Quantum Dot Day
Site Controlled Quantum Emitters

18 November 2025
Cardiff University, Cardiff, UK

iop.org

IOP Institute of Physics

Programme

09:00 Arrival and refreshments

Session I: Epitaxy and Site Control of Emitters

09:15 (Invited) Exploring the MOVPE growth of Droplet Epitaxy InAs/InP Quantum Dots for Quantum Photonic Applications
Elisa Sala, University of Sheffield

09:45 In-situ pulsed laser interference patterning for the site-controlled MBE growth of III-V quantum dots
Mark Hopkinson, University of Sheffield/School of EEE

10:00 Laser activation of single group-IV colour centres in diamond
Andreas Thurn, University of Cambridge

10:15 InGaAs/GaAs:Sb quantum dot-in-nanowires as site-selective single photon emitters
Stephen Church, University of Salford

10:30 Laser-written quantum emitters in semiconductor
Yanzhao Guo, Cardiff University

10:45 Coffee Break

Session II: Optics of Quantum Emitters

11:15 (Invited) Controlled positioning and integration of coherent single photon emitters in hBN
Aymeric Delteil, University of Versailles

11:45 Exciting the Dark: Deterministic Optical Access to Quantum Dot Dark States
Yusuf Karli, University of Cambridge

12:00 Silane-assisted growth of room-temperature quantum emitters in gallium nitride
Katie Eggleton, Cardiff University

12:15 Resonance Fluorescence as a Highly Sensitive Probe of Spectral Diffusion in Nanowire Quantum Dots
Toby Rawlings, University of Sheffield

12:30 Sharp zero-phonon line emission in single CuInZnS3/ZnS Quantum Dots
Nasser Alhazmi, Cardiff University

12:45 Lunch and Posters

Session III: Photonic Integration

13:45 (Invited) Engineering optically-interfaced spin qubits in silicon carbide
Cristian Bonato, Heriot-Watt University

14:15 Enhanced photon emission from site- and energy-controlled quantum dots coupled to nanowire antennas
Benjamin Dwir, EPFL

14:30 Purcell enhanced and tunable single-photon emission from telecom quantum dots in circular photonic crystal resonators
Ginny Shooter, Toshiba Europe Limited, Cambridge Research Laboratory

14:45 Independently tuneable emitters coupled to a chiral photonic crystal waveguide
Dominic Hallett, University of Sheffield

15:00 Coherent Control of Quantum-Dot Spins with Cyclic Optical Transitions
Zhe Xian Koong, University of Cambridge

15:15 Refreshments, Posters and Exhibition

Session IV: From Devices to Systems

15:45 (Invited) UK Quantum dot integration and commercialisation of QD/cavity systems
Charlotte Ovenden, Aeqiq

16:15 Panel Discussion – Recent Progress and Future Challenges

17:15 Closing Remarks

Posters

P1 Creating diamond nanoparticles for Quantum Applications
Soumen Mandal, Cardiff University

P2 Shaping the near- and far-field emission of a site-controlled quantum dot in photonic crystal cavities
Biao Chen, Aalto University

P3 Density control of InGaN Quantum Dots Grown via Modified Droplet Epitaxy
Chunyu Zhao, University of Cambridge

P4 Correlating Morphology and Emission in InGaN Quantum Dots via Cathodoluminescence Spectroscopy
Zeki Semih Pehlivan, University Of Cambridge.

P5 Aspheric lens design proposal for near-perfect mode-matching of a broadband quantum dot micropillar to a single-mode fibre
David Dlaka, University of Bristol

P6 Site-controlled [111]-oriented GaAs Quantum Dots – Consequences of symmetry and light-hole states for excitonic properties
Neil O'Connor, Tyndall National Institute, University College Cork

P7 Colloidal quantum dot lasers throughout the short-wave infrared,
Guy L Whitworth, Kings College London

P8 Variational Polariton-Polaron Approach: Exciton–Cavity Interactions under Environmental Coupling
Barry Lynch, Tyndall National Institute / University College Cork School of Physics

P9 Site-control of InAs/InP quantum dots by droplet epitaxy in MOVPE with high optical quality
Guoliang Zhou, University of Sheffield

P10. Inkjet Printing Heavy-Metal-Free Quantum Dot LEDs for Flexible Displays and Optical Communications
Sri Datta Aneesh Chodavarapu, Cardiff University

P11. Improving Recombination in Quantum Dot Assemblies for lasing by concurrent Direct N-type doping of Quantum Dots and P-type modulation Doping
Lydia Jarvis, Cardiff University

P12. Spatial quantum-interference landscapes of multi-site-controlled quantum dots coupled to extended photonic cavity modes
Jiahui Huang, University of California

P13 Quantum Dot Telecom C-Band Single-Photon Sources
Anna Tomlinson, University of Sheffield

P14 Correlative Scanning Electron Microscopy for Exploring Quantum Emitters in GaN
Kimberly Nicholson, Cardiff University

P15 Calming Nuclear Spins in Quantum Dots to Extend Electron Spin Coherence Times
Thomas Bryce, University of Bristol

P16 Power-dependent Faraday spin pumping in single InAs/GaAs quantum dots
M. Alvarez Perez, Cardiff University

Sponsors

Institute for Compound Semiconductors (ICS)

The ICS has established a world-class compound semiconductor research and small scale manufacturing facility. Available to all on an Open Access basis, the ICS provides a platform for fabrication on wafers up to 200mm in diameter where researchers and industry can work together to progress academic research to a point where it can be translated reliably and quickly into the production environment. Part of Cardiff University, the ICS aims to be the UK facility of choice with worldwide recognition for stimulating, facilitating and enabling CS research. www.cardiff.ac.uk/institute-compound-semiconductors

Lambda Photometrics Ltd

Lambda Photometrics is a leading supplier of characterisation, measurement and analysis equipment, applied to signals from DC to Light. From fundamental materials research to volume manufacture, our consultative approach ensures you receive the best advice and get the best solution for your needs. Representing world leading manufacturers and providing full consultation and application support, we specialise in microscopy, optical metrology, vision systems, laser systems and accessories, EO&IR test, spectroscopy, fibre optics & scientific instrumentation. www.lambdaphoto.co.uk

Laser 2000 (UK) Limited

Laser 2000 UK is a value-added reseller of photonics products, including lasers, optical and fibre optic components, and telecoms systems. With a highly qualified team and trusted global suppliers, we support academic, government, research, and industrial clients by delivering tailored solutions and expert technical support for every application. www.laser2000.co.uk

PIKEM

PI-KEM LTD is a specialist supplier of advanced materials and equipment, enabling innovative research and production across science and technology. For over 30 years, we've supported the semiconductor industry, providing standard and custom products through our trusted global partners leveraging niche sourcing & bespoke manufacturing. Our materials offering includes II–VI & III–V semiconductor wafers, single crystals, hBN, coating materials, substrates, wafers, and materials for quantum dot and quantum well research. www.pi-kem.co.uk

Quantum Design UK and Ireland

At Quantum Design UK and Ireland, we're passionate about providing high-tech scientific instrumentation to researchers, universities, and industries across the UK and Ireland. We are confident that our suite of cryogenic instrumentation represents the ideal solution for advancing research into new materials and driving innovation, particularly in optical quantum computing and QUBIT technology. But more than just supplying instruments, we work closely with our customers to understand their unique research challenges and help them find the best solutions.
qd-uki.co.uk

Toptica Photonics Ltd

TOPTICA's cutting edge laser systems combine world class specifications with highest precision, reliability and longevity. By providing high-power lasers even at exotic wavelengths TOPTICA is renowned for the widest wavelength coverage of state-of-the-art lasers on the market. www.toptica.com

Session I: Epitaxy and Site Control of Emitters

(Invited) Exploring the MOVPE growth of Droplet Epitaxy InAs/InP Quantum Dots for Quantum Photonic Applications

Elisa Sala[1]
[1] University of Sheffield, UK

We study the Droplet Epitaxy (DE) in Metal Organic Vapour Phase Epitaxy (MOVPE) of InAs/InP quantum dots (QDs) for applications in quantum photonics at the telecom C-band. Among III-V QDs, InAs/InP are very attractive as high-performance single and entangled photon sources. Here, we investigate their growth dynamics in MOVPE on different surfaces and present detailed morphological and optical characterizations, revealing bright single-dot emission covering the C-band. Recently, the Purcell enhancement of single photons at the C-band from such InAs DE QDs has been reported, alongside the first demonstration of both Stark tuning and charge state control of individual QDs. We also present a novel approach of site-control of such QDs by DE in nanohole arrays, showing localization of droplets and their subsequent crystallization into QDs. Such method is decoupled from strain and thus differs from the traditional Stranski-Krastanov (SK). Finally, we present preliminary results on local droplet etching (LDE) studies on bare InP by using Indium droplets for the first time in MOVPE. Our studies explore the flexibility of the droplet epitaxy in the MOVPE environment for the large-scale fabrication of a broad range of high-quality nanostructures for quantum photonics at the telecom C-band.

In-situ pulsed laser interference patterning for the site-controlled MBE growth of III-V quantum dots

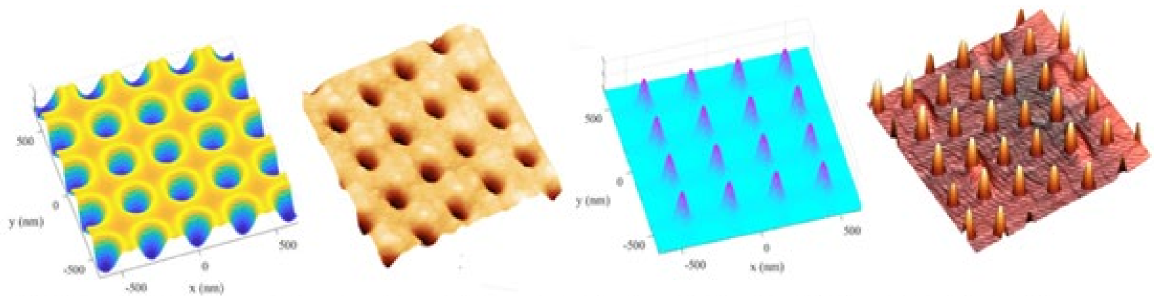
Mark Hopkinson[1], Yun Ran Wang[1], and Im Sik Han[3]
[1]University of Sheffield, UK

The spontaneous formation of nanometer-sized epitaxial islands by self-assembly has enabled significant progress in the development of III-V quantum dots (QDs) and their application to quantum photonic components. However, integrating lithographic techniques for site-control is a requirement for future device architectures. A significant body of work exists using ex-situ pre-pattern and etch approaches. However, this adds complexity to the manufacturing process which makes process integration challenging and time-consuming. There is also significant contamination risk. We have therefore looked for vacuum compatible direct-write alternatives.

In our study, we highlight the successful integration of direct laser interference patterning (DLIP) with molecular beam epitaxy (MBE) to achieve precise site control in a single, streamlined process, removing the need for additional ex-situ processing and re-growth. Our method employs a four-beam laser interference system, generated by splitting a beam from a Q-switched solid-state laser, which emits single pulses of 7 ns duration at a wavelength of 355 nm. These beams are directed onto the substrate through optical vacuum viewports at a 58° incidence angle. This configuration results in a square array

pattern with a lattice pitch of 200-300 nm, dictated by the angle and polarization state. We have performed single-pulse DLIP on MBE-grown surfaces to create periodic islands attributable to adatom surface diffusion influenced by a localized thermal gradient produced by the laser pulse.

The formation of these periodic nanoislands establishes effective nucleation sites for the formation of QDs through the Stranski-Krastanov process and through this we can build arrays with pitches of 200-300 nm. Depending on the nanoisland size and deposition amount, we can fine-tune the number of quantum dots per site. Moreover, we have accomplished site control of group III liquid droplet formation, allowing for the creation of droplet QD arrays in systems such as GaAs/AlGaAs with superior optical properties. Additionally, our approach enables the structuring of silicon wafers, opening new avenues for III-V/Si integration.



