QLITES
Quantum Light Sources in Solid State Materials and their Applications

Universidad de Oviedo

09-10 February 2026, Oviedo (Spain)

QUANTUM LIGHT SOURCES IN SOLID STATE MATERIALS AND THEIR APPLICATIONS

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Quantum Light Sources in Solid State Materials and their Applications

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Cofinanciado por la Unión Europea
AGENCIA ESTATAL DE INVESTIGACIÓN

	Monday 09.02.2026
09:30-12:30	EQUAISE & COMPHORT Meetings
12:45-14:15	Lunch
14:15-14:45	Registration
14:45-15:00	Opening
15:00-15:30	Invited talk: Elena Blundo (TUM)
15:30-15:50	Contributed talk: Antonio Polimeni (La Sapienza)
15:50-16:10	Contributed talk: Giorgio Pettinari (CNR)
16:10-16:40	Coffee Break
16:40-17:10	Invited talk: Carlos Sanchez Muñoz (IFF-CSIC)
17:10-17:30	Contributed talk: Victor Mitryakhin (Univ. of Oldenburg)
17:30-17:40	Workshop Picture
17:40-19:30	Poster Session
20:30-23:30	Dinner

	Tuesday 10.02.2026
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10:50-11:10	Contributed talk: Maxime Gaignard (CEA)
11:10-11:40	Coffee Break
11:40-12:10	Invited talk: Doris Reiter (TU Dortmund)
12:10-12:30	Contributed talk: Julia García Prieto (Univ. Oviedo)
13:00-15:00	Lunch
15:00-15:30	Invited talk: Luca Sortino (LMU)
15:30-15:50	Contributed talk: Juan V. Vidal Martinez-Pons (UAM)
15:50-16:10	Contributed talk: David Dlaka (Univ. Bristol)
16:10-16:40	Coffee Break
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17:10-17:30	Contributed talk: Pawel Wyborski (DTU)
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PROGRAMME

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15:30	Contributed: Antonio Polimeni (Sapienza University of Rome, Italy) *Electronic properties of single photon emitters in transition metal dichalcogenide micro-domes*
15:50	Contributed: Giorgio Pettinari (Institute for Photonics and Nanotechnologies CNR, Italy) *Bull's eye cavities for TMDC-based single photon emitter integration*
16:10	Coffee Break
16:40	Invited: Carlos Sánchez Muñoz (Institute of Fundamental Physics IFF-CSIC, Spain) *On-demand single-photon source over the terahertz regime*
17:10	Contributed: Victor N. Mitryakhin (University of Oldenburg, Germany) *Monolayer Single Photon Emitter Coherently Driven through Its Excited State*
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TUESDAY – 10 February

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10:30	Contributed: Christopher Gies (University of Oldenburg, Germany) *Can we expect great single photon sources from two-dimensional semiconductors?*
10:50	Contributed: Maxime Gaignard (University of Grenoble Alpes, CEA, France) *Indistinguishable single photons from a quantum dot in a nanopost cavity*
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11:40	Invited: Doris Reiter (TU Dortmund University, Germany) *Interplay of excitation and cavity in shaping photons from solid-state quantum emitters*
12:10	Contributed: Julia García-Prieto (University of Oviedo, Spain) *Reversible strain control of quantum Emitters in 2D Semiconductors*
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15:30	Contributed: Juan V. Vidal Martínez-Pons (Autonomous University of Madrid UAM, Spain) *Open Fabry-Pérot cavities for bright single photon generation at room temperature*
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16:40	Invited: Chanaprom Cholsuk (University of Munich, Germany) *Solid-state hBN single photon sources for quantum communication*
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ABSTRACTS
INVITED
SPEAKERS

Moiré trapping of excitons in 2D heterostructures

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The weak van der Waals interaction that keeps the layers together in layered crystals has opened new avenues for heterostructures, introducing a new degree of freedom: the twist angle. Twisted 2D HSs have attracted great attention for the fascinating physics they unleash. The twisting leads in fact to the formation of a periodic interference pattern, the moiré pattern (Fig. 1a), which results in the creation of a periodic potential for charge carriers that is twist-dependent and strongly affects the system (opto)electronic properties. In semiconducting HSs based on transition metal dichalcogenides (TMDs, such as $MoSe_2$ and WSe_2) interlayer excitons (with electrons and holes lying in the different constituent materials of the HS) form (Fig. 1b). Interlayer excitons are further trapped by the moiré potential, offering a means to tune their properties and showing promise for the formation of Bose-Einstein condensates and highly correlated exciton states, or as nanoscale-ordered quantum emitters [1].

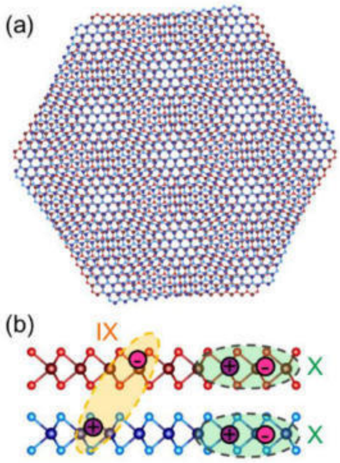

Fig. 1. Sketch of a TMD HS. (a) Top view, showing the formation of a moiré pattern (twist angle equal to 7°). (b) Side view, showing the formation of interlayer excitons (IXs), besides intralayer excitons (Xs).

In this talk, we address the properties of moiré-trapped excitons in TMD HSs, shedding light on their origin and nature and thus on their potential for quantum applications. An analysis of the exciton lineshape demonstrates clear evidence of moiré trapping [2], along with the involvement of phonons in shaping the spectrum [3]. More specifically, photoluminescence measurements of $MoSe_2/WSe_2$ HSs clearly reveal the presence of spectrally narrow discrete emission lines conventionally associated with moiré-trapped interlayer excitons. A strikingly uniform line-spacing of the discrete emission lines is observed, suggesting an entirely new picture of the discrete interlayer exciton emission in which non-thermal phonons play a crucial role in shaping the spectrum. An analysis of the PL spectrum of the intralayer excitons in these HSs further reveal the role played by the moiré potential in affecting exciton physics in 2D superlattices.

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On-demand single-photon source over the terahertz regime

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We propose a deterministic single-photon source in the terahertz (THz) regime, triggered by a sequence of coherent optical pulses [1]. The scheme leverages the permanent dipole moment of a single-polar quantum emitter to induce THz transitions between optically dressed states, enhanced by a resonant coupling to a hybrid THz cavity [2]. We present a cavity design that delivers high efficiency, purity, and indistinguishability while also enabling easy tunability of the emission frequency across the THz range. A key challenge in this new class of dressed-state sources is that, unlike standard solid-state single-photon sources, the dressed nature of the transitions can lead to undesired optical repumping during emission due to spontaneous photon emission in the visible range, which reduces the purity of the THz single-photon state. We show that this issue can be mitigated through optimized pulse areas and a sufficiently high Purcell rate, criteria that are met by our proposed cavity design. Finally, we demonstrate the significant purity enhancement of postselected THz photons by means of optical heralding, illustrating the new opportunities unlocked by the unique integration of terahertz and visible technologies with dressed polar quantum emitters.

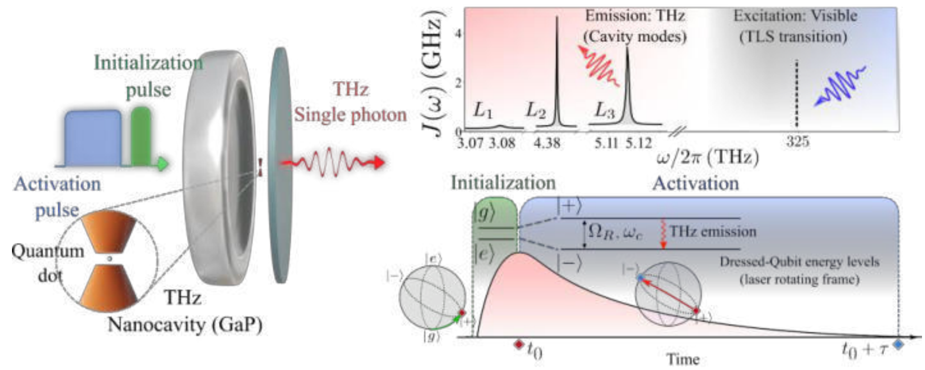

Figure 1: Overview of a proposed deterministic single-photon THz source based on a quantum emitter in a hybrid nanocavity formed by GaP nanocones inside a Fabry–Pérot resonator. The system is driven by optical pulse protocols to initialize and activate THz emission, with simulations illustrating emitter dynamics.

