SAND96-1283C

CONF-960642--13

Images and Spectra of Inhibited Light Propagation in a 2-dimensional Photonic Lattice at 1.5 μm

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Abstract

Using infrared light scattering microscopy, We have directly observed the inhibition of photon propagation in a 2-dimensional photonic lattice fabricated as a hexagonal array of AlGaAs posts. The lattice was formed by reactive ion etching of ~400 nm diameter posts defined by electron beam lithography. A schematic and scanning electron micrograph of the lattice is shown in Fig. 1. The lattice design parameters (post diameter d and spacing a) correspond to a photonic bandgap near 1.5 um as calculated by Meade et al.[1,2] This hexagonal array of posts is an improvement over early honeycomb lattices (triangular arrays of air holes)[1-3] because it is easier to fabricate. The photonic lattice of 1.4 μm high posts was incorporated into waveguide designed for single mode at 1.5 μm. Several waveguide/lattice combinations were fabricated, including M-bar and K-bar lattice orientations aligned parallel to the waveguide and different numbers of lattice periods. The waveguide/lattice structures were fabricated on GaAs substrates that were subsequently thinned and cleaved to couple light into the waveguide facets.

Using a specially designed triple infrared microscope system illustrated in Fig. 2, we simultaneously imaged the input and output facets and the top surface of the waveguide as laser light was focussed onto the input facet. Because of internal scattering in the waveguide, light is scattered upward outward and can be imaged with an infrared camera. Images for reflected input, waveguide scattered light, and transmitted ouput light for the waveguide with (left images) and without the

This work was supported by the United States Department of Energy under Contract DE-AC04-94AL85000.

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photonic lattice (right images) are shown in Fig. 3. The lefthand image shows how the lattice interrupts the transport of light through the waveguide.

The laser used to create these images was an TiS-pumped Optical parametric Oscillator with signal and idler tunable from 1.38 to 1.75 um. Thus the photon transport through the lattice could be studied as a function of wavelength near the predicted bandgap. Tuning curves for the lattice/waveguide combination (top) and air reference (no waveguide present, bottom) are shown in Fig. 4. The upper curve reveals a distinct bandgap between 1.45 and 1.50 um. This gap occurs near the design wavelength and has width of about 4% which is slightly less than theoretical predictions.

References

1. R. D. Meade, K. D. Brommer, A. M. Rapper, and J. D. Joannopoulos, Appl. Phys. Lett. **61**, 495 (1992).

2. J. Joannopoulus, R. D. Meade, and J. N. Winn, *Photonic Crystals*, Princeton Press, Princeton, NJ (1994).

3. P. L. Gourley, J. R. Wendt, G. A. Vawter, T. M. Brennan, and B. E. Hammons, Appl. Phys. Lett. **64**, 687 (1994).

Figure Captions

Fig. 1. Schematic diagram of (a) top view of lattice/waveguide nanostructure, (b) side view of nanostructure (dark layer is GaAs, light layer is $Al_{0.35}Ga_{.65}As$), (c)end view of ridge waveguide showing contours of constant electric field amplitude, (d) scanning electron micrograph of lattice posts.

Fig. 2. Experimental arrangement employing three infrared cameras for recording microscopic images of the reflected input light (IR1), upward scattered light (IR2), and transmitted output light (IR3). The orientation of the input laser beam and lattice is shown in the lower right inset. TE (TM) polarization is in (normal to) the wafer plane.

Fig. 3. Microscopic images showing the reflected laser spot (top), upward scattered light from the waveguide (middle), and the TE and TM versions of the transmitted output light (bottom). The waveguide ridges are 4 microns wide and spaced either 25 or 40 microns from neighboring ridges.

Fig. 4. Transmitted light intensity for the lattice/waveguide combination (top curve). Transmittance for the microscope system with no wafer present (bottom curve).

