Lithium niobate photonic crystals for integrated optics

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It is now commonly known that photonic crystals can enhance the non-linear and other phenomena of the material in which they are made [1, 2]. Lithium niobate is a particularly intriguing material for this, since the capabilities of the bulk material are already significant. We have been studying a structure composed of 15×15 holes arranged in a square lattice fabricated by Focused Ion Beam (FIB) milling in an Annealed Proton Exchange (APE) lithium niobate waveguide. Two titanium electrodes have been deposited on each side of the structure along the propagation direction.

We have previously shown experimentally that the stop band of this structure can be shifted by 200nm with a voltage of 80V [3]. This phenomenon is due to an electro-optic effect that is induced by the presence of the nanostructure, and that is 300 times larger than in the bulk material. Using 2-D Finite Difference Time Domain (FDTD) simulations, we have shown that the slow light at the edges of the stop band is responsible for this enhancement, and we have been able to derive a theoretical enhancement that matches with our experimental results [4].

However, the depth of the holes is only around 2µm and the core of the APE waveguide mode is 1.4µm below the surface. Moreover, due to the FIB milling, the holes have a conical shape. Here we will present full 3-D FDTD simulations to study the interaction between the optical guided mode and the holes of the nanostructure in order to optimize the tunable photonic crystal device.

An interesting potential application of photonic crystals, based on the superprism phenomena first shown by Kosaka et al [5], would be the realisation of ultracompact optical components for beam-steering and beam-switching. We have been studying photonic crystals in an electro-optical material ($LiNbO_3$) in order to fabricate an ultrafast, ultracompact electro-optic superprism device.

We have studied the superprism effect in lithium niobate with both the Plane Wave Expansion Method (PWE) and 2D Finite Difference Time Domain (FDTD). These numerical simulations, for a triangular lattice of air holes in lithium niobate substrate (r=105nm, a=525nm) at λ=1550nm, have shown an angular sensitivity of 0.8°/nm and 10.8° for a refractive index variation of 1% [6].

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