# Photon extraction enhancement and suppression of multi-photon emission from an InAs quantum dot in a metal-embedded nanocone structure

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Semiconductor quantum dots (QDs) are potential candidates for bright single-photon sources in the context of quantum information processing and quantum communications. Significant progress has been made to achieve efficient single-photon sources.[1-4] Although photonic nanowires and distributed Bragg reflector microcavity pillars exhibited high photon-extraction efficiencies, mechanical stability related to their high aspect ratio and their stability to couple to outer photon-collection optics remain as challenging issues. In this abstract, we introduce a metal (silver)-embedded GaAs nanocone structure containing an InAs QD showing high photon extraction and suppression of multi-photon emission under quasi-resonant excitation.

The InAs QDs were grown on GaAs (100) substrate by metal organic molecular-beam epitaxy (MOMBE). To fabricate a tailored nanocone structure, electron beam lithography and dry etching processes were performed. Such a tailored structure was then deposited with a $SiO_2$ layer and Ag film. Sequential polishing followed by dry etching of GaAs was carried out for the fabrication of Ag-embedded nanocone structure including InAs QDs (see Fig. 1).

The μ-PL spectrum of an InAs QD in an Ag-embedded nanocone structure at 4 K is shown in the inset of Fig. 2(a). The PL peaks at 944 and 945.9 nm were determined as a neutral exciton ($X^0$) emission and a negatively charged exciton ($X^-$) emission, respectively. For the $X^-$ line at saturation, the photon count rate was measured to be ~200 KHz as shown in Fig. 2(a) and the photon-extraction efficiency was 21.5% under 800 nm pulsed excitation with a repetition rate of 76 MHz. Considering the competition between the $X^0$ and $X^-$, our photon-extraction efficiency was as high as 24.6%. It can be seen that this newly developed structure exhibited an enhancement in photon extraction compared with our previous structure.[4] Second-order correlation function $g^{(2)}(\tau)$ was also measured under quasi-resonant excitation using 897 nm pulsed laser with a Hanbury-Brown and Twiss (HBT) setup.[5] Figure 2(b) shows the antibunching behavior of $g^{(2)}(\tau)$ without subtracting any background counts. The $g^{(2)}(0)$ was calculated to be 0.025, indicating strong suppression of multi-photon emission.

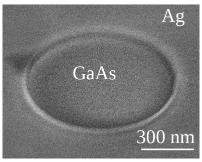


Fig. 1. Top-view SEM image of the Ag-embedded nanocone structure with removed substrate.

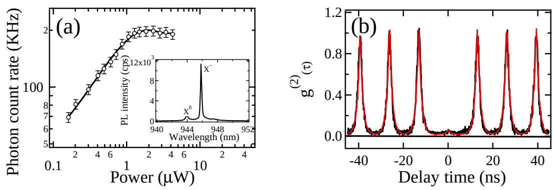


Fig. 2. (a) Photon count rate of the $X^-$ line as a function of excitation power. The inset is the μ-PL spectrum. (b) $g^{(2)}(\tau)$ as a function of delay time τ. The red curve is the fit to the data.

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