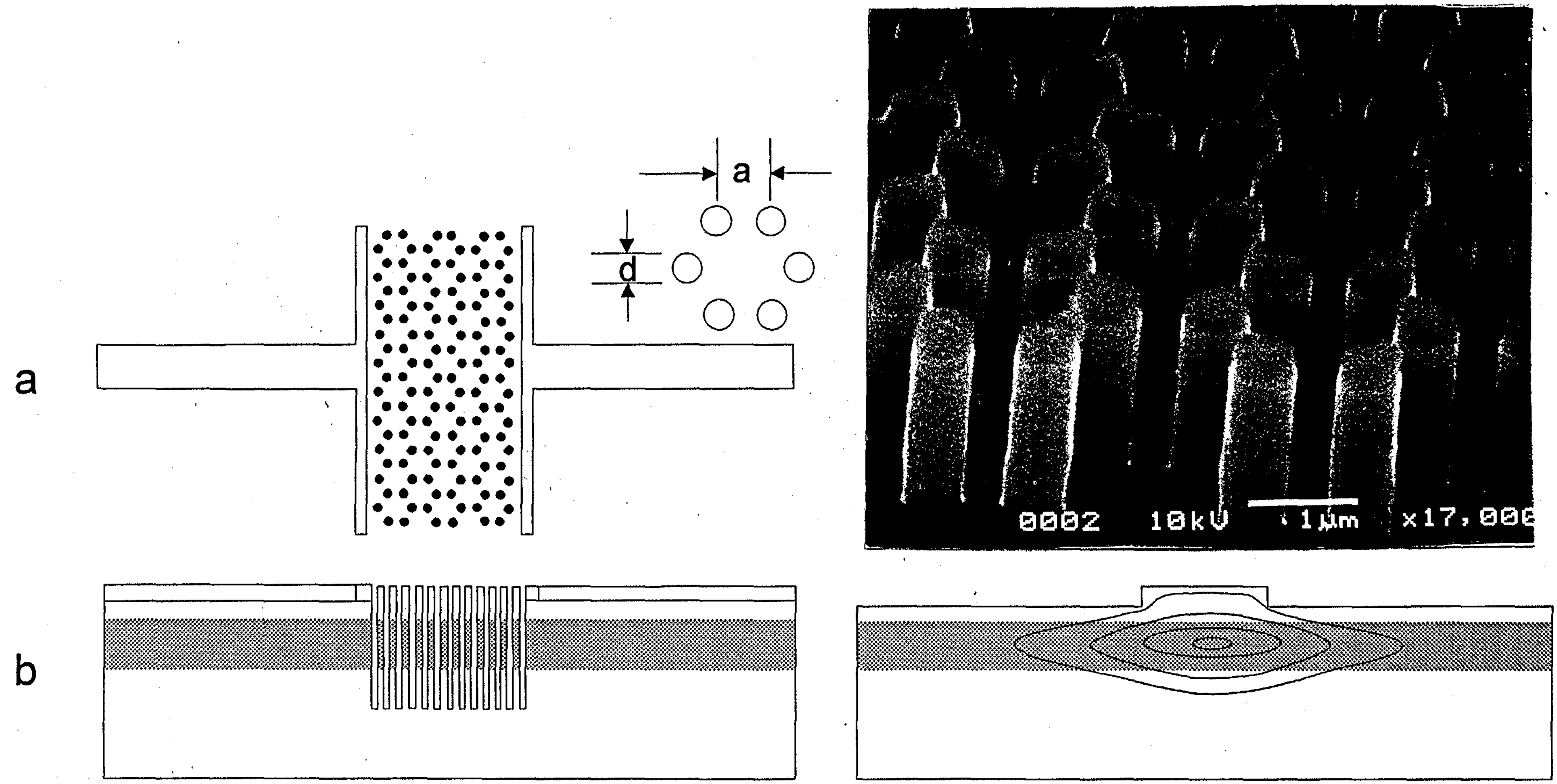


FIG. 1

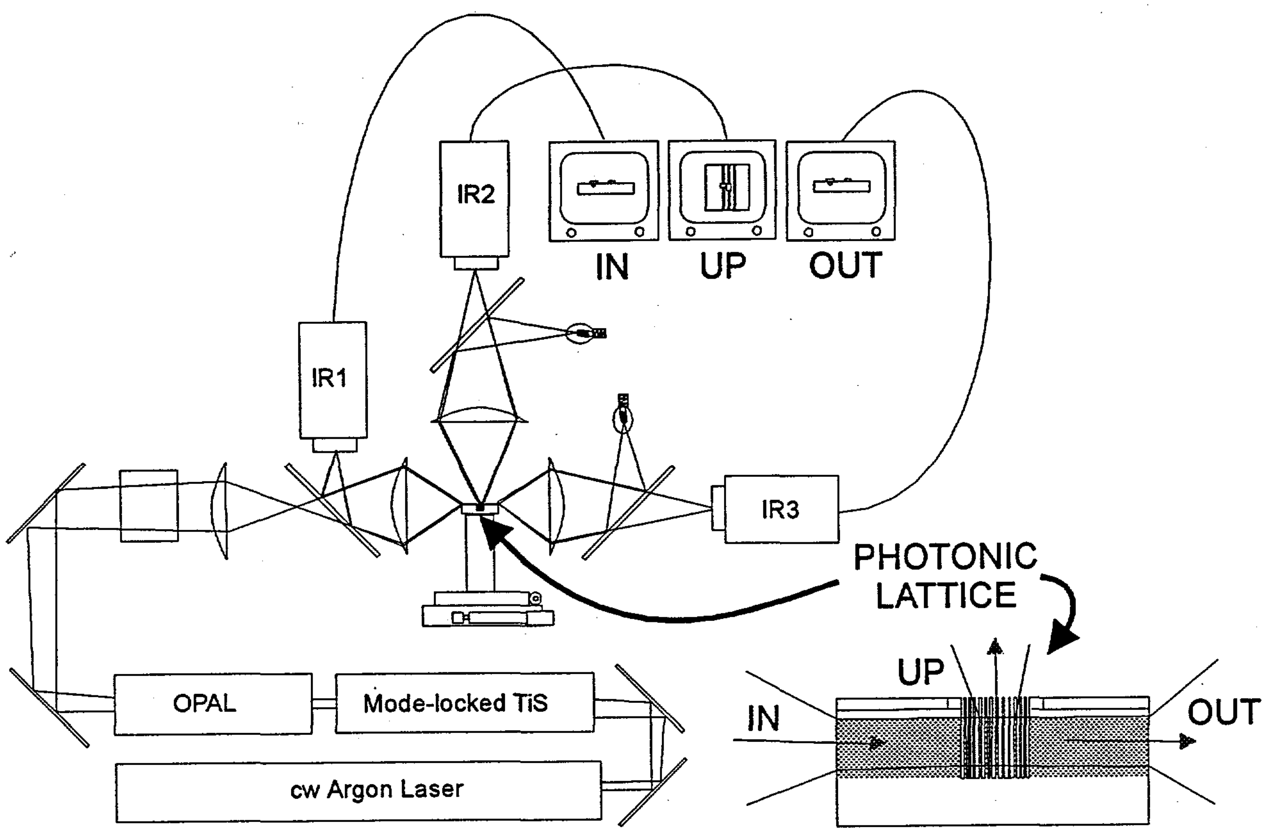

IR2
IN
UP
OUT
IR1
IR3
PHOTONIC
LATTICE
UP
IN
OUT
OPAL
Mode-locked TiS
cw Argon Laser