Simulated interference patterns and the resulting surface structures. Left shows the formation of nanoholes and right shows the accumulation of islands to form quantum dots

Laser activation of single group-IV colour centres in diamond

Xingrui Cheng[1,2], **Andreas Thurn**[2,3], Guangzhao Chen[1], Gareth S. Jones[1], James E. Bennett[1], Maddison Coke[4], Mason Adshead[4,5], Cathryn P. Michaels[3], Osman Balci[6], Andrea C. Ferrari[6], Mete Atatüre[3], Richard J. Curry[4,5], Jason M. Smith[1], Patrick S. Salter[2], and Dorian A. Gangloff[2,3]

[1]Department of Materials, University of Oxford, UK, [2]Department of Engineering Science, University of Oxford, UK, [3]Cavendish Laboratory, University of Cambridge, UK, [4]Photon Science Institute, Faculty of Science and Engineering, University of Manchester, UK, [5]Department of Electrical and Electronic Engineering, Faculty of Science and Engineering, University of Manchester, UK, [6]Department of Engineering, University of Cambridge, UK

Spin-photon interfaces based on group-IV colour centres in diamond offer a promising platform for quantum networks. A key challenge in the field is realising precise single-defect positioning and activation, which is crucial for scalable device fabrication. Here we address this problem by demonstrating a two-step fabrication method for tin vacancy centres that uses site-controlled ion implantation followed by local femtosecond laser annealing with in-situ spectral monitoring [1]. The ion implantation is performed with sub-50 nm resolution and a dosage that is controlled from hundreds of ions down to single ions per site, limited by Poissonian statistics. Using this approach, we successfully demonstrate site-selective creation and modification of single tin vacancy centres. Our in-situ spectral monitoring opens a window onto materials tuning at the single defect level, and provides new insight into defect structures and dynamics during the annealing process. While demonstrated for tin vacancy centres, this versatile approach can be readily generalised to other implanted colour centres in diamond and wide-bandgap materials.

[1] Cheng, X., Thurn, A., Chen, G. et al. Laser activation of single group-IV colour centres in diamond. Nat. Commun. 16, 5124 (2025).

InGaAs/GaAs:Sb quantum dot-in-nanowires as site-selective single photon emitters

Stephen Church[1,4], Hyowon Jeong[2], Markus Döblinger[3], Akhil Ajay[2], Benjamin Haubmann[2], Jonathan Finley[2], Patrick Parkinson[4], and Gregor Koblmüller[2,5]
[1]Materials and Physics Research Group, University of Salford, UK [2]Walter Schottky Institute, TUM School of Natural Sciences, Technical University of Munich, Germany, [3]Department of Chemistry and Center for NanoScience, Ludwig-Maximilians-Universität München, Germany, [4]Department of Physics and Astronomy & Photon Science Institute, University of Manchester, UK [5]Technical University of Berlin, Germany

We utilize nano-heteroepitaxy to incorporate InGaAs axial QDs into selective-area MBE-grown GaAs:Sb nanowires (Fig. 1a) [1]. This enables the emitters to be positioned at specific locations for coupling into photonic circuits (Fig. 1b), and the properties can be tuned by modifying the QD axial position, size and composition. Precise control of the quantum dot is achieved through catalyst-free nanowire growth which is facilitated through Sb-doping of the GaAs nanowire core [2]. We use high-throughput micro-spectroscopy to explore the photoluminescence (PL) properties of 10,000's of individual QDs (Fig. 1c) [3] and use this information to inform subsequent growths to improve the repeatability and quality of the QDs. The same QDs are cooled to 4K and an automated procedure is used to determine their PL spectra and single photon statistics (Fig. 1d) - we will present the results of these measurements and report on progress towards the goal of a 2nd order autocorrelation function (g2(0)) of less than 0.5 (Fig. 1e).

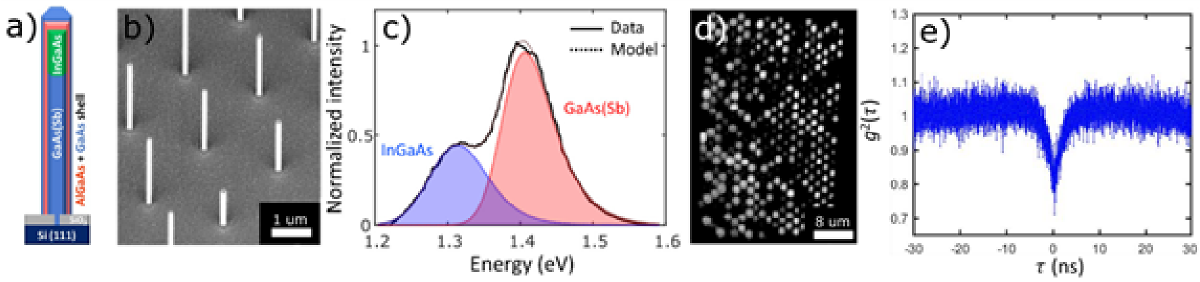


Figure 1.(a) Schematic of nanowire structures, (b) SEM image of nanowires, (c) 300K PL spectrum of one nanowire, (d) 5K single photon map of 400 QDs, (e) g^2 measurement of one QD.

[1] H. W. Jeong et al, ACS Appl. Nano. Mater. 7: 3032-3041 (2024).
[2] A. Ajay et al, Appl. Phys. Lett. 121: 072107 (2022).
[3] H. W. Jeong et al, Nano Lett. 24: 14515-14521 (2024).

Laser-written quantum emitters in semiconductor

Yanzhao Guo[1], Giulio Coccia[2], Federico Gorrini[5], Vibhav Bharadwaj[3], Vinaya Kumar Kavatamane[4], Roberta Ramponi[2], Paul E Barclay[4], Alexander Kubanek[6], Angelo Bifone[7], John P Hadden[1], Shane M Eaton[2], Anthony J Bennett[1]
[1]School of Engineering, Cardiff University, UK [2]Department of Physics, Politecnico di Milano, Piazza Leonardo da Vinci, 32, 20133 Milano, , Italy, [3]Department of Physics, Indian Institute of Technology, India , [4]Institute for Quantum Science and Technology, University of Calgary, Canada, [5]Department of Molecular Biotechnology and Health Sciences, University of Torino, Italy, [6]Institute for Quantum Optics, Ulm University, Germany, [7]Institute for Photonics and Nanotechnologies (IFN)–CNR, Italy

Quantum emitters in semiconductors are leading quantum platform at room temperature, which hardness advanced quantum applications, such as light-matter interaction, hybrid quantum processing, and high-resolution and high-sensitivity sensing. However, due to the complex coupling to the solid-state environment, it is still a challenge to fabricate quantum emitters with both excellent optical and spin coherence properties. One solution is to use the photonics structure and advanced fabrication to improve these properties of the well-understood quantum emitters, such as highly coherent negatively charged nitrogen-vacancy centres in the photonics structure. Another path is to keep looking for and identifying novel quantum emitters with superior properties in semiconductors with better growth processes and commercial availability. Recently, laser writing has emerged as a powerful tool to fabricate the quantum emitters in semiconductors. Due to its highly controllable fabrication, the quantum emitters can be deterministically created via laser writing. In particular, these laser-written quantum emitters exhibit excellent spin coherence properties and spectral properties.

We fabricated highly coherent single and ensemble laser-written waveguide-integrated NVs in diamond, which possess coherence times comparable to native NVs. We also employ a laser writing approach to prepare the bright quantum emitters with near MHz count in aluminum nitrides and gallium nitrides. We used the time resolution photoluminescence spectrum and photon emission correlation spectrum to investigate the photodynamics of these quantum emitters. Our study paves the way for scalable photonics circuits based on the quantum emitters in semiconductors, and also provides important information for the creation mechanism of quantum emitters in semiconductors.

Session II: Optics of Quantum Emitters

(Invited) Controlled positioning and integration of coherent single photon emitters in hBN

A. Delteil[1]
[1] Université Paris-Saclay, France

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 [1]. The B centers are created by local irradiation in a scanning electron microscope (fig. 1). I will first present their optical properties, including coherence, indistinguishability and quantum efficiency, inferred using quantum optics techniques, such as resonant laser excitation [2-4], Hong-Ou-Mandel interference [5,6] and the Purcell effect [7]. I will also present their controlled integration into monolithic photonic devices [8]. Altogether, the controlled generation of coherent quantum emitters in a 2D material opens appealing perspectives in quantum photonics, with applications in optical quantum technologies.

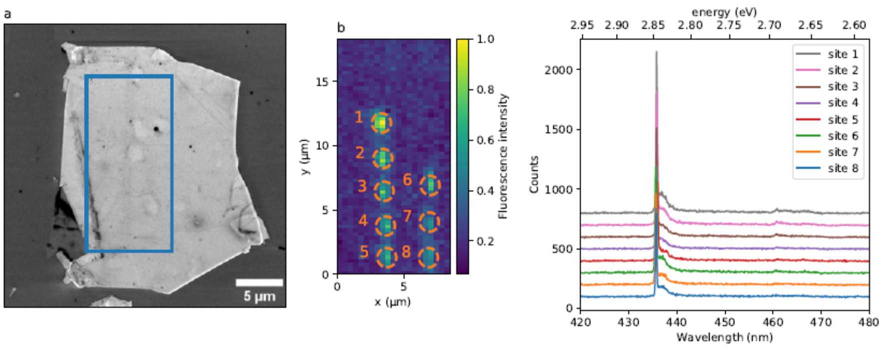


Fig. 1 (a) hBN flake (single crystal of a few tens of nanometers thickness).
(b) Confocal photoluminescence map showing color center luminescence in 8 irradiation sites.
(c) Emission spectra of the eight sites, revealing similar narrow emission lines.

[1] C. Fournier *et al.*, Nature Commun. 12, 3779 (2021).
[2] C. Fournier *et al.*, Phys. Rev. B 107, 195304 (2023).
[3] D. Gérard *et al.*, arXiv:2411.07202 (2024).
[4] A. Delteil *et al.*, Phys. Rev. B 109, 155308 (2024).
[5] C. Fournier *et al.*, Phys. Rev. Appl. 19, L041003 (2023).
[6] D. Gérard *et al.*, arXiv:2506.16980 (2025)
[7] D. Gérard *et al.*, ACS Photonics 11, 5188 (2024).
[8] D. Gérard *et al.*, Appl. Phys. Lett. 122, 264001 (2023).

Exciting the Dark: Deterministic Optical Access to Quantum Dot Dark States

Yusuf Karli[1], Florian Kappe[2], René Schwarz[2], Armando Rastelli[3], Vikas Remesh[2], Doris Reiter[4], and Gregor Weihs
[1]University of Cambridge, UK, [2]University of Innsbruck, Austria, [3]JKU Linz, Austria [4]TU Dortmund, Germany

Quantum dots offer a high-quality, on-demand source of single and entangled photons, making them ideal candidates for quantum computation and secure quantum communication. New excitation strategies, such as the use of chirped pulses in combination with stimulated two-photon excitation (sTPE) [2,3], enable not only high-fidelity single-photon generation with near-unity exciton or biexciton state preparation, but also minimize re-excitation and spectral filtering requirements.Positively chirped pulses have been shown to provide plug-and-play-level robustness in single-photon generation. Furthermore, the use of chirped pulses for precise population inversion and access to spin-forbidden dark states, enabling coherent optical control of a full few-level quantum system. In this work, we demonstrate all-optical storage and retrieval of the spin-forbidden dark exciton in a quantum dot from the ground state using chirped pulses and an in-plane magnetic field [1]. Our scheme enables full optical control of dark states without relying on any preceding radiative decay.

