Q 30: QuanTour III – Spin Physics & Coherence

Inspired by QuanTour, the traveling quantum-dot light source, the sessions QuanTour I-V focus on the physics of quantum light generation in solid-state systems and applications in quantum networks.

Time: Wednesday 14:30–16:30 Location: P 1

Invited Talk Q 30.1 Wed 14:30 P 1

Shedding light on nuclear spins: from collective states to a quantum memory — •Mete Atature — Cavendish Laboratory, University of Cambridge

Optically active spins in solids are strong candidates for scalable devices towards quantum networks. Semiconductor quantum dots set the state-of-the-art as single-photon sources with high level tuneability, brightness, and indistinguishability. In parallel, their inherently mesoscopic nature leads to a unique realisation of a tripartite interface between light as information carrier, an electron spin as a proxy qubit, and an isolated nuclear spin ensemble. The ability to control these constituents and their mutual interactions create opportunities to realize an optically controllable ensemble of ~50,000 spins. The talk will take a journey from treating the quantum dot nuclei as an uncontrolled noise source limiting spin coherence to the observation of their collective magnon modes and eventually to their function as a quantum register, all witnessed via a single electron spin driven by light.

Q 30.2 Wed 15:00 P 1

Spin-photon entanglement for the generation of multiphotonic graph states — •Lara Couronné[1,2], Hêlio Huet[2], Emilio Annoni[1,2], Petr Steindl[2], Aristide Lemaître[2], Martina Morassi[2], Anton Pishchagin[1], Sébastien Boissier[1], Olivier Krebs[2], Samuel Mister[1], Stephen Wein[1], Viviana Villafane[1], Dario Fioretto[1,2], and Pascale Senellart[2] — [1]Quandela, Massy, France — [2]C2N, Palaiseau, France

Measurement-based quantum computing requires large multi-photon entangled states. We generate these resource states using InGaAs quantum dots as high-efficiency single-photon sources. Each dot holds an extra charge carrier whose spin state maps to the polarization of an emitted photon via optical selection rules, enabling the Lindner-Rudolph protocol.

A small transverse magnetic field causes spin precession. Triggering photon emission while the spin is in superposition produces spin-photon entanglement; repeating this cycle yields multi-photon cluster states. This approach has been shown by several groups and recently extended to more complex states.

In this talk, we present our implementation, achieving entanglement of up to 10 photons. The main challenges are limited spin coherence and excited-state precession. To mitigate these, we use dynamical decoupling to extend coherence and time-filtering to remove photons affected by long excited-state precession. These advances mark a key step toward small-scale demonstrations of fault-tolerant photonic quantum computing.

Q 30.3 Wed 15:15 P 1

Modeling coherent Faraday spin control in semiconductor quantum dots — •Jan M. Kaspari[1], Zhe Xian Koong[2], Dorian Gangloff[2], and Doris E. Reiter[1] — [1]TU Dortmund, Dortmund, Germany — [2]University of Cambridge, Cambridge, United Kingdom

Semiconductor quantum dots (QDs) not only offer exceptional optical coherence and efficiency when coupled to photonic structures but also exhibit remarkably long electronic and nuclear spin coherence times, which makes them stand out as promising building blocks for memory-assisted quantum network protocols. However, these schemes require both the ability to encode information via quantum control over the spin and the possibility to perform single-shot readouts. While spin control in QDs is possible by applying an in-plane magnetic field (Voigt configuration), attempts to overcome the limitations given by the lack of intrinsically cyclic transitions to realize simultaneous single-shot readouts have shown limited success. In the presence of a magnetic field oriented along the growth-axis of the quantum dot (Faraday geometry) circularly polarized cyclic transitions allow for efficient single-shot readouts. Here, we show that electron-spin resonance can be driven and quantum control over the spin can be achieved using a narrowband stimulated Raman scheme exploiting the small light-hole admixture. This slightly breaks the full cyclicity and leads to a highly asymmetric Λ system, which our theoretical model reproduces in excellent agreement with experiment [1].