FIG. 2

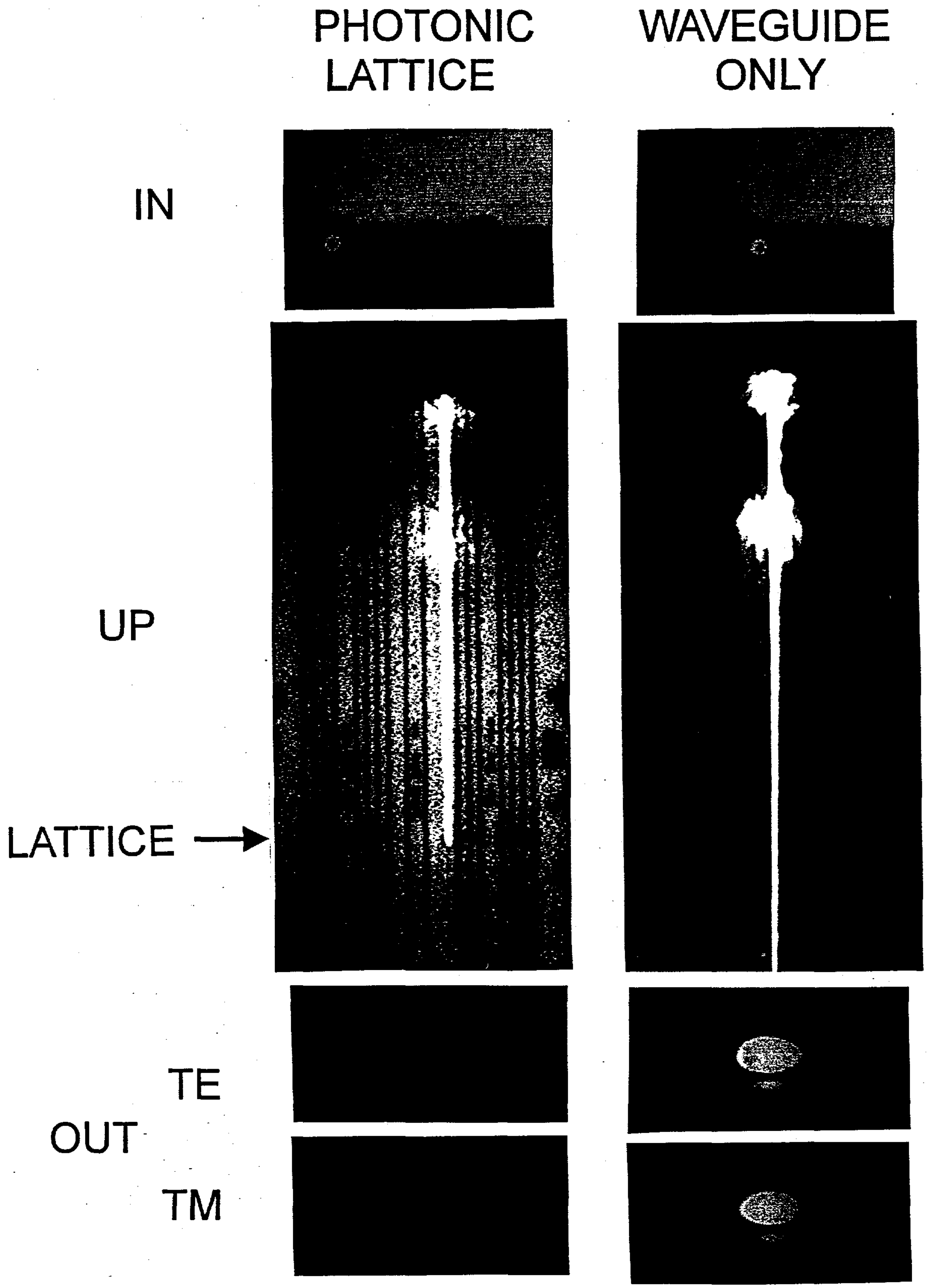
