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Photonic Bandgap Waveguides – 2D PBG Materials Embedded in a GaAs/AlO Slab

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Abstract: A new two-dimensional photonic crystal (2D PC) slab structure was created with a full three-dimensional light confinement. Guided modes with broad bandwidth and high transmission for such PC waveguides and bends are also observed.

As an optical analog to electronic crystals, PC promises a revolution in the photonic world similar to the electronic revolution created by the electronic band gap engineering in semiconductor. 2D PC has an advantage of being easier to fabricate at optical wavelength (λ) comparing with 3D PC. However, the light leakage in the vertical direction has been the main problem for using 2D PC in opto-electronic application. In this study, we solve this problem by combining traditional 2D PC with strong vertical index guiding between the waveguide layer (GaAs) and the cladding layer (Al_xO_y).

A set of triangular lattice holes 2D PC's were fabricated with lattice constant a=400,410,430,450,460,470 nm, hole diameter (d=0.6a) and waveguide layer thickness (t=0.5a). Those parameters were chosen to maximize [1,2] the TE photonic band gap (PBG) around λ=1.55μm. Fig.1a shows the SEM top view of a nine periods (a=460nm) PC. The depth of etched holes is ~0.6μm and the 2μm thick Al_xO_y cladding layer is obtained by thermal oxidation of $Al_{0.9}Ga_{0.1}As$. The PC waveguide is created by introducing a triple-lines defect along the ΓK direction.. The diameter (d'=0.8a) of defect holes are wider than that of the regular one.

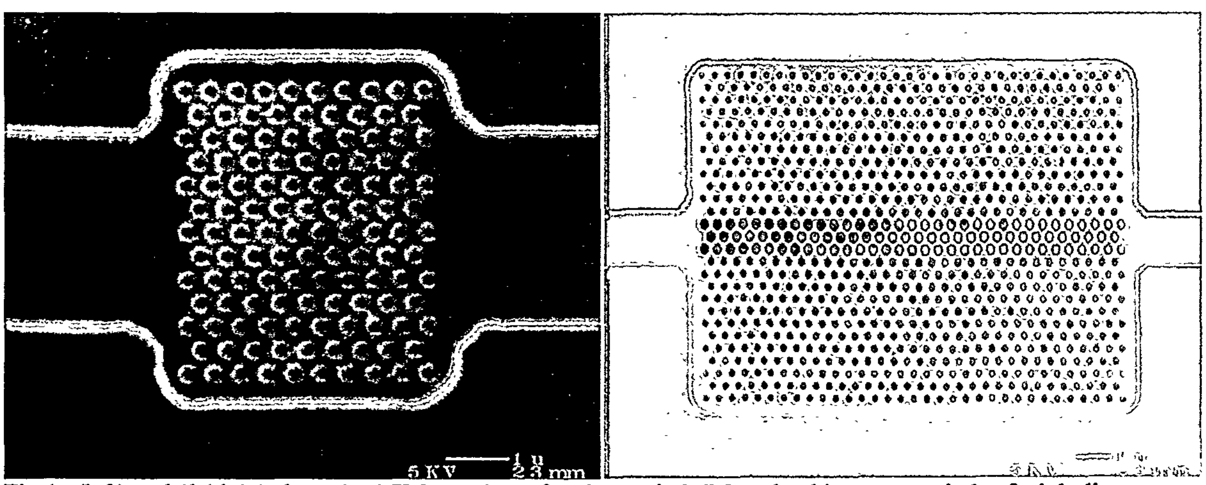

Fig.1a (left) and 1b(right) show the SEM top view of a nine periods PC and a thirty-two periods of triple-line-defects PC waveguide.

We perform transmission measurement by coupling light to PC with ridge waveguides which extends ~0.6mm on both sides of PC. The absolute transmittance is obtained by normalizing the transmission with a reference measured with a nominally identical waveguide without PC. To map out the transmittance spectrum (T versus ω (=a/λ), we have measured samples of six different a's with three tunable diode lasers to tune λ from 1290nm-1680nm.

