TuA3.1 (Invited)
1:30 pm – 2:00 pm

2-D Photonic Crystal Microcavities

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Abstract

We have recently developed photonic crystal nanocavities and lasers from both InGaAsP quantum well and InGaAs/GaAs quantum dot materials. We have explored the design compromises for developing high-Q cavities and developed new geometries for sensitive low-threshold optical switches and spectroscopy sources. In this talk, we will review the design, fabrication and characterization of optical cavities defined within photonic crystals.

Summary

When combined with high index contrast slabs in which light can be efficiently guided, microfabricated two-dimensional photonic crystals provide us with the geometries needed to confine and concentrate light into extremely small volumes and to obtain very high field intensities. Fabrication of optical structures has now evolved to a precision which allows us to control light within such etched nanostructures. Sub-wavelength nano-optic cavities can be designed for efficient and flexible control over both emission wavelength and frequency, and nanofabricated optical waveguides can be used for efficient coupling of light between devices. The substantial reduction of the size of optical components leads to their integration in large numbers and the possibility to combine different functionalities on a single chip, much in the same way as electronic components have been integrated for improved multi-functionality of microchips. Here we describe the use of microfabricated periodic structures, photonic crystals, to define functional nano-optic cavities for efficient confinement and emission of light, which leads to the desire for miniaturization of optical devices.

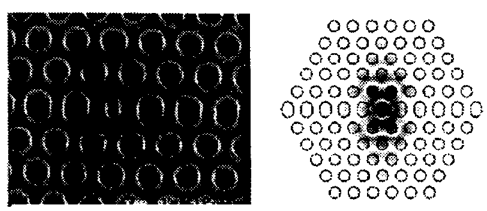

Figure 1. Scanning electron micrograph and calculated field distribution of a photonic nanocavity laser sensor

When we generate light in cavities with very small volumes, we also decrease the number of modes the emitted light can couple into. This effect was first recognized by Purcell, and leads to the conclusion that, if the emission spectrum is narrower than the cavity resonance peak, the spontaneous emission rate of light into one of the supported modes can be enhanced. Thus, spontaneously emitted light can be more efficiently coupled into an extracted mode when it is generated within a small cavity. This can lead to the improvement of efficient light emitters, which are based on nanocavities with very small volumes and high Q values. We have developed new cavity designs based on partial edge dislocations, in which the out of plane losses from the photonic crystal cavity are significantly reduced. Since the Qs of two-dimensional optical nanocavities are typically dominated by these out of plane losses, our new approaches have allowed us to design cavities with Q values in excess of 10,000. We have used these new device designs to fabricate low-threshold lasers in InGaAsP quantum well material, and have observed 0.2 mW threshold power with highly localized lasing modes. We have optimized some of these new nanocavity designs with holes in the center of the nanocavity. In this case, the optical field intensity overlaps with a void in the structure, which can later be backfilled with material of choice. Alternatively, we can use such laser nanocavities as chemical sensors, in which the threshold current of the laser is strongly dependent on the amount and type of absorbing material contained within the central hole.