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Recent developments in novel silica-based optical fibers

Key words: Optical fiber; Fiber optic device; Silica-based special fiber

Corresponding author: Li-bo YUAN
E-mail: lbyuan@vip.sina.com
ORCID: https://orcid.org/0000-0002-2425-4553

Motivation

1. Driven by optical communication and optical sensing, the design and fabrication of functional silica-based optical fibers, including active and passive fibers, is of great interest.

2. To improve the capacity of optical communications, functional active fibers are expected to emit light covering a broadband range.

3. For optical sensing, the target application of optical fibers is prone to harsh environments, due to the lack of electrical counterparts.

4. Micro-structured holey fibers with different hole arrangements have attracted great interest for bio-logical and chemical sensing for their inherent microfluidic channels in the fibers.

Main idea

1. To achieve spectral emission covering 1000–1400 nm, we have co-doped the Bi/Al elements in the silica fibers.

2. To achieve radiation detection, the silica fiber could be doped with Ce.

3. Sensors that can withstand up to 1200 °C can be developed by constructing the Fabry-Perot (FP) interferometer in the sapphire-derived optical fiber.

4. The micro-structured multicore fiber is designed to have a strong evanescent field, which enhances its usefulness for the applications in biological fiber optic sensing and chemical measurement.

Method

1. We have fabricated Bi/Al co-doped silica fibers for the first time by integrating ALD and MCVD techniques.

2. A Ce-doped silica fiber with germanium dopants was fabricated using a powder-in-tube technique via the sol-gel method.

3. To create an FP interferometer on SDF, a new mechanism of refractive index modulation based on the crystallization of mullite was designed to form reflected mirrors.

4. We focused on the two kinds of refractive index-guiding fibers: multi-core polarization maintaining fiber and CCF.

Major results

1. The Bi/Al co-doped silica fiber fabricated using the ALD technique exhibits a fluorescence spectrum covering 1000–1400 nm with FWHM of about 150 nm.

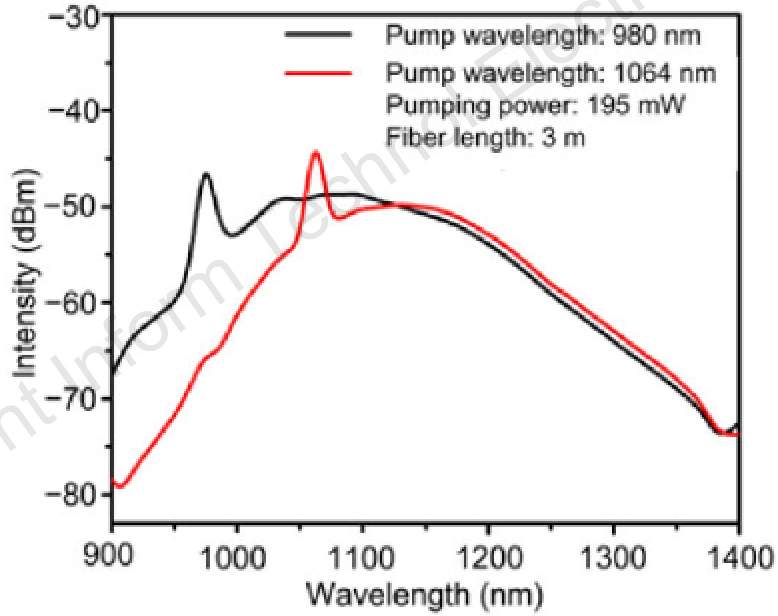

Fig. 2 Fluorescence spectra of Bi/Al co-doped silica fiber with 980-nm and 1064-nm pumping

Major results (Cont’d)

