All optical fiber whispering gallery mode resonator

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Abstract

We present a new type of optical fiber whispering gallery mode resonator based on cylindrical cavity, which is located in the multimode fiber core and fabricated by femtosecond laser micromachining together with fast hydrofluoric acid etching techniques. When light traveling in the fiber core is tangent to the cylindrical cavity wall, it is coupled into the cavity and circulates along the cavity wall to excite whispering gallery mode resonance before being coupled out to the same tangential path and continuing propagation in the fiber core. The device is fully integrated into optical fiber, simple in fabrication, convenient in operation and low in cost and has a good quality factor (Q) of 1.06×10^4. The device enriches the family of whispering gallery mode resonator.

Introduction

Whispering gallery mode (WGM) resonator can strongly confine light within the structure by continuous total internal reflection [1], and is widely used in optical filters, modulators, micro-lasers, frequency comb generators, nonlinear optics and high-sensitivity sensor devices. However, most of WGM resonators are usually discrete optical devices, which have integration difficulties with optical fiber system. Here, a new type of WGM resonator based on a cylindrical cavity inside the fiber core, fabricated by femtosecond laser inscription together with fast hydrofluoric acid etching is proposed and demonstrated.

Working Principle

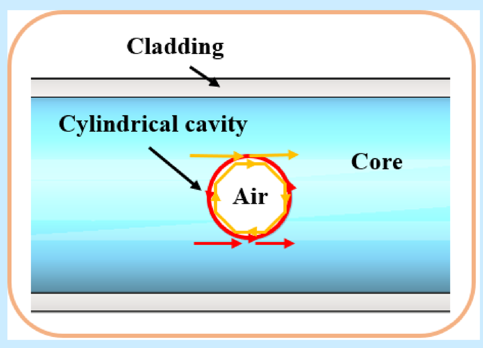

Fig. 1. Schematic of the WGM resonator

Device fabrication

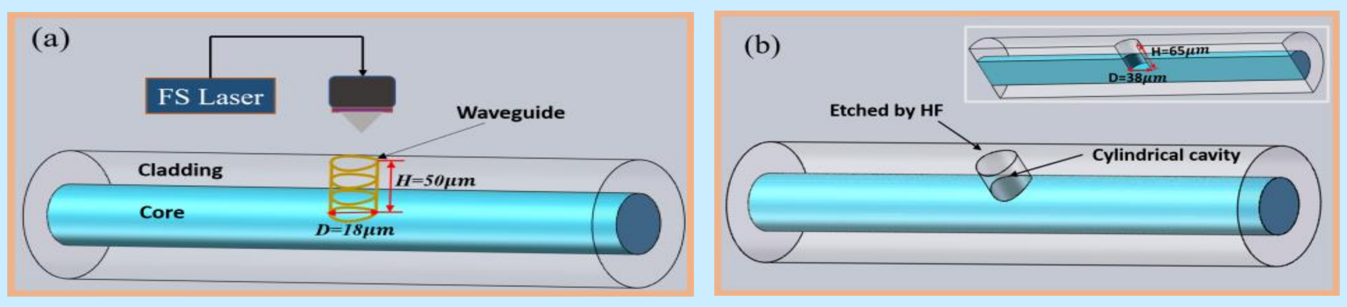

Fig. 2. Fabrication process of the cylindrical cavity based WGM resonator. (a) Femtosecond laser inscription of cylindrical structure in MMF. (b) Cylindrical cavity formed after etching. Inset: the cross section view of the cylindrical cavity.

Device image

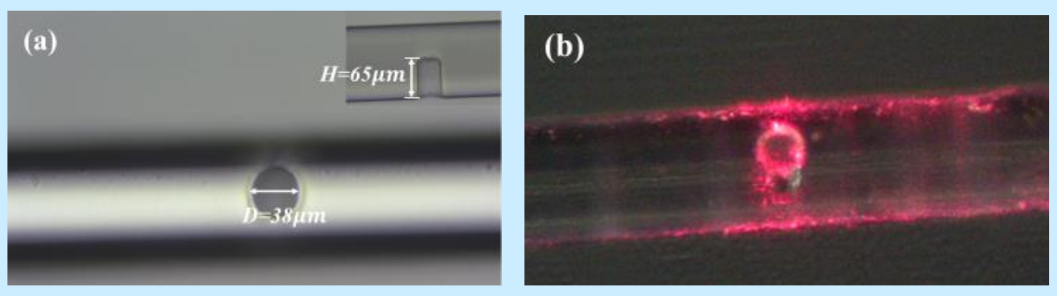

Fig. 3. Microscope image of the WGM resonator. (a) Top view. Inset: the cross-section view. (b) Top view under the red light illumination.

