14. Supercollimation of Light within Photonic Crystal Slabs

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A super-collimator is a device in which light is guided by the dispersion properties of a photonic crystal slab rather than by photonic crystal defects or waveguiding structures. Photonic crystals form the essence of the supercollimation effect. Being able to realize supercollimation would be very useful for optical interconnects on planar lightwave circuits.

The device consists of a 2D photonic crystal with a square lattice of cylindrical air holes in a high index material such as silicon. The top view schematic of the device shape with its cross-section is shown in Fig. 1. The device consists of a cleaved sample with millimeter dimensions, with the photonic crystal (PC) occupying the full sample area. The device was fabricated using silicon-on-insulator (SOI) wafers purchased from an outside vendor. The edge of the sample functions as input or output facets of the device. The initial design has focused on realizing super-collimation at a wavelength of 1.44 mm. A thick low index layer is used to minimize radiation loss into the high index substrate.

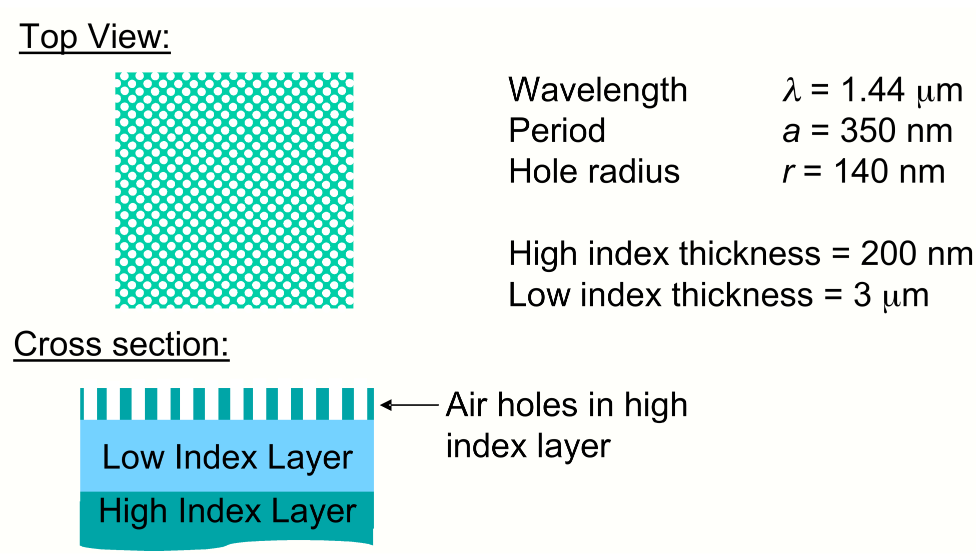

Figure 1: Super-collimator device design showing top and side views of the device.

The feature sizes of the photonic crystal can be scaled depending on the desired wavelength. A wavelength 1.44mm implies a hole lattice constant of 350nm, and a hole radius of 140nm. The total thickness of the device (excluding substrate) is about 3.2 microns (200nm Si, 3mm SiO_2) while the top surface has an area of about 1x1cm.

The photonic crystal holes are patterned using interference lithography. After the lithography step, the photonic crystal holes are etched into an SiO_2 hard mask layer via reactive ion etching (RIE). The fully patterned hard mask layer is then used to etch the high index silicon layer via another RIE step.

Figure 2 shows images of the fabricated device. In the left inset to Figure 2, the full 1cm x 1cm device is shown with its cleaved input and output facets. The photonic crystal occupies the full sample area and SEM images at the center and right inset to Figure 2 show details of the photonic crystal cross-section. The center image illustrates how the periodic pattern of the photonic crystal is fabricated over large areas. The right inset shows air holes etched in silicon with a depth of 200 nm. The photonic crystal rests on a buried SiO_2 layer as shown.

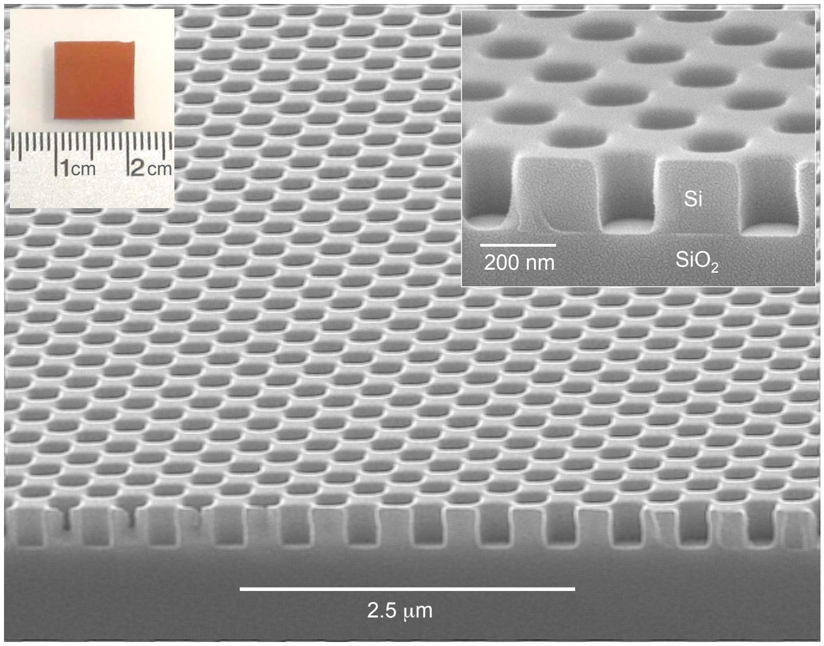

Figure 2: Images of fabricated supercollimator device. Left inset: Digital photograph showing full sample. Center: Scanning electron microscope (SEM) image showing large area 2D periodic photonic crystal. Right inset: SEM image showing cross-sectional image of the device fabricated using an SOI sample.

Testing of the supercollimator device is currently in progress. Preliminary results show that the supercollimation effect is wavelength dependent with strongest collimation occuring at a wavelength of 1495nm. Results also suggest that supercollimation can be sustained within the photonic crystal for millimeter length scales with very little divergence.