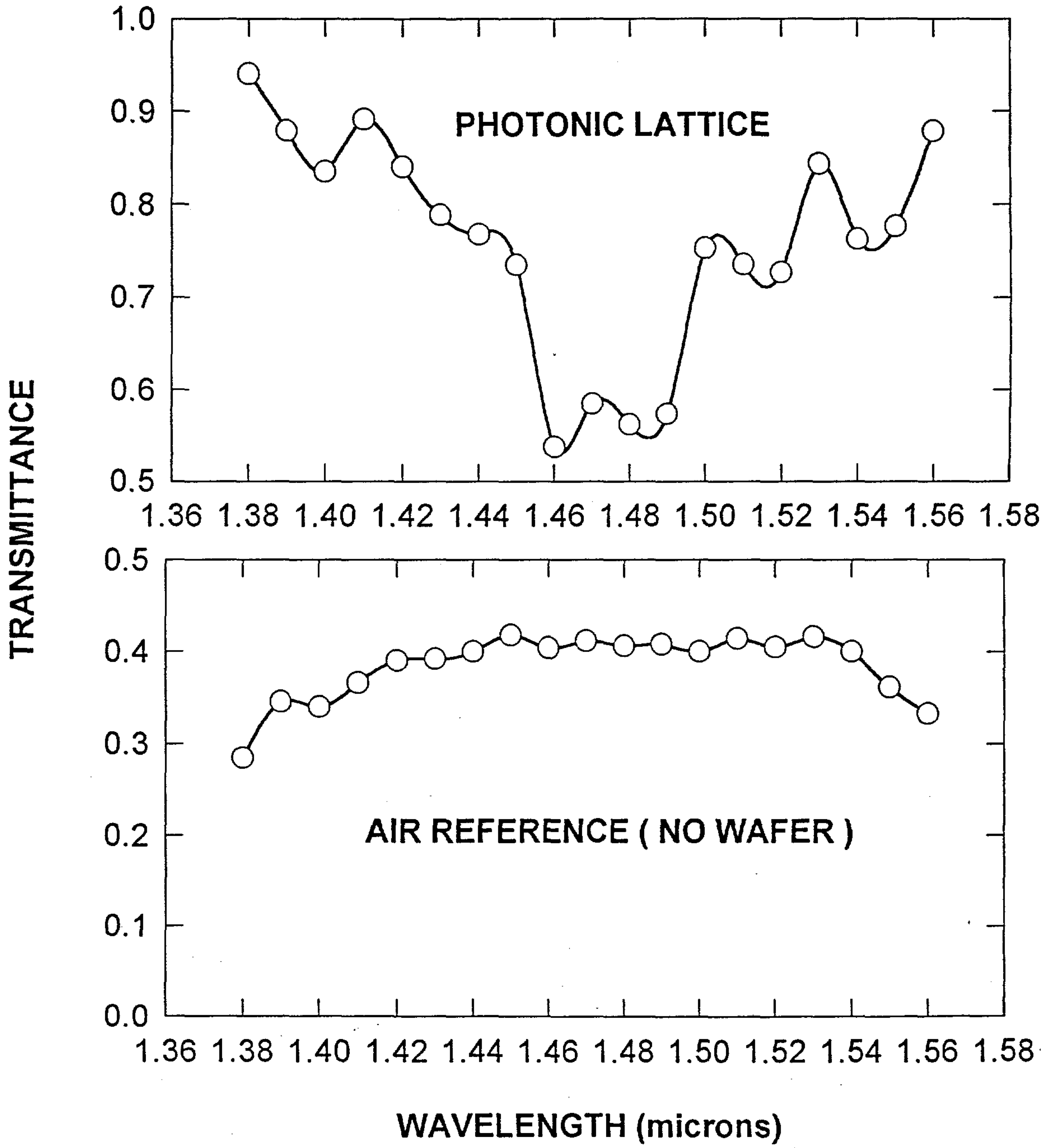