[1] Kappe, F., Schwarz, R., Karli, Y., et al. (2025). Keeping the Photon in the Dark: Enabling Full Quantum Dot Control by Chirped Pulses and Magnetic Fields. Science Advances, 11(28).
[2] Karli, Y., Schwarz, R., Kappe, F., et al. (2024). Robust Single-Photon Generation for Quantum Information Enabled by Stimulated Adiabatic Rapid Passage. Appl. Phys. Lett. 125, 254002
[3] Karli, Y., Vajner, D. A., Kappe, F., et al. (2024) Controlling the Photon Number Coherence of Solid-state Quantum Light Sources for Quantum Cryptography. npj Quantum Inf, 10, 17.

Silane-assisted growth of room-temperature quantum emitters in gallium nitride

Katie Eggleton[1], Joseph Cannon[1], Sam Bishop[1], John Hadden[1], Chunyu Zhao[2], Menno Kappers[2], Rachel Oliver[2], and Anthony Bennett[1]
[1]Cardiff University, UK, [2]University of Cambridge, UK

There is a growing interest in room-temperature (RT) quantum emitters (QEs) that can be implemented in practical and scalable photonic applications. Among various host materials, QEs in wide band gap semiconductors have emerged as leading candidates. GaN, in particular, has demonstrated capability to host bright, stable QEs with high Debye-Waller factors, some of which have been reported to emit at telecoms wavelengths [1]. Heteroepitaxial growth of gallium nitride on silicon substrates offers the opportunity to leverage existing expertise and wafer-scale manufacturing, to integrate bright quantum emitters in this material inside cavities, diodes and photonic circuits. Until now it has only been possible to grow GaN quantum emitters at uncontrolled depths on sapphire substrates, which is disadvantageous for potential device architectures.

We report quantum emitters in gallium nitride, grown by metal-organic vapour phase epitaxy on silicon substrates, that emit quantum light at RT with a high Debye-Waller factor and strongly anti-bunched emission. We report low-density growth of these QEs at a controlled depth, away from the highly-defective epilayer-substrate interface region, by application of a silane treatment and subsequent growth of 3D islands. These results establish GaN on Si as a viable and scalable platform for integrated RT quantum photonic devices and opens new pathways for III-V and Si-based quantum technologies.

[1] Y. Zhou et al., "Room temperature solid-state quantum emitters in the telecom range," Science Advances, vol. 4, no. 3, p. eaar3580, 2018.

Resonance Fluorescence as a Highly Sensitive Probe of Spectral Diffusion in Nanowire Quantum Dots

Toby Rawlings[1], Catherine Phillips[1], Jake Iles-Smith[1], Philip Poole[2], Dan Dalacu[2], and Alistair Brash[1]
[1]University of Sheffield, UK, [2]National Research Council Canada, Canada

Quantum dot (QD) devices experience charge noise which results from an unstable electrostatic environment. This can cause a time-varying shift in the QD resonance known as spectral diffusion (SD). This noise can be highly complex, with timescales from nanoseconds up to microseconds present. Accurate 11haracterize11ion is necessary to select the best devices and develop a deeper understanding of the underlying physics.

We present a 11haracterize11ion technique for SD based on measuring the second-order correlation function (g(2)(t)) under resonance fluorescence, which combines both exemplary spectral and temporal resolution, allowing multiple timescales to be accessed in a single measurement. Furthermore, it allows access to the time-dynamics of the emitter indistinguishability when SD is the dominant noise process. This could be applied to 11haracterize SD in any quantum emitter.

We go on to apply this technique to study the emission of InAs/InP nanowire QDs under resonance fluorescence. These have numerous benefits including site-controlled growth, highly efficient in- and out-coupling of light and deterministically controlled confinement lengths. However, they can suffer from significant charge noise due the proximity of the QD to the nanowire surface. We investigate the influence of additional above-band excitation on the linewidth of the QD and the dynamics of SD. Finally, we perform HOM indistinguishability measurements to demonstrate that g(2)(t) fully reproduces the time dynamics of the indistinguishability.

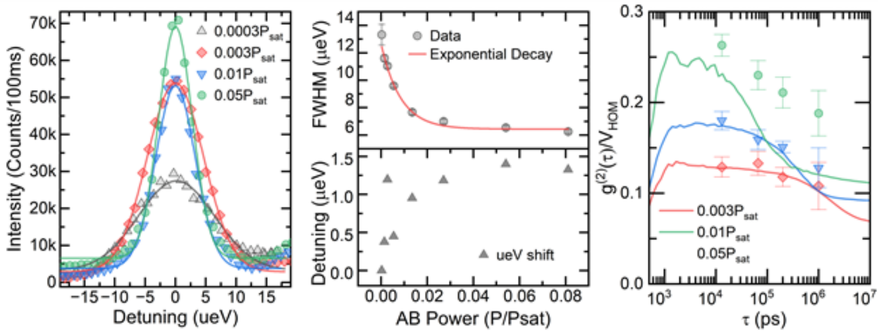


Figure 1: a) QD linewidth measured under resonance fluorescence with increased application of above-band excitation power expressed as a function of saturation power Psat.
b) QD linewidth and detuning as a function of above-band excitation power.
c) g(2)(t) measurements at different above-band excitation powers overlayed with HOM visibility measurements under the same conditions

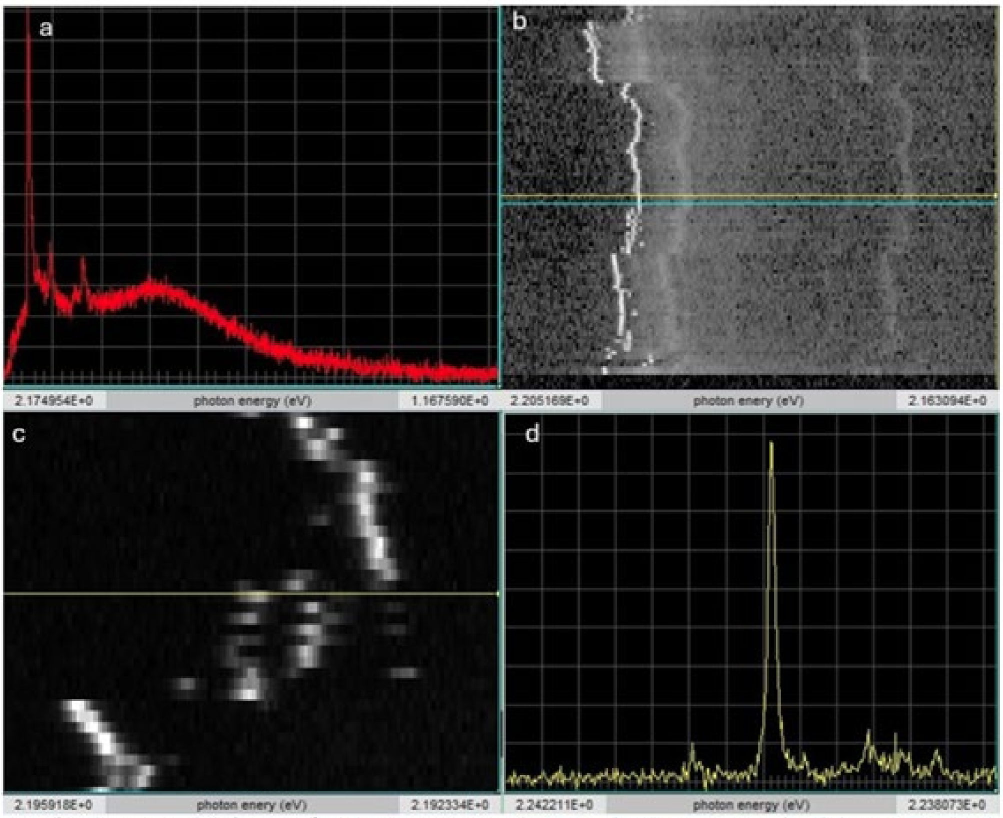
Sharp zero-phonon line emission in single CuInZnS3/ZnS Quantum Dots

Nasser Alhazmi[1], Wolfgang Langbein[1], and Bo Hou[1]
[1]Cardiff University, UK

CuInZnS3 colloidal quantum dots (QDs) are promising in solar cells, lighting, energy storage and image sensors [1,2]. However, the suitability for quantum technology applications such as single photon sources has not been explored [3]. This study investigates the photon of single QDs at low temperature.

Sharp zero-line phonon lines were observed in the emission of CuInZnS3/ZnS thick shell single QD at temperature 5K, and linewidths down to 70 μeV were found. Spectral wandering was found to be strongly dependent on the individual QD, with some showing very stable emission over minutes to hours. Moreover, phonon replica from both acoustic and optical phonons were observed, as well as a broad emission attributed to polaron formation and phonon assisted decay, enabled by hole trapping in Cu d bands. These findings are exemplified in the figure.

[1] B. Hou et al., Nano Energy 62, 771 (2019) doi.org/10.1016/jnanoen.2019.05.088
[2] Chenghui Xia et al., ACS Nano.21 , 17573 (2021), doi.org/10.1021/acsnano.1c04909
[3] S.O.M. Hinterding et al., Nano Led.21, 658 (2021), doi.org/10.1021/acs.nanoled.0c04239



Emission of single quantum dot of $CuInZnS_3/ZnS$ at 5K temperature under 532nm a) Wide spectra range (1 eV) showing ZPL merged with acoustic phonon sideband, an optical phonon sideband, and an about 170 meV shifted line of unknown origin. b) Time trace for the same QD on a logarithmic grey scale over 3 orders magnitude, 5s per spectrum using a high resolution spectra, 42meV range. c) as b) but on a linear greyscale over a selected 3.6meV range to exemplify ZPL spectral wandering. d) selected narrow ZPL spectrum of another QD over a 2.6meV range, showing a 70 μeV width.

Session III: Photonic Integration

(Invited) Engineering optically-interfaced spin qubits in silicon carbide

Cristian Bonato
Heriot Watt University, UK

I will present some of our group's working in developing quantum technologies based on single spins in silicon carbide [1], a semiconductor which uniquely combines excellent spin properties with mature microelectronics and promising photonics.

In the first part of my talk, I will present our work on single vanadium centres in SiC, emitting in the telecom O-band [2]. I will discuss the optical selection rules at the basis of spin-photon interfacing, and how material engineering (doping, isotopic composition) can be used to tune the quantum emitters properties, in terms of charge state control and tailoring of optical emission. In particular, we have shown that, by engineering the isotopic composition of the SiC matrix, we reduce the inhomogeneous spectral distribution of different emitters down to 100 MHz, significantly smaller than any other single quantum emitter [2].

In the second part of my talk, I will discuss our progress in fabricating large arrays of photonic microstructures [3] to enhance photon collection efficiency, and in marker-free registration of single quantum emitters aligned to solid immersion lenses by femtosecond laser writing [4].