2. Excitation and emission spectra of the Ce-doped silica fiber locate at about 340 and 430 nm.

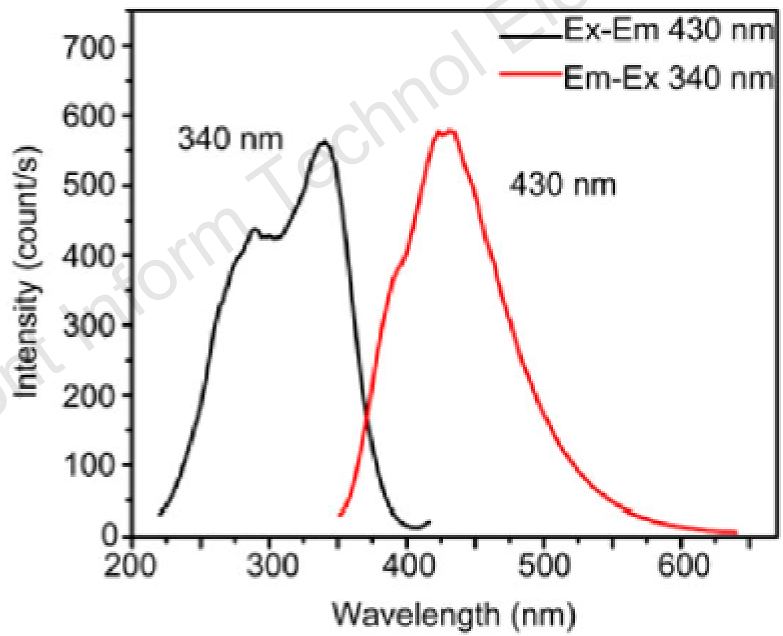

Fig. 5 Excitation and emission spectra of the Ce-doped silica fiber

Major results (Cont'd)

3. The SDF-based FP sensor can keep working at 1200 °C for several hours.

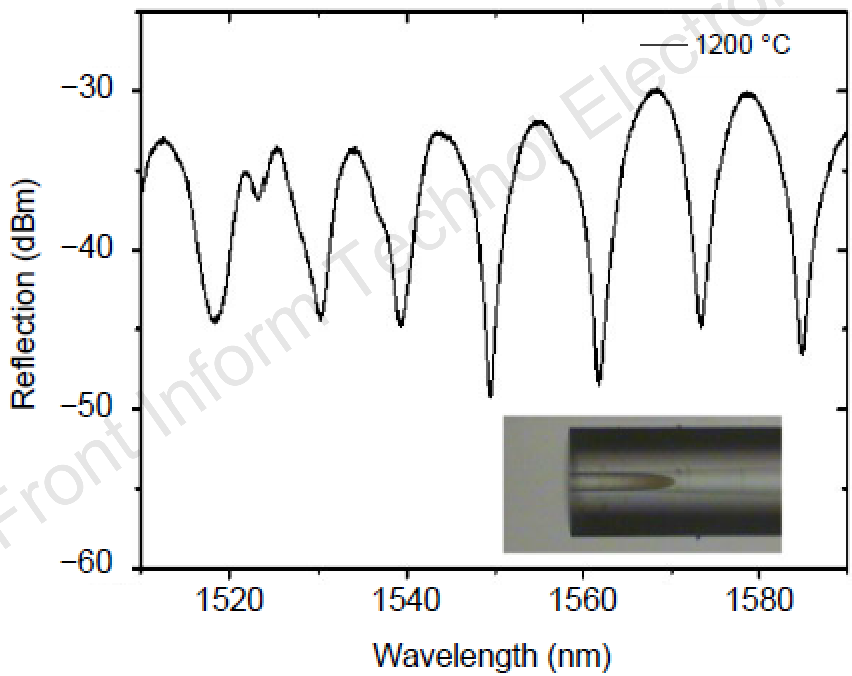

Fig. 6 Reflective spectrum of the SDF-based FP sensor during the constant temperature process at 1200 °C

Major results (Cont'd)

