Spontaneous Emission of PbS Quantum Dots Controlled by Silicon Photonic Band Gap Crystals

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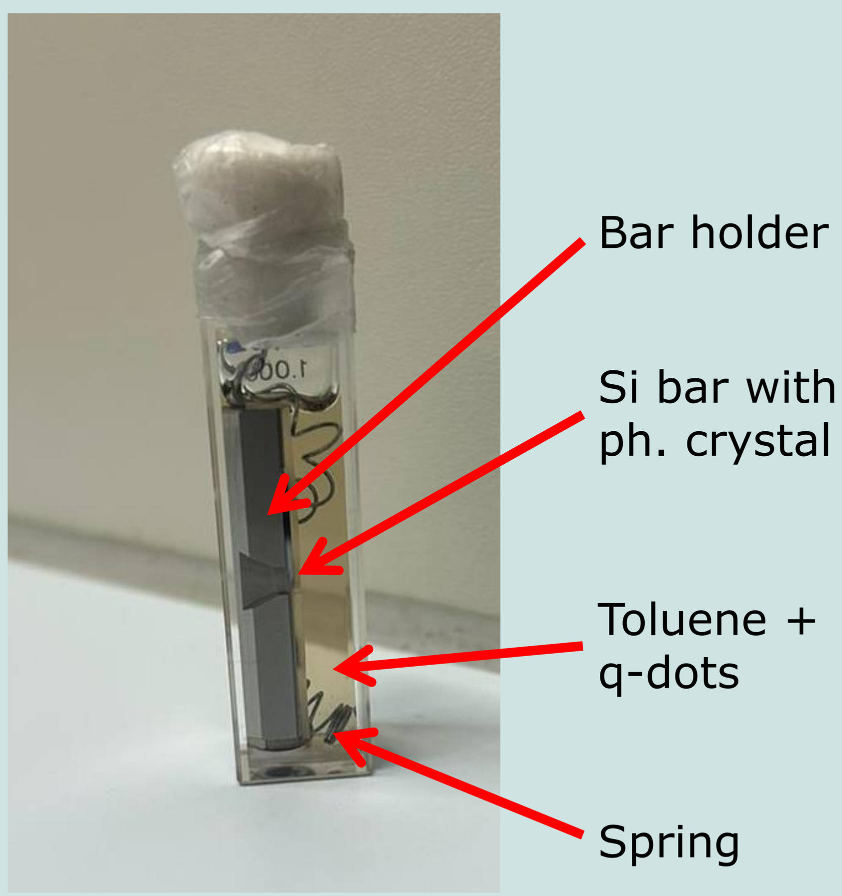
Introduction

Photonic crystals are being pursued for their great potential to control spontaneous emission of excited classical and quantum emitters.

Here, we study the radiative decay rate of excited PbS quantum dots inside a photonic crystal (Ph. C.).

