Towards the silicon-vacancy centre in diamond as a spin-photon interface

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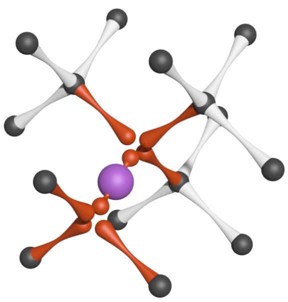
Effective interfaces between solid state qubits (which can have long storage times) and photon "flying" qubits (which can distribute entanglement) are an important resource for quantum communication and information processing. The negative silicon-vacancy (SiV) defect in diamond has recently gained considerable attention in this context.



The SiV centre consists of a silicon atom taking the place of two adjacent carbon atoms. It is understood that the silicon atom relaxes to sit at the bond-centred position, giving this defect inversion symmetry. This colour centre is a remarkable solid-state single photon source, with more than 70% of its fluorescence concentrated in a strong narrow zero-phonon line. Using photoluminescence excitation spectroscopy at 5 K we measured the individual transitions to have linewidths limited by the 1.7 ns excited state lifetime [1]. In addition, these transitions show no frequency variation over hours. Exceptional optical properties such as these facilitate efficient generation of indistinguishable photons from multiple distinct SiV emitters [2]. Such photons are ideal for distributing entanglement.

Progress has also been made towards spin manipulation in the SiV centre, which is an electronic spin-$\frac{1}{2}$ system [3]. An external magnetic field Zeeman splits the spin levels and makes individual spin-selective transitions optically resolvable at low temperature. Resonant excition of specific transitions provides the capability to initialise electron spin into a defined projection with high ($> 95\%$) fidelity. The spin relaxation time has been measured to be $T_1 = 2.4\,\text{ms}$ for a well-aligned magnetic field [4]. Two photon resonance has been used to optically prepare dark superposition states, with a spin coherence time of $T_2 = 35\,\text{ns}$ [4,5]. Work is ongoing to extend this coherence time, based on an understanding of the physical process that dephases spin states [6].

Beyond the technical applications, studying SiV centres has generated more general insights into the physics of colour centres. These inform the Quest for a Perfect Qubit.

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