[1] S. Ecker et al, "Quantum communication networks with defects in silicon carbide", arXiv:2403.03284 (2024)
[2] P. Cilibrizzi et al, "Ultra-narrow inhomogeneous spectral distribution of telecom-wavelength vanadium centres in isotopically-enriched silicon carbide", Nature Communications 14, 8448 (2023)
[3] C. Bekker et al, "Scalable fabrication of hemispherical solid immersion lenses in silicon carbide through grayscale hard-mask lithography", Applied Physics Letters 122, 173507 (2023)
[4] A. R. Jones et al, "Scalable registration of single quantum emitters within solid immersion lenses through femtosecond laser writing", Nano Letters 25, 30, 11528 (2025)

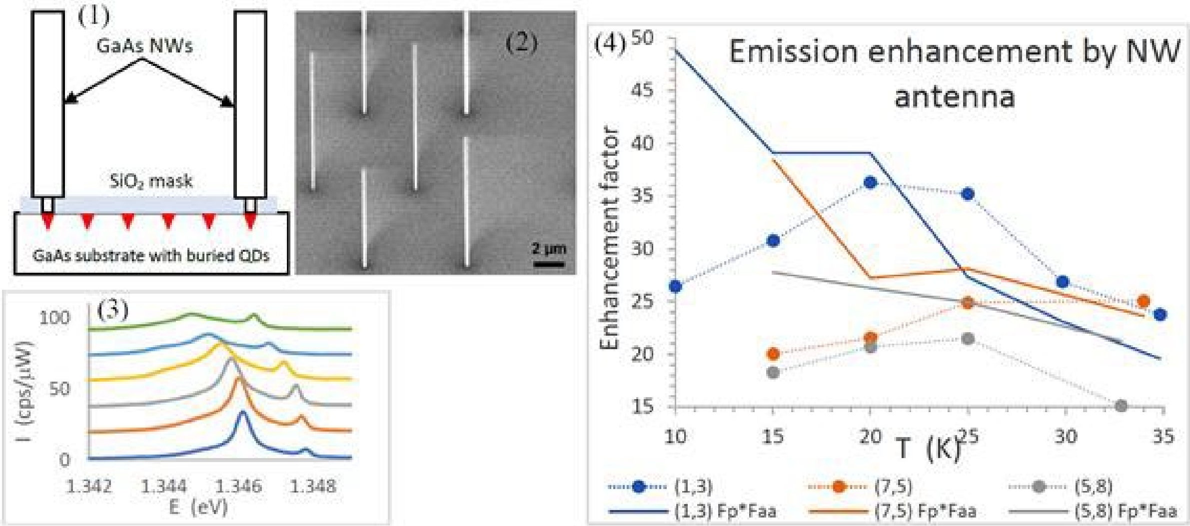
Enhanced photon emission from site- and energy-controlled quantum dots coupled to nanowire antennas

Benjamin Dwir
EPFL, Lausanne, Switzerland

InGaAs quantum dots (QDs) embedded in a GaAs substrate are very useful single and entangled photon sources, due to their unperturbed environment. Such QDs, grown by MOVPE inside inverted pyramidal pits etched into the substrate, allow deterministic position- (±20nm) and energy (few 10meV) control, making them ideal for scalable integrated optical systems[1]. Unfortunately, they suffer from low collection efficiency, due to the high GaAs refraction index leading to poor emission angle (<10°).

Here we show a novel approach to enhancing photon emission from position and energy controlled QDs, by growing aligned GaAs vertical nanowire (NW) antennas on top of them, using masked selective-area growth MOVPE (See schematic diagram in Fig.1 and SEM image in Fig.2). Better index matching and cavity effects in the NWs enhance the coupled QD emission, compared to non-coupled QDs[2].

The emission was measured by low-temperature photoluminescence, showing typical sharp QD emission lines (Q≈4000), as seen in Fig.3, but with enhanced power from the QD-NW devices. The enhancement factor (full lines, Fig.4) was temperature-dependent, due to resonance effect of NW modes with QD emission. It can be explained (dotted lines) as a combination of the Purcell effect in the NWs Fp and the increased radiation acceptance angle by the NW Faa. The observed enhancement of up to x36 shows the high potential of this approach to obtain improved single-photon sources for quantum photonics applications.



[1] Irina V. Kulkova et al., Jour. Crystal Growth 464, 69-74 (2017).
[2] B. Dwir, Optics and Laser Technology, 181, 111934 (2025).

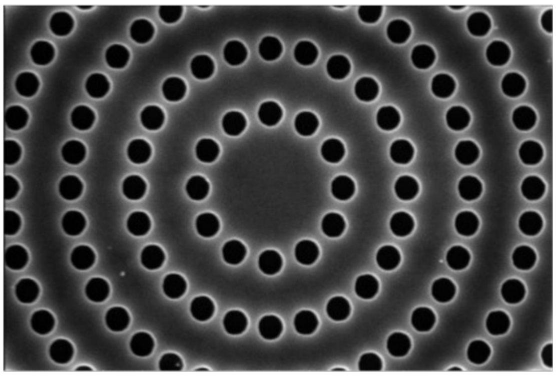
Purcell enhanced and tunable single-photonvemission from telecom quantum dots in circular photonic crystal resonators

Andrea Barbiero[1], **Ginny Shooter**[1], Joanna Skiba-Szymanska[1], Junyang Huang[1], Loganathan Ravi[2], J. Iwan Davies[2], Benjamin Ramsay[2], David. J.P. Ellis[3], Andrew .J Shields[1], Tina Müller[1], and R. Mark Stevenson[1]
[1]Toshiba Europe Limited, UK [2]IQE Europe Limited, UK, [3]Cavendish Laboratory, University of Cambridge, UK

III-V semiconductor quantum dots (QDs) are promising candidates for single and entangled photon sources for quantum network applications. Their direct emission at telecom wavelengths enables compatibility with installed fiber networks, with different material compositions and strain engineering affording coverage of both the O-band and C-band. The advent of circular Bragg gratings (CBGs) with a backside gold mirror has lead to an explosion in demonstrations of bright photon sources.

The integration of semiconductor QDs into diode structures using standard doping techniques can unlock wavelength tunability, deterministic charging, and enhanced coherence. However, conventional CBGs have fully etched rings which would electrically isolate the central mesa containing the QD from any electrical contacts. In a recent work [1], a variant on the conventional CBG design was simulated for the telecom C-band, featuring rings of holes rather than continuous rings, but experimental implementation is still outstanding.

We first demonstrate Purcell-enhanced C-band single-photon emission with InAs/InP QDs, displaying brightness comparable to conventional ring CBGs, with a 20 MHz photon detection rate [2]. We then realise electrically contacted circular photonic crystal resonators with InAs/GaAs QDs, enabling wavelength tuneability in the telecom O-band [2]. These results show significant progress toward bright scalable and tunable quantum light sources.



⊢⊣ = 500 nm

[1] C. Ma, et al, Circular photonic crystal grating design for charge-tunable quantum light sources in the telecom c-band, Optics express 32, 14789 (2024).
[2] A. Barbiero, et al, Purcell enhanced and tunable single-photon emission at telecom wavelengths from InAs QDs in circular photonic crystal resonators. arXiv:2505.11069. (2025)

Independently tuneable emitters coupled to a chiral photonic crystal waveguide

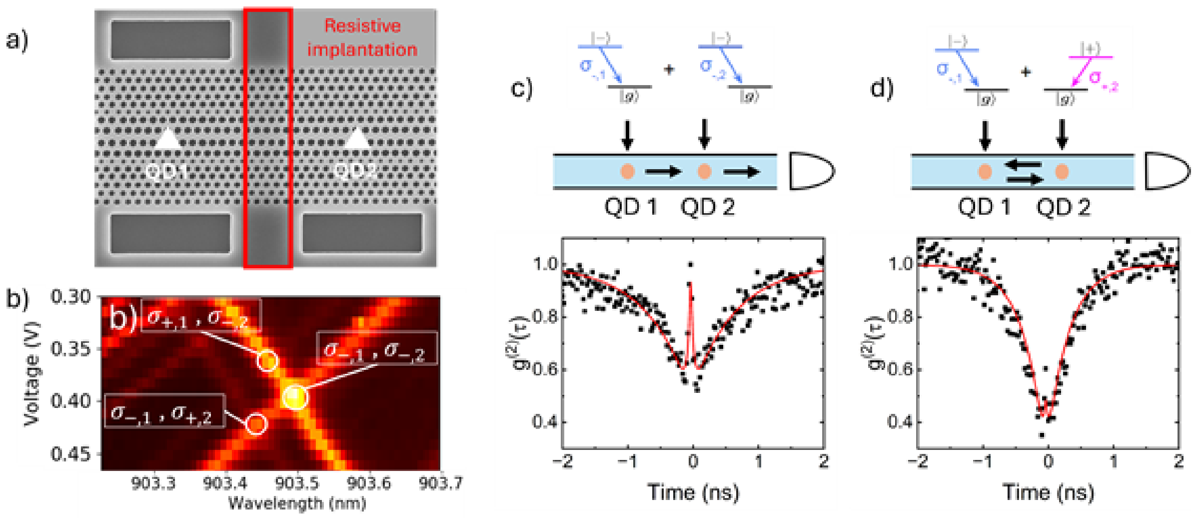
Dominic Hallett[1], Luke Hallacy[1], Aspen Fenzl[1], Nick Martin[1], Rene Dost[1], Akshay Verma[2], Julian Fletcher[3], Ian Farrer[2], Luke Antwis[3], Maurice Skolnick[1], and Luke Wilson[1]
[1]School of Mathematics and Physical Sciences, University of Sheffield, UK, [2]School of Electronic and Electrical Engineering, University of Sheffield, UK [3]Ion Beam Centre, University of Surrey, UK

A key challenge in scaling systems of quantum dots is making different QDs in a device indistinguishable. Variations in QD formation lead to an inhomogeneous ensemble of emission energies. Post-growth tuning is essential to bring multiple QDs into resonance.

QD wavelength can be tuned using several mechanisms - most notably temperature, strain, magnetic and electric fields. Of these methods, electric tuning allows fast, local and reversible tuning, making it the obvious choice for scaling a system of QDs. A key challenge in this system is enabling separate electrical control of different QDs without compromising the photonic properties of the device.

We present a scalable, non-destructive method for electrical tuning of multiple quantum dots embedded in photonic crystal waveguides. Ion implantation is used to create high-resistance barriers that enable separate Stark tuning of different sections of the device. As this method doesn't require etching the structure, the photonic properties of the waveguide are unaffected. We use this technique to realise a system of two chirally-coupled QDs.

Using a combination of individual electric tuning, and Zeeman splitting, we tune different spin states of the QD into resonance. Photon correlation measurements show an interaction between the spin states that are coupled to the same propagating direction in the waveguide, while states coupled to opposite directions do not interact.



Coherent Control of Quantum-Dot Spins with Cyclic Optical Transitions

Zhe Xian Koong[1], Urs Haeusler[1], Jan Kaspari[2], Christian Schimpf[1], Benyam Dejen[1], Ahmed Hassanen[3], Daniel Graham[1], Ailton Garcia Jr.[4], Melina Peter[4], Edmund Clarke[5], Maxime Hugues[6], Armando Rastelli[4], Doris Reiter[2], Mete Atatüre[1], and Dorian Gangloff[1]
[1]University of Cambridge, UK, [2]TU Dortmund University, Germany, [3]University of Oxford, UK, [4]Johannes Kepler University, Linz, Austria, [5]University of Sheffield, UK, [6]CNRS, CRHEA, France

Solid-state spins are promising as interfaces from stationary qubits to single photons for quantum communication technologies. Semiconductor quantum dots have excellent optical coherence, exhibit near-unity collection efficiencies when coupled to photonic structures, and possess long-lived spins for quantum memory. However, the incompatibility of performing optical spin control and single-shot readout simultaneously has been a challenge faced by almost all solid-state emitters. To overcome this, we leverage light-hole mixing to realize a highly asymmetric lambda system in a negatively charged heavy-hole exciton in Faraday configuration. By compensating GHz-scale differential Stark shifts, induced by unequal coupling to Raman control fields, and by performing nuclear-spin cooling, we achieve quantum control of an electron-spin qubit with a π-pulse contrast of 97.4 % while preserving spin-selective optical transitions with a cyclicity of 409. We demonstrate this scheme for both GaAs and InGaAs quantum dots, and show that it is compatible with the operation of a nuclear quantum memory. Our approach thus enables repeated emission of indistinguishable photons together with qubit control, as required for single-shot readout, photonic cluster-state generation, and quantum repeater technologies.

Session IV: From Devices to Systems

(Invited) UK Quantum dot integration and commercialisation of QD/cavity systems

Charlotte Ovenden
Aeqiq, UK

In this talk I will introduce Artemis, Aegiq's first generation quantum computer, deployed to the UK National Quantum Computing Centre (NQCC). Artemis is a technology demonstrator designed to showcase the advantages of combining compound semiconductor quantum dot light sources with low-loss silicon nitride integrated photonic circuits for quantum computing. I will highlight some of the engineering challenges that we have faced, inherent to rapid technology development.