Experimental set up and results

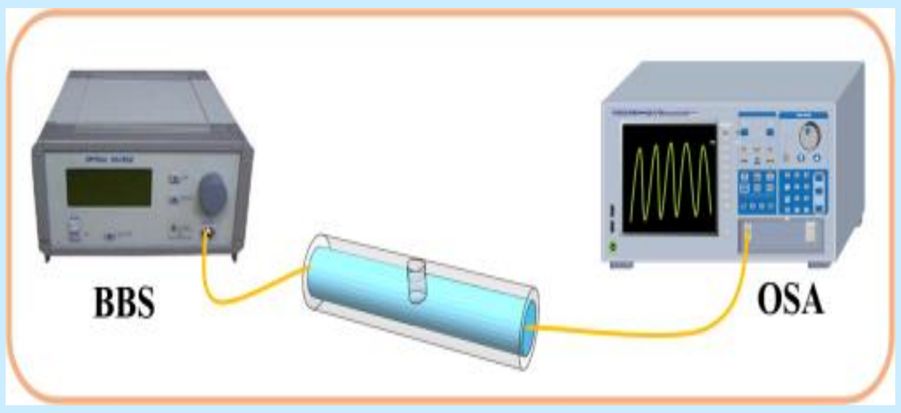

Fig. 4. Experimental set-up for optical fiber integrated WGM cylindrical cavity resonator.

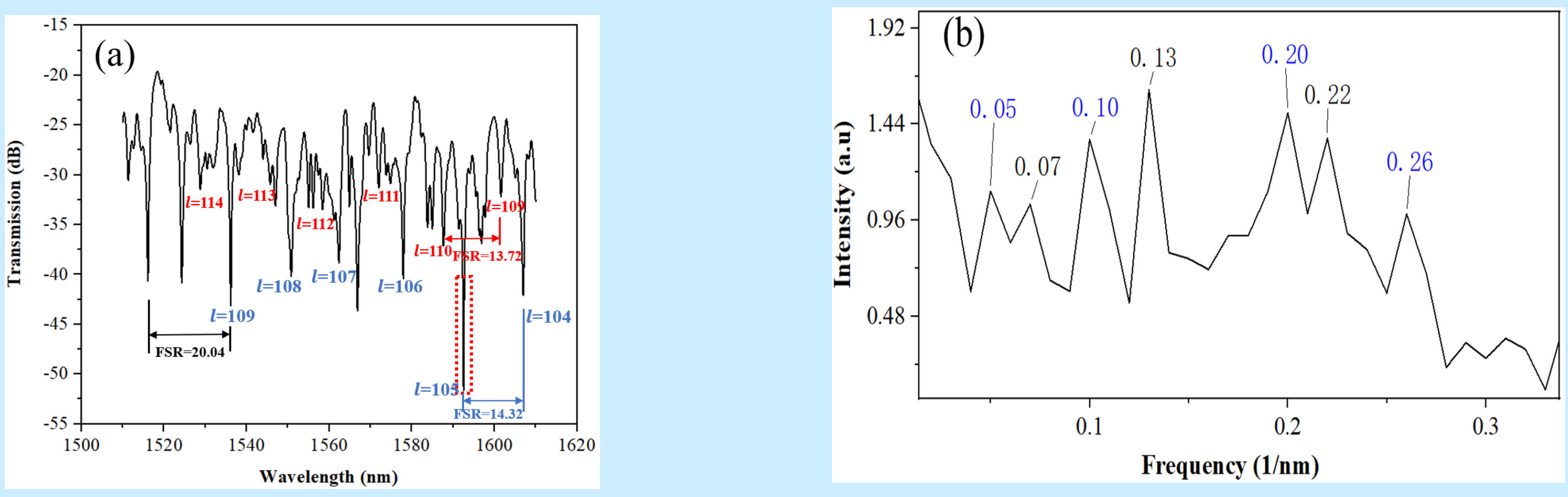

Fig. 5. (a) The transmission spectrum of the optical fiber WGM cylindrical cavity resonator with diameter of 38 μm. (b) The corresponding spatial frequency spectrum.

Fig.5(a) shows the transmission spectrum of the WGM resonator. The corresponding spatial frequency spectrum is shown in Fig. 3(b). It can be observed that the first two peaks are located at 0.05 nm^{-1} and 0.07 nm^{-1}, respectively, and the rest peaks are multiples of these two peak frequencies. It can be determined that these two peaks correspond to WGM resonator operation.

Conclusion

In conclusion, an optical fiber integrated WGM resonator based on cylindrical cavity is demonstrated. The cylindrical cavity is fabricated by femtosecond laser micromachining together with fast hydrofluoric acid etching techniques. The cylindrical cavity exhibits a smooth inner wall and is located in the core of MMF. When light propagating in the fiber core is tangent to the inner wall of the cylindrical cavity, it is coupled into the cylindrical cavity and circulating along the cavity wall to excite WGM resonance before being coupled out in the same tangential path and traveling in the core of MMF. The device is fully integrated into the optical fiber, simple in fabrication, convenient in operation, low in cost, and has a good quality factor of 1.06×10^4. The device enriches the family of WGM resonators and is expected to have promising applications in micro lasers, nonlinear optics and many other photonics areas.

Acknowledgment

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REFERENCES

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