Accelerated spontaneous emission of PbS quantum dots in 3D silicon photonic band gap crystals

Timon J. Vreman, Melissa J. Goodwin, Ad Lagendijk, and Willem L. Vos

Complex Photonic Systems (COPS), MESA+ Institute for Nanotechnology, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

Photonic band gap crystals are being pursued for their ability to control emission and vacuum fluctuations radically. Here, we examine the spontaneous emission of lead sulfide quantum dot nanocrystals within 3D photonic band gap crystals. These crystals, formed by etching deep pores in a silicon bar from two directions, possess a diamond-like inverse-woodpile structure, with quantum dots infiltrated into the pores using a toluene suspension. At frequencies just above the band gap, we observe 24x more intensity from quantum dots inside the crystal than the same number of dots outside, indicative of strongly enhanced emission. Time-correlated single photon counting shows fast non-exponential decay, reflecting the varied local densities of states of different quantum dots within the nanopores. We employ a log-normal model to interpret properties of the time-resolved decay at different emission frequencies and observe that the most frequently occurring decay rate is up to a factor 7x greater in the photonic crystal than outside. Current efforts focus on enhancing signal-to-background and signal-to-noise ratio, essential for probing inhibited decay within the band gap, and further studies on 3D band gap cavity superlattices and quasicrystals.