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積層方向に鏡像対称性を有する三次元フォトニック結晶における高Ｑ共振器の設計

Design of high-Q three-dimensional photonic crystal nanocavities with vertically mirror-symmetric structures

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Introduction: Three-dimensional (3D) photonic crystal (PC), possessing a complete PBG (cPBG), has been receiving growing attention for their ability to control light of all polarizations in all directions, and already been investigated on function as a light source with high quality (*Q*) factor [1, 2]. However, so far the *Q*-factor of 3D PCs cavity mode is still far behind 2D PCs. There are not many good ways reported on the enhancement of *Q*-factor of 3D PCs except enlarging the number of PC periods, which will enlarge the size of the device simultaneously. In this work, we propose a simple way that can enhance the *Q*-factor of ordinary woodpile structure just by changing the stacking order of the layers with the same device size, which could be realized by typical planar processes and by layer-stacking techniques.

Results and Discussion: The theoretical analysis was performed by the finite-difference time-domain (FDTD) method, using RSoft version 9.0 (RSoft Inc.). The dielectric materials of the rods that constitute the 3D PC with woodpile cladding structure and cavity layer were assumed to be Si and GaAs, with refractive index of 3.5 and 3.4, respectively. Each rod of all 25 layers has a width of 0.24*a* and a height of 0.3*a*, while the cavity size is 2.24*a* by 2.24*a* in XY plane and has the same height as the rods, where *a* represents the center-to-center spacing of the rods. As shown in Fig. 1(a), a red layer represents the cavity layer, which is sandwiched by two stacks of woodpile structures. By changing the stacking order of the layers of upper side of the cavity layer, which could be seen as turning the original stack of the upper cladding upside down, the designed mirror-symmetric woodpile structure becomes symmetric in all directions around the cavity layer, instead of in only XY plane for the ordinary woodpile structure. Fig. 1 (b) shows the cross-sectional field distributions of cavity modes for the ordinary and the mirror-symmetric woodpile structures. Reflecting the symmetry of the structure, the mode becomes symmetric with respect to the center plane of the cavity layer in the mirror-symmetric structure. The *Q*-factor as a function of the in-plane rod number is shown in Fig. 1(c). The *Q*-factor of the mirror-symmetric woodpile is enlarged by almost 10 times comparing with that of the ordinary woodpile when the number of in-plane rods is 17, which is the size of the device operating at a telecom wavelength that could be realized using the current micromanipulation technique [1]. Note that the *Q*-factor of the ordinary woodpile is barely increased with the increasing number of in-plane rods, because it is limited by losses into the vertical direction. On the other hand, in mirror-symmetric structure the vertical *Q* is largely improved and consequently results in the enhancement of the total *Q*. Details will be discussed in the presentation.

Reference: [1] A. Tandaechanurat et al, Nat. Photon. 5, 91-94 (2011).　[2] L. Tang and T. Yoshie, Opt. Express 15, 17254-17263 (2007).

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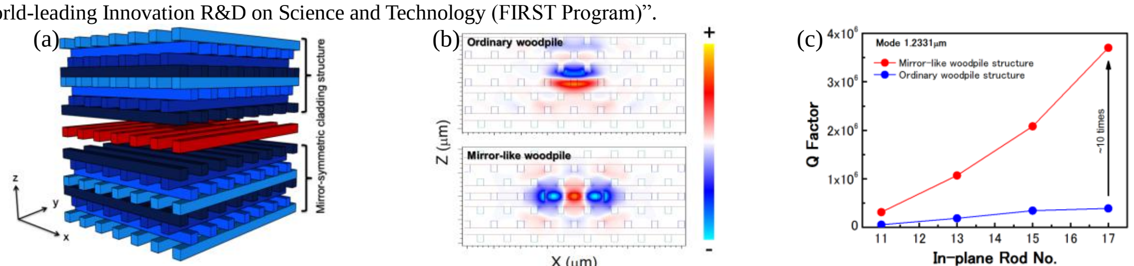

Fig. 1(a) Schematic of 3D photonic crystal with plane defect (GaAs) and two stacks of woodpile structures (Si). (b) Vertical cross-section of cavity mode profile *Ex* component of both ordinary woodpile structure and mirror-like woodpile structure. (c) *Q*-factor of original (blue) and mirror-like (red) woodpile structures as a function of number of in-plane rods.