Engineering and Physical Sciences Research Council Doctoral Landscape Award

PROJECT TITLE: Magnetically Controlled Quantum Emitters in 2D Heterostructures

Lead Supervisor: Dr Maciej Dabrowski, M.K.Dabrowski@exeter.ac.uk

Co-Supervisors: Dr Isaac Luxmoore, i.j.luxmoore@exeter.ac.uk

Webpage: https://experts.exeter.ac.uk/26487-maciej-dabrowski

Project details: Exploiting photons as quantum information carriers presents a highly promising platform for future quantum technologies. A crucial component in such technologies is the single-photon emitter or quantum emitter (QE), capable of generating one photon at a time. On demand QEs that produce indistinguishable photons at a high rate are essential for performing quantum operations with high fidelity. Recently, van der Waals (vdW) materials have emerged as a promising platform for localized QEs due to their strong light–matter interaction and inherent quantization in the two-dimensional (2D) limit. The diversity of vdW materials provides numerous opportunities for designing QEs with desired characteristics. Particularly promising are single atomic layers of transition metal dichalcogenides (TMDCs), which feature a band structure composed of degenerate but inequivalent valley states (local energy extrema) that can be manipulated to encode, process and store information.

Traditionally, QE properties are manipulated via crystallographic defects, strain, or by controlling the number of vdW layers. In this project, we aim to explore an alternative method of localizing excitons and creating QEs by constructing metamaterials combining semiconducting TMDCs and magnetic vdW layers. This approach offers enhanced tunability in single photon generation through spin-dependent and valley-dependent selection rules, enabling precise control over the polarization, position, and temporal shape of emitted photons. Central to this project is the utilization of ultrafast charge transfer processes between 2D magnets and TMDC layers to achieve all-optical control of QE properties. The project will focus on the design and characterization of various heterostructure combinations, such as WSe2/CrI3. A significant aspect of this project involves time-resolved measurements using ultrafast laser pulses to investigate the fundamental dynamic properties of quantum emitters on a picosecond timescale and to explore their polarization.

Our recent work has shown that WSe2/CrI3 heterostructures can lead to exotic phenomena like all-optical switching via ultrafast charge transfer and formation of magnetic skyrmions, confirming that such materials can be effectively studied in our laboratories [Dabrowski et al. Nature Communications vol. 13, 5976 (2022)]. Prof. Isaac Luxmoore, an expert on QEs in 2D materials [Guo et al., ACS Photonics 10, 2549 (2023)], will co-supervise the project. He will provide access to, and training in, advanced techniques for spatially and temporally resolved photoluminescence measurements and single-photon detection. The heterostructures will be developed in collaboration with Prof. Hidekazu Kurebayashi at University College London (UCL), a leading expert in the fabrication of 2D magnets. This collaboration will offer significant training opportunities for the student at UCL. Additionally, the project involves a partnership with Aeqig Ltd, a UK start-up based in Sheffield with expertise in quantum light sources and computing solutions, which will provide industrial insight and support for device commercialization.

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Project specific entry requirements: Applicants should have an undergraduate degree in Physical Science or Engineering that includes knowledge of quantum mechanics, optics and condensed matter physics.

Potential PhD programme of study: PhD in Physics

Department: Physics and Astronomy

Location: Streatham Campus

Please direct project specific enquiries to: Maciej Dabrowski, m.k.dabrowski@exeter.ac.uk

Please ensure you read the entry requirements for the potential programme you are applying for.

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