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[2] C. Groiseau, A. I. Fernández-Domínguez, D. Martín-Cano & C. Sánchez Muñoz, Single-Photon Source Over the Terahertz Regime, PRX Quantum 5, 010312 (2024).

Photoluminescence of hBN single-photon emitters in a near-field microscope

Iris Niehues[1]*, Daniel Wigger[2], Korbinian Kaltenecker[3], Annika Klein-Hitpass[1], Johannes Binder[4],
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Single-photon emitter (SPE) in hexagonal boron nitride (hBN) have emerged as intensively investigated quantum light sources due to their stable and bright single-photon emission at room temperature.

We utilize a scattering-type near-field optical microscope (s-SNOM) to study the photoluminescence (PL) emission characteristics of such quantum emitters in metalorganic vapor phase epitaxy grown hBN [1]. In our specific experiments, we employ the near-field optical microscope in tapping mode, to detect PL signals influenced by the presence of the metallic tip.

On the one hand, we demonstrate direct near-field optical excitation and emission through interaction with the nanofocus of the tip resulting in a sub-diffraction limited tip-enhanced PL hotspot. This signal appears as dot in the map in Fig. 1, marked by the circle. On the other hand, we observe a more pronounced ‘arc’ around the dot (violet area). We explain this feature by constructive interference between direct beams to/from the SPE and those scattered from the AFM tip (indirect beams) leading to a significant increase of the recorded PL intensity. We apply the TAPL method to map the in-plane dipole orientations of the hBN SPEs.

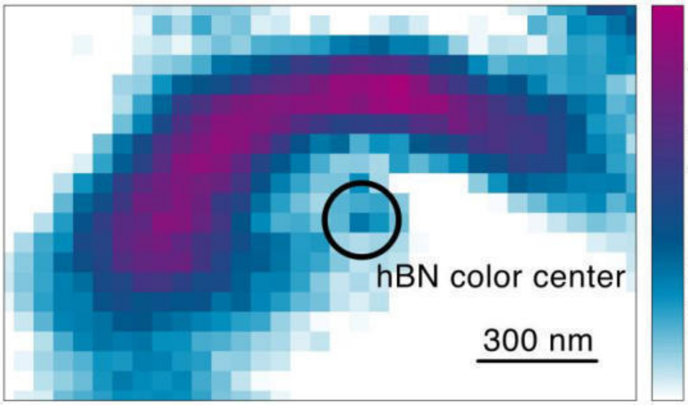

Figure 1. Photoluminescence intensity map of a single color center taken in a near-field microscope.

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Interplay of excitation and cavity in shaping photons from solid-state quantum emitters

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For the generation of photons with optimal properties, the excitation process of quantum emitters plays a crucial role. Over the past years, several coherent excitation schemes beyond resonant excitation via Rabi oscillations have been developed and implemented for quantum dots, including adiabatic rapid passage, the detour scheme and the Swing-up of quantum emitter population (SUPER) scheme. While each of these schemes has its respective advantages and disadvantages, the impact of the excitation scheme on the photon properties becomes even more prominent when the quantum emitter is placed inside a cavity. Because the cavity frequency acts as a filter, this gives rise to novel mechanisms that in turn affect the properties of the emitted photons.

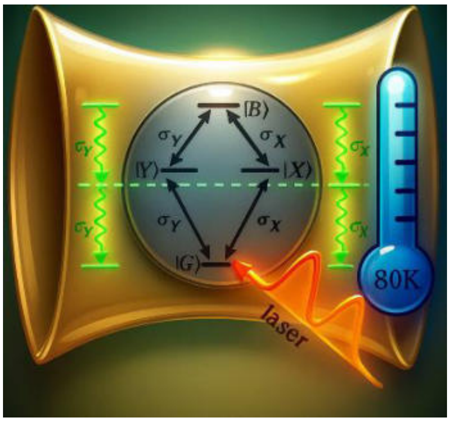

Figure 1 Artistic version of a four-level quantum emitter in a cavity excited by two

In this talk, I will discuss two examples where the interplay between excitation scheme and cavity enhances photon properties. First, when a quantum dot acts as a source of polarization entangled photons, resonant excitation yields imperfect excitation due to Stark shifts during the pulse. However, if the quantum dot is excited via the SUPER scheme, near unity concurrence can be achieved, which remains almost perfect even at elevated temperatures [1].

As a second example, I will discuss the impact of the excitation process on the photon number coherence (PNC) of the emitted photons [2]. While in resonant excitation the pulse area can in principle serve as a tuning knob for the PNC, phonons that are typically known to destroy coherences can surprisingly enhance it [3]. Within the SUPER scheme, the PNC can become stronger than under resonant excitation.

These examples illustrate that it is crucial to account for the excitation process when evaluating the quality of a quantum emitter.

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Integrating 2D quantum emitters with nanophotonic structures

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Engineering light-matter interactions within tailored photonic environments offers a powerful route to enhance and control quantum emission, enabling the realization of efficient single-photon sources. Two-dimensional semiconductors and other van der Waals layered materials host atomically thin quantum emitters that can be spectrally and spatially tuned, making them ideal candidates for integrated quantum photonics. Their compatibility with photonic architectures further allows to study coupling to passive nanoscale dielectric resonators for enhanced emission control.

In this talk, I will present experimental results on coupling WSe_2 quantum emitters to dielectric nanoantennas [1], and on integrating optically active defects in hBN with high-Q factor optical metasurfaces [2]. Together, these approaches illustrate a versatile platform for scalable quantum nanophotonics, where emission properties, coherence, and efficiency can be engineered within a compact solid-state environment.

References

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Solid-state hBN single photon sources for quantum communication

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Reliable single photon generation lies at the heart of quantum communication. While pseudo single photon sources have been widely used, true single photon sources can significantly improve data transmission rates and overall system performance. One of the most elegant implementations relies on the fluorescence of a single two-level quantum system: since excitation and emission between ground and excited states occur over a finite time, the emitter can ideally release one photon per excitation cycle. In this talk, I will present such a system originating from atomic-scale defects in two-dimensional hexagonal boron nitride (hBN). The comprehensive properties of these defects have been theoretically characterized and compiled in our online database, https://h-bn.info [1]. These hBN quantum emitters offer high quantum efficiency and single-photon purity at room temperature [2].

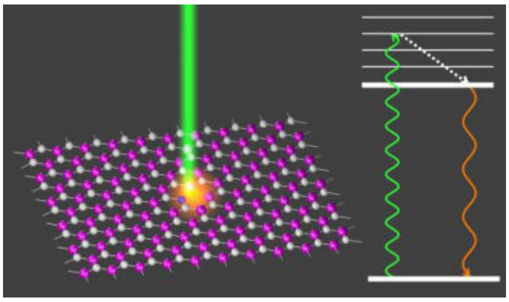

Figure 1. Single photon emission from a defect in hBN arising from transitions between two-level defect states.

I will then discuss how these systems can be harnessed for quantum memories and satellite-based quantum communication, highlighting our work on the QUICK3 satellite mission [3]. Finally, while the conventional Gottesman–Lo–Lütkenhaus–Preskill (GLLP) formalism ensures security against photon-number-splitting (PNS) attacks by demanding extremely low second-order correlation $g^{(2)}(0)$ values, we have developed a decoy-like protocol that relaxes this strict requirement [4]. By exploiting $g^{(2)}(0)$ variation as a diagnostic tool, our approach securely enables the use of single photon sources even with $g^{(2)}(0) > 0.5$, a regime routinely achieved in experiments but rarely considered viable for quantum key distribution (QKD). Therefore, hBN defects represent a promising platform that offers a practical and broadly applicable route toward high-performance quantum communication.

