Designing Photonic Crystal Microcavity for Quantum Gate Application

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Photonic crystal (PC) microcavities with high quality factor (Q) and small mode volume (V) are essential for solid-state implementation of quantum gates like CNOT, Phase gate, and quantum memory device. With their mature fabrication technologies, semiconductors offer a great potential to realize solid-state devices. There are several works in the literature on the design of high-Q cavity and its demonstration [1-4]. However, most of the work is on single photon source [2], quantum cascade laser [3], and devices for communication networks [4]. Very high-Q of the order of 10^5 has been experimentally demonstrated recently [4]. Some of the issues in realizing PC microcavity based semiconductor devices are, introducing quantum dots (QDs) into the defect region of the microcavity, and coupling light to and from the PC cavity structure efficiently among others.

We are working on high-Q cavity designs that are suitable for semiconductor nonlinearities especially quantum well and quantum dot structures as the defects. It is well known that the in-plane Q value can be easily obtained to be large, but the overall Q value depends on the out of plane losses. We are currently optimizing the structures to get high-Q value by minimizing the out of plane losses.

To improve the coupling efficiency to and from the PC cavity structures, plasmonic structures or metallic PCs may play an important role. We have initiated studies on 1D metallic nanostructure to understand the coupling mechanism of light to surface plasmons and the short pulse transmission properties. A combination of metallic and dielectric photonic crystal structures may eventually be useful to realize planar optical circuits that are ideal for both classical and quantum computing or classical and quantum information processing, in general.

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