FIG. 3



TRANSMITTANCE
1.0
0.9
0.8
0.7
0.6
0.5
PHOTONIC LATTICE
1.36 1.38 1.40 1.42 1.44 1.46 1.48 1.50 1.52 1.54 1.56 1.58
0.5
0.4
0.3
0.2
0.1
0.0
AIR REFERENCE (NO WAFER)
1.36 1.38 1.40 1.42 1.44 1.46 1.48 1.50 1.52 1.54 1.56 1.58
WAVELENGTH (microns)

FIG. 4

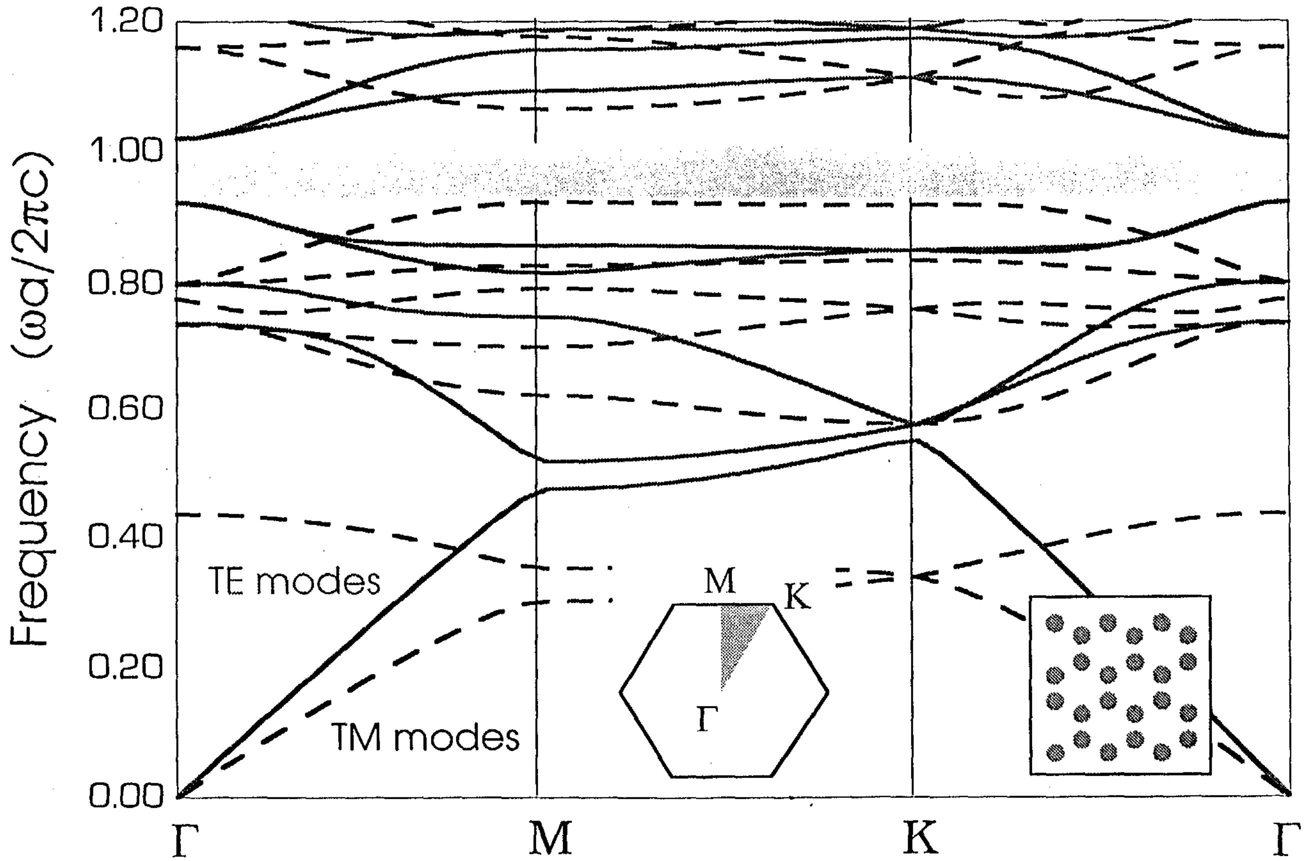

1.20
1.00
0.80
0.60
0.40
0.20
0.00
Frequency (ωa/2πc)
TE modes
TM modes
M
K
Γ
Γ
M
K
Γ

Fig. 5