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ABSTRACTS CONTRIBUTED SPEAKERS

Electronic properties of single photon emitters in transition metal dichalcogenide micro-domes

Salvatore Cianci[1], Elena Blundo[1], Federico Tuzi[1], Nikodem Sokołowski[1], Giorgio Pettinari[2], Katarzyna Olkowska-Pucko[3], Antonio Miriametro[1], Takashi Taniguchi[4], Kenji Watanabe[5], Adam Babinski[3], Maciej R. Molas[3], Marco Felici[1], Antonio Polimeni[1]*

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The presence of single photon emitters (SPEs) in two-dimensional (2D) crystals is certainly a valuable asset of these systems. Several 2D materials, including semiconducting transition metal dichalcogenides (TMDs), hexagonal boron nitride (hBN), GaSe, and MoO_3 host defect states that give rise to quantum emission.[1] The exceptional mechanical properties of 2D materials along with their manageability and relatively easy integration in photonic structures made the SPEs therein embedded particularly attracting. SPEs based on TMDs are especially important since they prompt a rather wide palette of quantum emission energis and the possibility to tune their emission via mechanical deformations.[2] Indeed, the strain itself is deemed to be at the origin of the formation of SPEs in 2D TMDs.[3]

In this work, we address the physical origin of SPEs in WS_2. To this end, we exploit the peculiar formation of hydrogen-filled micro-domes obtained by low-energy (10 eV) proton irradiation.[4] The micro-domes are subjected to internal pressures as high as hundreds of atm. The ensuing high strain values attained promote an especially favourable electronic configuration, whereby defect levels admix with extended state levels leading to intense and narrow emission lines featuring quantum properties.[5] Magneto-optical provide compelling evidence of the involvement of dark states at the origin of SPEs, while emission polarization studies emphasize the role of strain.

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Bull’s eye cavities for TMDC-based single photon emitter integration

Daniele Cecchetti[1] and Giorgio Pettinari[1*], on behalf of EQUAISE collaboration
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Single-photon emitters (SPEs) are key building blocks for emerging quantum technologies. Efficient SPE generation has been routinely demonstrated in two-dimensional (2D) materials such as hexagonal boron nitride (hBN) and transition metal dichalcogenides (TMDCs, e.g., WSe_2, WS_2, $MoSe_2$). Within the *EQUAISE* project (*Enabling QUAntum Information by Scalability of Engineered quantum materials*), funded under the QuantERA II Cofund 2021 EU programme, we have developed a new approach for the realization of SPEs based on strained 2D TMDCs and their integration into Bull’s Eye (BE) optical cavities, aiming to enhance and control photon extraction [1,2].

In this contribution, we report on the fabrication of BE cavities in silicon nitride (Si_3N_4) membranes, either sputtered on conventional semiconductor substrates (i.e., Si or GaAs wafers) or directly deposited onto piezoelectric substrates to enable strain control of the cavity properties. The cavity design has been optimized through finite-difference time-domain (FDTD) simulations to match the emission energy of SPEs in WSe_2 and WS_2 monolayers, respectively around 750 nm and 650 nm. Cavity fabrication was carried out by electron-beam lithography (EBL) and dry etching. First results of BE cavities fabricated on membranes directly sputtered on piezoelectric substrates will be presented and compared with simulations.

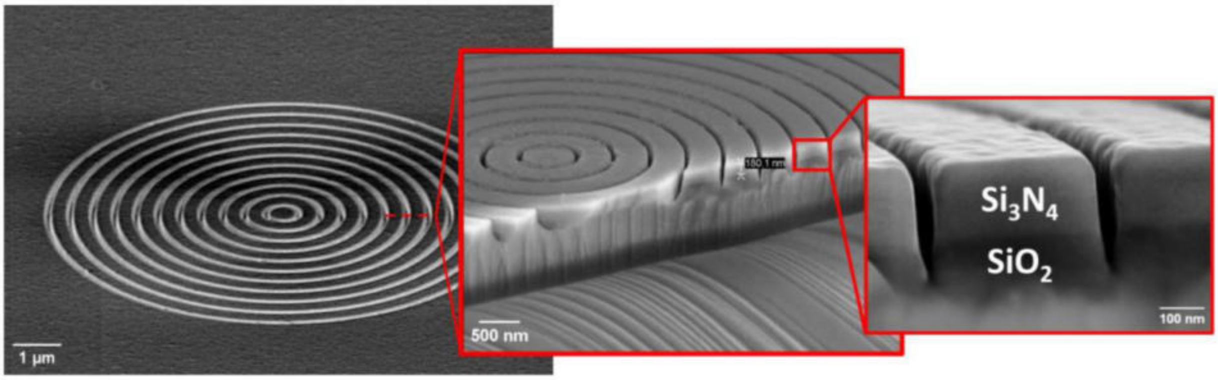

Figure 1. SEM image of a Bull’s Eye (BE) cavity fabricated on a Si_3N_4/SiO_2 membrane deposited on a GaAs substrate. The zoomed-in images show a 60°-tilted view and a cross-sectional view along the cut indicated by the red dashed line.

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Monolayer Single Photon Emitter Coherently Driven through Its Excited State

Victor N. Mitryakhin[1*], Ivan A. Solovev[1], Alexander Steinhoff[1], Jaewon Lee[2], Martin Esmann[1], Ana Predoević[1, 2], Christopher Gies[1] and Christian Schneider[1]

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The recent discovery of single photon emitters in novel two-dimensional materials such as transition metal dichalcogenides (TMD) [1] has drawn explicit attention of the quantum optics community. Relative inexpensiveness and ease of fabrication, along with an ability to deterministically seed such emitters and integrate them with photonic and plasmonic structures [2], have given rise to a particular interest for their use in quantum technologies. However, a significant limitation on possible applications of such single photon sources (SPS) has been revealed by the recent studies of their coherence properties showing severe decoherence effects, e.g. due to strong phonon coupling [3]. Though the impact of the latter can be reduced by integration of single emitters into photonic structures [4], a well-established method to mitigate decoherence effects is to use resonant excitation schemes.

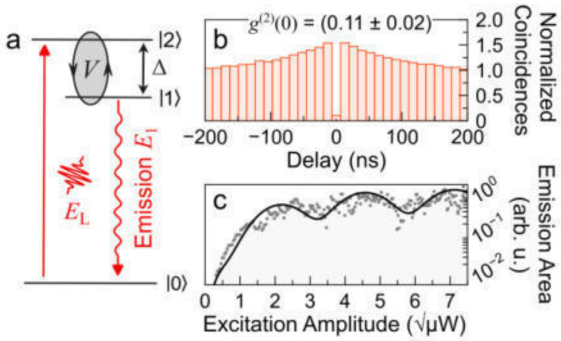

Figure 1. (a) Scheme of the energy level structure (b) Second-order correlation chart of the emission under pulsed excitation. (c) Normalized area of PL emission vs square root of power of a laser tuned to the higher state

In this work, we show resonant excitation of a SPS in WSe_2 monolayer flake by driving it through its excited state (see Fig. 1a). We investigate its energy level structure by means of photoluminescence excitation spectroscopy, which in turn reveals multiple resonances, some of which we attribute to higher-lying electronic shells. Consequently, the single photon character of the emission is studied in a typical Hanbury-Brown-Twiss experiment, while the emitter is excited through one of such resonances (see Fig. 1b). Then, we carry out a series of measurements, while pumping into the aforementioned resonance and monitoring the intensity of emission as a function of the pump field amplitude. Here, we observe an oscillatory behavior manifesting emergence of Rabi oscillations (see Fig. 1c). At last, we explain this behavior by examining a problem of a three-level system with introduction of a coupling and electric field pump terms to the Hamiltonian of the system.

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Indistinguishable single photons from a quantum dot in a nanopost cavity

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On-demand and wavelength-tunable sources of identical single photons are key devices for scaling up photonic quantum technologies. Semiconductor quantum dots (QDs) are artificial atoms with remarkable optical properties. To enable wavelength tuning, a single QD should ideally be integrated in a photonic structure that maintain a large Purcell acceleration of spontaneous emission over a broad spectral range.

