COLLOIDAL NANOCRYSTALS FOR QUANTUM INFORMATION TECHNOLOGY

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Efficient single photon sources (SPSs) are now catching the scientific community attention. Quantum information technology algorithms are based on antibunched photon fluxes and on the fine control of their quantum states and polarization properties. Among the proposed approaches for SPSs based devices, actually two technologies are in competitions: the Stranski-Krastanov epitaxial quantum dots (QDs) and wet-chemically synthesized colloidal nanocrystals (NCs). Epitaxial QDs have been deeply studied in past years and antibunched photon fluxes up to a temperature of ~200 K have been achieved by using either GaN QDs [1] or a single QD embedded in a single quantum wire [2]. In spite of the possibility to simply achieve electrical injection [3] and positioning inside photonic crystals nanocavities [4], room temperature single photon emission in epitaxial nanostructures has not been demonstrated so far. On the other hand, colloidal core/shell NCs are efficient sources of antibunched photons at room temperature [5] and show several advantages which let us envision their application to final devices. It has been demonstrated that the shape and size of the NCs can be tailored to overcome the drawbacks which so far limited the nanocrystals applications, such as blinking [6] and unpolarized emission [7]. Beside the characterization of their physical properties [8,9], the compatibility with the nano-engineering techniques has been recently demonstrated [10] and the first evidence of SPSs based on single nanocrystal coupled to a cavity mode has been demonstrated [11].

In this work we report on efficient SPSs based on a particular type of nanocrystals, in which a CdSe rod-like shell surround a CdS spherical core (Fig.1(a)). The polarization properties of these nanoparticles make them suitable for the implementation of quantum information technology algorithms based on photon polarization, such as BB84 and B92 for private cryptography keys distribution [12][13]. The CdSe/CdS core/shell dot-in-rod (DR) nanocrystals have been synthesized with a seeded growth approach [14], which yields nanorods with narrow distributions of both lengths and diameters. A DR mono-molar solution (in toluene) was dropcasted on a microscope glass coverslip and excited using a picosecond pulsed laser. By means of a high sensitivity Hanbury-Brown and Twiss setup, based on two avalanche photodiodes, we performed time and polarization resolved measurements. In order to proof the non classical behavior of the light emitted from the single DR, the coincidence histogram (proportional to the autocorrelation function $g^{(2)}(\tau)$) was measured for several nanocrystals, showing a near perfect antibunching (see Fig.1(b)): the few coincidences near zero delay mean that the probability to detect more than one photon at the same time is extremely low and the sharp periodic peaks indicate that two photons are usually spaced of a multiple of the period of the laser pulses.

The photoluminescence mean value, excluding the time intervals in which the single nanocrystal was not emitting due to the blinking, was computed for several values of the polarization-detection angle (θ); the obtained values, reported in Fig.1(c), follow the function $\cos^2(\theta)$, achieving a degree of linear polarization of ~75%. By measuring the distances between every received photon and the laser pulses (used as a trigger) we computed the mean lifetime of the electron-hole pair excited in the nanoparticles (ideally one for each laser pulse) obtaining $\tau_r \sim 11.1ns$. In conclusion, in this work we have shown that single colloidal DRs, by virtue of their relatively short lifetime, good antibunching and a high degree of linear polarization (~75%), represent a key building block for the realization of high rate and efficient single photon sources for quantum cryptography applications.

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Figures:

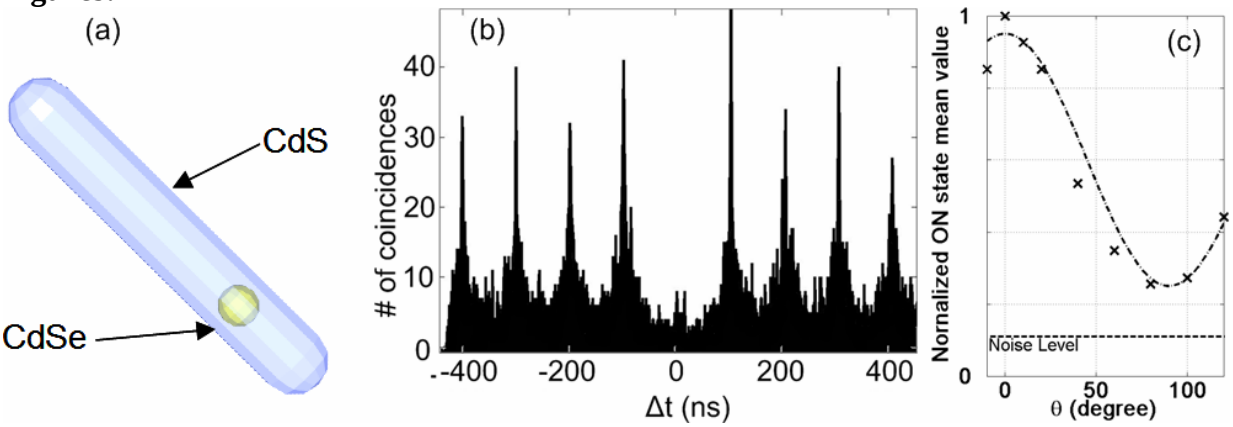

Fig. 1 (a) Schematic representation of the analyzed dot-in-rod. **(b)** Typical coincidences histogram obtained from a single and isolated dot-in-rod. **(c)** Normalized intensity for several polarization angles computed by excluding the time intervals in which the nanocrystal was not emitting.