fundamental polarization phenomena and advancing nanoscale electric field sensing for applications in neuroscience and beyond.

(1) Muraleedharan, A. K., Co, K., Vallet, M., Zaki, A., Karolak, F., Bogicevic, C., Perronet, K., Dkhil, B., Paillard, C., Fiorini-Debuisschert, C. & Treussart, F. Ferroelectric Texture of Individual Barium Titanate Nanocrystals. *ACS Nano* **18,** 18355–18367 (2024).
(2) Muraleedharan, A. K., Zou, J., Vallet, M., Zaki, A., Bogicevic, C., Paillard, C., Perronet, K. & Treussart, F. Submillisecond Electric Field Sensing with an Individual Rare-Earth Doped Ferroelectric Nanocrystal. *ACS Appl. Mater. Interfaces* **16,** 60800–60810 (2024).

Keywords: ferroelectric nanocrystals, polarization texture, rare, earth ions, up, conversion, sensor

LIGHT-MATTER INTERACTIONS ANDCOLLECTIVE EFFECTS
28-30 april 2025 Paris, France

Poster

EXCITED-STATE ABSORPTION ASSISTED BY PHOTONIC CRYSTALS FOR UPCONVERSION AND PHOTON-AVALANCHING IN LANTHANIDES-DOPED THIN FILMS.

D. Rinnert[1,2], E. Drouard[1], A. Pereira[2], C. Chevalier[1], H. S. Nguyen[1], G. Ledoux[2], and C. Seassal[1]

[1]CNRS, INSA Lyon, Ecole Centrale Lyon, Université Claude Bernard Lyon 1, CPE Lyon, INL, UMR 5270, F-69622, Villeurbanne, France
[2]Univ Lyon, Université Claude Bernard Lyon 1, CNRS, Institut Lumière Matière, UMR 5306, F-69622, Villeurbanne, France

The excited-state absorption (ESA) process enables to achieve upconversion and photon-avalanching in lanthanides ions. However, as their absorption cross-sections are low, these phenomenon require high excitation intensities. Here, we present a photonic crystal engineered to enhance the ESA in Yb^{3+},Tm^{3+} co-doped thin films resulting in an increase in upconversion yield. Then, we discuss the possibility to use a similar approach to reduce the photon-avalanching intensity threshold in Tm^{3+} doped thin-films.

It has been shown that multicolor absorption process involving energy transfer upconversion and excited-state absorption reduces the non-linearity of the UV upconversion in Tm^{3+} sensitized by Yb^{3+} [1]. As a result, the upconversion yield for low excitation intensities is enhanced (interesting for solar-based applications). By embedding a doped oxide thin film in an appropriate photonic crystal, we demonstrate an additional enhancement of more than a factor 6 (Fig. 1).

We are also interested in photon-avalanching in lanthanide-doped oxide layers assisted by photonic crystal. Tm^{3+} being well known candidate, which achieves high non-linearity [2]. We are currently investigating the impact of Yb^{3+} as a sensitizer on the photon-avalanching threshold and its non-linear order.

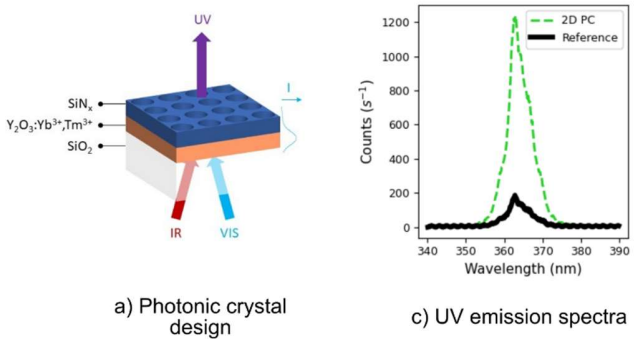


Figure 1 : a – Scheme of a doped oxide thin film embedded in a photonic crystal. b – Photonic crystal UV emission (green dashed line) compared to a flat reference (black continuous line).

References

[1] B. Purohit, ... & G. Ledoux. Multicolor solar absorption as a synergetic UV upconversion enhancement mechanism in LiYF4: Yb3+, Tm3+ nanocrystals. *ACS photonics*, **6**, 3126-3131. **2019**

[2] Y. Liang, ... & Q. Zhan. Migrating photon avalanche in different emitters at the nanoscale enables 46th-order optical nonlinearity. *Nature Nanotechnology*, **17**, 524-530. **2022**

cnrs GDR Groupement de recherche
HOWDI Low dimensional van der Waals heterostructures

corresponding author : damien.rinnert@ec-lyon.fr

SPONSORS

Organized by :

LuMIn Lumière, Matière et Interfaces — CRHEA — Institut d'Optique Graduate School ParisTech — école normale supérieure paris-saclay — cnrs — université PARIS-SACLAY


QuanTiP


QUANTUM
SACLAY


FRANCE
2030
PROGRAMME
DE RECHERCHE
QUANTIQUE


université
PARIS-SACLAY
Institute for the
Sciences of Light


Qnity


cnrs
Inria
cea
anr