Paderborn Photonics Lecture

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Solid-state nanophotonics with quantum dots

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Abstract:

Quantum dots have attracted much attention in recent years, particularly owing to their excellent properties as sources of non-classical light for optical quantum technologies. A key example is an “on-demand” single photon source: a single classical trigger causes the emission of a single photon with close to unity probability, a valuable resource for optical quantum communication and computing. Whilst quantum dots have achieved the best performance recorded to date for this kind of source [1], imperfections remain. In particular, working in the solid-state inevitably introduces couplings to the host lattice through phonons that cause a simple “two level atom” picture to break down.

In this seminar I will present our implementation of such a single photon source based on a quantum dot in a photonic crystal nanocavity [2] and demonstrate how ultrafast techniques can reveal critical dynamics on picosecond timescales. These ultrafast techniques reveal a radiative recombination rate that is enhanced by a Purcell factor of 42, enabling potential source repetition rates as high as 10 GHz. To understand the critical role of the solid-state environment in determining both the excitation [3] and emission [4] dynamics on picosecond timescales, I will outline a comprehensive picture of interactions between quantum dots and acoustic phonons that is based on joint theoretical and experimental investigations. Understanding these processes, particularly in the presence of an optical cavity, is key to maximising the performance of solid-state optical quantum devices and also presents the opportunity to realise new functionalities.

References:

[1] N. Somaschi *et al.*, ‘Near-optimal single-photon sources in the solid state’, *Nat. Photonics*, vol. 10, no. 5, pp. 340–345, May 2016.
[2] F. Liu, A. J. Brash *et al.*, ‘High Purcell factor generation of indistinguishable on-chip single photons’, *Nat. Nanotechnol.*, vol. 13, no. 9, pp. 835–840, Sep. 2018.
[3] J. H. Quilter, A. J. Brash *et al.*, ‘Phonon-Assisted Population Inversion of a Single InGaAs / GaAs Quantum Dot by Pulsed Laser Excitation’, *Phys. Rev. Lett.*, vol. 114, no. 13, Mar. 2015.
[4] A. J. Brash *et al.*, ‘Light Scattering from Solid-State Quantum Emitters: Beyond the Atomic Picture’, *Phys. Rev. Lett.* in press, *ArXiv:1904.05284 Cond-Mat Physics quant-Ph*, Apr. 2019.

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