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A Tunable Microcavity with Elliptical Rods in A Rectangular Photonic Crystal

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***Abstract*—We propose a light capacitor made of a tunable microcavity with elliptical rods in a rectangular photonic crystal. The elliptical rods give different defect bandwidths for different orientations. Light in the cavity can be stored and released by rotating the rods.**

I. Introduction

Photonic crystals [1] are dielectric structures with refractive index profiles having periodicity in the scale of electromagnetic wavelength. Due to this periodicity, the propagation of light is forbidden for some frequency band, which is called the band gap resembling the electronic band gap of the solid states. Their operation mechanism is very different from conventional optoelectronic devices. Some structures exhibit complete bandgaps, which gives engineers much freedom in designing. When point and line defects are introduced into the photonic crystals, miscellaneous devices, e.g. high-Q cavities, low-loss sharp-bending waveguides, compact WDM filters, are proposed [2]. In addition, photonic crystal fibers are intensively studies due to their extraordinary flexibility in wide single-moded range, ultra high/low nonlinearity, easily tailored dispersion, high power transmission, etc [3].

In this paper, we propose a tunable microcavity with a line defect of rotatory elliptical rods as shown in Fig. 1. The microcavity is formed by taking out of one dielectric rod. One line defect connected to the cavity is formed by elliptical rods. The cavity can be opened and/or closed as the elliptical rods rotate. Therefore, light can be charged into, stored in, and released from the cavity, like a electrical capacitor. Such "light capacitor" can not only store the 0/1 information by low/high energy but also more information by storing electromagnetic waves of of different frequencies.

II. Line Defects for Elliptical Rods at Different Orientations

The background of the photonic crystal is free space with refractive index $n_0 = 1$. The circular rods are made of semiconductor with refractive index $n_{rod} = 3.4$, radius $r = 0.18a$, where a is the lattice constant. The elliptical rods are made of the same material as circular ones, but with long axis $R_x = 2.7a$ and short axis $R_y = 0.6a$. When the elliptical rods are horizontally positioned as shown in Fig. 1, the resonant mode of the cavity is a monopole mode with normalized resonant frequency $\omega a/2\pi c = 0.3875$, which is calculated by the plane wave expansion method (PWE). This state is called "closed," which is illustrated by the following analysis.

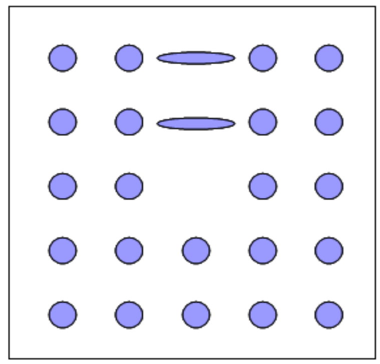

Fig. 1. Proposed Microcavity

We use the PWE method to solve the band structures for different orientated line defects. Fig. 2(a) shows the band structure of a line defect with the elliptical rods being horizontally positioned. The defect band exists in the center of bandgap. The cavity resonant frequency lies above the band of line defect and light at the cavity resonant frequency can not propagate, which accounts for the closed state of the cavity. The elliptical rod are up-righted gradually from horizontally positioned to monitor the variation of the band structures. Our calculation shows, the bandwidth of the line defects does not change much as the elliptical rods are positioned from horizontally in Fig. 2(a) to 45 degree slanted in Fig. 2(b). However, as the elliptical rods are close to up-righted, the bandwidth expands. It covers almost the whole bandgap when the defect rods are 90 degree up-righted as shown in Fig. 2(c), in which the line defect will guide the light and such state is called closed.

III. Transient Response of the Microcavity

The finite-difference time-domain method is adopted to simulate the transient response of the microcavity. First, light at the resonant frequency is launched from the opened line defect into the cavity. After the cavity is charged, the line defect is rotated to horizontal arranged as shown in Fig. 2(a) and the light is stored as shown in Fig. 3(a). Then the line defect is opened again to release the stored light as shown

