Very low losses for TM polarized light in photonic crystal waveguides

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Abstract: Straight photonic crystal waveguides have been fabricated. Experimentally observed transmission spectra for TE and TM polarizations agree very well with 3D-FDTD simulations. Very low coupling and propagation losses are observed for the TM polarization.

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The recent progress in the design of photonic crystal waveguides (PCWs) has paved the way for exploitation of low-loss propagation in real 2D-patterned PCWs [1,2]. The next natural step is to deepen the knowledge of the physics of the PCW enabling the implementation of PCW-based integrated circuits. One particularly important goal is to determine the useful bandwidth of the photonic crystal guiding effect by comparing numerical calculations with experimental transmission spectra.

Seven straight PCWs of lengths 10-150µm consisting of perforated SiO_2/Si/SiO_2 trilayer films were fabricated as described in [1]. Holes with diameter D=0.76µm were arranged in a triangular array with lattice constant Λ=428nm. Single rows of missing holes defined the PCWs as shown in Fig. 1.

Fig. 1. SEM image of a PCW.

Tapered lensed fibers were used to couple light in and out of the ridge waveguides connected to the PCWs. The light sources were broadband LEDs centered at 1310nm and 1550nm. Transmission spectra were collected with an optical spectrum analyzer and normalized to ridge waveguide measurements.

3D-FDTD calculations of transmission spectra for TE and TM polarizations for four straight PCWs of lengths 29-59µm were performed using an improved version of the ONYX-2 code [3]. The output light intensity of the PCW was normalized to the entrance light intensity.

Fig. 2 shows the measured transmission through a 10µm straight PCW for TE and TM polarizations. Also shown are 3D-FDTD calculations for a PCW of similar length. The 3D-FDTD calculations successfully explain all essential features of the spectra as well as the actual transmission level. The position of the sharp cut-off for the TE polarization at longer wavelength is in excellent agreement with previous band gap calculations [1]. The small frequency shift (approximately 2%) between the experimental and simulated spectra is due to the 25nm grid resolution of the 3D-FDTD calculations.
Fig. 2. Measured and calculated transmission through a 10 μm PCW.

Fig. 3 displays the measured and calculated propagation losses for TE and TM polarized light. The losses are extracted by calculating the slope of the measured transmission as function of PCW length. The average coupling loss between the PCW and a connecting ridge waveguide is found to be 0.07±0.39dB for the experimental data and 0.06±0.27dB for the 3D-FDTD data. Thus, the transmission levels shown in Fig. 2 are essentially due to the propagation losses through the PCWs. In Fig. 3 the displayed wavelength range has been chosen to highlight the lowest loss regions for each polarization, i.e., the usable regions for future applications of PCWs.

Again excellent agreement is seen between experiment and simulation. Especially noteworthy is the 200nm bandwidth with propagation losses around 9±5dB/mm for the TM polarization.

Band calculations show that the very low propagation losses for the TM polarization take place below the valence band. Further experiments have shown that TM polarized light is well-guided through more complicated PCW structures such as couplers and sharp bends. The wavelength range of the low loss TM mode propagation overlaps one of the TE photonic band-gap modes; this may be employed to design polarization independent PCW components.

