Microcavity molecular photon sources

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Background. Efficient photon sources are required for many quantum technologies, from quantum sensing and communication to full-scale photonic quantum computing. Cryogenically cooled organic dye molecules are excellent sources of indistinguishable photons [1]. In the Centre for Cold Matter we have developed methods to grow organic anthracene crystals which we can controllably dope with dibenzoterrylene (DBT) molecules [3]. DBT is an excellent single photon emitter with a short lifetime (4 ns) and unity quantum yield that produces photons at 785 nm, a favourable wavelength for common laser systems and detectors. At cryogenic temperatures the photons have a very narrow bandwidth which only depends on the excited state lifetime of the molecule, meaning each successive photon generated is identical to the last. We have also been developing open-access fibre microcavities [3] to efficiently collect the photons emitted by a molecule. These cavities are formed between a plane mirror on the end of an optical fibre and a concave mirror etched in silicon, both mounted on piezoelectric transducers (Fig. 1(a)). A crystal containing molecules is placed on the fibre facet and then the whole cavity is cooled to below 4 K. We excite the molecule by sending a laser into the fibre, and can monitor the reflection from the cavity as we tune the cavity length and laser frequency (Fig. 1(b)). The molecule couples well to the cavity when the cavity resonance matches the molecular transition frequency.

MRes Project. In this project you will fabricate micron-scale spiral electrodes inside a glass substrate using our in-house sputtering plant, and characterise the DC fields that can be setup using this device. You will then place DBT-doped anthracene crystals on the surface near these electrodes and perform optical spectroscopy to characterise the frequency tuning of DBT emission. The electrode design will allow characterisation for various angles between the electric field and molecular dipole, to find the case for maximum tuneability.

PhD Project. The aim of this PhD project is to develop fibre microcavities coupled to organic molecules, and to prove that these can be used as fast, high-fidelity single photon sources. Quantum technologies have a real need for such sources. You will design and test new flexure designs for miniaturised cavities (Fig. 1(c) for example) which can be used in our closed-cycle cryostat. You will tailor the strength of the coupling by varying the number of layers in the DBRs, and will incorporate the electrode designs from the MRes project into the cavity. After measuring the reflection spectrum, you will switch to pumping the molecule with pulsed blue-detuned light to a higher vibrational level, which allows the excited state to become fully populated. We predict with the current mirrors that when the molecule is excited it will emit a photon and be collected in the fibre with a total efficiency of >20%, better than any current photon sources available. By increasing the mirror reflectivities we predict an efficiency of >80%, meaning interference experiments with >20 photons could be performed in feasible times. Due to the miniaturised and tuneable nature of the system, you will finally build two cavity-coupled molecules and operate them synchronously to show that photons from separate sources can interfere.