Spectral redistribution in spontaneous emission from quantum dot infiltrated three-dimensional photonic crystals

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The strong three-dimensional (3D) confinement of light in 3D photonic crystals (PCs) provides a powerful tool for research on nanocrystals and quantum electrodynamics. Recently, the control of radiation dynamics of nanocrystal quantum dots (QDs) inside PCs has received a great attention for its scientific significance in quantum optics, as well as its potentials for diverse applications [1]. However, study on emission control of the QDs within 3D PCs in the telecommunication wavelength region has not yet been demonstrated.

Here, we report on the study of the emission property of PbSe QDs embedded in 3D woodpile polymer PCs fabricated by the two-photon polymerization (2PP) method. Photonic band gaps (PBGs) of PCs were tuned towards longer wavelengths by infiltrating the QDs. A spectral redistribution in spontaneous emission from QDs inside a 3D PC has been measured for both low and high concentrations of infiltration.

The 3D woodpile PCs in our work were fabricated directly on a cover glass by the 2PP method [2]. PbSe QDs stabilized with oleic acid were prepared using the method described by Yu et al [3]. The infiltration process was performed through drop casting QD solution directly onto the PC sample fabricated on the cover glass. With the assist of the frame and with the fast evaporation process under heating, the QDs can be well deposited on the rods of PCs. Meanwhile, a QD film (~ 0.5-1 µm thickness) was formed outside the PC during the infiltration, thus providing a direct and convenient reference for our studies of QD emission inside the PC.

![Fig. 1](image)

**Fig. 1** (a) Normalized absorption (Abs) and photoluminescence (PL) spectra from PbSe QDs on the cover glass. (b) Normalized PL spectra from QDs inside PC and outside PC at the same excitation power level.

The PBGs of the PC were tuned towards longer wavelengths by infiltrating the structure with QDs of different concentrations. The dried PbSe QDs sample on the coverslip had absorption and photoluminescence (PL) emission peaks centred at wavelengths of 1500 nm and 1580 nm (Fig. 1a), respectively. The spectral redistribution in spontaneous emission from QDs inside the 3D PC has been observed for different concentrations. As we excited the doped sample with a femtosecond laser operating at wavelength 800 nm, the PL spectra from the QDs outside the PC increased uniformly with the excitation power and showed an almost identical shape. By comparison, the PL spectra from QDs inside the PC showed a wavelength-dependent change. The intensity in the shorter wavelength range increased with the excitation power faster than that in the longer wavelength range, showing a relative enhanced spectrum at the shorter wavelength range compared with that of QDs outside the PC (Fig. 1b). The intensity ratio between wavelengths 1350 nm and 1580 nm indicate clearly an enhancement or a spectral redistribution of the QD emission in the shorter wavelength region compared to the emission intensity in the longer wavelength. It should be pointed out that 3D woodpile structures with band gaps outside the QD emission wavelength range did not exhibit such a spectral redistribution.

**References**