Single Photon Generation and Frequency Conversion

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Core-shell colloidal semiconductor nanocrystals are very efficient single photon emitters at room temperature [1]. This is due to the strong confinement of the charge carriers in these nanostructures that leads to a fast nonradiative relaxation of multi-excitons and results in photon antibunching. However in such structures, the competition between radiative and non-radiative recombination channels induces photoluminescence fluctuations between on and off states known as blinking. Shell engineering [2] in asymmetric core/shell nanoparticles (dots-in-rods) with a spherical CdSe core surrounded by a rod-like CdS shell has allowed us to reduce the blinking effects without enhancing multi-excitonic emission [3,4].

Moreover, dots-in-rod (DR) emit photons with a significant degree of polarization along the c-axis of the wurtzite crystal, which is also the axis of the rod. This linearly polarized emission is due to the fine structure splitting, the levels ordering and the oscillator strengths of the various transitions, which depend on the elongated shape of the DRs. Here we show that the polarization of the emitted photons can be controlled by tuning the shell dimensions. This allows an unprecedented capability in radiative channels engineering, making dot-in-rods “state of the art” blinking-free sources of polarized single photons on-demand [5].

With the presently available nanocrystals the single photons are emitted in the visible range, with a wavelength close to 0.60μm in the case studied here. In order to allow more flexibility in the use of the single photons, frequency conversion can be implemented. It relies on sum-frequency generation (SFG) or difference-frequency generation (DFG), using a nonlinear crystal (PPLN in the present case) and an efficient pump laser. Sum frequency generation allowed to convert photons at 1.04 μm into photons at 0.62 μm using a pump laser at 1.55 μm, with an efficiency up to 80% [6]. With a pump frequency at 1.05 μm, photons at 3.39 μm could be converted to 0.80 μm with an efficiency of 64% [7].

A symmetrical process, difference frequency generation (DFG) [8] with the same crystals should allow to down convert the 0.60 μm photons emitted by the nanocrystals to 1.560 μm using a 0.975 μm pump. This frequency conversion will open the way to the use of these sources for practical applications such as quantum key distribution in telecom lines.

References
