COUPLING BEHAVIORS OF VERTICALLY COUPLED PHOTONIC CRYSTAL NANO-CAVITIES

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Abstract—*The coupling behaviors of closely placed, parallel slab photonic crystal nano-cavities are numerically studied. The separations between split resonance frequencies as functions of slab separation, slab thickness, and photonic crystal parameters are demonstrated.*

Photonic crystal nano-cavities with one or a few point defects have been widely designed and fabricated for implementing compact semiconductor lasers, add/drop filters, coupled-cavity waveguides, etc. Recently, because of the interest in the coupling phenomena between a quantum dot and a small resonance cavity, photonic crystal nano-cavities have been fabricated for such a study. Photonic crystal nano-cavities, compared with other types, have the advantages of compactness and versatility. The coupling behaviors between two co-plane photonic crystal nano-cavities have been studied. However, such a co-plane configuration will limit the device integration to a two-dimension geometry. If layer structures of semiconductors can be properly used, a three-dimension integration of devices can be implemented, even with a two-dimension photonic crystal structure. In this situation, the function of device integration becomes more versatile and more useful. In this paper, we report our study results on the coupling behaviors between two vertically coupled photonic crystal nano-cavities. The two cavities belong to two successive layers of semiconductor epitaxial growth. They are spaced with a lower-index layer (can be air). With coupling, the originally single-mode cavity will have two modes or two resonance frequencies. We will show the dependencies of the frequency spacing on various parameters of the vertically coupled nano-cavities. Also, the polarization dependence on the vertically asymmetric structure will be discussed.

The vertical coupler is schematically drawn in Fig. 1. Here, square photonic crystal of air holes and the point defects are vertically aligned. The two parallel slabs are supposed to be surrounded by free space. The thickness of the upper (lower) slab is d_1 (d_2). The air gap spacing between the two slabs is l. The refractive index of the slab material is assumed to be 3.4. The slab is set in the x-y plane. The FDTD method is used for solving for the mode field distributions and resonance frequencies in the system. To show the dependence of the mode frequency separation, $\delta\omega$, on the slab spacing, we show Fig. 2. Here, one can see that $\delta\omega$ decreases with the slab spacing. In the presentation of this paper, other dependencies of mode frequency separation on the slab thickness and other parameters will be discussed. Particularly, the effects of vertically asymmetric structure will be investigated.

Acknowledgement

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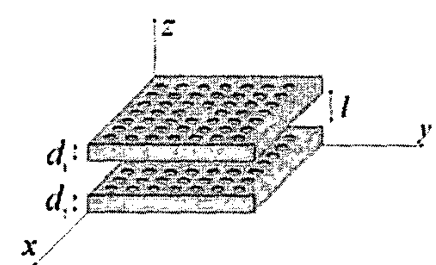

Fig. 1 Schematic drawing of the vertically coupled photonic crystal nano-cavities.

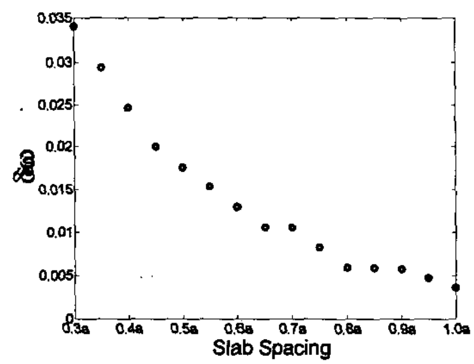

Fig. 2 Mode frequency splitting as a function of slab spacing.

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