Prospects for Strong Optical Coupling between Single Erbium Ions and Silicon Photonic Cavities

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Optically active spins in solids are promising for many applications in quantum Information science, such as entanglement distribution nodes in quantum networking, single photon sources for linear optical quantum computing, and as a platform for cluster state quantum computing. Their optical connectivity could also be leveraged to implement low-density parity check (LDPC) error correction codes. Erbium ions implanted in silicon are a particularly promising system, due to erbium’s emission in the Telecom C band, where attenuation in optical fibres is at a minimum, and where optical components are mature. Furthermore, the maturity of silicon fabrication allows for the fabrication of optical resonators with high Q/V. We have undertaken bulk ensemble measurements of erbium in silicon, exploring how the properties of implanted erbium ions vary with the concentration of erbium, concentration of background dopants, and proximity to surfaces. By doing spectral hole burning measurements using a doublet frequency comb, we have determined an upper bound for the homogeneous linewidth of several erbium sites. Furthermore, we have extracted the dipole moment of the optical transition from power dependent spectral hole measurements. Obtained homogeneous linewidths and dipole moments of two sites have been used to predict cavity QED parameters in the single ion regime based on the quality factors and mode volumes of different types of photonic crystal (PC) cavities reported in the literature. This indicates that high co-operativity coupling and potentially strong coupling to a single ion should be possible using state-of-the-art silicon photonic crystal cavities.