We introduce here the nanopost optical cavity, a simple photonic nanostructure that provides a large Purcell acceleration (up to 7 at resonance) over a broad range of wavelengths (30 nm at half maximum) [1]. We next present two recent experiments performed on a self-assembled InAs QD embedded in a Gas nanopost cavity. In the first one, we excite resonantly the QD with a continuous wave laser and detect its resonance fluorescence with a large signal-to-background ratio [2]. Linescans and intensity autocorrelation measurements reveal an excellent single-photon purity ($g^{(2)}(0) = 0.006$) and a close to lifetime-limited homogeneous linewidth (40% above the Fourier limit). In the second experiment, we employ a pulsed, quasi-resonant excitation scheme to deterministically excite the emitter and explore photon-photon interference of consecutive photons emitted by the source [3]. For two photons separated by 2 ns, we obtain a mean wavepacket overlap as high as 45%, a state-of-the-art value among nanowire-based photonic structures.

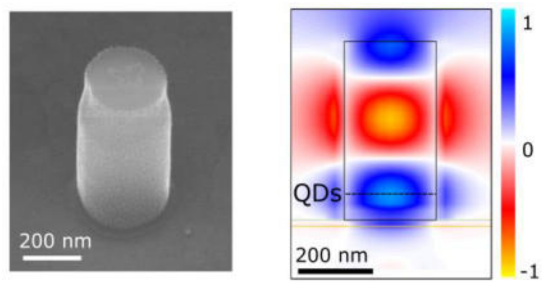

Figure 1. Left: Scanning electron micrograph (tilted view) of a representative device. Right: Map of the electrical field of the cavity resonance.

These results, combined with further improvements of the device, pave the way for the realization of broadly-tunable sources of single and indistinguishable photons.

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Reversible Strain Control of Quantum Emitters in 2D Semiconductors

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In recent years, atomically thin semiconductors based on transition-metal dichalcogenide (TMD) monolayers have emerged as a versatile platform for solid-state quantum emitters (QEs), combining exceptional optical quality with intrinsic mechanical flexibility [1]. This remarkable stretchability allows their optical response to be tuned over a wide range through elastic strain engineering [2]. Although the microscopic origin of QEs is still under active investigation, limiting the deterministic fabrication of identical emitters, it is widely accepted that their formation is closely linked to local strain fields and lattice defects. Position-controlled QEs can thus be realized by introducing static strain gradients via nanoscale features such as pillars or bubbles, which funnel excitons into localized regions where quantum light emission occurs [3].

Here, we present our recent results on the reversible tuning of the emission energy and brightness of QEs in WSe_2 monolayers. This control is achieved using a hybrid semiconductor–piezoelectric platform, in which the monolayer is integrated onto piezoelectric nanopillars that generate both static and dynamic strain fields. By combining numerical simulations with exciton drift–diffusion modeling, we demonstrate that these strain fields reshape the confining-potential landscape, leading to a reversible redistribution of excitons among individual emitters [4]. Finally, we present complementary high-resolution optical and structural characterization at the nanoscale, which provides a quantitative mapping of the static strain in nanobubbles, a key aspect in the formation of QEs in TMD monolayers.

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Open Fabry-Pérot cavities for bright single photon generation at room temperature

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Single-photon sources are a key resource for many of the applications envisioned in quantum photonics. In particular, solid-state emitters are highly attractive, as they enable integration into optical circuits and compact devices, and have been shown to offer higher efficiencies than probabilistic sources [1,2]. Moreover, single-photon emission at room temperature opens the door to the implementation of quantum key distribution protocols and true random number generation, where fast decoherence rates are not a limiting factor since quantum entanglement is not required. To increase the brightness of these emitters, resonant optical cavities can be used which, through the Purcell effect, modify the photonic density of states and therefore reduce the radiative decay time of the emitter, increasing its emission rate [3].

In this work, we address the challenge of developing such a solid-state single-photon source operative at room temperature, based on hBN defects resonant to a single mode of a tunable Fabry-Pérot concave-plane microcavity. We present the characterization of our source, showing single-photon emission, and we discuss its design and operation protocol. We show that a good match between the defect emission and the cavity mode is crucial for maximal brightness, which poses extra challenges at room temperature such as the need to use a cavity design with low quality factor, nearly optimal mirror alignment, and good mechanic stability of the device.

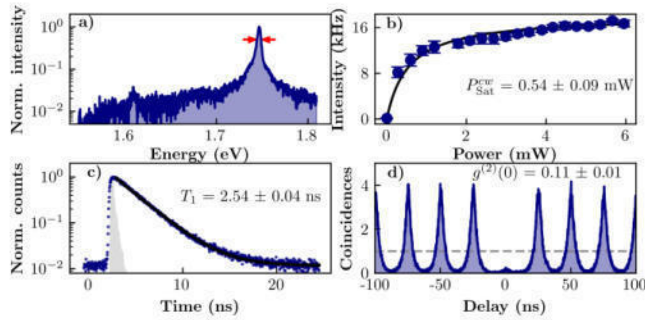

Figure 1. Basic characterization of an hBN defect outside the optical cavity showing **a)** PL spectrum, **b)** Saturation curve, **c)** Spontaneous decay histogram, **d) Second order correlation function under pulsed excitation.**

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Enhancing Room-Temperature Single Photon Sources with Open Cavity Systems

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The ability to extract single photons at (near) unity efficiency remains a topic of interest in the community, producing a variety of structures and devices. Open cavity structures are an attractive contender due to the possibility of precise spatial alignment to an emitter, Purcell enhancement to increase the efficiency and emitter rate, as well as the ability to shape the emission for mode-matching to a single mode fibre [1][2]. In this work, we simulate structures with varying structural parameters (Fig. 1) to test device performance of a wide, to reflect devices which may not require the very intricate engineering required to align the two mirrors at a distance of ~few μm.

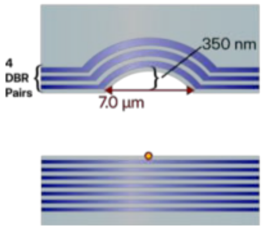

Figure 1. Schematic of the simulated open cavities and the variable parameters.

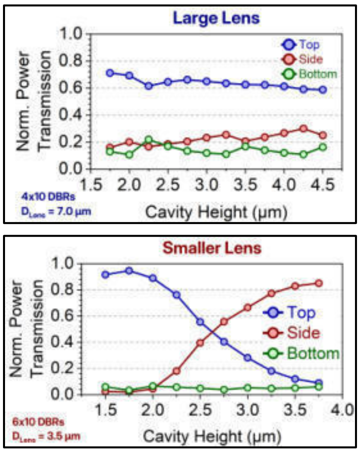

Figure 2. The normalised power transmission for a large RCurv~16um (top) and a smaller RCurv~5um (bottom) structure.

We find that the curvature of the top DBRs provides radial confinement of the cavity E-field, increasing the Purcell enhancement of the cavity mode at the cost of requiring a lower distance between the mirrors, labelled cavity height (Fig. 2). Large RCurv structures are insensitive to cavity height and do not demand technically intricate <2um mirror distances, but offer less on-peak efficiency.

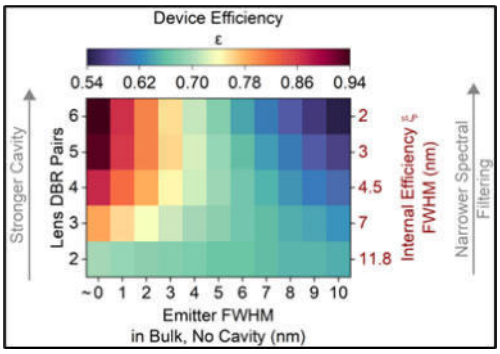

Figure 3. The efficiency of the device integrated over the entire spectrum appears as function of the cavity and emitter FWHM.

We also investigate the efficiency integrated over the full spectrum (labelled device efficiency) as a function of both the FWHM of the spectral filter of the cavity, and the FWHM of the emitter in bulk (Fig. 3), demonstrating the ability to extract ~70% of emitted photons from a room temperature emitter with bulk FWHM ~5 nm and as high as 94% if cryogenically cooled. This demonstrates the potential of achieving record-breaking efficiency and count-rates from room temperature emitters with a wide range of applications in quantum communications.

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Single-photon sources based on a nanoengineered two-dimensional transition metal dichalcogenides platform for quantum photonics

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Efficient single-photon emitters are a key element for future photonic quantum technologies. Especially, the realization of emitters at telecom wavelengths is important for achieving long-distance, large-scale, and secure quantum communication and distributed quantum computing through existing fiber-optic networks [1]. From the perspective of sample preparation, a promising platform is two-dimensional transition metal dichalcogenides (TMDs), as they allow for easy preparation via scotch tape exfoliation and exhibit already promising properties for quantum emitters, including relatively simple optical property manipulation and straightforward integration with other photonics structures [2].

