Focused ion beam engraved phase-shifted Bragg grating microcavity resonator

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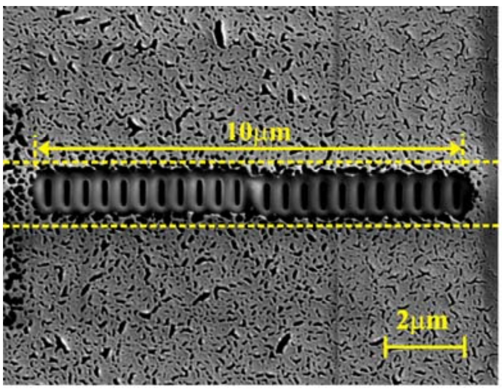
A cavity with minimal-volume confinement was created in a microfiber engraving a high-contrast phase-shifted Bragg grating by focused ion beam. While waveguiding by the air/silica boundary provides a diffraction-limited 2D confinement, the grating introduces the third degree of confinement. Theoretical simulations verified the phase-shifted cavity confinement and showed a reasonable agreement with the experimental demonstration. This cavity can find a variety of applications ranging from sensing to quantum dynamic experiments.

Resonators based on optical microcavities can confine light in a small volume by resonant recirculation and have been demonstrated in several structures [1] including microtoroid, microsphere, microdisk, and Fabry-Perot cavities manufactured in a quantum-dot-loaded micropillar.

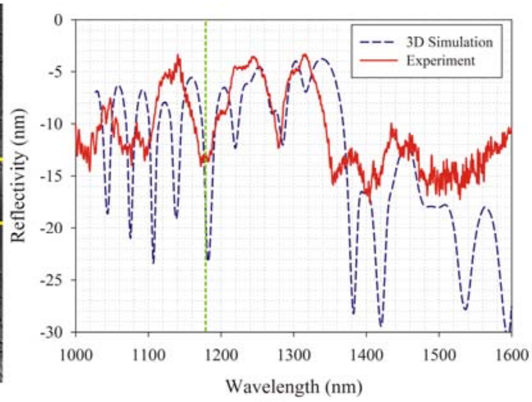
In this paper, a microfiber phase-shifted Bragg grating (PSBG) cavity is proposed for 3D light confinement. In optical fibers the small refractive index difference in the grating pitches implies that thousands of periods are needed to provide strong reflectivity; on the contrary, in microfiber PSBG, focused ion beam caved the notches and the large refractive index contrast between taper and air requires only dozens of periods to achieve a strong grating. Fig. 1 shows a SEM image of the gold-coated microfiber PSBG: Gold was removed after FIB milling was completed.

Fig. 1 (b) shows the reflection response of the proposed microfiber PSBG. The red solid line shows the experiment results while the blue dashed line presents the simulation data calculated by COMSOL Multiphysics 4.1. Experiments show a resonance dip at λ~1180nm, which corresponds to the cavity resonant wavelength. Other dips have been observed at shorter and longer wavelengths are associated with the Fabry-Perot nature of the gratings at either side of the cavity. The experimental and simulation lines show a reasonable agreement. The small wavelength peak shift (~5 nm) can be due to the surrounding refractive index, which in the simulations is taken as polymer, while in the experiments is a combination of air and polymer (the microfiber is only partially embedded in the polymer). Possible explanations for the other spectral mismatches include the presence of unwanted high order modes, the only-partial cavity embedding in the experiments, a different effective index of the mode propagating in the microfiber between experiments and simulations and an imperfect periodicity in the grating notches.

Further optimization of manufacturing parameters (such as the grating pitch number and period, the notch width and the length and the microfiber diameter) can provide a more compact device with improved performance. This microfiber cavity can be used for a wide range of applications, ranging from sensing to triggered single-photon sources [2] and the measurement of Casmir effect.



(a)



(b)

Fig. 1. (a) SEM image of the gold-coated microfiber PSBG; (b) Reflection spectra of PSBG. The red solid line is experiment result and the blue dash line is simulation line with the same structure as the sample. The vertical green line indicates the resonance wavelength λ=1180nm.

Reference

[1] K. Vahala, "Optical microcavities," Nature **424**, 839-846 (2003).
[2] J. M. Gérard, B. Sermage, B. Gayral, B. Legrand, E. Costard, and V. Thierry-Mieg, "Enhanced Spontaneous Emission by Quantum Boxes in a Monolithic Optical Microcavity," Phys. Rev. Lett. **81**, 1110-1113 (1998).