Posters

P1. Creating diamond nanoparticles for Quantum Applications

Soumen Mandal[1], and Oliver Williams[1]
[1]Cardiff University, UK

Diamond nanoparticles with colour centres offer exceptional quantum potential due to stable spin states, room-temperature coherence, biocompatibility, scalability, and strong photonic emission, enabling sensing, communication, and quantum information technologies. In this study, the fabrication of nanoparticles from bulk diamond is explored [1]. Bulk diamond plates containing colour centres are processed in a planetary mill with grinding balls. Two milling materials were tested: tempered steel and silicon nitride. While tempered steel introduces iron oxide contamination that is difficult to remove, silicon nitride avoids this but produces more non-diamond carbon. Therefore, the choice of milling material depends critically on the acceptable level of contaminants for the intended application. Commercially available nanodiamond particles often contain metallic impurities [2], making them unsuitable for many quantum and biological applications. In addition, their nitrogen content typically exceeds 100 ppm, which significantly reduces NV^- spin coherence times and consequently lowers sensitivity [3]. Milled diamond has enabled the levitation of nanodiamonds without excessive heating, creating a platform to explore diverse quantum phenomena [4]. Furthermore, nanodiamonds with colour centres derived from milling demonstrate long coherence times [5,6], which are absent in commercially available particles.

[1] Gines et al. ACS Omega 3, 16099 (2018)
[2] Volkov et al. Carbon 74, 1 (2014)
[3] Ronding et al. Rep. Prog. Phys. 77, 056503 (2014)
[4] Frangeskou et al. New J. Phys. 20, 043016 (2018)
[5] Wood et al. Phys. Rev. B 105, 205401 (2022)
[6] March et al. Phys. Rev. Appl. 20, 044045 (2023)

P2. Shaping the near- and far-field emission of a site-controlled quantum dot in photonic crystal cavities

Andriy Shevchenko[1], **Biao Chen[1]**, Alexey Lyasota[2], and Elyahou Kapon[3]
[1]Aalto University, Espoo, Finland, [2]University of New South Wales, Australia, [3]École Polytechnique Fédérale de Lausanne, Switzerland

Photonic crystal (PhC) cavities are among the smallest optical resonators with high quality factors, and semiconductor quantum dots (QDs) are among the most stable point-like emitters of photons. By combining QDs with PhC structures, one can create compact photonic devices that can operate in both classical and quantum regimes. The emission of the QD can be shaped by placing it in a PhC cavity and thereby tailoring the local density of states, as well as by using photonic mode interference inside and outside the cavity.

Considering quantum dots at prescribed positions in a PhC cavity, experimentally implemented with a precision of ~20nm, we find that the interference of the two decay paths of the QD exciton through the cavity mode and directly to free space can significantly affect the emission due to quantum interference [1]. For example, by adjusting the location of the quantum dot in the cavity and the mode-exciton energy detuning, one can suppress the free-space radiation loss and increase the quantum efficiency of the emission into the cavity. Moreover, at certain positions of the QD, the detuning can make the emission profile highly asymmetric (see Fig. 1), which can be used, e.g., to create on-chip photonic switches and spatially tunable single-photon sources [2]. We study these effects both experimentally and theoretically.

[1] A. Lyasota, et al., Phys. Rev. X 12, 021042 (2022).
[2] J. Huang, et al., Commun. Phys. 8, 152 (2025).

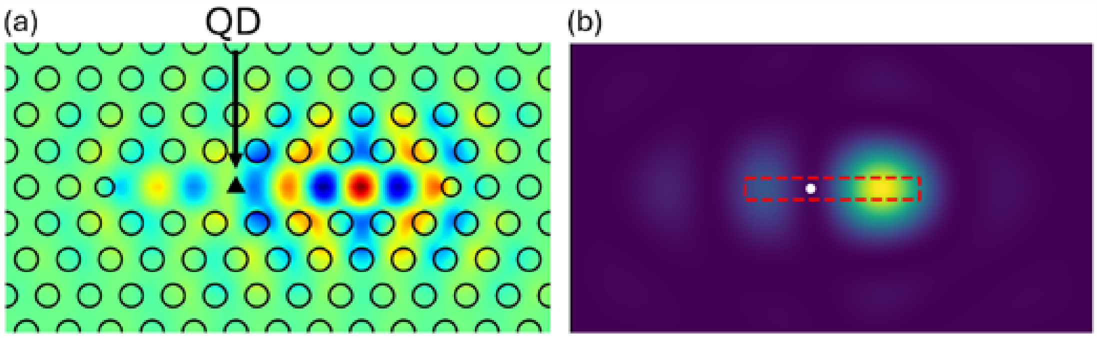
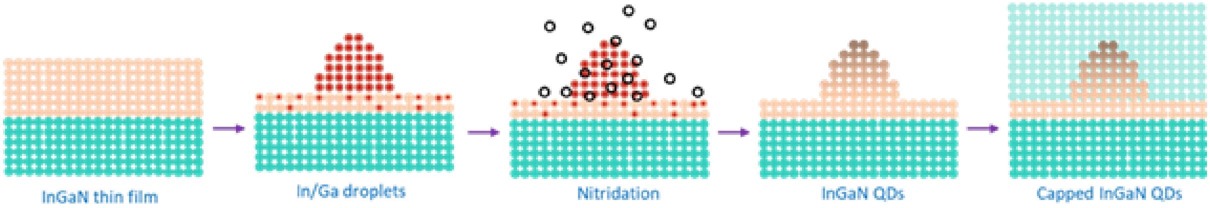


Fig. 1: (a) The intensity profile of the field emitted by a QD into the cavity. (b) The far-field image of the cavity formed by the emitted light at a different detuning; the locations of the QD and the cavity are marked with the white dot and the dashed line, respectively.

P3. Density control of InGaN Quantum Dots Grown via Modified Droplet Epitaxy

Chunyu Zhao[1], Zeki Semih Pehlivan[1], Louise Holman[1], Gunnar Kusch[1], Menno J. Kappers[1], and Rachel A. Oliver[1]
[1]University of Cambridge, Cambridge, UK

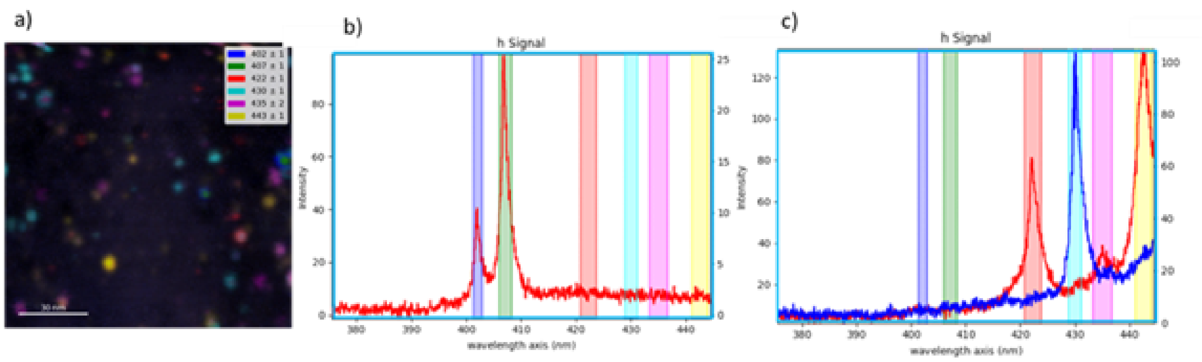
InGaN quantum dots (QDs) show great promise as single-photon emitters (SPEs) for quantum information technologies. However, achieving a sufficiently low density of epitaxially grown InGaN QDs in metal-organic vapour phase epitaxy (MOVPE) remains a challenge. In this study, we investigate the growth mechanism of InGaN QDs grown by MOVPE using a modified droplet epitaxy (MDE) method. The MDE approach relies on the decomposition of a thin InGaN quantum well (QW) into metallic In/Ga droplets, followed by nitridation to form InGaN QDs. We investigate the Influence of annealing atmosphere (pure N_2 versus N_2/H_2) and annealing duration on QDs formation. The reduction in QD density is analysed within a dynamic equilibrium framework that considers Ostwald ripening, continuous fragmented QW decomposition supplying new material, and droplet volatilisation. By optimising these annealing parameters, we successfully reduced the QD density by nearly half, from 3.2 × 1010 cm-2 to 1.8 × 1010cm-2, while preserving the optical quality of the QDs, as evidenced by low temperature cathodoluminescence measurement with a FWHM less than 2 nm. This work offers key insights into the controlled growth of low-density InGaN QDs by the MDE method, paving the way for their integration into quantum photonic devices.



P4. Correlating Morphology and Emission in InGaN Quantum Dots via Cathodoluminescence Spectroscopy

Zeki Semih Pehlivan[1], Chunyu Zhao[1], Louise Holman[1], Gunnar Kusch[1], Menno J. Kappers[1], and Rachel A. Oliver[1]
[1]University of Cambridge, UK

Cathodoluminescence (CL) spectroscopy offers high-resolution spatial and optical analysis of nanoscale morphology and emission characteristics. We utilized low-temperature CL to study InGaN quantum dots (QDs) grown by metalorganic chemical vapor epitaxy (MOVPE). A range of QD morphologies was achieved by varying the annealing atmosphere (N_2 vs. N_2/H_2) and duration. CL analysis reveals distinct morphology-dependent optoelectronic relationships: prolonged N_2 annealing produces larger QDs that exhibit a blue shifted emission and reduced CL intensity, which is attributed to indium loss and weakened quantum confinement. In contrast, extended N_2/H_2 annealing generates smaller QDs with narrow emission lines (FWHM ≈ 1 nm) and high intensity, indicative of superior compositional stability and strong quantum confinement. This study establishes a direct correlation between annealing-controlled QD morphology and optical performance, providing critical insight for advancing single-photon emitters in quantum photonics. We also show that CL can be used to resolve the 22olarization of the emission from the QDs, with degrees of linear 22olarization of up to 85% observed.



P5. Aspheric lens design proposal for near-perfect mode-matching of a broadband quantum dot micropillar to a single-mode fibre

David Dlaka[1], Yichen Zhang[1,2], James McDougall[1], James Y Tai[1], Petros Androvitsaneas[1], Edmund Harbord[1], Ruth Oulton[1], and Andrew B Young[1]
[1]University of Bristol, UK, [2]University of Cambridge, UK

Quantum dots in micropillars are one of the most promising options for a bright, deterministic single photon source. While highly efficient devices (>95%) have been designed, there remains a significant bottleneck that impacts the overall system efficiency: the large numerical aperture of the output mode. This leads to inefficient coupling of emitted photons into single-mode fibre, thus limiting practical integration into quantum computing and communication architectures. In this work [1], we address the issue of near-lossless fibre coupling of ultra-efficient SPSs by using FDTD simulations of previously optimised micropillar cavity designs with internal efficiency of 96% [2] with the addition of an aspheric SiO_2 microlens on top; by controlling the lens profile, the mode field diameter and numerical aperture (NA) of the pillar emission can be carefully tailored to match that of an industry standard single mode fibre (see attatched fig. 1). We show that with the addition of a well designed aspheric SiO_2 microlens we can decrease the mode-matching losses to a SMF from 83.1% to <0.1(0.1)%. We also examine the tolerance to lateral misalignment and errors in the lens shape/profile, finding that aspheric lenses on micropillars are robust to fabrication errors and should be manufacturable using standard clean-room processing (see attached fig 2). Our results show the imminent plausibility of a single photon source design with 96.4(0.1)% end-to-end efficiency, paving the way for scalable photonic quantum technologies.