Here, I will present our research activities on developing single-photon sources based on a promising TMD platform, specifically WSe_2 [3,4] and $MoTe_2$ [5], which demonstrate a method for obtaining emitters in the ~730-810 nm and above 1100 nm ranges. Focusing on the WSe_2 quantum emitters, I will present our results regarding charge noise mitigation using hBN-based encapsulation and electrical biasing. Besides electrical tuning of the emission line (~280 µeV), the mentioned technique reveals a significant reduction in the line broadening of the quantum emitters (~100 µeV) and their improved spectral stabilization (~40 µeV). Moreover, we utilized those emitters for integration with TMD-based photonic structures, namely WS_2-based waveguides and grating outcouplers, to verify the potential of coupling single-photon emission to an on-chip platform [6]. Integrating those emitters with waveguides enables single-photon emission detection through the photonic structure and the realization of an on-chip Hanbury Brown-Twiss measurement with high single-photon purity ($g^{(2)}(0) < 0.1$).

Finally, based on the other $MoTe_2$ platform, we also investigated the fabrication of quantum emitters with potential for realizing single-photon sources in the telecom range. Integrating this host material with a DBR-based photonic structure and nanopillar strain-inducing structures enables the creation of single quantum emitters [5]. The optical characterization of these emitters reveals strong linear polarization (DOLP > 70%), sub-nanosecond lifetimes ($\tau \leqslant 450$ ps), high single-photon purity ($g^{(2)}(0) < 0.1$), and resolution-limited emission (~150 µeV). Additionally, we verify the reproducibility of the quantum emitters and demonstrate electrical tuning of the emission line (~3 meV). Moreover, two-photon interference measurements reveal a Hong-Ou-Mandel visibility of $V_{HOM} \sim 10\%$, demonstrating the first characterization of indistinguishability in the near-infrared regime for the TMD-based quantum emitters platform.

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Can we expect great single photon sources from two-dimensional semi-conductors?

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Two-dimensional transition-metal dichalcogenide (TMD) semiconductors and their hetero-structures possess extensive possibilities in material design and band-structure engineering without the usual demands on semiconductor processing. At the same time, their excitonic properties render TMDs extremely useful as light emitters and detectors. In particular, TMD based single-photon sources are promising for their cost efficiency over epitaxially grown quantum dots. Single photon emission can arise from defects, as well as strain-induced local modifications of the band structure. While antibunching has been demonstrated in many cases, limitations of the indistinguishability of the emitted photons remain an open research question.

We explore aspects of TMD-based single photon sources by applying quantum-optical methods on the foundation of TMD material properties, including the interaction with phonons [1]. In this framework, indistinguishability is obtained by numerically computing two-time correlation functions. Implications of our results are discussed to evaluate the application potential of using TMD nanostructures as single-photon sources. We also address the possibility of cavity engineering, i.e. embedding TMDs into optical cavities, to control not only the spontaneous-emission time, but also emitter coherence [2], leading us to the important question if cavity engineering can be a viable route towards achieving well-performing sources of indistinguishable photons on the TMD material platform.

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GHz-clocked Generation of Highly Indistinguishable Photons in the Telecom C-band

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Many photonic quantum technologies rely on sources providing single and indistinguishable photons on demand and at high rates.

Here we present an ultra-fast quantum dot (QD) single-photon source in the telecom C-band, based on InAs/InAlGaAs QD integrated in a circular Bragg grating cavitiy. We observe record-short biexciton decay time of T_1 = 68 ps under resonant two-photon-excitation (TPE), which allows us to generate highly indistinguishable single photons at clock rates > 1 GHz. The two-photon interference visibility of photons emitted via the biexciton-exciton transition was measured in a Hong-Ou-Mandel-type experiment to be 92.4% and 82.6% at clock rates of 100 MHz and 2.5 GHz, respectively. Applying stimulated TPE in the telecom C-Band for the first time, we show that the photon indistinguishability can be further enhanced for exciton photons.

Our results show promises to advance QD-based implementations of quantum cryptography to unprecedentedly high clock rates at wavelengths suitable for large-scale fiber-optic networks.

ABSTRACTS

POSTERS

Quantum dots as single photon source: Reaching high indistinguishability at elevated temperatures

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Applications in quantum communication technologies call for on-demand generation of indistinguishable photons. Semiconductor quantum dots have shown to be promising single photon sources, where interactions with the solid state environment influence the photon quality. As these interactions are temperature dependent, we focus on the photon indistinguishability for higher temperatures.

We first model the quantum dot as a two-level system and account for its coupling to a non-Markovian phonon environment. The model is then extendend to include higher excited, so called hot states, as can be seen in Fig. 1. These hot states are connected to the excited state through temperature-dependent transitions [1].

At low temperatures, the loss of coherence is mainly caused by pure dephasing processes, while at higher temperatures the decrease of the indistinguishability is dominated by the hot states dynamics.

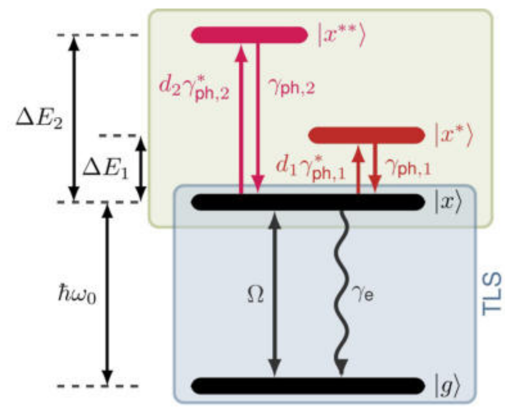

Figure 1. Scheme of the system, a driven two-level system coupled to two hot states.

Our results show excellent agreement between measurement and simulation, which demonstrates that the inclusion of such hot states is crucial to explain the temperature dependence of photon indistinguishability. These insights help to clarify the limitations of often assumed two-level system dynamics and offer guidance for optimizing quantum dots as applicable single photon sources.

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Photoluminescence spectroscopy of Interlayer Excitons in $MoSe_2/WSe_2$ Heterostructures

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We study the photoluminescence (PL) emission of interlayer excitons (IXs) in a $MoSe_2/WSe_2$ heterostack at cryogenic temperatures using non-resonant excitation; we also implement a tunable continuous-wave PL excitation (PLE) spectroscopy to identify efficient pathways for IX formation (Figure 1a). IXs in transition metal dichalcogenide (TMD) heterostructures provide a platform for realizing long-lived, spatially indirect excitonic states, with tunable recombination dynamics [1] and promising optoelectronic applications [2].

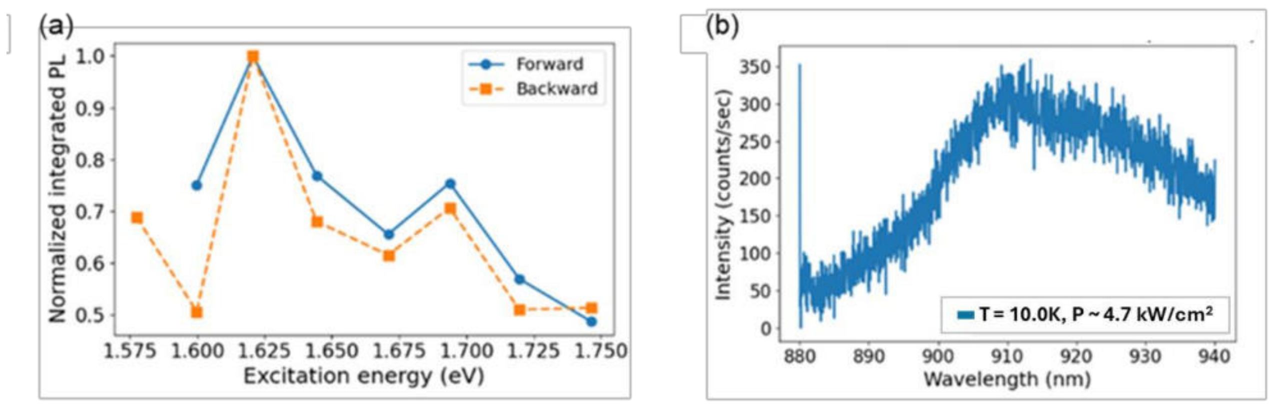

Figure 1. (a) PLE spectrum of a $MoSe_2/WSe_2$ heterostructure detected between 1.580 and 1.746 eV, showing two prominent resonances attributed to the intralayer exciton transitions of $MoSe_2$ (1.621 eV) and WSe_2 (1.694 eV). (b) IX PL under excitation resonant with the $MoSe_2$ intralayer exciton transition.

