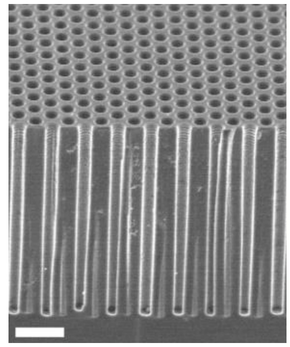
Probing the local density of states in 2D photonic crystals

Bachelor project

Ever since their conception, photonic crystals are being pursued for the great potential to control spontaneous emission [1]. Central to this pursuit are the photonic gaps that strongly modulate the local density of optical states [2]. While 3D band gap crystals are desirable due to the radical control in a 3D gap [3], 2D crystals have generally a much larger extent [4], advantageous for device applications like efficient light sources or sensors.



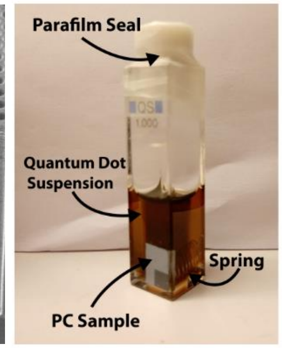


Figure 1 (left): SEM image of the 2D photonic crystal at a cut. Scale bar is 1 μm. Image by Melissa Goodwin.
Figure 2 (right): Photo of the cuvette with a 2D photonic crystal being held in a cuvette with toluene. Image by Pieter van Essen.

At COPS, large 2D photonic crystals are fabricated by etching 5 μm deep pores in a silicon wafer, see figure 1 and figure 2. We would like to probe the local DOS (LDOS) inside the photonic crystals by measuring the radiative decay rate of quantum dots that are inside the structures. That way, we better understand the optical properties of these photonic crystals.

To measure the radiative decay rate of quantum dots inside our photonic crystals, we immerse the crystal in toluene, which enters the pores. Quantum dots are added to the liquid. The quantum dots diffuse through the liquid and thus also enter the pores. As shown in Figure 2, the silicon wafer with the photonic crystal is pressed against the cuvette wall such that we can excite the quantum dots and measure their emission properties.

The project is very diverse. To name a few of the challenges you will encounter: (A) Quantum dots oxidize quickly when they are in contact with air, so filling the cuvette with quantum dots has to be done in a glove box. (B) There should be little to no space between the crystal and the cuvette wall, as we only want to measure emission out of the pores, and not outside. We have to measure the distance between the wafer and the cuvette wall and make sure it is much less than the pore depth, which was only 5 μm. (C) Explaining experimental results using photonic crystal theory.

There will be little time, so we will make sure that the photonic crystal, chemical lab, and optical setups are ready to be used right from the start. Only basic chemistry knowledge is required. If there is more time, we can also investigate the polarization dependence of the emitted light.

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[2] W.L. Barnes, *et al.*, J. Opt. **22**, 073501 (2020); R. Sprik, *et al.*, EPL **35**, 265 (1996)
[3] M.D. Leistikow, *et al.*, Phys. Rev. Lett. **107**, 193903 (2011); C.M. Mavidis, *et al.*, Phys. Rev. B **101**, 235309 (2020)
[4] M Fujita, *et al.*, Science **308**, 1296 (2005); M Kaniber, *et al.*, Phys. Rev. B **77**, 073312 (2008)