High-Q Photonic Crystal Microcavities in Diamond

S. Tomljenovic-Hanic[1], **M. J. Steel**[2,1], **and C. M. de Sterke**[1]

[1]University of Sydney, Australia
[2]RSoft Design Group, Inc., Australia

There has recently been great interest in optical microcavities based on photonic crystal slabs (PCS) [1–3]. Almost all of these studies consider a two-dimensional PCS composed of a hexagonal array of cylindrical air holes in a silicon dielectric slab ($n \approx 3.4$). In this study, the material chosen is diamond ($n \approx 2.4$) because of its unique possibilities for demonstrating quantum entanglement of N-V centres. The photonic crystal geometry is potentially advantageous in achieving entanglement, since it can enable strong confinement in cavities and optical coupling between different centres [4].

The quality factors of defects in PC slabs are strongly influenced by the position and widths of the photonic band gaps (PBG). Consequently, the first step is to design an infinite periodic structure without a cavity. Subsequently, the finite structure including the cavity defect can be optimized to obtain the highest quality factor possible. We find that the PBG widths of diamond PCS are comparable with silicon-based PCS whereas the positions of corresponding gaps differ. Consequently the in-plane quality factors for the two materials are similar, whereas the out-of-plane factor for diamond is smaller.

The optimization of optical cavity design, i.e., further tuning of the quality factor is possible by modifying the geometry of the lattice structure surrounding the cavity. For example Noda et al. constructed a cavity by three missing air holes in a row of a silicon slab with hexagonal lattice structure [1, 2]. They optimized the structure by shifting the left and right air holes outwards. We apply a similar method to the diamond based structure and find that high-Q microcavities can be designed in this material.

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