Wavelength-selective robust fiber coupler for high-Q micro-resonators

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We present results on the implementation of a robust fiber based system able to efficiently and selectively couple light to high-Q whispering gallery mode optical micro-resonators.

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1. Introduction

High-Q whispering gallery mode (WGM) micro-resonators offer unique properties thanks to their long cavity lifetime and small mode volume, and are extensively used for practical applications as well as for fundamental studies. However, their full exploitation requires a controllable and reliable light coupling system. In this presentation we review results on a new approach based on robust fiber couplers allowing a quasi-distributed and wavelength selective addressing of different resonators along the same fiber.

2. Coupling unit

Thin silica fiber tapers with minimum waste of few microns are extensively used in laboratories as light couplers to high-Q WGM resonators either in non-linear optics or for sensing applications. However, these couplers are very fragile and therefore their use is critical in practical devices. We propose an innovative and robust fiber based coupling unit which also allows wavelength selective addressing of different resonators along the same fiber. The unit is sketched in the bottom inset of Fig. 1 and consists of two identical long period fiber gratings (LPG) with an adiabatically tapered section in between. The first LPG couples the light within its attenuation band from the core mode to a specific azimuthally symmetric cladding mode. This latter mode keeps propagating in the tapered section of the fiber and evanescently couples light to the resonator [1]. Finally, the second LPG couples the light back into the fiber core [2]. The tapered section is one order of magnitude thicker than a standard fiber taper, and therefore it is much more robust for practical applications. Additionally, this unit can be replicated more times on the same fiber with LPGs operating at different wavelengths.

The adiabatic fiber tapers with diameters in excess of 15 μm are fabricated first, by a heating and pulling procedure. The coupling unit is completed by manufacturing the pair of identical LPGs on both sides of the taper. The fiber is a UV photosensitive single-mode boron-germanium co-doped optical fiber. Direct UV writing process from an excimer laser with a point-by-point technique is used to fabricate volume LPGs with a grating period Λ ranging from 100 to 600 μm.

3. Results

The coupling unit allows excitation of high-Q resonances in silica micro-resonators as shown in the transmission spectrum of Fig. 1 for a silica microsphere with a diameter of 280 μm. Coupling efficiencies were up to 60%. We also demonstrated independent and selective coupling of different WGM micro-resonators placed along the same fiber link. Each resonator could be independently excited around the relevant LPG central wavelengths without cross-talk, thus improving the perspective of optical fiber-based sensing and biosensing.

Finally a comprehensive model for designing the proposed structure was also developed [3]. By solving the Helmholtz equation in spherical and cylindrical coordinates, we find the electromagnetic fields of the microresonators and the fiber, respectively. Then, the coupled-mode theory allows for modeling the optical interaction between the calculated microresonator modes and fiber modes. The model was successfully validated by comparing the simulated results with the experimental data and can be therefore useful for designing devices based on the proposed structure.

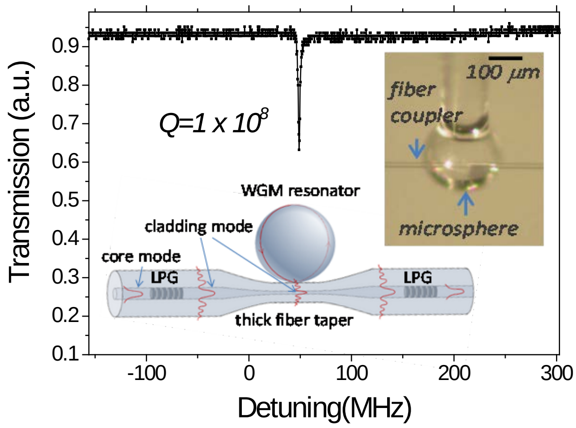

Fig. 1 Transmission spectrum around 1550 nm showing a typical high-Q resonance excited in a silica microsphere using LPG assisted fiber couplers. Bottom inset shows a sketch of the coupling unit based on a couple of identical LPG gratings with a thick fiber taper in between. The microscope picture in the second inset shows both the microsphere resonator on the top of a silica fiber and the coupler.

References

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