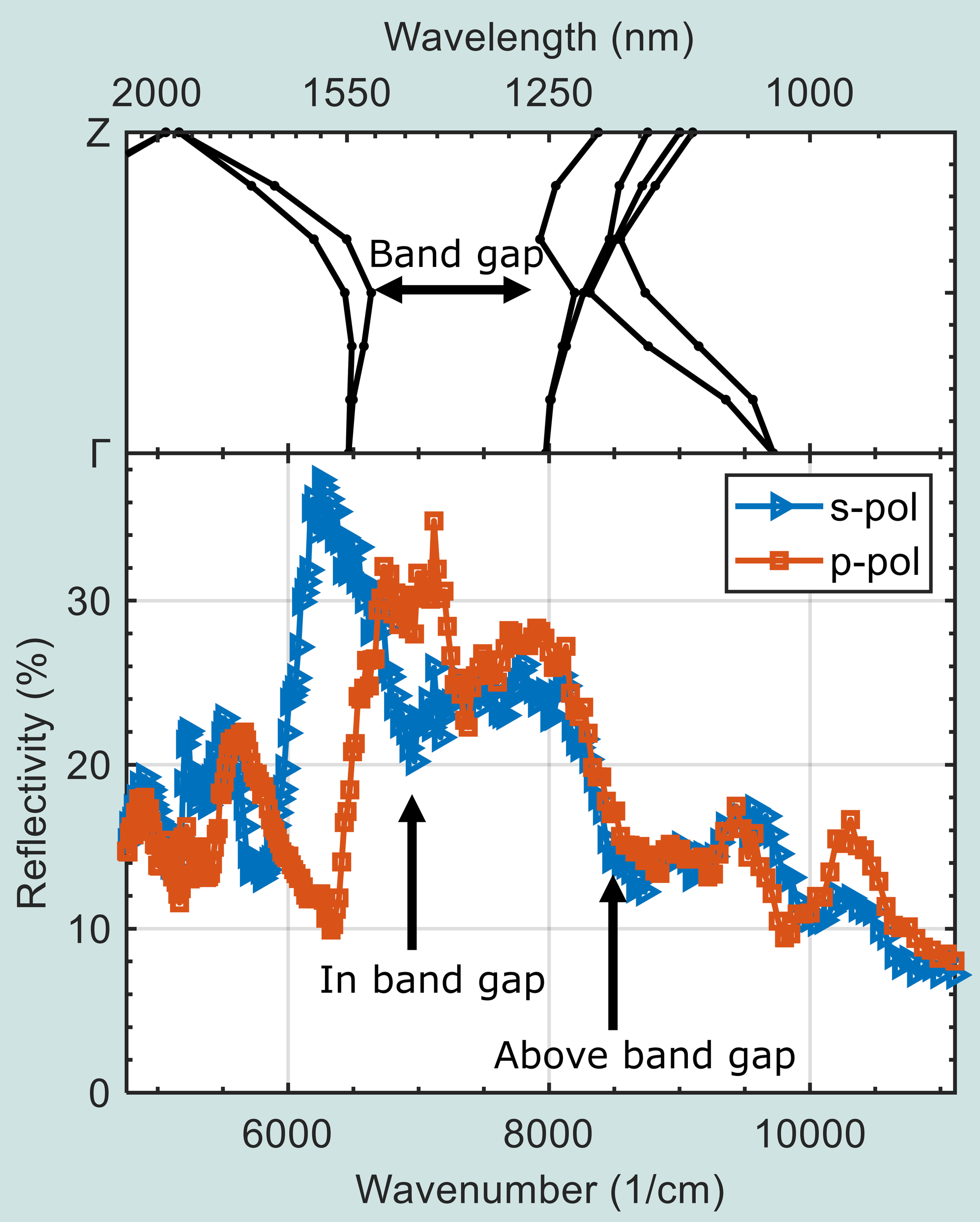
The photonic crystal consists of long pores etched from two directions in a silicon bar.

