Single photon emission from site-controlled pyramidal quantum dots

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The development of reliable semiconductor single photon emitters[1] is crucial for applications in future opto-electronic devices for quantum computing,[2] and quantum cryptography,[3] as well as for fundamental quantum optics experiments.[4] Here we report on the realization of single-photon emission from site-controlled, highly uniform pyramidal quantum dots (QDs). The collaboration resulting in these results has been generously funded by the Quantum Information Processing and Communications Network of Excellence (QUIPROCONE) of the European Commission. Samples were provided by the group of Prof. E. Kapon and measurements were performed using the measurement setup of I. Abram.

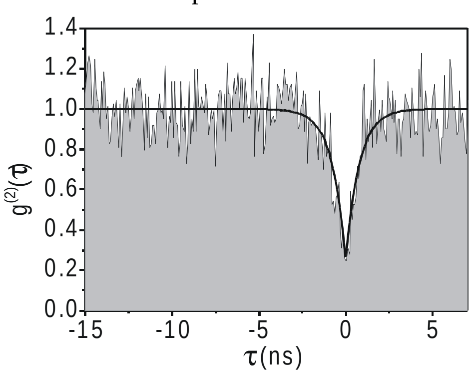

Fig. 1: Anti-bunching signature in the second order correlation function of single exciton (X) photons emitted by a pyramidal QD.

The investigated QDs are grown by organo-metallic chemical vapor deposition of $Al_xGa_{1-x}As/In_yGa_{1-y}As/Al_xGa_{1-x}As$ layers on (111)B-GaAs substrates patterned with tetrahedral pyramids.[5,6] QD positions are precisely controlled by their self-formation at the tip of each pyramid. The QD ground state emission energy can be tuned in the range of 1.65 to 1.43 eV by varying the QD size and In- as well as Al-mole fractions. The inhomogeneous broadening of the QD ground state emission energy has been determined to be less than 8 meV for an s-p-separation of 55 meV by statistical single QD spectroscopy.

Using optical excitation with a frequency-doubled Nd:YAG laser (532nm), we measured the time correlation of photons resulting from the single exciton (X) decay in single pyramidal $In_{10}Ga_{90}As/Al_{30}Ga_{70}As$ QDs emitting at 1.55 eV at 10K. By means of a micro-photoluminescence setup combined with a Hanbury Brown and Twiss detection unit we have experimentally determined the second order correlation function $g^{(2)}(\tau)=\langle I(t+\tau)I(t)\rangle/(\langle I(t+\tau)\rangle\langle I(t)\rangle$ of the X emission, see Fig.1. A central dip at $\tau=0$ ns was observed, with a minimum of $g^{(2)}(0) = 0.2$, clearly demonstrating the non-classical nature of the emission process. Indeed, this anti-bunching effect is the signature of the single photon nature of the emission, since the single photon cannot be split into two to activate both the start- and stop signals simultaneously. The residual measured value of $g^{(2)}(0) = 0.2$ is due to a combination of the finite temporal resolution of the setup (460 ps) and the detection of uncorrelated back-ground photons.

We have observed photon anti-bunching from several single QDs within the same matrix. The single photon emission of the pyramidal QDs makes them attractive light sources for novel single photon emitter applications. Site-controlled grown QDs have a particular advantage over other single-photon sources since the position, the spacing and the size uniformity of the QDs can be precisely and reproducibly controlled during the growth process, thus possibly permitting the design of particular photonic circuits for quantum information processing.

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