In twisted TMD heterostructures, finite twist angles generate moiré superlattices that modify the excitonic energy landscape and interlayer coupling [3]. For our $MoSe_2/WSe_2$ heterostack with a large twist angle (~4.4°), we observe a broad IX PL emission (Fig. 1b) under continuous-wave excitation in the 1.746-1.580 eV range. This is consistent with a reduction of interlayer hybridization, a larger momentum mismatch requiring phonon-assisted recombination, and the presence of multiple weak radiative channels [1]. Future work will explore alternative excitation schemes, including pulsed excitation, to probe IX dynamics and potentially enhance IX formation.

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Electronic localization and optical activity of strain-engineered transition-metal dichalcogenide nanobubbles

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Strain-engineered transition-metal dichalcogenide nanobubbles are promising platforms for quantum emission, as revealed by recent experimental observations, but the microscopic origin of their optical activity remains unclear [1]. Using *ab initio* calculations, we compare periodic MoS_2, WS_2, $MoSe_2$, and WSe_2 nanobubbles, illustrated in Figure 1, across a range of inflation forces, linking their structural and electronic properties to predictions of their optical activity [2]. Strain affects band structures, inducing non-dispersive valence states, localized at the tensile-strained apex of the nanobubbles, exhibiting a composition-dependent orbital character. Crucially, transitions from these apex-localized valence states are predominantly dark. This characteristic is attributed to their localization at the Γ-point, inhibiting transitions to the lowest unoccupied states that reside at the K-valley. While revealing that the herein considered sub-10-nm nanobubbles fall short as single-photon emitters, our findings provide essential understanding of the relations between the tunable geometric properties of the nanobubbles and their properties, providing robust design guidelines to optimize their characteristics for novel quantum applications.

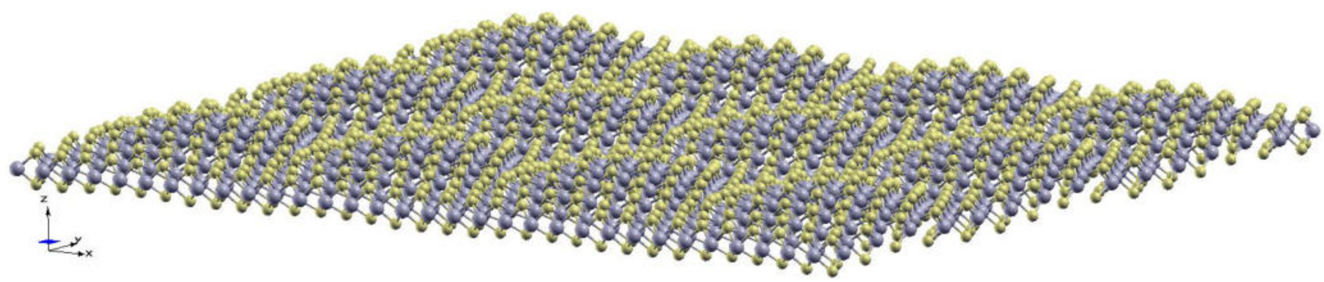

Figure 1. Ball-and-stick representation of the TMDC nanobubbles considered in this work depicted in a 4x3 supercell. Metal atoms are depicted in gray and chalcogen atoms in yellow. Graph produced with XCrySDen.

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Real-Space Visualization of Canalized Ray Polaritons in a Single Van der Waals Thin Slab

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Polaritons [1] are central to the development of nanophotonics, as they provide mechanisms for manipulating light at the nanoscale. A key advancement has been the demonstration of polariton canalization [2-4] in which the energy flow is directed along a single direction. An intriguing case is the canalization of ray polaritons [5], characterized by an enhanced density of optical states. Experimental demonstrations of ray polaritons are scarce and their observation in single crystal slabs remains elusive. Here [6], we propose a novel polaritonic platform based on single thin slabs allowing for the excitation of canalized ray polaritons. By performing near-field nanoimaging, we demonstrate that the necessary conditions for their observation (a synergistic combination of large material permittivity modulus and dielectric environment) are fulfilled for phonon-polaritons at mid-IR frequencies in thin α-MoO_3 slabs on SiO_2 substrates. Our real-space images reveal the propagation of unidirectional phonon-polaritons exhibiting a constant propagating phase. These results might impact the development of compact, low-loss optical nanodevices for applications requiring strong light directionality.

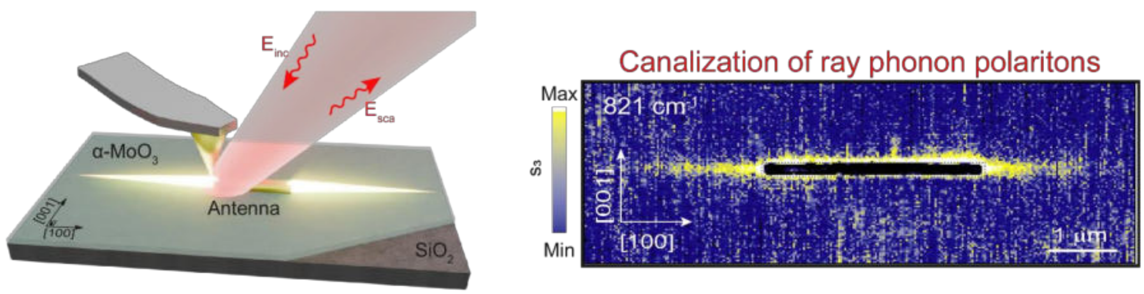

Figure 1. Near-field real-space visualization of canalized ray phonon polaritons launched by an Au rod nanoantenna in a single thin slab of α-MoO_3 placed on top of a SiO_2 substrate.

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Controlling dephasing mechanisms in semiconductor quantum emitters for the generation of indistinguishable photons

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The generation of high-quality single photons is an important prerequisite for a multitude of quantum applications, including linear (photonic) quantum computing and quantum communication. While antibunching has been demonstrated in many cases, understanding and controlling various dephasing mechanisms occurring in the solid-state environment is essential to overcome limitations of the Hong-Ou-Mandel (HOM) indistinguishability, quantifying the ability of emitted photons to interfere with each other.

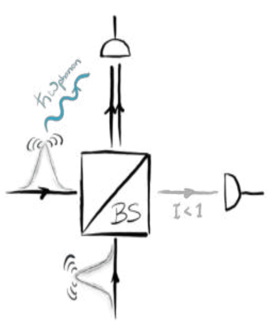

Figure 1. Set-up of the simulated Hong-Ou-Mandel experiment.

We analyze the influence of different dephasing mechanisms, i.e., the interaction with acoustic phonon modes as well as the spectral diffusion caused by fluctuations in the surrounding charge environment for two different kinds of emitters: single quantum dots, and quantum-dot molecules. We compute the two-photon indistinguishability by simulating the HOM experiment (cf. Fig. 1) and evaluating the two-time correlation function, both analytically and numerically [1].

The influence of an external bias, controlling both the electronic states and the diode current is investigated. Taking into account finite phonon lifetimes and the bias-dependent electron-phonon interaction strength in quantum-dot molecules, we compute the correlation function and indistinguishability using a generalized independent phonon model.

We also show the dependence of the charge noise intensity on the external voltage experimentally, backing it with theoretical simulations taking into account imperfect excitation conditions [2].