In Fig.2, the black color symbols represent the measured TE transmittance of nine periods of PC. This agrees very well with the 3D finite difference time-domain simulations, which is shown as the black curve in

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Fig.2.In the band gap region, ω=0.26 to 0.32, both the predicted lineshape spectrum and intensity attenuation (T~10^{-3}-10^{-4}) agree with experimental data, yielding a large gap-to-midgap ratio of 20%.

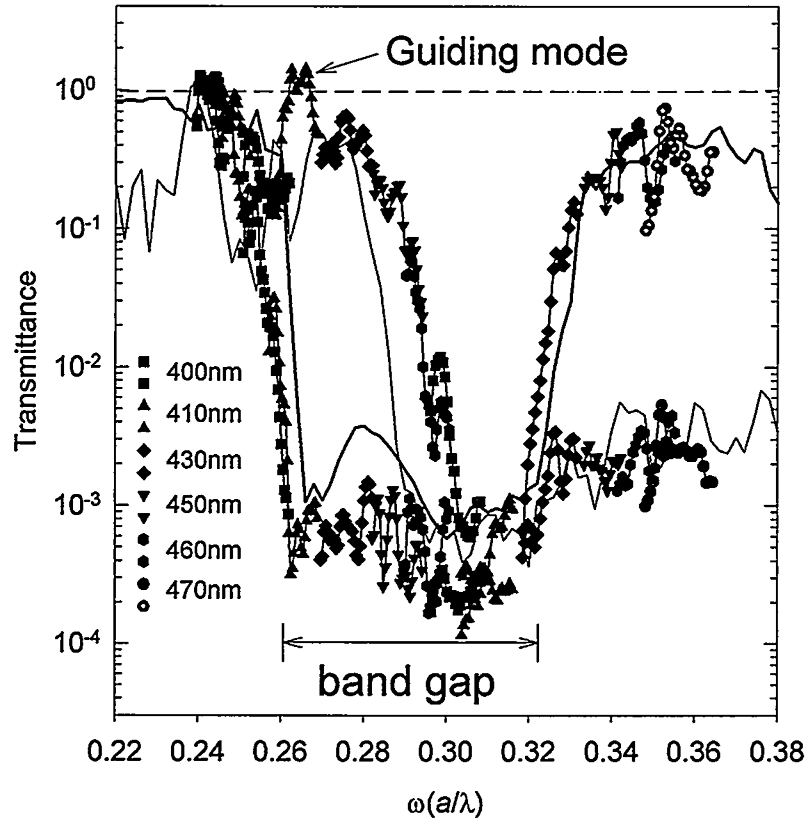

Fig.2, Transmittance (T) of nine periods of PC (black color) and guiding efficiency (η) of sixteen periods of triple-line-defects PC waveguide versus ω (=a/λ) over the entire band gap.

The measured guiding efficiency (η) of sixteen periods of triple-line-defects PC waveguides is also plotted in Fig.2 as red color symbols. Highly efficient guiding starts from the valence band edge (ω=0.26) and extends into the mid-gap at ω=0.285, consistent with the band structure calculation of the triple-line-defects PC waveguide [3].A nearly perfect η-value of ~100% is observed at ω~0.265. This is in sharp contrast to the strong attenuation (T~3×10^{-4}) at the same ω for the regular PC and clearly demonstrates the guiding effect introduced by the triple-line-defect PC waveguide. The observed η also agrees with the computed red curve, other than it extends slightly more into the mid-gap by Δω~0.08. It is possible that the etched defect holes are slightly larger than the nominally designed d'=0.8a and thus pushes the guiding mode into the band gap. With a=410nm, η>70% is observed over the whole fiber communication wavelength λ=1.535-1.575μm.

To fully make use of PC waveguide, we have recently studied different PC waveguide 120 degree bends based on the similar slab structure. Our preliminary data has shown bending efficiency >80% over the communication wavelength. More detail measurement and analysis is currently under progress.

1. S.G. Johnson, S.Fan, P.R. Villeneuve, J.D. Joannopoulos, Phys. Rev. B **60** 5751-5758 (1999).
2. E. Chow etal, submitted to Nature.
3. S.Y. Lin, E.Chow, S.G. Johnson, and J.D. Joannopolous, in press Opt. Lett (Sep. 2000).

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