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Integrated optics coupled with tunable colour centers in nanodiamonds

The rise of quantum technologies, especially the development of quantum networks, has made it important to develop reliable and robust quantum nodes which can communicate with each other through exchange of qubits. The biggest challenge in the way of developing such networks is to find suitable qubits which do not easily succumb to decoherence. Employing a scheme that relies on the coupling between single photons and atom-like transitions among spin states in a diamond colour center, it is possible to exploit both the strong coherence properties of photons and the easy control of spin states within the colour centers. In this work, we propose to couple single photons, generated by one germanium vacancy (GeV)center located within one nanodiamond, to other GeV centers in other nanodiamonds. The advantage of using nanodiamond-based GeV centers is in the ease of photon extraction along with the ability to control the colour center more easily through external fields without sacrificing spectral purity1. The superior conversion rate of GeV centres compared to nitrogen vacancy centres is also a strong point, as well as the larger splitting of the spin levels compared to silicon vacancy centres, which makes control of the spin qubit easier2.

We propose to couple individual nodes, each consisting of a single GeV contained in a nanodiamond, to a common glass waveguide optical bus. We will then have a hybrid quantum photonic platform made of GeV centres that act as stationary matter qubits and single photons that act as flying qubits, connecting nodes together. Our initial attempt will be focused on establishing a two-node network and then look towards scaling up to a multiple node quantum network. The first step would be to ensure that the colour center produces single photons. We have set up a Hanbury Brown & Twiss interferometer to measure the second order correlation function and select the single photon capable colour centres.Each center exhibits a slight deviation in ZPL wavelength owing to their different environments and we propose to counter this by either stress tuning or Stark effect tuning of the emission wavelength. Another challenge is to produce indistinguishable photons from these nodes. This can be verified by setting up a fiber-based Hong-Ou-Mandel experiment. Photons from different nanodiamond GeV centers, once collected through the common optical bus, will show a dip in the coincidence counts if they are indeed indistinguishable. We started by conducting a photoluminescence study of several GeV centers within our sample to pick out outstanding examples with high brightness. This will be followed by correlation experiments and low temperature fine structure analysis. Once suitable quantum node candidates are found among the nanodiamonds, a pick and place scheme will be adopted to position the pair of nanodiamonds onto the photonic structure. The challenge here is to optimize position of the nanodiamond so as to ensure optimal coupling.

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