Photon-Mediated Interactions among Solid-State Quantum Emitters

Quantum technologies show immense promise for future applications, particularly in the integration of single-photon sources, such as defect centres in solids, with photonic technologies. This PhD project focuses on both experimental investigations and theoretical studies concerning cooperative interactions among quantum emitters that share a common mode within various nanophotonic/plasmonic waveguide configurations. In one-dimensional settings, confined optical modes result in directional correlations, leading to the spontaneous breaking of mirror symmetry and the emergence of chirality. The primary objective is to achieve coherent coupling among multiple emitters embedded within these waveguides. The research encompasses both fundamental exploration and practical applications in the field of collective and chiral quantum optics [1-4].

The specific project objectives include several key areas, primarily centered on developing experimental and computational tools customized for designing nanophotonic/plasmonic waveguides. These goals involve exploring scenarios for the seamless integration of single emitters into waveguides, considering quantum emitters such as defects in solids, two-dimensional materials, and semiconductor quantum dots. Moreover, the project aims to achieve collective coupling phenomena within chiral nanophotonic waveguides, significantly contributing to our understanding of fundamental physical phenomena associated with light-matter interactions at the nanoscale.

The PhD project offers a unique opportunity to gain diverse experiences in a cutting-edge research environment and to develop expertise in nanophotonic design, laser spectroscopy, single-photon measurements, nanofabrication, and fluorescence microscopy. Two positions are available, with one focusing primarily on experimental quantum optics and the other on nanophotonic design and fabrication. The research is multidisciplinary, involving nanophotonics, quantum optics, solid-state physics, materials science, and quantum information processing.

For informal inquiries, please feel free to contact Dr. Hamidreza Siampour (h.siampour@qub.ac.uk) at the Centre for Quantum Materials & Technologies, School of Mathematics & Physics, Queen’s University Belfast.

Entry requirements

Applicants are expected to possess a first or upper-second class degree in physics, electrical engineering, or a relevant discipline (or an equivalent overseas qualification), or a lower second-class degree along with a Master's degree.

References

1. Lodahl, P. et al. Chiral quantum optics. *Nature* **541**, 473 (2017).
2. Evans, R. E. *et al.* Photon-mediated interactions between quantum emitters in a diamond nanocavity. *Science* **362**, 662 (2018).
3. Cardenas-Lopez, S., Masson, S. J., Zager, Z. & Asenjo-Garcia, A. Many-body superradiance and dynamical mirror symmetry breaking in waveguide QED. *Physical Review Letters* **131**, 033605 (2023).
4. Siampour, H. et al. Observation of large spontaneous emission rate enhancement of quantum dots in a broken-symmetry slow-light waveguide. *npj Quantum Information* **9**, 15 (2023).