[1] Zhe Xian Koong et al., arXiv:2509.14445 (2025)

Q 30.4 Wed 15:30 P 1

Temporal coherence of interlayer excitons in TMDC heterobilayers — •Ibrahim sarpkaya — Bilkent University - UNAM, Ankara 06800, Turkey

Semiconducting transition metal dichalcogenides (TMDCs) and their van der Waals heterostructures have been extensively studied during the last decade. Due to their long spontaneous emission lifetime, permanent electric dipole moment, and tunable light emission characteristics, interlayer excitons (IXs) of TMDC heterobilayers have great potential to be the primary candidates for the advancement of valleytronic and optoelectronic devices in the future. However, some open questions related to their temporal coherence and the nature of the interaction between the two spin states of them still need to be answered. In this talk, I will first talk about our recent work focusing on the effect of moiré potentials on the temporal coherence properties of IXs [1]. Then, I will discuss the coherent coupling between two spin states of the IXs and demonstrate the quantum beat pattern as a signature of this coupling [2].

[1] Durmuş et al. npj 2D Mater Appl 7 (2023).

[2] Durmuş, M. A. & Sarpkaya, I. Nano Lett. 24 (2024).

Q 30.5 Wed 15:45 P 1

Single photons for quantum position verification — Kirsten Kanneworff, Mio Poortvliet, Petr Steindl, and •Wolfgang Löffler — Leiden Institute of Physics, Leiden, the Netherlands

We show our progress towards experimental demonstration of quantum position verification using demultiplexed photons from a quantum dot - microcavity single photon source. Quantum position verification is a future quantum network application where the geographic location enables remote authentication of a party, without the need that the parties exchange private keys physically. This remote position verification cannot be done classically and might provide a clear quantum advantage - based on combining the speed of light limit of special relativity with the quantum no-cloning principle. We implement a loss-tolerant protocol with photons produced in a semiconductor quantum dot - cavity system that undergo Hong-Ou-Mandel quantum interference at the location to be verified. We show our lab demo experiment, and discuss challenges for future implementations of quantum position verification in quantum networks.

Q 30.6 Wed 16:00 P 1

Fourier-transform limited, blinking-free quantum dots — •Patricia Kallert[1], Lukas Hanschke[1], Eva Schöll[1], Melina Peter[2], Juan Nicolás Claro-Rodríguez[1], Ailton José Garcia Jr.[2], Saimon Filipe Covre da Silva[2], Santanu Manna[2], Armando Rastelli[2], and Klaus D. Jöns[1] — [1]PhoQS Institute, CeOPP, and Department of Physics, Paderborn University, Paderborn, Germany — [2]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Linz, Austria

Most photonic quantum technologies require a source of highly indistinguishable photons. Achieving Fourier-transform limited photons is considered a pathway to near perfect indistinguishability. Our work highlights the capability of semiconductor quantum dots. Typically charge and spin noise limit the proximity to it, while the preparation of the quantum dot in a charge-stable state is crucial for non-blinking behaviour. [1] The integration of droplet-etched GaAs in AlAs in p-i-n diodes leads to Fourier-transform limited and blinking-free single-photon emission that leads to raw Hong-Ou-Mandel visibilities of (91.7 ± 0.6) % for the negative trion at resonant π excitation.

[1] A. V. Kuhlmann et al. Charge noise and spin noise in a semiconductor quantum device. Nature Physics (2013), pp. 570-575. issn: 1745-2481. doi: 10.1038/nphys2688.

Q 30.7 Wed 16:15 P 1

Floquet-Engineered Two-Photon Excitation of Biexcitons —

•Paul C. A. Hagen[1], Jun-Yong Yan[3], Moritz Cygorek[2], Doris E. Reiter[2], Feng Liu[3], and Vollrath M. Axt[1] — [1]TPIII, Universität Bayreuth, Germany — [2]CMT, TU Dortmund, Germany — [3]Zhejiang University, China

Semiconductor quantum dots (QDs) are promising solid-state platforms for generating on-demand single and entangled photons in quantum technology applications. Two-photon excitation (TPE) is a key technique for creating biexcitons, where two degenerate photons are simultaneously absorbed by a QD to excite it into the biexciton state. We show that this process also occurs when both photons are symmetrically detuned so that their combined energy matches the ground-to-biexciton transition. The excitation becomes most efficient when the detuning exceeds the biexciton binding energy, and a short temporal delay between pulses is introduced. We refer to this approach as Floquet engineered two-photon excitation (FTPE)[1]. FTPE offers concrete advantages over conventional TPE: it is more robust against laser power variations, allows efficient laser filtering, and exhibits both theoretically and experimentally higher excitation efficiency, even in the presence of phonons [1]. Using Floquet theory, we explain its dynamics and demonstrate that stroboscopic models provide an accurate description of the underlying mechanism.

[1] J. Y. Yan, P. C. A. Hagen et al. arXiv: 2504.02753