Photonic crystal inside cuvette

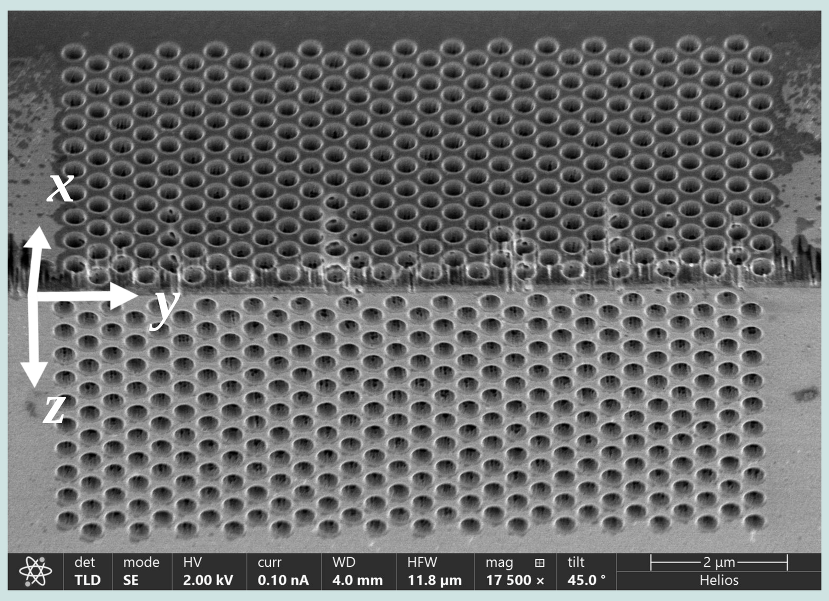


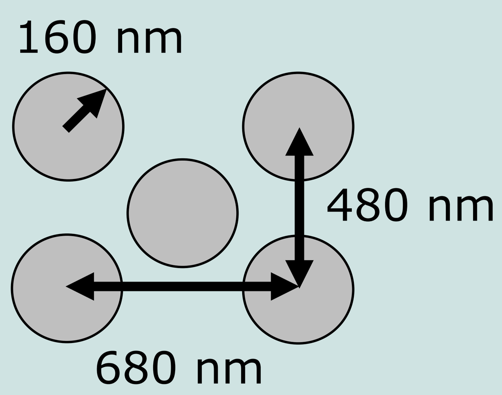
Photonic crystal on Si bar

Band gap between wavenumber 6600 and 8000 1/cm



Photonic crystal made by us in the MESA+ NanoLab [1]:

