Tunable transition energies, entangled photon pairs and coherent control of the exciton using quantum dots in diodes

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We have developed a *p-i-n* diode structure that allows vertical electric fields of 500 kV/cm to be applied to InAs/GaAs quantum dots without tunnelling-induced quenching of radiative emission. This allows us to tune their transition energies by 25meV, in principle allowing all dots in an inhomogeneously broadened ensemble to emit at the same energy (R. Patel *et al*, Nature Photonics 4, 632 (2010)).

We have found that this large electric field is also a promising way to control the neutral exciton's fine-structure splitting (*s*). We find *s* shifts linearly with field at a remarkably similar rate for all dots, even if they differ in wavelength or *s* at zero field (A. J. Bennett *et al*, Nature Physics 6, 947 (2010)). In a large fraction of the dots we can tune *s* to a minimum value where we observe an avoided crossing in the two exciton energy levels and rotation of the eigenstates in the plane of the sample. When *s* is reduced to a few micro-eV efficient emission of polarization entangled photon pairs occurs with a fidelity of 71%.

The use of a static electric field is useful for entangled photon pair emission, but perhaps uniquely amongst the various methods for tuning *s* this mechanism allows dynamic control. In one experiment we have used a quasi-resonant laser to excite a certain spin-state in the exciton and then through application of sub-nanosecond electrical pulses coherently manipulated this state by modulating *s.* The induced phase shift is proportional to the area of the electrical pulse. If working near the minimum in *s*, a spin flip can be achieved by simultaneous rotation of the eigenstates. (A. Boyer de la Giroday *et al*, Phys. Rev. B 82, 241301R (2010)).