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HIGH-PRECISION DRY-TRANSFER SYSTEM FOR THE ASSEMBLY OF 2D VAN DER WAALS HETEROSTRUCTURES

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In recent years, two-dimensional (2D) van der Waals (vdW) materials have gained central relevance in nanooptics and quantum optics research due to their novel optical properties. This interest has intensified particularly after the observation of diffractionless canalization of nanolight in vdW homostructures, stacks of the same single vdW material, where the relative twist angle between layers emerges as a new degree of freedom. This parameter, crucial for controlling the optical properties of the homostructure, demands assembly methods capable of ensuring precise and reproducible alignment. The dry-transfer technique, widely used for the assembly of vdW heterostructures, enables the controlled pickup and release of individual layers without liquid solvents, reducing defects such as wrinkles and bubbles and preserving clean interfaces. In this context, the fabrication of high-quality vdW heterostructures requires dry-transfer systems able to ensure accurate alignment between layers, a need that commercial setups fail to fulfill due to their limited angular precision. Here we design a non-commercial dry-transfer system that enables the assembly of vdW heterostructures with a relative rotational precision on the order of one-tenth of a degree, thereby providing a robust platform for the controlled study of emerging optical phenomena in 2D materials.

Micrometer laser-induced local wetting (LILoW) of self-assembled monolayers (SAM) for colloidal quantum sources isolation applications

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Precise and flexible control of surface wettability is crucial for applications ranging from microfluidics to biosensing and surface-guided chemistry. Here, we introduce Laser-Induced Local Wetting (LILoW). This maskless and energy-efficient method enables micrometer-scale patterning of wettability by selectively ablating self-assembled monolayers (SAMs) using a nanosecond ultraviolet laser.

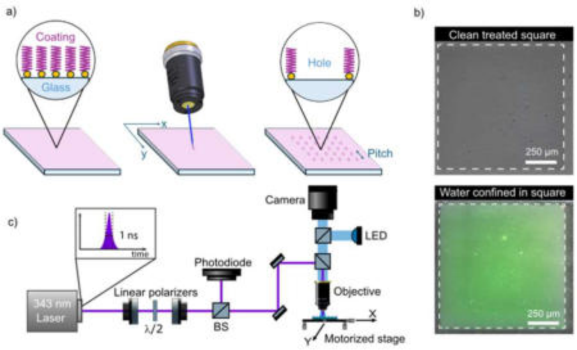

Figure 1. Principle and implementation of LiLoW. (a) Schematic of the LILoW process. A hydrophilic glass substrate is first coated with a hydrophobic SAM. A focused UV pulsed laser, synchronized with motorized translation stages, selectively ablates the SAM, exposing the underlying hydrophilic surface and generating wettability patterns with micrometer-scale precision. (b) Demonstration of wettability contrast after laser patterning. A droplet of aqueous fluorescein solution (green) remains strongly confined to the laser-irradiated region, while the surrounding SAM-coated area remains non-wetting, highlighting the sharp boundary. (c) Experimental setup, consisting of a 343 nm, 1 ns pulsed UV laser focused onto the substrate through a microscope objective. The beam energy is monitored in situ, and the sample is scanned using a computer-controlled motorized stage, enabling programmable and mask-free patterning.

Hydrophilic glass substrates were rendered hydrophobic by coating them with a DMOAP alkylsilane monolayer, after which a 343 nm pulsed laser was used to locally remove the SAM without damaging the underlying substrate. By tuning the laser fluence to the ablation threshold of the monolayer, wettability patterns were produced with a lateral resolution of ~1 µm, limited by optical diffraction. Contact-angle measurements reveal a tunable wettability contrast approaching 90°, controlled by the laser writing pitch while maintaining minimal surface roughness. As a proof of concept, we fabricated open-air, pumpless microfluidic guides in which liquids are confined and transported solely by surface-energy gradients, achieving laminar capillary-driven flow chemical selectivity of SAM-based surface functionalization with the flexibility of laser direct writing, offering a rapid, low-cost, and highly adaptable platform for creating programmable wettability landscapes for microfluidics, biosensing, and surface-driven fluidic devices.

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Study of C_{60} fullerene photoinduced functionalization for room temperature single photon generation

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C_{60} fullerene embedded in polystyrene exhibits on-demand single-photon emission at room temperature, making it a promising candidate for scalable quantum communication devices [1]. However, pristine C_{60}'s icosahedral symmetry suppresses the lowest-energy HOMO-LUMO transition, predicting negligible photoluminescence. We hypothesize that photo-oxidative functionalization, forming $C_{60}O_n$ species, breaks the symmetry to enable emission.

To test this mechanism, we employ time-resolved photoluminescence spectroscopy and time-dependent density functional theory (TD-DFT) calculations. We measured photoluminescence spectra of C_{60} embedded in a polystyrene matrix under continuous 405 nm excitation to monitor spectral evolution, replicating the behaviour reported in Ref. [2]. We also performed TD-DFT calculations using ORCA to predict emission spectra for C_{60} with varying epoxide group positions [3].

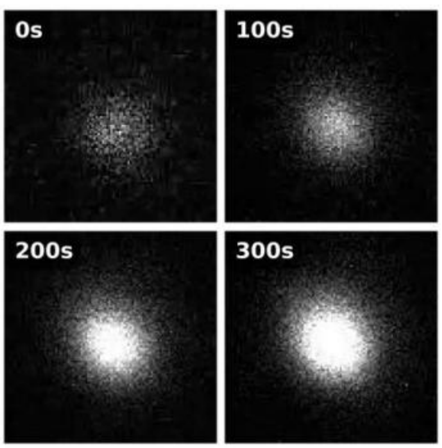

Figure 1. Micrographs showing the time evolution of the light emitted by C_{60} embedded in a polystyrene matrix when exposed to a 405 nm, 0.2 μW laser beam. The photoluminescence intensity increases until it reaches saturation.

Upon 405 nm excitation, the photoluminescence spectrum undergoes measurable changes: the dominant emission peak shifts from approximately 710 nm to 580 nm. The photoluminescence intensity increases by a factor of four before reaching saturation, indicating completed functionalization of individual C_{60} molecules. TD-DFT predictions are under evaluation to identify the number of epoxide groups required to break symmetry and match experimental observations.

By comparing photoinduced spectral shifts with TD-DFT predictions for various oxidated species, we aim to provide evidence for oxidative functionalization as the single-photon emission mechanism and guide the design of future C_{60}-based quantum light sources.

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Substrate-engineered canalized phonon polaritons in monolayer α-MoO_3 for super-resolution nanoimaging

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Canalization is an optical phenomenon that enables unidirectional light propagation without predefined wave guiding designs. In van der Waals (vdW) polaritonic platforms, canalization has been demonstrated in twisted α-MoO_3 bilayers and trilayers, but applications have been limited by fabrication complexity and the need for precise twist-angle control [1-5].

In this work [6], we propose theoretically and demonstrate experimentally a previously unexplored canalization phenomenon for phonon polaritons (PhPs) that takes place in single individual, unstructured, pristine α-MoO_3 layers when placed on a substrate with a given negative permittivity. The inherent ease of implementation, low-loss nature (PhPs lifetimes of ~2 ps), and broad spectral coverage (~50 cm^{-1}) of this single-layer canalization allow us to introduce a first proof-of concept application based on this phenomenon: nanoimaging of buried nanostructures. A single α-MoO_3 layer on SiC functions as a near-field hyperlens (or equivalently, a laterally shifting superlens), transferring subwavelength near-field information to the top surface. Experiments on arrays of buried Au nanodisks resolve edge-to-edge separations down to ~50 nm at λ_0=11.3 μm, corresponding to a deep sub-diffraction resolution of ~λ_0/220. Importantly, this imaging scheme transcends conventional projection constraints, allowing super-resolution images to be obtained at any desired location in the image plane by manipulating parameters such as the incident frequency, the rotation angle of the thin layer, and its thickness.

Although demonstrated using SiC, our results can be generalized to many other substrates whose metallic properties are tunable, such as graphene, doped semiconductors, or phase change materials. Together, our results thus open avenues for integrated flat optics, nanoscale information transfer, and heat management applications using highly collimated PhPs.

Keywords: phonon polaritons, canalization, α-MoO_3, van der Waals materials, super-resolution imaging, near-field microscopy, hyperlens.