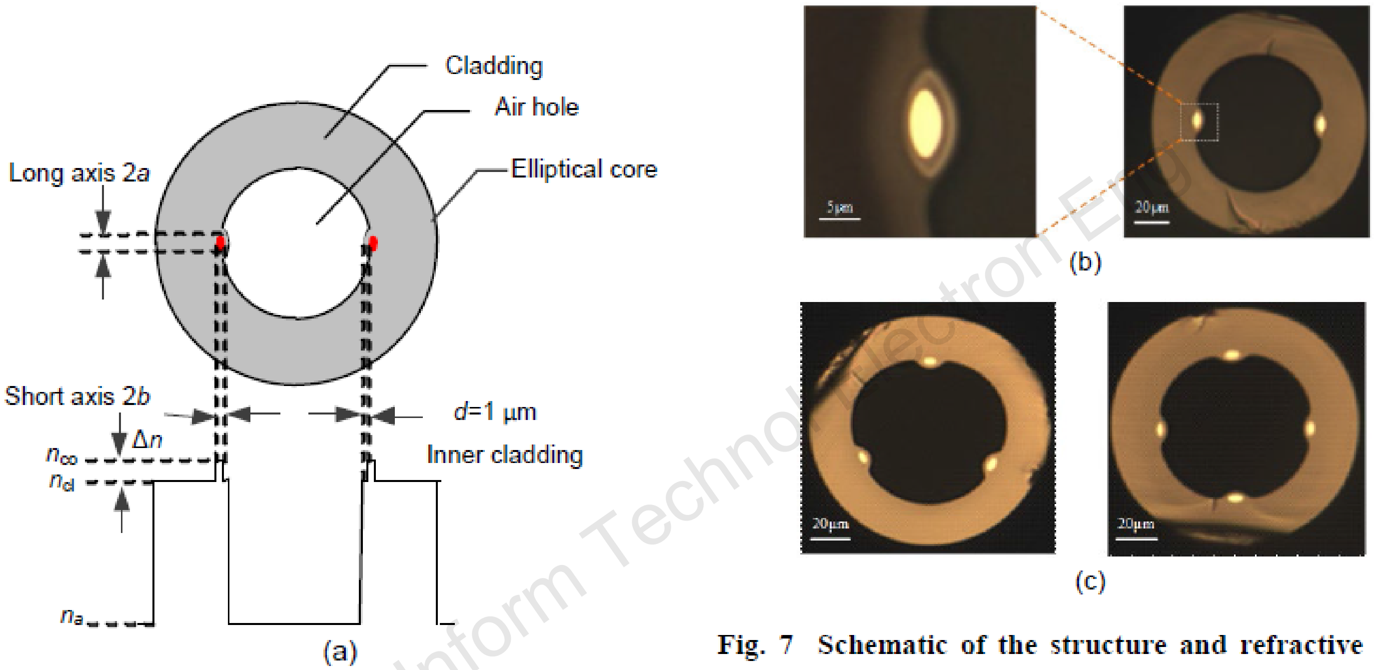

Fig. 7 Schematic of the structure and refractive index profile of the hollow elliptical twin-core fiber (a), the shape of the elliptical core structure diagram (b), and the cross section of the hollow elliptical three- and four-core polarization-maintaining fiber (c)

4. For a multi-core polarization-maintaining fiber, the weak birefringence highly depends on the thickness of the thin cladding and the size of the central air hole, which allows this kind of fiber to have a strong evanescent field, enabling its applications in biological fiber optic sensing, chemical measurement, and interference-related devices.

Major results (Cont’d)

5. For a coaxial-core optical fiber, the refractive indices and geometric size of both the center and circular cores can be designed according to practical demands.

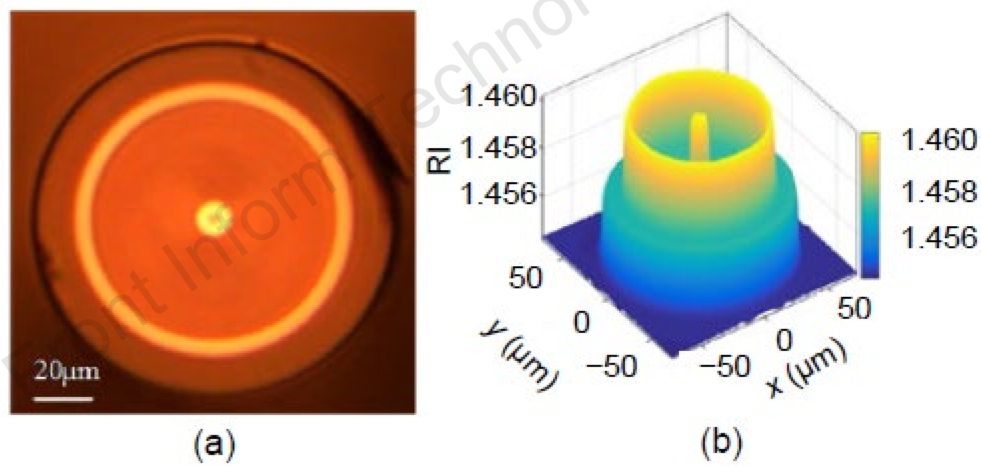

Fig. 8 The cross-section image (a) and 3D refractive index profile (b) of the CCF

Conclusions

1. We have accomplished active fibers including Bi/Al co-doped silica fibers exhibiting a fluorescence range of 1000–1400 nm with FWHM of about 150 nm.

2. We have fabricated the Ce-doped silica fibers with excitation and emission wavelengths of about 340 and 430 nm, respectively.

3. Sapphire-derived fiber has been realized to construct a Fabry-Perot interferometer with high mechanical strength for ultra-high-temperature measurement.

4. Multi-core polarization maintaining fibers have been produced for applications in biological sensing, chemical measurement, and polarization interference devices.

5. Coaxial-core optical fiber has been demonstrated to develop a multifunctional optical micro-manipulation device.