[1] Y Zhang et al 2025 arXiv:2508.06223 (Preprint)
[2] D Dlaka et al 2024 New J. Phys. 26 093022

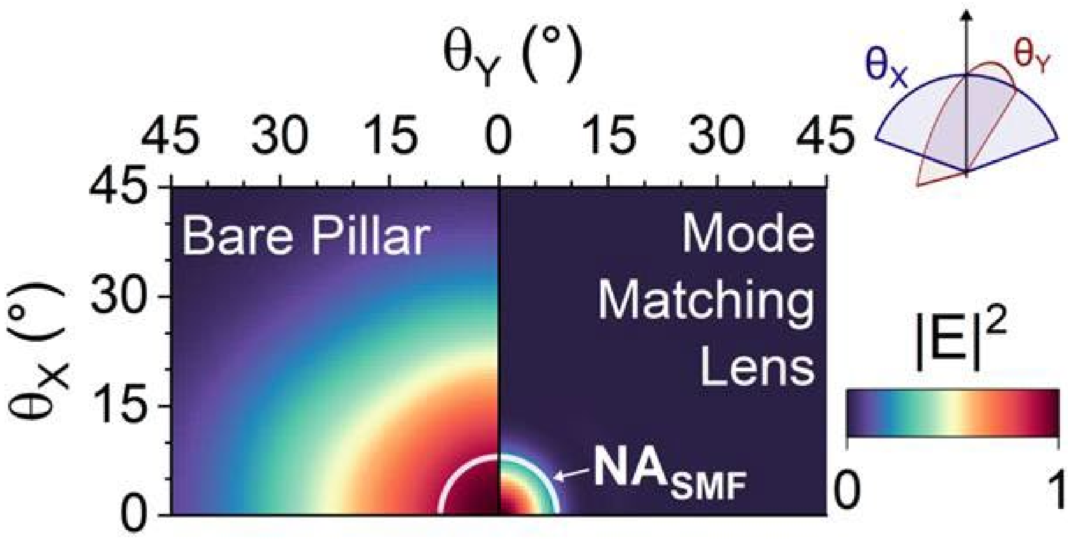


Fig. 1. The far-field profiles of the field intensity $|E|^2$ are shown as a function of angle from the normal along the x and y axes (θ_x, θ_y as shown in the inset) for the lensless bare micropillar and the optimised R = 5.7 μm, k = 0, $k_4 = 3.75 \times 10^{-3}$ μm^{-3} lens. The NA of a SMF is shown as a white circle.

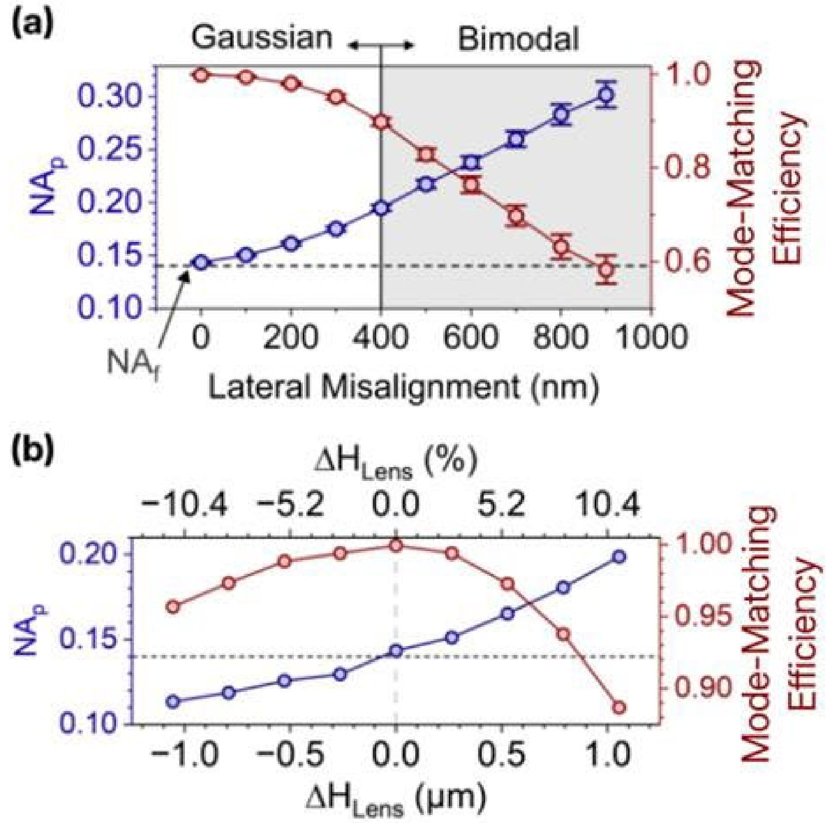


Fig. 2. (a) The device NA (left y-axis, blue) and mode-matching efficiency (right, red) to a SMF as a function of lateral lens offset for the R = 5.7 μm, k = 0, $k_4 = 3.75 \times 10^{-3}$ μm^{-3}; (b) The device NA (left, blue) and SMF mode-matching efficiency η_{SMF} (right, red) are shown as a function of fabrication tolerance quantified as an error in the lens height ΔH in units of μm on the bottom x-axis, and as a percentage on the top axis. The grey dashed lines mark the SMF NA.

P6. Site-controlled [111]-oriented GaAs Quantum Dots – Consequences of symmetry and light-hole states for excitonic properties.

Neil O'Connor[1,2], Ruben Santana[1,2], Francesco Mattana[1], Gediminas Juska[1], Emanuele Pelucchi[1], and Stefan Schulz[1,2]
[1]Tyndall National Institute, University College Cork, Ireland, [2]School of Physics, University College, Ireland

In recent years, photonic cluster states (PCS) have attracted significant attention for scalable numbers of photonic qubits [1].

Site-controlled [111]-oriented GaAs quantum dots (QDs) [2], offer exciting prospects for generating PCS, owing to their superior structural control compared to [001]-oriented Stranski-Krastanov (SK) QDs. To utilize site-controlled [111]-oriented GaAs QDs for PCS generation, detailed understanding of electronic and excitonic properties is required. Changing the growth direction from [001] to [111] alters the symmetry of the QD system, meaning insights from [001]-oriented SK dots generally do not apply to [111]-oriented structures.

We present a theoretical study on electronic and excitonic properties of [111]-oriented GaAs QDs. Our investigations reveal several bound hole states but only a single bound electron state. The first excited hole state exhibits a large light-hole (LH)-like character, usually not found in SK dots. The existence of this LH-like state is confirmed by photoluminescence (PL) studies.

Based on the obtained electronic structure, the excitonic fine-structure of [111]-oriented QDs is analyzed. We find that our theoretical model yields good agreement with PL data only when a symmetry reduction is introduced via QD shape anisotropies. This highlights the critical role played by the combined symmetry of QD and underlying lattice for the excitonic fine structure of [111]-oriented QDs. The established theory-experiment framework presents an ideal starting point to further explore properties of site-controlled QDs and target the generation of PCS.

[1] S. Economou et al., PRL 105,093601 (2010).
[2] L. Mereni et al., Appl. Phys. Lett. 94, 223121 (2009).

P7. Colloidal quantum dot lasers throughout the short-wave infrared

Guy L Whitworth[1], Carmelita Roda[2], Mariona Dalmases[2], Gerasimos Konstantatos[2], Anatoly Zayats[1], and Mark Green[1]
[1]Kings College London, UK [2]Institut de Ciènces Fotònitques (ICFO), Spain

The short-wave infrared (SWIR) region of the electromagnetic spectrum (1300 nm – 2500 nm) has very few gain media for the fabrication of lasers, making it a challenging region to explore for optoelectronic applications. Colloidal quantum dots (CQDs) with their broad bandgap tunability have had several semiconductor candidates which could be used as gain media. Here I present how CQDs from the low bandgap semiconductor, PbS, was demonstrated to lase in this region. The emission was tuned throughout the SWIR from 1550 nm (telecoms wavelengths) to 2400 nm. Building on these successes, I explore combining PbS CQD lasers with integrated photonics and the potential for plasmonic enhancement.

P8. Variational Polariton-Polaron Approach: Exciton–Cavity Interactions under Environmental Coupling

Barry Lynch[1,2], and Stefan Schulz[1,2]
[1]Tyndall National Institute, Cork, Ireland, [2]School of Physics, University College Cork, Ireland

Semiconductor quantum dots (QDs) are promising platforms for scalable quantum photonics and technologies owing to their compatibility with established semiconductor fabrication techniques and their discrete energy levels, which enable single- and entangled-photon emission [1,2]. Embedding QDs in optical microcavities provides additional means to engineer light–matter interactions, enhancing control over non-classical light emission [2].

However, given that QDs exist in a solid-state environment, coupling to phonons can cause decoherence and complex dynamical effects [3]. Understanding these system–environment interactions is key when designing non-classical QD-based light emitters [3]. Theoretical frameworks have been developed to gain insight into exciton–phonon interactions, including path integral [4] and Master equation (ME) approaches: Weak Phonon and Standard Polaron methods [3].

We present a variational ME framework for a QD–cavity systems coupled to a phonon bath. By exploiting Jaynes–Cummings symmetries we naturally incorporate non-Markovian memory effects into the model. Unlike Polaron approaches, our method applies to a broad class of spectral densities and bridges the gap between the Weak and Polaron limits, providing accurate results across regimes where common ME methods fail. We provide new insight into phonon sidebands and exciton–cavity emission spectra, while clarifying the validity range of Weak and Polaron approaches.

[1] Nature Nanotechnology 12, 1026 (2017)
[2] Phys. Rev. Lett. 121, 11, 110 503 (2018)
[3] Phys. Rev. B. 92, 205406 (2015)
[4] Phys. Rev. B 84, 195 311 (2011)

P9. Site-control of InAs/InP quantum dots by droplet epitaxy in MOVPE with high optical quality

Guoliang Zhou[1]
[1]University of Sheffield, UK

We investigate the site-control of InAs/InP quantum dots (QDs) fabricated by droplet epitaxy (DE) in metal-organic vapour phase epitaxy (MOVPE) [1]. InAs/InP QDs can emit photons around 1.55 µm. The optical signal has the smallest attenuation at this telecom window which is also known as the C-band [2]. Therefore, InAs/InP serves as an ideal quantum light source capable of emitting single photons, making it suitable for applications in quantum computing and quantum key distribution as single photon emitters (SPEs). DE relies on the formation of metallic droplets which are then crystallized into uniform and symmetric QDs. To accurately control the location of QDs growth, namely site-control of QDs, the pre-patterning of substrates has been proposed and developed. The purpose of site-control QDs is to achieve the low densities required for single photon sources and to scale up quantum devices.

In this work, the process of fabricating nanohole arrays using electron beam lithography (EBL) has been explored. Following the fabrication, the droplet epitaxy in MOVPE growth of InAs QDs produced dots localized in nanoholes, which means the positioning of the dots was fully controllable.

Here, we present the results of achieving site-control of QDs. A QD positioned within a nanohole is realized. The µPL measurements reveal a high-occupancy quantum dot array with single-line emission in the telecom C-band, with linewidths reaching 25 µeV for 70% of the dots.