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Towards Room-Temperature Single Photon Emitters Using Zwitterionic-Stabilized Perovskite Nanocrystals

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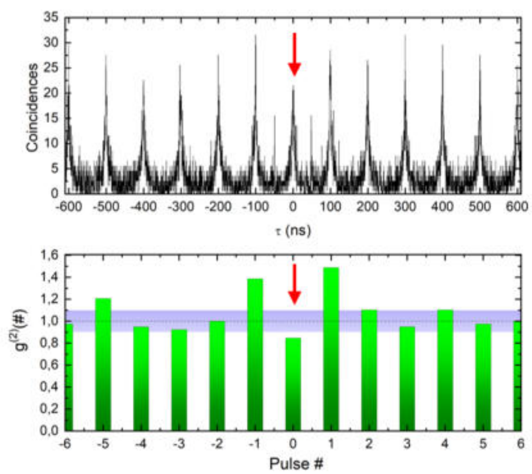
Lead halide nanocrystals are established as low-cost nanostructures for realizing perovskite-based single-photon emitters. In 2015, Park and colleagues demonstrated the first perovskite-based single-photon source operating at room temperature (RT) using all-inorganic $CsPbI_3$ quantum dots [1]. Since then, quantum light emission has been observed in various perovskite nanocrystals (PNCs) at both RT and cryogenic temperatures. Despite their remarkable optical properties, the use of PNCs in emerging quantum technologies is limited by photostability issues and challenges in integrating them into photonics platforms.



$$g^{(2)}(0) \approx 0.85 \pm 0.10 < 1$$

Figure 1. Second-order correlation measurements in $CsPbBr_3$ single nanocrystals at room temperature confirm the quantum nature of the optical emission.

As reported by Setatira *et al*. [2], cryogenic μ-photoluminescence (μ-PL) and μ-time-resolved PL spectroscopy were employed to investigate the spectral stability of single colloidal cesium lead halide PNCs with different capping ligands. Notably, the use of a zwitterionic (ZW) ligand significantly reduces blinking and spectral diffusion in $CsPbBr_3$ PNCs, enhancing spectral stability and narrowing μ-PL linewidths to approximately 125-140 μeV. Furthermore, single $CsPbBr_3$ PNCs capped with this ZW ligand exhibit a slightly longer decay time (by a factor of ≈1.35), indicating a reduction in undesirable processes such as Auger recombination.

Building on these results, preliminary RT measurements of single-photon emission from $CsPbBr_3$ PNCs yield a second-order correlation of $g^{(2)}(0) \approx 0.85$, confirming the quantum nature of the optical emission. Efforts are now focused on integrating these emitters into open-cavity systems, such as bullseye or fiber-based cavities, with the goal of enhancing the emission through efficient emitter–cavity coupling. In parallel, initial studies with lead-free $CsSnI_3$ PNCs are being conducted, offering a more environmentally friendly alternative.

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UNIDIRECTIONAL RAY POLARITONS IN TWISTED ASYMMETRIC STACKS

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The emergence of a vast repository of van der Waals (vdW) materials supporting polaritons – light coupled to matter excitations – offers a plethora of different possibilities to tailor electromagnetic waves at the subwavelength-scale [1]. In particular, the development of twistoptics – the study of the optical properties of twisted stacks of vdW materials – allows the directional propagation of phonon polaritons (PhPs) along a single spatial direction, which has been coined as canalization [2,3]. Here we demonstrate a complementary type of nanoscale unidirectional propagation that naturally emerges in twisted homostructures of α-MoO_3 and heterostructures of α-MoO_3 and β-Ga_2O_3: unidirectional ray polaritons (URPs) [4]. URPs are characterized by the absence of diffraction and the presence of a single phase of the propagating field. Importantly, we demonstrate that this ray behavior can be tuned by means of both relative twist angle and illumination frequency variations. Our findings demonstrate a natural way to excite unidirectional ray PhPs and offer a unique platform for controlling the propagation of PhPs at the nanoscale with many potential applications like nanoimaging, (bio)-sensing or polaritonic thermal management.

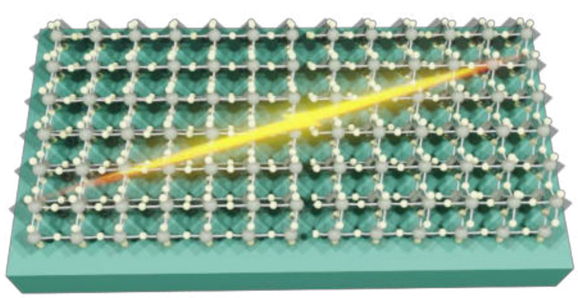

Figure 1: Schematic of the unidirectional ray propagation of polaritons in a twisted homostructure biaxial stack made of two asymmetric α-MoO_3 layers.

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Strain Engineering of Single-Photon Emitters in hBN: Linking Optical Responses and Defect Structures

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In the field of nanophotonics, the introduction of elastic deformation fields (elastic strain engineering) can be used to efficiently and reversibly tune the optical emission properties of optically active nanomaterials such as hexagonal boron nitride [1]. Although the origin of the hBN optical emissions is still under debate, the most widely accepted theory attributes them to intraband localized states originating from crystalline defects such as vacancies or substitutions. The intraband nature of these emissions makes them excellent candidates for single-photon sources at room temperature, thereby increasing the interest in this material [2]. When combined with strain engineering, this provides the set of tools to achieve the fine tuning required to generate entangled photon pairs for use in KQD protocols or, as in this case, to shed further light on the origin of the emissions.

In this work, we present a device based on flexible mechanisms (compliant mechanisms) capable of introducing uniaxial elastic deformation fields exerting sufficient strain to observe up to 35meV shifts. By taking advantage of the elastic and planar characteristics of the device, a highly directional motion is achieved without the use of traditional mechanical joints. As a proof of concept, we demonstrate the capability of this device to tune the optical emission energy of two different types of SPE in hBN, and we compare their markedly different responses through both experimental measurements and theoretical calculations.

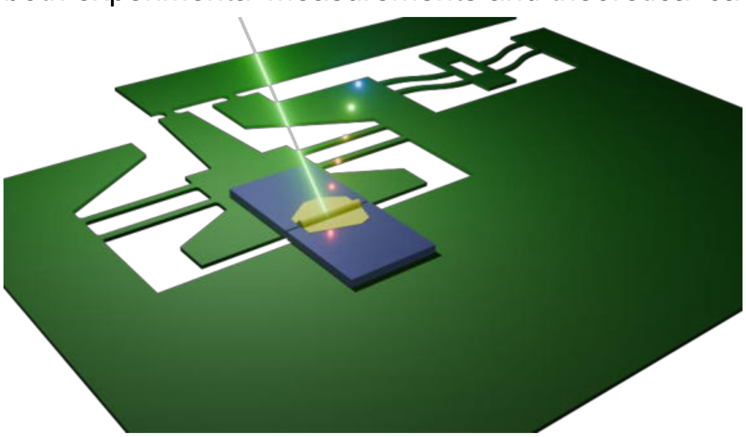

Figure 1.- A novel customized hybrid 3D-printed compliant mechanism device to introduce large strain fields in nanomaterials [1].

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Correlative chemostructural nanoscopy in emerging thin semiconductors

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The I14 Nanoprobe beamline at Diamond Light Source offers a unique platform for correlative X-ray characterisation of low-dimensional materials with spatial resolution down to 50 nm. [1] By combining nano-X-ray fluorescence (XRF), nano-X-ray diffraction (XRD) and nano-X-ray absorption near-edge structure (XANES), I14 enables simultaneous access to local composition, crystal structure and strain at the length scales relevant for emergent quantum and optoelectronic phenomena in two-dimensional systems.

Here we highlight how these capabilities can be exploited to address one of the central challenges in the field of 2D semiconductors: understanding the nanoscale structural origin of localized excitonic states in transition metal dichalcogenides. Using WSe2 monolayers as a model system, correlative nanoscale X-ray mapping allows strain domains associated with wrinkles and bubbles to be directly visualised and quantitatively linked to optically active regions hosting single-photon emission. The approach provides a direct structural counterpart to optical spectroscopy, enabling correlations that are inaccessible with either technique alone. [2]

Beyond static mapping, I14 allows in-situ experiments under external perturbations, including controlled illumination and piezoelectric strain actuation, enabling deterministic tuning of local structural landscapes while monitoring the X-ray response at the nanoscale. This methodology establishes a powerful route to probe how strain and local structural heterogeneity govern quantum emission in 2D materials.

Finally, we illustrate the broader versatility of the technique through nanoscale X-ray studies of halide perovskites, in line with recent benchmark work, [3] demonstrating that the same correlative framework can be extended to other structurally soft and compositionally complex semiconductors.

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