Control of exciton fine structure splitting in quantum dots

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Entangled photon pair sources are essential for applications such as entanglement based quantum key distribution [1], and optical quantum computers [2], for which it is important that no more than one entangled photon pair is generated in a cycle. If multiple pairs are generated, then errors are introduced which severely limits the scalability of the application. The most widely used technique to generate entangled photon pairs is parametric down conversion, which produces a probabilistic number of photons pairs per excitation cycle. In contrast, the biexciton decay in a single quantum dot was proposed [3] to provide a source of ‘triggered’ entangled photon pairs, so called because it can produce no more than two photons per excitation cycle. However, the realisation of such a device has been prevented due to polarisation splitting of the dot emission lines. The ‘which-path’ information that this provides destroys any entanglement, resulting in only classically correlated entangled photon pairs [4].

We will present two techniques which we developed to control the polarisation splitting in a quantum dot both irreversibly and reversibly. The first, irreversible, technique relies on the discovery that the polarisation splitting of a quantum dot is strongly dependent upon the emission energy, or lateral confinement, of the quantum dot [5]. Thus by precise control of the InAs deposition thickness, or post growth annealing, it is possible to produce ensembles from which dots with zero polarisation splitting can be easily selected. The second, reversible, method of splitting reduction uses modest in-plane magnetic fields to partially mix the bright and dark exciton states, and can tune the polarisation splitting to zero for most dots of a certain type [6].

Finally, we will show that these techniques enable the emission of entangled photon pairs from a quantum dot [9,10]. Polarisation dependent correlation measurements show features expected for entangled photon emission only for dots with zero polarisation splitting, such as correlation in rectilinear, diagonal and circular bases, and insensitivity to rotation of the input light relative to the polarisation analysers. The fidelity of the emission with the entangled state \(\frac{|HH>+|VV>}{\sqrt{2}}\) is >70%, violating the limit for a classically correlated photon source of 50%. Our results represent the first demonstration of a ‘triggered’ semiconductor source of entangled photons, and we hope that with further optimisation, the future for an entangled photon LED, and associated applications, is very promising.