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フォトニック結晶レーザと埋め込みナノ金属構造における相互作用に関する理論検討

Theoretical investigation of local interaction and effects in photonic-crystal laser with embedded metallic nano-structures

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[Introduction] Our research on hybrid photonic systems which consist of a photonic crystal (PC) and metallic meta-atoms have successfully demonstrated nano-scale controllability of light in a small region even less than diffraction limit range [1]. Recently, we extended our techniques into large area PC structures in order to control the photonic-band edge modes effectively [2]. It was suggested that the coupling between the low-quality (Q) mode of meta-atoms and the infinite-Q mode in PC slab occurs selectively when the structure is appropriately designed. Such a selective interaction might provide a crucial method to control local absorption over large scale PC area, in order to maintain single mode envelope while suppressing the couplings to the unwanted modes. In this report, we discuss concrete calculation results; we embedded metallic structures nearby a large area PC layer to investigate the local absorption effect. It is shown that the Q factor of the target mode can be retained high while lowering those of other modes when the position and shape of metallic element is appropriately designed.

[Structure and Results] Figure 1 (a) depicts an InP based square lattice PC laser, where the corresponding band diagram is presented in Fig. 1 (b). Two guided modes (A, B) in the PC layer are marked in red and blue-colored dot, respectively, and the other degenerated radiative modes are denoted as C and D with black-colored dot. Figure 2 (c) depicts a metallic (Ag) bar structure, where the size ($\ell = 150\text{nm}, \text{w} = 60\text{nm}, \text{t} = 40\text{nm}$) is designed to resonate with the PC guided modes (f~0.3c/a). It is seen in Fig. 1 (d) that the resonant spectrum for E_x polarization matches with PC guided modes while that of E_y is far off resonant. We embedded this bar structures into the high refractive index medium on top of the PC layer as shown in Fig 2 (a). Two types of geometric configurations are considered. In the case of type A (See Fig. 2 (b)), bar is located along with magnetic nodes of mode A (See Fig. 2 (b) blue-dashed line), and center of bars are slightly shifted from the cross point of the node lines ($\delta_x = 0.3\text{a}, \delta_y = 0.3\text{a}$). This structure can selectively avoid the absorption of mode A while absorbing modes B, C and D because this bar structure resonate only to electric field in the *width* direction and does not resonate with the longitudinal electric field as shown in Fig. 1 (d). In the FDTD simulation of this structure, only mode A was observed with relatively high Q value after large time steps from the excitation. On the other hand, in the case of type B structure, mode B was observed with high Q value while the other modes dissipated. Further details will be discussed at conference.

[Ref.] [1] 李他、春季応物 28p-c1-2 (2013) [2] 李他、秋季応物 17a-PA14-2 (2013)

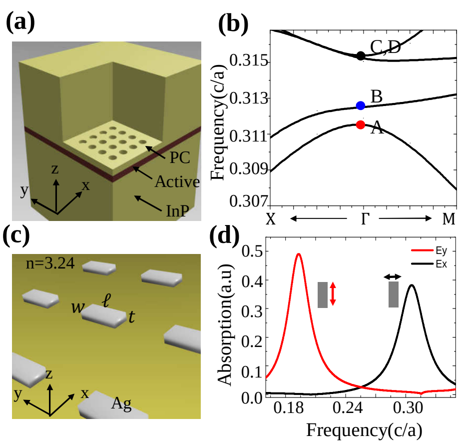

Figure 1. (a) Configuration of PC laser, (b) Calculated band diagram, (c) Configuration of bar array (a=450 nm), (d) Related resonant spectrum

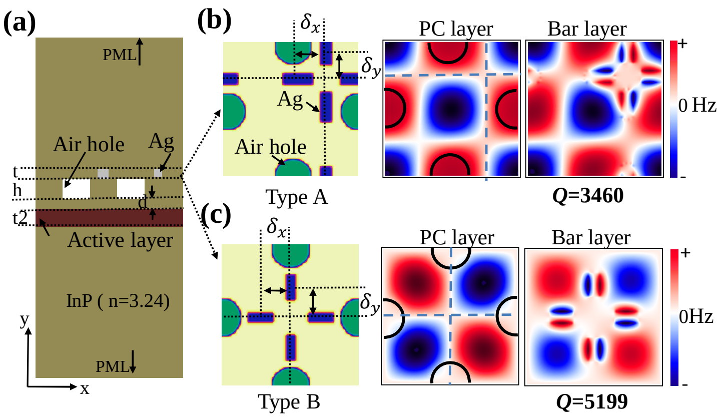

Figure 2. (a) Cross sectional view of the PC laser + bar structure (t=40 nm, h=200 nm, d=150 nm, $t2$=200 nm), (b)Geometrical distribution of Type A structure and calculated field profiles at each layer, (c)Type B structure and calculated field profiles