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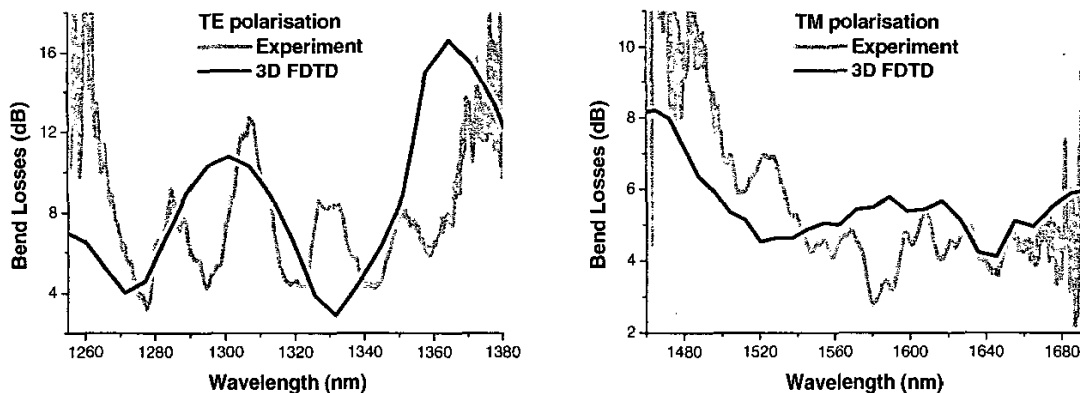
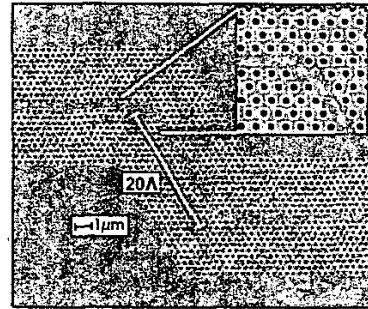
Propagation of TE and TM polarised light through smoothed sixty degree bends in planar photonic crystal waveguides

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Low-loss straight photonic crystal waveguides (PCWs) have previously been demonstrated [1]. In this work, bends in planar PCWs are investigated by introducing two smoothed 60° bends each having one hole relocated as shown in the SEM image to the right. Holes, in a $\text{SiO}_2/\text{Si}/\text{SiO}_2$ trilayer film, with diameter $D_{\text{glass}}=0.76\Lambda$ are arranged in a triangular lattice with $\Lambda=428$ nm constructed using e-beam lithography, reactive ion etching, and thermal oxidation. The PCWs are defined by leaving out single rows of holes. The fabricated 60° bends are separated by 20Λ . In and out coupling of light to the PCWs is obtained utilising tapered ridge waveguides and tapered lensed fibres. Transmission spectra are recorded for both the TE and TM polarisation with an optical spectrum analyser by using two LED sources centred at 1330 nm and 1550 nm. The measured spectra are compared to 3D FDTD simulations performed on a PCW containing two smoothed 60° bends separated 7Λ by using an improved version of the ONYX-2 code [2]. In order to extract the bend losses for the two consecutive 60° bends the experimental and calculated spectra for the smoothed 60° bends are normalised to straight PCWs of the same length. The results are, for a given polarisation, shown in the figure below in the wavelength ranges, where the lowest propagation losses for straight PCWs were measured and calculated.



The oscillations observed in the spectrum for the TE polarisation have conclusively been identified as Fabry-Perot resonances by recording experimental spectra for PCWs having different lengths ($20-40\Lambda$) of the intermediate straight PCW connecting the two bends. The Fabry-Perot cavity oscillations in the measured and simulated spectra for the TE polarisation are found to be in good agreement, when the different lengths of the intermediate straight PCW are taken into account. Thus, it is seen that the 3D FDTD simulations successfully explain the observed bend losses both for the TE and TM polarisations. Losses as small as 2 dB are observed per bend for the TE polarisation. For the TM polarisation the average loss per bend is experimentally found to be 2.1 ± 0.3 dB in the wavelength range 1540-1680 nm. Hence, the smoothed bends work equally well for the TE and TM polarisation even though band calculations have shown that propagation for the TM polarisation take place below the valence band in the investigated wavelength range. Further experiments have shown that modifying the bends as illustrated in the top figure improves the transmission per bend by 4 dB for both the TE polarisation and TM polarisation compared to un-smoothed sharp 60° bends.

[1] J. Arentoft, T. Søndergaard, M. Kristensen, A. Boltasseva, M. Thorhauge, and L. Frandsen, "Low-loss silicon-on-insulator photonic crystal waveguides," *Electron. Lett.* **38**, 274-275 (2002).

[2] A.J. Ward and J.B. Pendry, "A program for calculating photonic band structures, Green's functions and transmission/reflection coefficients using a non-orthogonal FDTD method", *Comp. Phys. Com.* **128**, 590-621 (2000).