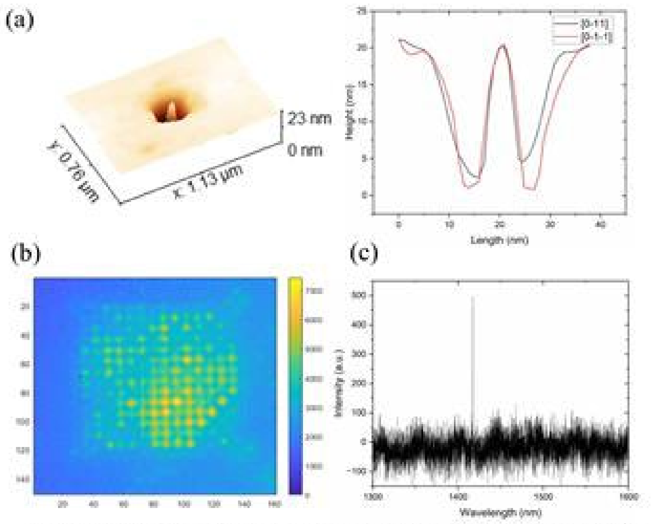


Figure 1: (a) A 3D of a single nanohole with one dot inside and its profile line **(b)** µPL image of the site-controlled QD area at 4 K. **(c)** Low temperature (T = 4 K) µPL spectrum of an individual QD under low excitation power (1 µW)

P10. Inkjet Printing Heavy-Metal-Free Quantum Dot LEDs for Flexible Displays and Optical Communications

Sri Datta Aneesh Chodavarapu[1], Benxuan Li[2], and Bo Hou[1]
[1]School of Physics and Astronomy, Cardiff University, Cardiff, UK [2]Nanoglow Ltd, UK

Developing environmentally sustainable alternatives to cadmium and lead-based solution-processed quantum dots (QDs) is critical for advancing next-generation optoelectronics. Indium Phosphide (InP) and Copper Indium Zinc Sulfide (CuInZnS) QDs are among the most promising candidates for display, image sensing, lighting applications. However, colloidal quantum dot light-emitting diodes (QLEDs) fabricated using conventional techniques often underperform relative to heavy-metal counterparts (CdSe, PbS), limiting scalability, commercialization. We report fabrication strategy for heavy metal-free, solution-processable QLEDs targeting applications from flexible displays to optical communication. Dip-coating was employed for the hole injection (HIL) and hole transport layers (HTL), followed by inkjet printing of the emissive InP-based QD layer on substrates including polymers and glass. Unlike spin-coating, dip-coating and inkjet printing minimize material waste while offering compatibility with large-area, flexible and pixelated device manufacturing. Process parameters like viscosity, surface tension, withdrawal speed, and solvent dispersibility are optimized for PEDOT:PSS (AL 4083) and PVK, ensuring uniform thickness, morphology. Inkjet-printed InP QDs were optimized via drop spacing, waveform control. Dip-coating of HIL, HTL revealed V-shaped thickness dependence on withdrawal speed for both PEDOT:PSS and PVK-based layers. Top centre thickness of 25–30 nm was obtained at 15–20 mm/min draw speeds. Inkjet printing of InP QDs with phenylcyclohexane co-solvent (70:30, 60:40 ratios) and 40 µm drop spacing produced smooth, defect-free films. As shown in figure, devices fabricated under these optimized parameters exhibited turn-on voltage near 3-5 V, demonstrating scalable routes for efficient QLEDs. This work demonstrates viability of dip-coating and inkjet printing as methods for producing efficient, environmentally sustainable QLEDs.

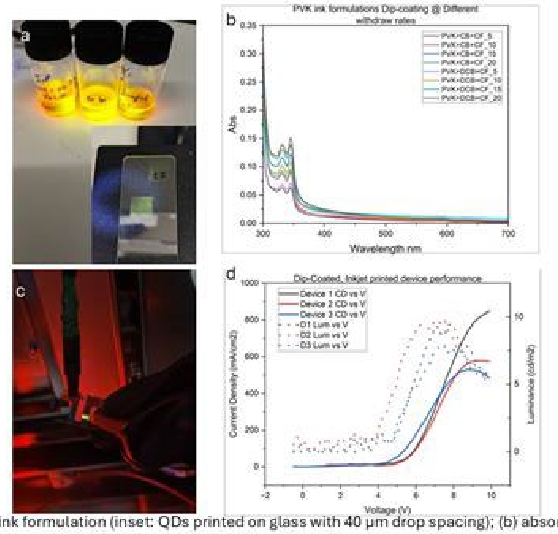


Fig: (a) InP QDs ink formulation (inset: QDs printed on glass with 40 µm drop spacing); (b) absorption spectrum of the PVK film; (c) A electroluminescent QLED under turn on condition; (d) performance metrics of the fabricated devices.

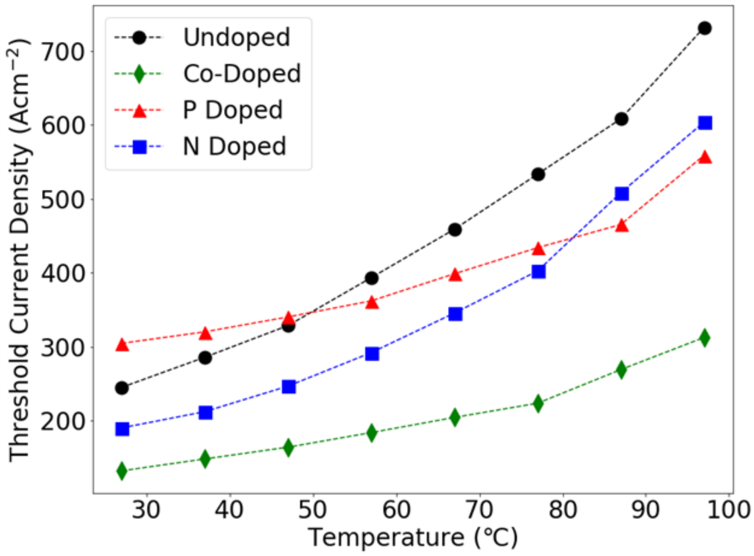
P11. Improving Recombination in Quantum Dot Assemblies for lasing by concurrent Direct N-type doping of Quantum Dots and P-type modulation Doping

Lydia Jarvis[1], Benjamin Maglio[1], Sara-Jayne Gillgrass[1], Craig Allford[1], Fwoziah Albeladi[1], Abigail Enderson[1], Samuel Shutts[1], Huiwen Deng[2], Mingchu Tang[2], Huiyun Liu[2], and Peter M. Smowton[1]
[1]EPSRC Compound Semiconductor Manufacturing Hub, School of Physics and Astronomy, UK, [2]Department of Electronic and Electrical Engineering, University College London, UK

Efficient recombination in III-V quantum dot assemblies is limited by valance band asymmetry, that is the conditions which arise from differences in the effective masses. Here, the holes have larger effective masses which reduce spacing between energy states in the valence band. The electrons are lighter leading to greater spacing between conduction band states. As charge carries spread due to thermal effects, the holes experience greater thermal broadening due to having more closely spaced states, allowing holes to spread out more easily, whereas the electrons are more likely to be found in the E1 state.

In III-V lasers, p-type modulation doping is a well-established technique to counter this on both GaAs and Si substrates. A more recent technique to improve laser performance is direct N type doping, where dopants are directly incorporated into the quantum dot. Here were explore the merits of both techniques separately and together, referred to here as co-doping.

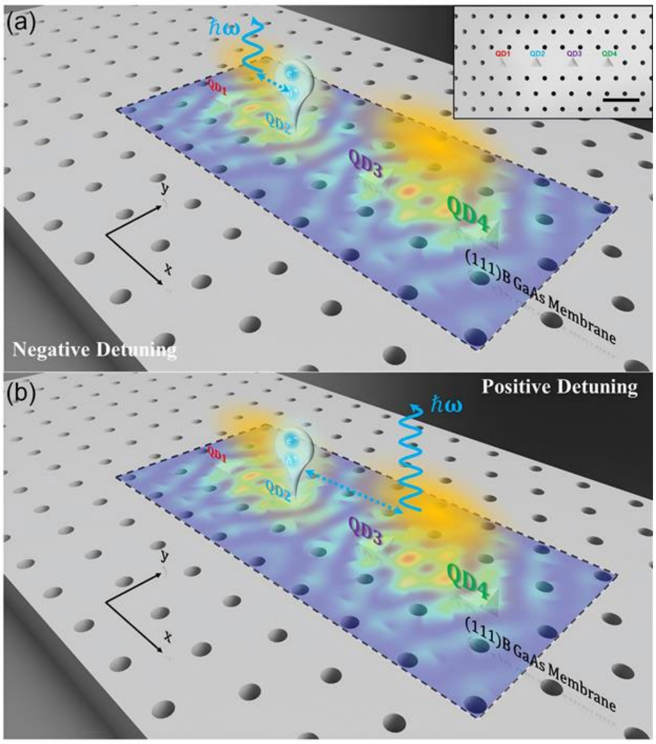
Co-doped laser devices are measured over a temperature range of 27°C – 97°C and are compared to devices grown with each individual doping strategy and reference devices with no active region doping. Co-doping is shown to produce a significant improvement in threshold current density across the temperature range, reducing threshold relative to the undoped case effectively halving threshold values: from 245 Acm-2 to 132 Acm-2 at 27°C and 731 Acm-2 to 312 Acm-2 at 97°C for 1 mm long lasers with uncoated facets.



P12. Spatial quantum-interference landscapes of multi-site-controlled quantum dots coupled to extended photonic cavity modes

Jiahui Huang[1], Alessio Miranda[2], Wei Liu[1], Xiang Cheng[1], Benjamin Dwir[2], Alok Rudra[2], Kai-Chi Chang[1], Eli Kapon[2], and Chee Wei Wong[1]
[1]Department of Electrical and Computer Engineering, University of California, USA, [2]Institute of Physics, École Polytechnique Fédérale de Lausanne, Switzerland

A compact platform to integrate emitters in a cavity-like support is to embed quantum dots (QDs) in a photonic crystal (PhC) structure, making them promising candidates for integrated quantum photonic circuits. The emission properties of QDs can be modified by tailored photonic structures, relying on the Purcell effect or strong light-matter interactions. However, the effects of photonic states on spatial features of exciton emissions in these systems are rarely explored. Such effect is difficult to access due to random positions of self-assembled QDs in PhC structures, and the fact that quantum well excitons' wavefunctions resemble photonic states in a conventional distributed Bragg reflector cavity system. In this work, we instead observe a spatial signature of exciton emission using site-controlled QDs embedded in PhC cavities. In particular, we observe the detuning-dependent spatial repulsion of the QD exciton emissions by polarized imaging of the micro-photoluminescence, dependent on the controlled QD's position in a spatially extended photonic pattern. The observed effect arises due to the quantum interference between QD decay channel in a spatially-extended cavity mode. Our findings suggest that integration of site-controlled QDs in tailored photonic structures can enable spatially distributed single-photon sources and photon switches.



P13. Quantum Dot Telecom C-Band Single-Photon Sources

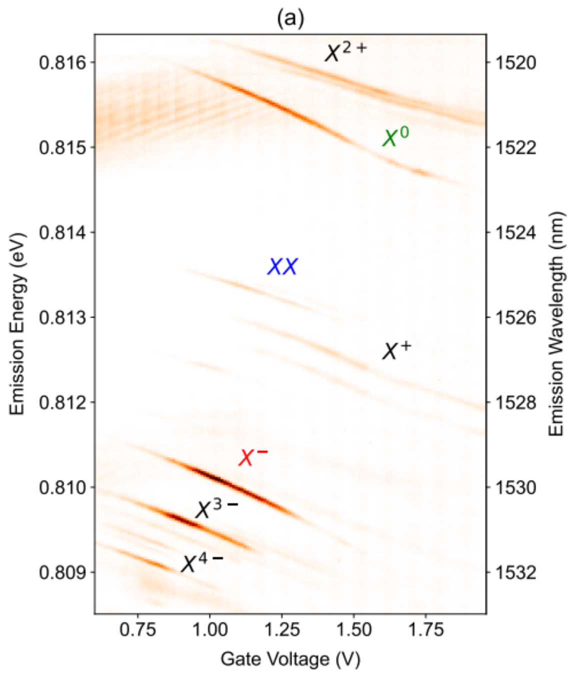
Anna Tomlinson[1], Nicholas Martin[1], Alistair Brash[1], Elisa Sala[1], Eve Mills[1], Rene Dost[1], Leila Najafi[1], Luke Hallacy[1], Dominic Hallett[1], Catherine Phillips[1], Katie O'Flaherty[1], Peter Millington-Hotze[1], John Heffernan[1], Maurice Skolnick[1], Mark Fox[1], and Luke Wilson[1]
[1]The University of Sheffield, UK

Single-photon sources are crucial in the development of quantum-secure telecommunication networks. Quantum dots, particularly those that emit in the telecom C-band, are promising candidates due to their deterministic emission, high brightness and tunable optical properties [1]. Integrating quantum dots into gated structures helps reduce charge noise and spectral diffusion. Similarly, coupling them to photonic devices enables Purcell enhancement – a phenomenon that increases the spontaneous emission rate – and improves in-plane photon col-lection efficiency.

