Investigating the effects of the position of the air-crystal interface on the reflectivity off 2D photonic crystals

Bachelor project

Summary: The goal is to measure the reflectivity as a function of frequency off a 2D photonic crystal etched in silicon where the interface between the air and the photonic crystal is varied in a controlled way.

Photonic crystals are materials with a spatially periodic dielectric constant $\epsilon(\boldsymbol{r})$, where r is the spatial location. For photonic crystals, the period is of the order of the wavelength. The periodicity may be constructed in one dimension only, *e.g.*, like a stack of planes, two dimensions only, *e.g.*, like a checkerboard pattern, or in all three dimensions, *e.g.*, like a tower of Jenga blocks [1].

Photonic crystals are called such because the electromagnetic waves in a photonic crystal are analogous to electron waves in an atomic or molecular crystal lattice. Instead of a periodic $\epsilon(\boldsymbol{r})$, atomic and molecular crystal lattices have a periodic potential created by atoms or molecules. Just like electrons in semiconductors, photonic crystals have a band gap for which propagation in any direction is not allowed for electromagnetic waves. Because of the analogy, many terms and effects of the electrons in crystal lattices are also used in the photonic analogy. For example, the direct lattices are both described using unit cells, are both transformed in reciprocal space. Additionally, for both propagation goes via Bloch modes, and both adhere to Bragg diffraction.

Just like normal crystals, photonic crystals must end somewhere, meaning that somewhere there is an interface. Reflectivity off this interface tells us something about the properties of the photonic crystal. For example, a reflectivity measurement may indicate the position of a photonic band gap, which is a frequency range for which propagation of light from any direction or polarization is forbidden. In the lab, we have seen that the cut that the interface makes between air and the photonic crystal, see Fig. 1, influences the reflectivity off the crystal, but we have not been able to quantify it yet.

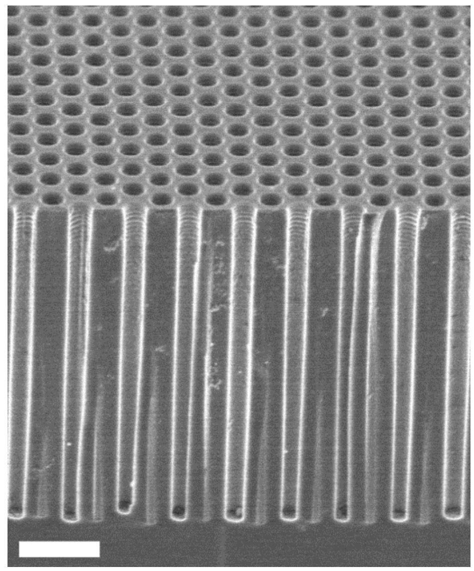

Figure 1. Two-dimensional photonic crystal consisting of air pores etched in a silicon wafer [2].

The goal of this project is to find out what the effect of the chosen interface is on the reflectivity off a 2D photonic crystal. The photonic crystal with different positions of the air-crystal interface will be prepared by our technician. The student will measure and simulate the effects of various interfaces on the reflectivity as a function of frequency.

[1] J. Joannopoulos, S. G. Johnson, J. Winn, and R. D. Meade, *Photonic Crystals: Molding the Flow of Light*, 2nd ed. Princeton University Press, 2008.
[2] Image by Melissa Goodwin.

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