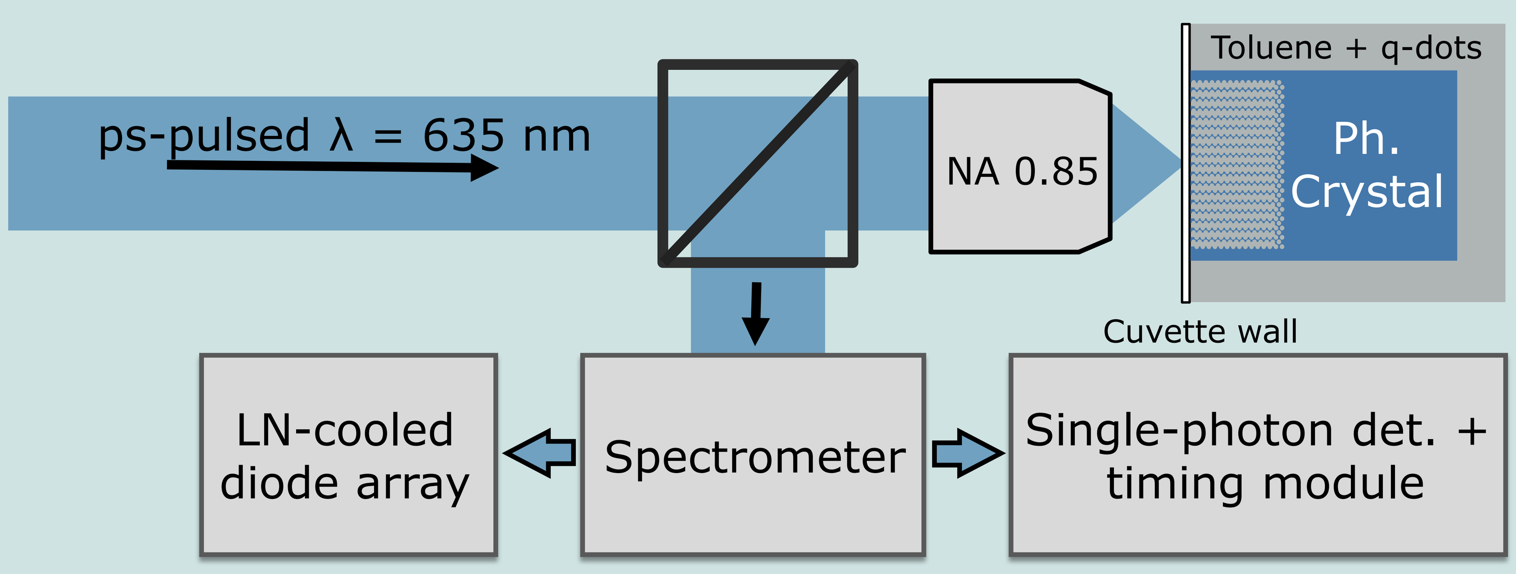




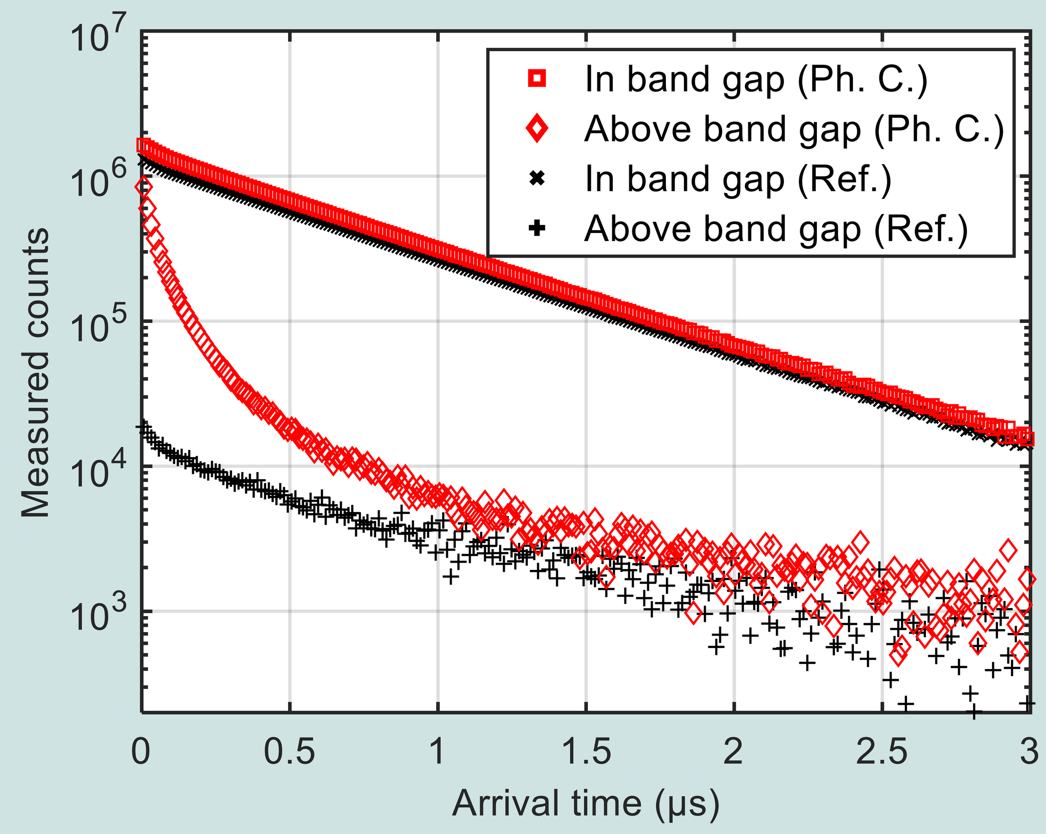
Pores with depth ≈ 4000 nm

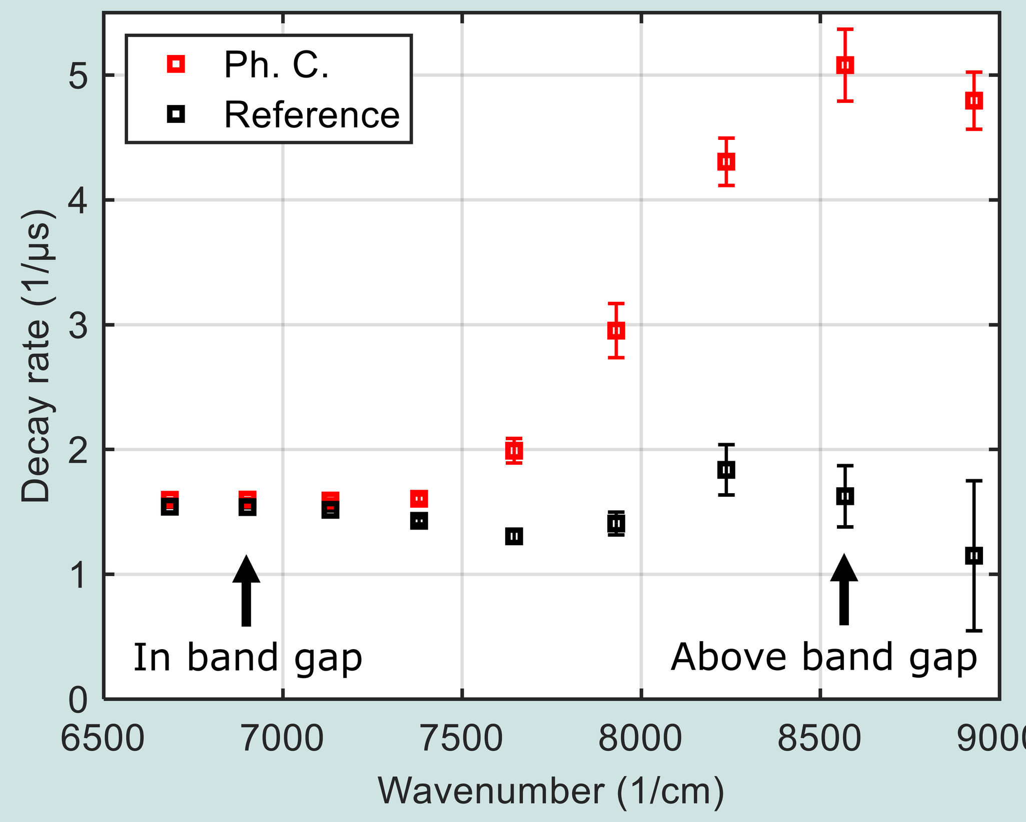
Setup to measure spontaneous emission

Exciting quantum dots and collecting emission using the same objective



Radiative decay rate





Steps (more details in [2]):

1. Choose a position on the silicon bar to measure, *i.e.*, on the photonic crystal (Ph. C.) or on the reference position (Ref.)
2. Send a short laser pulse to excite the quantum dots in the focus, and start a timer
3. Detect a photon and stop the timer
4. Repeat a million times and make a histogram (top)
5. From the slope, extract the decay rate
6. Repeat at several wavenumbers (bottom)

Conclusion

Emission just above the photonic band gap shows faster decay than inside the band gap.

That fits the theory: just above the band gap, there are many modes available for decay, meaning the decay goes faster [3].

Outlook

Improve decay rate fitting

Increase the percentage of light out of the photonic crystal compared to surroundings, such that we can see slower decay too

References

[1] This sample was made by Melissa Goodwin. D. A. Grishina, C. A. M. Harteveld, L. A. Woldering, and W. L. Vos, “Method for making a single-step etch mask for 3D monolithic nanostructures,” Nanotechnology, vol. 26, no. 50, p. 505 302, 2015.
[2] M. D. Leistikow, A. P. Mosk, E. Yeganegi, S. R. Huisman, A. Lagendijk, and W. L. Vos, "Inhibited Spontaneous Emission of Quantum Dots Observed in a 3D Photonic Band Gap," Phys. Rev. Lett. 107, 193903 (2011).
[3] W. L. Barnes, S. A R. Horsley, and W. L. Vos, "Classical antennas, quantum emitters, and densities of optical states," J. Opt. 22, 073501 (2020).