EPSRC DTP PhD Research Project

Project Title: 2D Quantum Technologies

Primary Supervisor details:
Prof Saverio Russo S.Russo@exeter.ac.uk

https://physics-astronomy.exeter.ac.uk/people/profile/index.php?web_id=sr330

Additional Supervisory team details:

Prof Monica Craciun M.F.Craciun@exeter.ac.uk

https://engineering.exeter.ac.uk/people/profile/index.php?web_id=mfc204

Department: Physics and Astronomy

Location: Physics Building, Streatham Campus

PhD Programme: PhD Physics

Project Description:

Quantum technologies are being harnessed to deliver functionalities and properties otherwise unattainable within the confines of classical physics. Whilst the more established solutions based on superconducting and semiconductor quantum bits (qubits) are transitioning to scale-up manufacturing of chips encompassing more than 100 qubits, the science discovery of new quantum platforms with key benefits such as room temperature (RT) operation and ease of practical implementation continuous to inspire vibrant interdisciplinary research across quantum physics and photonics. For example, quantum communication and information are increasingly reliant on light beams with strongly non-classical properties for the exchange of qubit states and quantum-protected information. However, the lack of interaction between photons limits their use for processing tasks.

To this end, the hybridization of the light quanta to material excitations in a solid-state quantum element may offer an elegant way forward to implement qubit-qubit interaction. Quantum two-level systems analogous to artificial atoms (e.g., nonlinear crystals, coloured centres in diamond, semiconductor quantum dots) have been successfully used to generate single-photons, and the efficiency of this process can be greatly enhanced by confining photons in optical resonators allowing for strong coupling in the limit of very sharp linewidth. However, this solution is often far from optimal due to the mismatch between the confined electronic structures and the photon wavelength.

This leads to intrinsically small light-matter coupling which limits the device performance. The discovery of atomically thin (2D) semiconductors − transition metal dichalcogenides (TMDs) − with strong RT exciton physics1 exhibiting an exquisite tuneability with external electric field and dielectric screening2,3 offers an unprecedented opportunity to pioneer RT hybrid photon/matter quantum platforms in the strongly correlated regime in optical cavities. This ambitious quest is the focus of this PhD research project which aims to explore experimentally and theoretically a new class of quantum two-level systems (qubits) and, in doing so, pioneer room temperature operation of polariton blockade reaching the quantum level, i.e. down to single-polariton, in layered TMDs.

More specifically, the PhD researcher will investigate experimentally three parallel routes to the confinement: (1) etching of the crystals, modulation of the exciton binding energy by means of heterogeneous (2) laser-oxidised dielectric4 and (3) chemical functionalized environment. The use of graded dielectrics is expected to generate a force able to funnel interlayer excitons towards designated accumulation points. This will facilitate the harvest of excitons and enable the system to achieve the required critical number density to enter the polariton blockade regime and attain single photon emission. Hence, by working with the PDRAs recruited on the £1M EPSRC project (EP/Y021339/1), the PhD will study how the electric dipole of interlayer excitons responds to external electric fields and exploit this physics to fine tune the exciton energy levels with optical cavity modes.

Project specific enquiries:

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