Coupling into Photonic Crystal Slab Waveguides

S. Assefa, P. Bienstman, P. Rakich, S.J. Johnson, J.D. Joannopoulos, G.S. Petrich, L.A. Kolodziejski, E. P. Ippen
Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, MA 02139
Phone 617 253 4346, fax 617 258 6640, email: solomona@mit.edu

Abstract: An adiabatic taper method is presented for coupling light into photonic crystal defect waveguides in a square lattice of circular dielectric rods. The taper consists of two coupling stages.

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Efficient coupling is necessary in order to use photonic crystals in integrated photonic circuits [1]. The two-dimensional (2D) photonic crystal slab investigated here consists of an array of high-index cylindrical rods residing on a low-index material (Fig. 1), where a photonic crystal waveguide is created by introducing a row of rods with a smaller radius. The 2D array of rods provide a photonic band gap (PBG) in the plane of the photonic crystal, while the radius of the cylinders in the line defect remains large enough to provide index guiding in the vertical direction [2]. Direct coupling from a conventional dielectric waveguide into a PBG defect waveguide suffers from Fabry-Perot resonances due to reflections at the interfaces between the two waveguides. To improve the poor coupling efficiency, an adiabatic taper having two coupling stages is described.

The first stage converts the forward dielectric mode into a mode with both forward and backward propagating components using an adiabatic transition from the dielectric waveguide to a coupled-cavity waveguide. The dielectric waveguide has an entirely forward propagating field component, while the photonic crystal Bloch mode has both forward and backward components due to strong scattering [3].

In the second stage, the coupled cavity waveguide is transformed into a photonic crystal defect waveguide by slowly introducing the photonic crystal cladding adjacent to the defect waveguide, thereby transforming the mode from conventional high-index guiding to low-index guiding within the photonic crystal. Light is guided by total internal reflection in the dielectric waveguide, while light is localized in the defect rods that are surrounded by two perfect mirrors formed by the bulk photonic crystal. In 2D eigenmode expansion calculations, an approach to achieve reflectionless adiabatic tapering is to keep the radius of the rods fixed, but to gradually decrease the distance between the cladding and the line defect. Fig. 2a shows 100% transmission over a broad bandwidth in the first coupling stage, while the transmission of the entire taper with both coupling stages (Fig 2b) is very close to 100% with a significant bandwidth. Initial three-dimensional (3D) calculations provide insight regarding the fabrication tolerances as the band gap is smaller and the defect mode has a smaller bandwidth. Currently, additional 3D FDTD calculations are being performed and transmission measurements through the various devices such as those shown in Fig. 3 are underway. In the structures, the GaAs waveguides reside on aluminum oxide with the photonic crystal region having a lattice constant of 500nm and a rod diameter of 300nm. The photonic crystal defect waveguide consists of dielectric rods with a diameter of 250nm. The operating wavelength is designed for 1550nm.

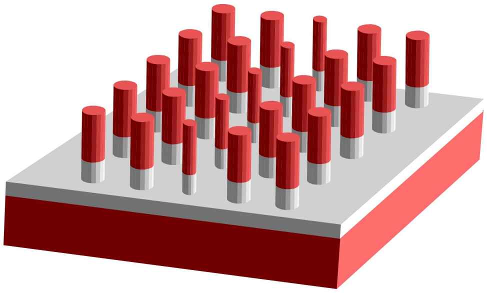

Fig. 1. Schematic representation of a 2D slab photonic crystal waveguide made of cylindrical dielectric rods.

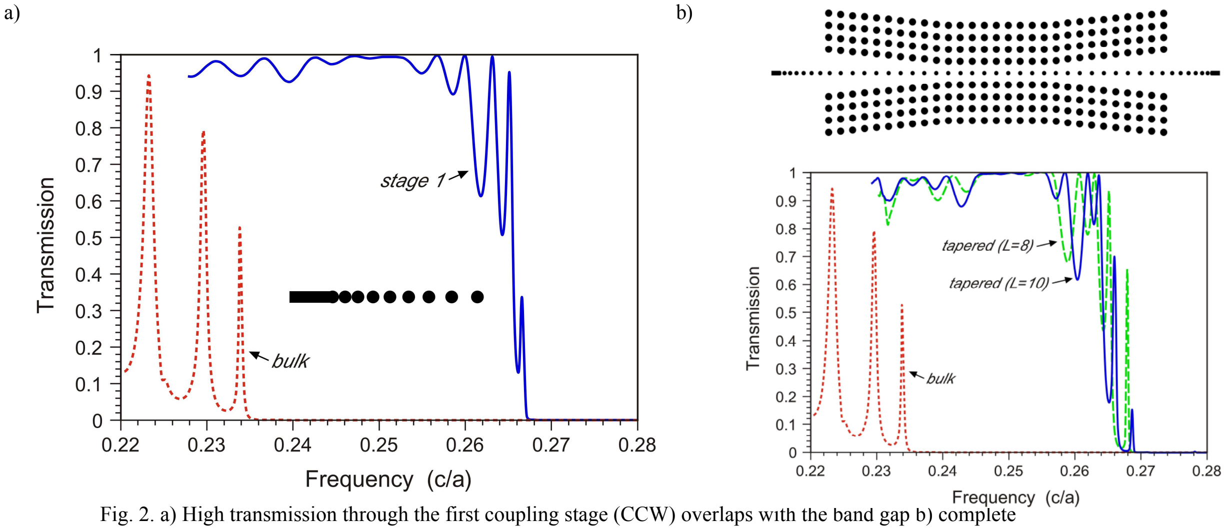

Fig. 2. a) High transmission through the first coupling stage (CCW) overlaps with the band gap b) complete structure with both coupling stages result in a high transmission in the band gap

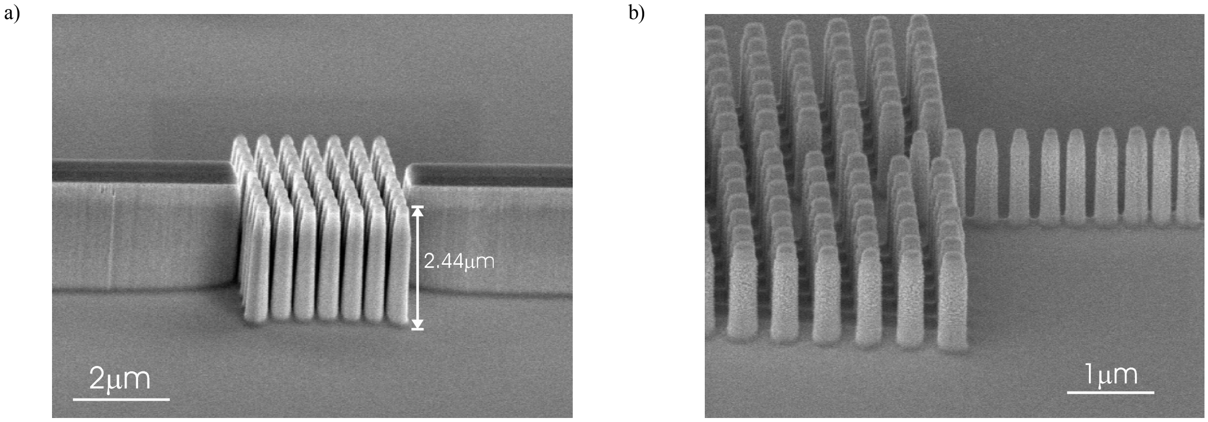

Fig. 3. a) Scanning electron microscope image (SEM) of a bulk photonic crystal fabricated in GaAs b) SEM of combined stages fabricated in GaAs

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