SiN 導波路上に集積されたダイヤモンドフォトニック結晶共振器の設計

Design of a diamond photonic crystal cavity integrated on a SiN waveguide

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Diamond with nitrogen–vacancy (NV) centers is one of the most promising platforms realizing high-performance solid-state quantum repeaters [1-3]. Towards the realization of large-scale quantum information processing systems, it is necessary to coherently connect individual NV centers spatially separated through low-loss optical waveguides [4]. It is numerically demonstrated that a simple hybrid structure locating a diamond nanobeam waveguide on an air-suspended SiN waveguide can realize almost loss-less light coupling between two waveguides [5]. Here, we report a design of diamond PhC cavity in such a hybrid structure. Our numerical simulations show that a Purcell factor (F_P) over 90 is attainable in the hybrid structure despite the small refractive index contrast between diamond (n = 2.4) and SiN (n = 2.01), indicating that the efficiency of zero-phonon-line (ZPL) emission of NV centers can be enhanced even in such hybrid structures.

Figure 1 (a) shows the structure studied here. A diamond PhC nanobeam cavity is formed by removing n holes at the center among 81 holes in total. The lattice constant (a) and the air-hole radius (r) of the PhC are set at 204 nm and 0.28a, respectively. We calculated cavity Q, mode volume V_{eff}, and F_P for the fundamental cavity mode of the structure with different n's by using the 3D-FDTD method. Figure 1(b) shows F_P as a function of n. Among the cavities investigated here, the maximum F_P of 93 (Q = 3,465 and $V_{\mathrm{eff}} = 2.83(\lambda/n)^3$) is obtained at n = 5 because Q does not increase for large n's due to the fixed total length of the PhC region. The cross-sectional field distribution (E_y component) at the center of cavity (x = 0) (the inset of Fig. 1 (b)) demonstrates that the field intensity has a peak within the diamond region. Thus, the structure is capable of enhancing the emission efficiency of NV centers located within the cavity. Although the cavity resonant wavelength for the structure is 640 nm, the wavelength can be easily tuned to the ZPL emission wavelength without significant degradation of F_p just by changing the structural parameters slightly.

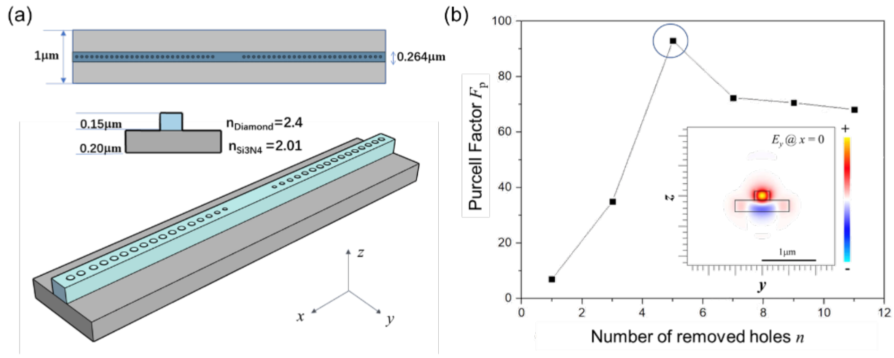

Fig.1 (a) Schematic of a diamond PhC nanobeam cavity on a SiN waveguide. Here, the structure with n = 5 is shown. The width and height for each waveguide are indicated in the figure.
(b) Calculated Purcell factor as a function of the cavity length. Insert: E_y component of the cavity mode for n = 5 at x = 0.

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