SINGLE PHOTON EMITTERS BASED ON InGaAs/AlGaAs NANOSTRUCTURES GROWN IN THE INVERTED PYRAMIDS.

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The emerging field of quantum information technology requires the development of the new types of light sources which can produce photons on demand. Especially useful would be an emitter of single photons emanating at predetermined times. This functionality is particularly crucial for technologies such as secure quantum communication and quantum computing.[1, 2]

As has been shown already, semiconductor quantum dots (QDs) can act as single photon emitters.[3] However, nearly all of the research in this area has been performed using QDs, which form spontaneously, via the strain-driven Stransky-Krastanow growth or colloidal nucleation. The resulting QDs are distributed at random sites on their substrate and exhibit large size fluctuations, which spreads their emission lines over wide spectral range. Additionally, colloidal QDs suffer from blinking and photobleaching/degradation, further complicating their applicability.

Pyramidal quantum dots grown by OMCVD on pre-patterned substrates present an alternative approach to the fabrication of semiconductor quantum dots. During the growth, a QD is formed at the tip of each pyramidal recess due to growth rate anisotropy, capillarity and entropy of mixing effects. Excellent position control, good size distribution and the possibility to tune the exciton emission energy over a relatively broad spectral range make them attractive candidates for single photon applications.[4] Photon antibunching of exciton emission from single pyramidal QD under cw (532 nm) and pulsed (740 nm, 2 ps, 82 MHz) excitation is shown on Fig.1. It is clearly visible that under both excitation conditions the QD emits single photons with virtually no uncorrelated background light. The dip depth of the second order correlation curve $g^2(\tau)$ under cw excitation is limited mainly by the detector's resolution (APDs jitter ~ 700 ps). Under pulsed excitation the probability that the QD emits two photons during the excitation cycle is reduced to less than 5% as estimated from the peak's areas on Fig.1 (b).

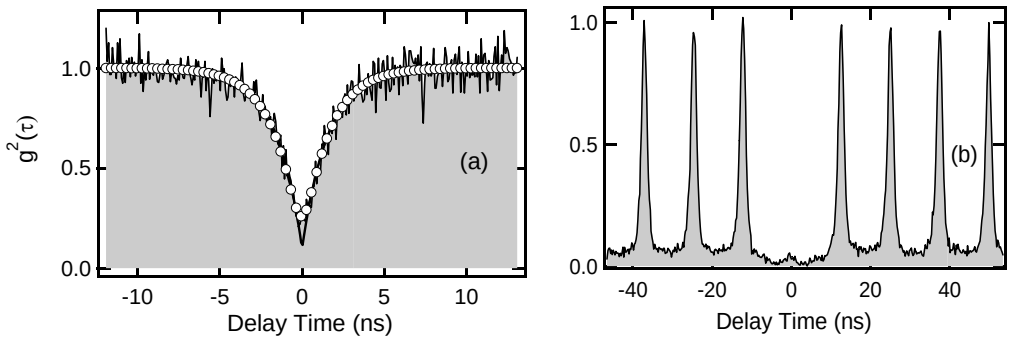

Fig. 1 Photon antibunching of the QD exciton emission in the low power regime (a) under cw and (b) pulsed excitations, T=10 K. (a) Circles - best fit to experimental data, solid line - deconvolution with the system's temporal response.

For practical applications it is important to have single photon emitter operating at high temperature, preferably higher than liquid nitrogen temperature. Using pyramidal QDs we were able to observe single photon emission at temperatures up to 90 K, which is one of the highest temperatures reported for single photon operation using III-V semiconductor QDs.

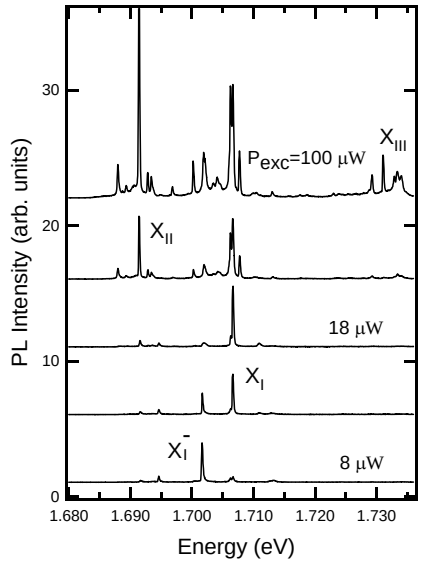

Fig. 2 Power dependent evolution of QWR emission under cw excitation showing emission from excitons localized at different sites (I, II and III). T=10 K

In addition to photoluminescence from the QDs, we have also studied the emission from single, self-ordered semiconductor quantum wires (QWRs) located in the corners between the sidewalls of inverted pyramids. We observed the appearance of sharp emission lines in QWRs spectra and interpreted them as arising from the localization of carriers at QD-like potential wells induced by the fluctuation of the QWR shape, size and/or composition (see Fig. 2). Moreover, we demonstrated photon antibunching of the PL emission coming from such localized excitons and have shown that they act as single photon emitters (Fig. 3 (a)). Using single photon correlation techniques we also observed that several pairs of emission lines exhibit cross-correlation signatures, proving that they originate from the same localization site, and, together with pump-power dependence support their assignment as exciton (X) and charged exciton (X^-) lines (Fig. 3(b)).

Our results demonstrate new ways for obtaining single photon emission from semiconductor nanostructures. They also illustrate the use of photon correlation spectroscopy to spatially map the recombination sites of excitons in nanostructures.

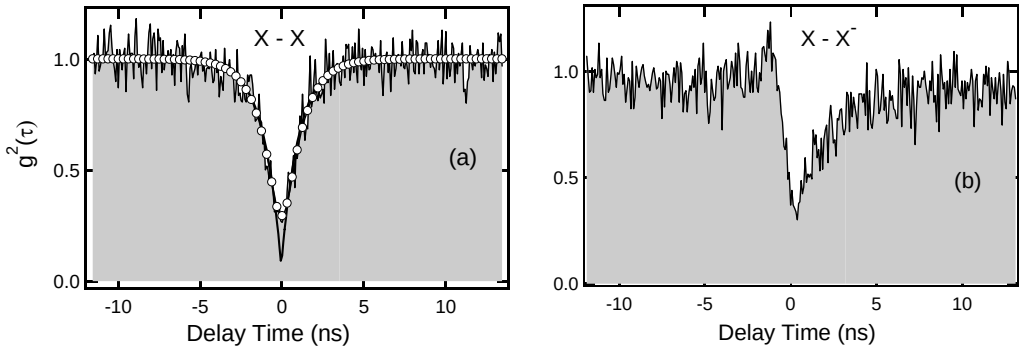

Fig. 3 (a) Auto-correlation of one of the QWR exciton lines under low power cw excitation (b) Cross-correlation between the emissions of the exciton (X) and the charged exciton (X^-) localized at the same spot. T=10 K

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