GaAs Superprism Using Two Dimensional Photonic Crystals for Enhanced Beam Steering

Personnel

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A superprism is an optical device similar to a conventional prism only with two enhanced properties: (1) super-dispersion and (2) ultra-refraction. Just as a conventional prism separates light into multiple wavelengths, a superprism separates these wavelengths over wider angles--termed "super-dispersion." A superprism can also be used to magnify the angle of propagation of a single wavelength of light to steer the beam over wide angles--termed "ultra-refraction." Photonic crystals form the essence of the superprism effect. The highly anisotropic nature of photonic crystals makes propagation of light through the superprism very sensitive to changes in direction and frequency. Being able to realize these superprism effects would be very useful for a number of applications ranging from enhanced devices for Wavelength Division Multiplexed (WDM) systems to a new class of ultra-refractive optical elements for beam manipulation. An additional advantage of the superprism is its potential to reduce the size of many conventional optical systems.

The device consists of a two dimensional photonic crystal with a square lattice of cylindrical air holes in a GaAs layer. The top view of the device design shows how the GaAs region is shaped as a parallelogram with the photonic crystal occupying a square region within the parallelogram (Figure 24). The input and output of the device are the edges of the parallelogram shape. The initial design has focused on realizing ultra-refraction such that an input angular sweep of approximately +/- 2 degrees is amplified to about +/- 30 degrees at the output for light with a wavelength of 3.2 microns. A thick aluminum oxide (Al_xO_y) layer is used to minimize radiation loss into the GaAs substrate. The depth of the holes will be as deep as possible to facilitate coupling from an input fiber.

The feature sizes of the photonic crystal can be scaled depending on the wavelength of operation. A desired wavelength range of 2.8 to 3.8 microns implies a lattice constant of 672 to 912 nm, and a hole radius varying between 269 and 365 nm, respectively. The total thickness of the device (excluding the substrate) is about 3.5 microns (460 nm GaAs, 3µm Al_xO_y) while the top surface will have an area of about 2x2 cm.

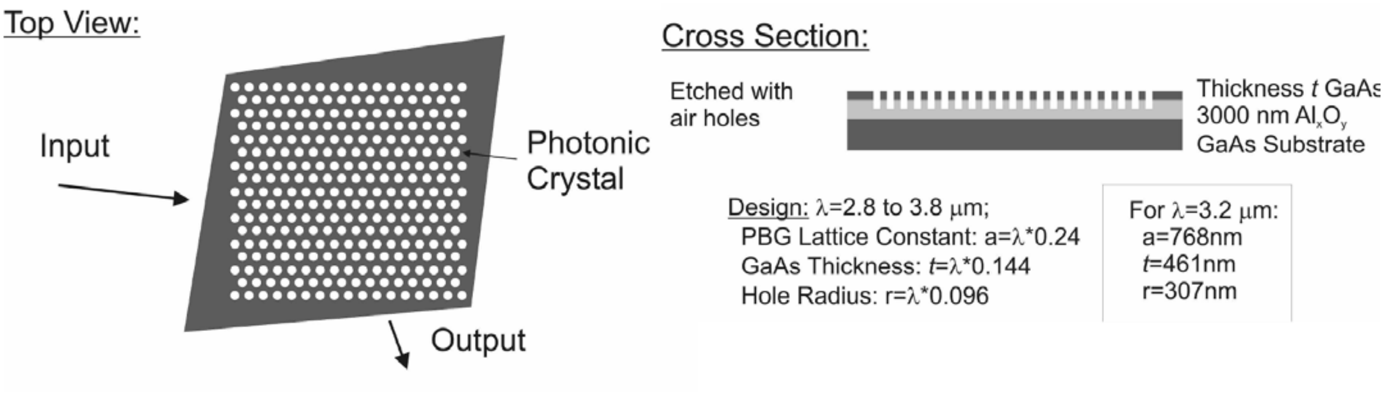

Fig. 24: Superprism device design.

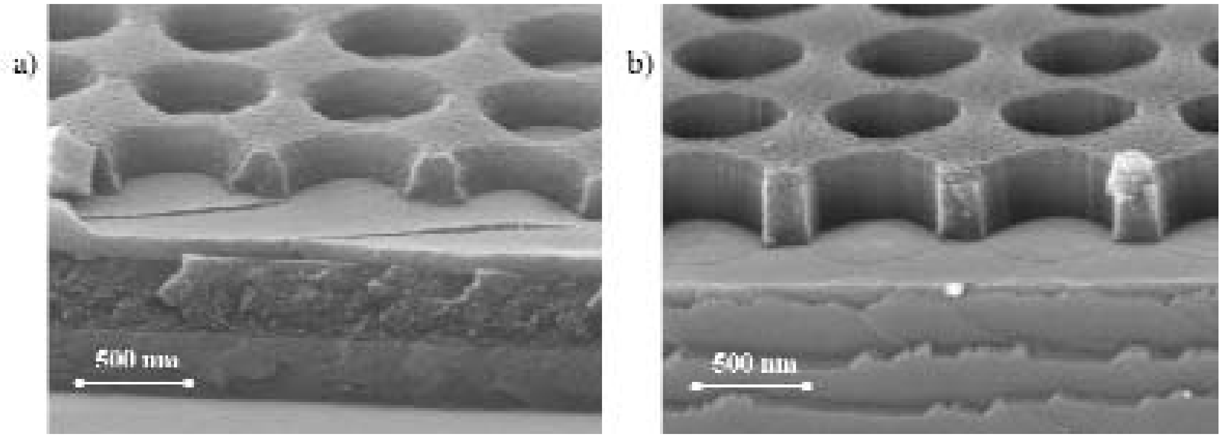

Fig. 25: Results of interference lithography exposure using the Lloyd's mirror. a) The pattern in resist with a 90nm thick SiO_2 *interlayer, a 300nm thick anti-reflective coating, and a 250 nm thick* SiO_2 *hard mask layer on a GaAs substrate. b) The pattern in the* SiO_2 *hard mask layer after reactive ion etching.*

Interference Lithography (IL) is used to pattern the photonic crystal holes due to the need to create a periodic pattern covering a large area with feature sizes less than one micron. A trilayer resist stack of resist, SiO_2, and an Anti-Reflection Coating (ARC) is used to minimize reflections off the substrate during exposure from a HeCd laser source (λ=325 nm). Figure 25(a) shows the results of an IL exposure using the Lloyd's mirror with the trilayer resist stack. The period is about 750 nm. Figure 25(b) shows the results after the pattern is transferred to a 250 nm thick SiO_2 hard mask layer using a reactive ion etcher within the NanoStructures Laboratory.

The heterostructure will be grown using gas source molecular beam epitaxy on a (100) GaAs substrate. The large parallelogram and square shapes will be made using contact photolithography. All patterns will be transferred to the GaAs/AlGaAs epilayers using reactive ion etching. A wet oxidation step will be used to oxidize the AlGaAs layer creating the low index Al_xO_y layer. Careful alignment steps must be used to ensure that lines of photonic crystal holes are aligned to the edges of the large square area.