In this work, InAs/InP dots grown by droplet epitaxy in a metal-organic vapor-phase epitaxy (MOVPE) reactor are presented. We introduce a novel n-i-n gated structure and demon-strate, for the first time, electrical Stark tuning and charge control of quantum dots emitting in the telecom C-band [2]. Tuning ranges of up to 2.4 nm are achieved, marking a key mile-stone toward enabling advanced functionalities in quantum communication applications.

We further demonstrate a reduction in emission lifetime by embedding the quantum dots in low-mode volume L3 photonic crystal cavities [3]. These exhibit a short radiative lifetime of 340 ps, corresponding to a Purcell factor of 5. This is achieved using a phonon-sideband pulsed excitation scheme and fine-temperature tuning to bring the dot closer to resonance with the cavity mode.

[1] D. A. Vajner, L. Rickert, et al., Adv. Quantum Technol. 5, (2022).
[2] N.J. Martin, A.J. Brash, et al., arXiv preprint arXiv: 2506.07951v1 (2025).
[3] C. L. Phillips, A. J. Brash, et al, Scientific Reports 14, 4450 (2024).



P14. Correlative Scanning Electron Microscopy for Exploring Quantum Emitters in GaN

Kimberly Nicholson[1], Joseph K. Cannon[2], Anthony J. Bennett[2], and Naresh K. Gunasekar[1]
[1]School of Physics and Astronomy, Cardiff University, UK, [2]School of Engineering, Cardiff University, UK

Single-photon emitters (SPEs) are essential for quantum technologies, with photostable emission demonstrated in SiC [1], hBN [2], GaN [3], and AlN [4]. GaN is particularly attractive due to room-temperature operation and broad spectral range, though the microscopic origin of its SPEs remains debated, with links proposed to point or extended defects [3,5]. The high cost of GaN substrates often necessitates heteroepitaxy on sapphire, introducing high threading dislocation densities that may influence emitter formation.

We investigate SPEs in unintentionally doped GaN epilayers on (0001) sapphire using correlative light–electron microscopy. Cathodoluminescence (CL) reveals threading dislocations as non-radiative recombination centers, while electron channelling contrast imaging (ECCI) shows them via black–white contrast, giving a density of $(8 \pm 1) \times 10^8$ cm^{-2}. Photoluminescence (PL) mapping of the same region shows isolated bright spots, consistent with SPE emission [3]. Correlation of these optical features with structural defects is limited by spatial resolution and the high dislocation density.

To address this, we propose combining SEM-CL with Hanbury Brown–Twiss interferometry for high-resolution, site-specific identification of SPEs. This enables wafer-scale mapping and direct correlation of single-photon emission with extended defects, offering new insight into their microscopic origin and informing controlled engineering of GaN-based quantum photonic platforms.

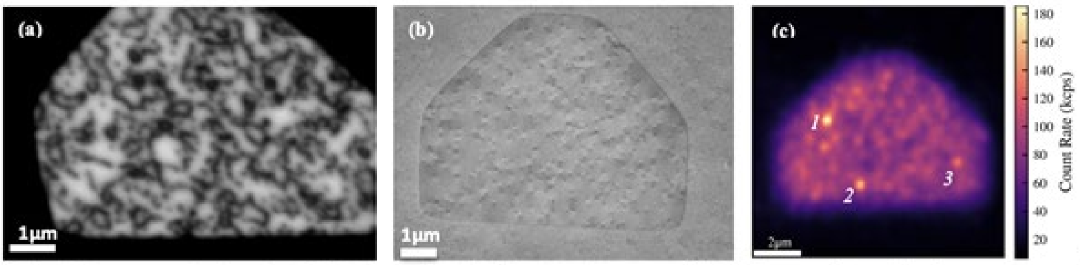


Fig 1. The same marked region of GaN on sapphire (a) Cathodoluminescence (CL) (b) Electron Channelling Contrast Imaging (ECCI) and (c) Photoluminescence showing bright regions of potential SPE.

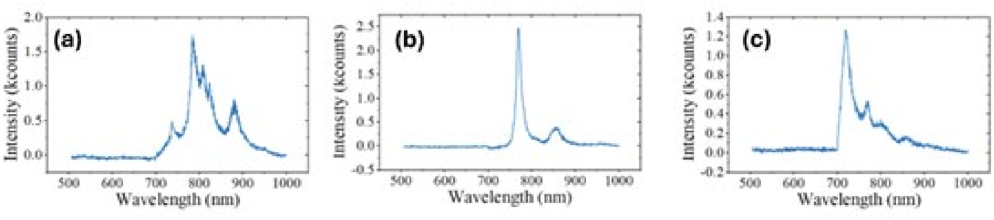


Fig 2. (a), (b), and (c) Expected photoluminescence spectra of sites 1, 2 and 3, respectively of the bright emitters in Fig 1(c).

[1] S.Castelletto et al, ACS Nano 8, 7938 (2014).
[2] T.T.Tran et al, Nat. Nanotechnol. 11, 37 (2016).
[3] A.M.Berhane et al, Adv. Mater. 29, 1605092 (2017).
[4] J.K.Cannon et al, Appl. Phys. Lett. 124, 244001 (2024).
[5] J.Lähnemann et al, J. Phys. 47, 423001 (2014).

P15. Calming Nuclear Spins in Quantum Dots to Extend Electron Spin Coherence Times

Thomas Bryce[1]
[1]University of Bristol, UK

Semiconductor quantum dots (QDs) embedded in photonic devices are highly attractive light sources with applications in many quantum photonic technologies. A primary area of interest is in storing information in single electron spins within QDs and then transferring the information efficiently to photons. Using semiconductor QDs embedded within DBR micropillar devices, we can combine the high extraction efficiencies of micropillar photonics with the long underlying coherence times of electrons, which are in the order of microseconds. This guarantees the transfer of quantum information between electron spins and photons. This technology will lead to applications in scalable and efficient quantum memory technologies for quantum communications, and quantum simulations using photonic and spin cluster states and distributed entanglement of spin states. However, a limitation of these technologies are the random nuclear spins within the quantum dot whose destructive effective fields negatively impact electron spin coherence. This poster discusses the development of nuclear spin calming techniques such as Dynamic Nuclear Polarisation (DNP) [1] and Nuclear Frequency Focusing (NFF) [2] which aim to make the long electron coherence times more accessible and lengthen them, as well as this project's ongoing search for candidate efficient QD-micropillar devices.

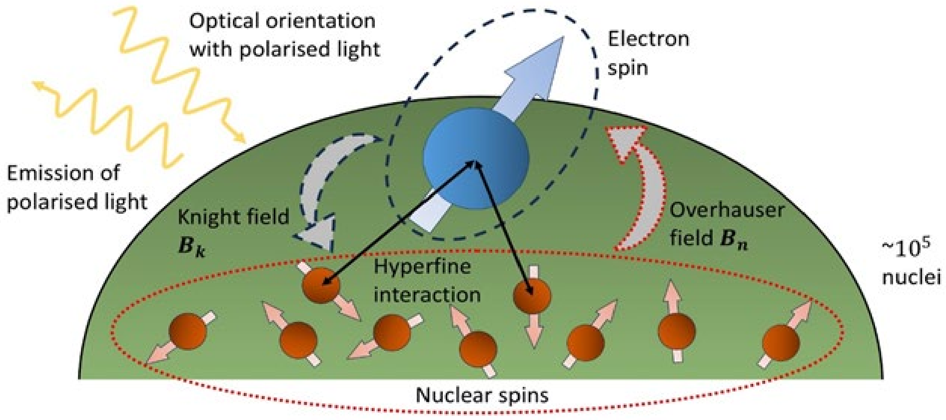


Figure 1: *Diagram demonstrating the reciprocal interactions between electron and nuclear spins in quantum dots.*

[1] Economou SE, Barnes E. Theory of dynamic nuclear polarization and feedback in quantum dots. Phys Rev B. 2014; 89(16):165301.
[2] Greilich A, et al. Nuclei-Induced Frequency Focusing of Electron Spin Coherence. Science. 2007; 317(5846):1896–9. Also Greilich A, et al. Mode Locking of Electron Spin Coherences in Singly Charged Quantum Dots. Science. 2006; 313(5785):341–345

P16. Power-dependent Faraday spin pumping in single InAs/GaAs quantum dots

M. Alvarez Perez[1], A. Broughton[1], H. Dyte[1], and A.J. Bennett[1]
[1]School of Engineering, Cardiff University, UK

We report time-resolved spin pumping in the Faraday geometry of single InAs/GaAs quantum dots using resonant square pulses at $B_z = 0.4\,\mathrm{T}$. With a trion lifetime $\tau_{\mathrm{rad}} \approx 400\,\mathrm{ps}$, we observe rapid pure spin state initialisation with time constant $T_{\mathrm{init}} \approx 6\,\mathrm{ns}$. Notably, the shelving rate increases above saturation with drive strength well above saturation, contrary to the simple saturation picture in which the excited-state population is capped at $\frac{1}{2}$. This indicates and additional power dependent shelving path (consistent with Raman-type spin control). To validate the experimental data, we model and simulate these phenomena with a 4-states model. Either direction's rate is given by:

$$\gamma_{\uparrow\to\downarrow}(P) \simeq \frac{b\,\Gamma}{2}\frac{s}{1+s} + \varepsilon_{\pm}(S_3)F_{\downarrow}(\Omega^2)$$

$$\gamma_{\downarrow\to\uparrow}(P) \simeq \gamma_{\mathrm{hf}} + \varepsilon_{\pm}(S_3)F_{\uparrow}(\Omega^2)$$

which includes optical saturation and a generic Raman term ($\varepsilon_{\pm}(S_3)F_{\downarrow}(\Omega^2)$) in the direction of our intendent initialisation ($\gamma_{\uparrow\to\downarrow}(P)$), as well as the hyperfine interaction and a power dependent repump term that are parasitic to our spin initialisation ($\gamma_{\downarrow\to\uparrow}(P)$). Which becomes more influential as the splitting becomes smaller (smaller B-field), as the pumping laser has a higher overlap on the opposite transition. Here $s = \frac{2\,\Omega_{\mathrm{on}}^2}{\Gamma\,\gamma_{\perp}}$, $\Gamma = \frac{1}{\tau_{\mathrm{rad}}}$ and b is the branching ratio. The effective couplings with each radiative leg ($\varepsilon_{\pm}(P)$) encompass polarisation content of the pump laser and selection-rule mixing. ($\gamma_{hf} = 1/T_{hf}$) captures power-independent spin-flip due to hyperfine interaction. We present dependences of these rates on polarisation (S_3), magnetic field (B_z), detuning, temperature, and duty cycle to discriminate potential contributions to the extra term in our rates (including hyperfine-assisted, off-resonant optical, phonon-assisted, and dressed-state effects). This method yields crucial figures of $T_{\mathrm{init}}, T_{\mathrm{hf}}, b, \gamma_0$, that mediate the spin initialisation process, which serves as a gauge for Faraday-only spin pumping in spin-photon interfaces found in quantum dots.

Quantum Dot Day
Site Controlled Quantum Emitters

18 November 2025
Cardiff University, Cardiff, UK

IOP Institute of Physics