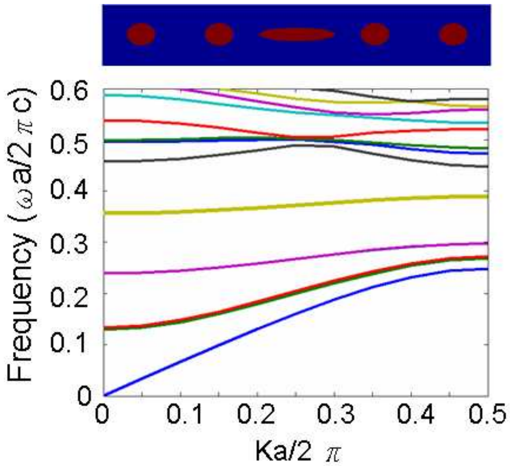

Fig. 2(a) $\theta = 0°$

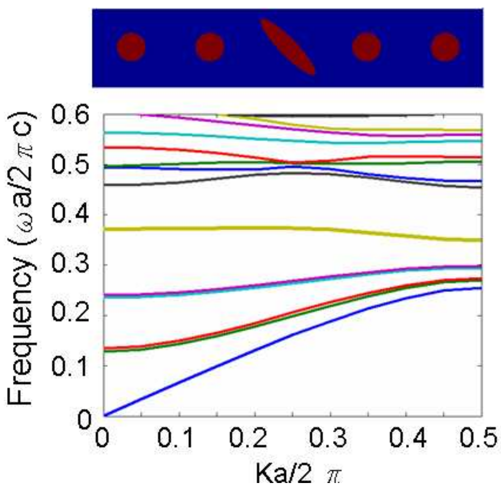

Fig. 2(b) $\theta = 45°$

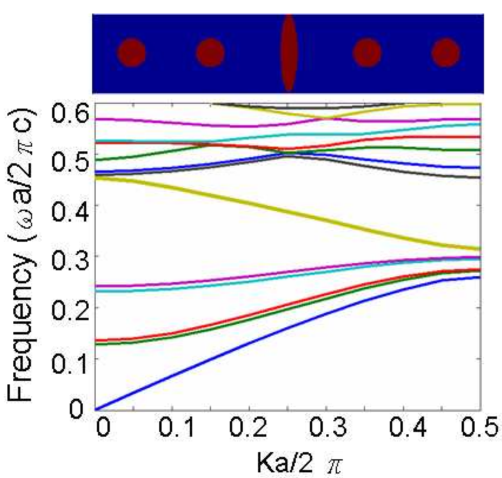

Fig. 2(c) $\theta = 90°$

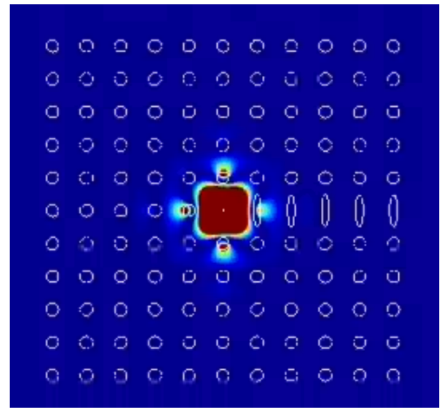

Fig. 3(a) Charged

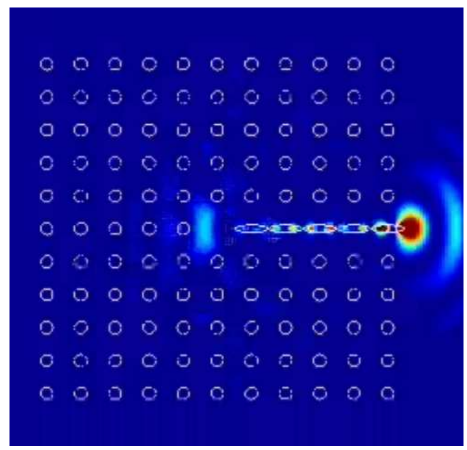

Fig. 3(b) Releasing.

in Fig. 3(b). Our Simulation shows the energy stored in the cavity remains less than 1 percent after ten periods.

IV. Conclusion

We have proposed a tunable cavity that can function as a light capacitor. The results are verified by the band structure of line defect of different orientated elliptical rods. Our simulation shows similar structure exist in hexagonal photonic crystals. In addition, we can design a Y-branched switch by adopting the line defect of elliptical rods in hexagonal photonic crystals instead of liquid crystal in photonic crystals [4]. Such switch based on the geometrical anisotropy of the line defect shows larger tuning range than that based on the refractive anisotropy.

Acknowledgment

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