Ultra-broadband Long Period Fiber Grating Mode Converter with Tunable Wavelength based on Dual-resonance Coupling Mechanism

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Introduction

- Space division multiplexing is one of the strong competitors for next-generation optical fiber communication technology, and it is expected to multiply the communication capacity of lightwave systems. Mode conversion is essential in space division multiplexing systems. One of the methods to excite a specific mode in a fiber is to modulate the beam with a spatial light modulator (SLM) and inject it into the fiber. This method is simple, fast, and easy to deploy, but has large insertion loss and poor stability. In contrast, all-fiber mode converter such as **long-period fiber grating (LPFG)** is easy to integrate with lower loss, better stability, and smaller size.
- **The main difficulty of LPFG is that the bandwidth cannot meet the requirements of the communication system.** Cascade, chirp and dual resonance effects have all been utilized to increase the conversion bandwidth of LPFG. Among them, the realization of the dual resonance effect is the most simple and easy to implement, with high conversion efficiency and great scalability. However, since the dispersion turning point of the fiber is fixed, the broadband effect can only be achieved near a specific wavelength. This limits the application of the dual resonance effect.
- In this work, **we use the fusing and pulling technology to move the dispersion turning point of the fiber to desired position, and achieve efficient broadband conversion at this position.** The experiment shows great agreement with simulation results. Our method can easily be extended to other types of optical fibers, making it a general method for LPFG broadbandization.

Methods

- The fiber used in this work is Thorlabs SM2000. The simulation results show that it supports two mode at 1082 nm-1724 nm, and the dispersion turning point is at 1444nm.

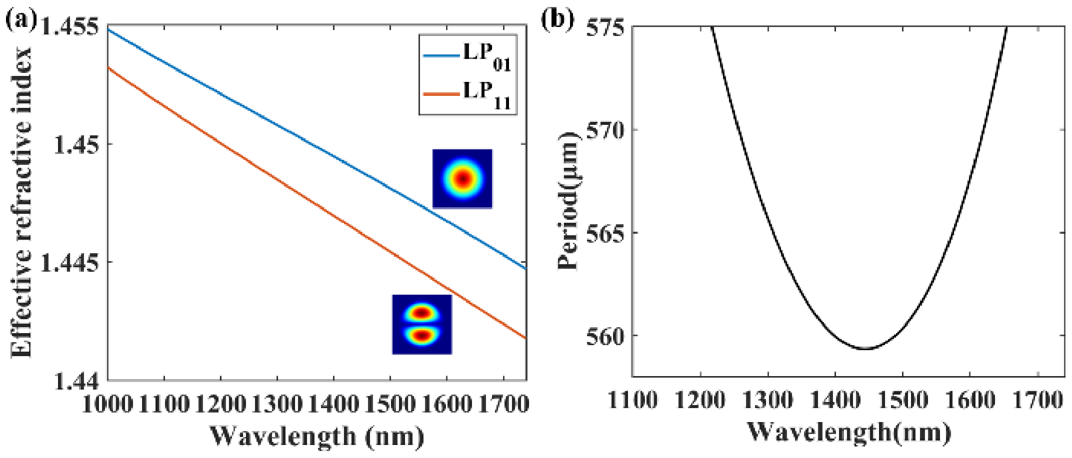

Figure 1. (a) Effective index of LP_{01} and LP_{11} in the fiber. (b) The simulated fiber grating period corresponding to mode conversion from LP_{01} to LP_{11}.

- The size of the core and cladding of the optical fiber will change equally after tapering. After the size of the optical fiber changed, its dispersion turning point will also change. In this way, we can control the position of the dispersion turning point by tapering the fiber.

Results

The simulation results in Figure 2 show that the movement of the dispersion turning point with the outer diameter of the fiber is almost linear. By controlling the outer diameter of the fiber, we can make the dispersion turning point move from 1444 nmto 1029 nm. Special attention should be paid to the fact that in order to ensure the performance of the grating, the taper should be as long as possible to ensure adiabatic transmission. We draw the fiber down to 113 µm, and use the CO2 laser to write the grating uniformly in the center of the taper, as shown in Figure 3(a).

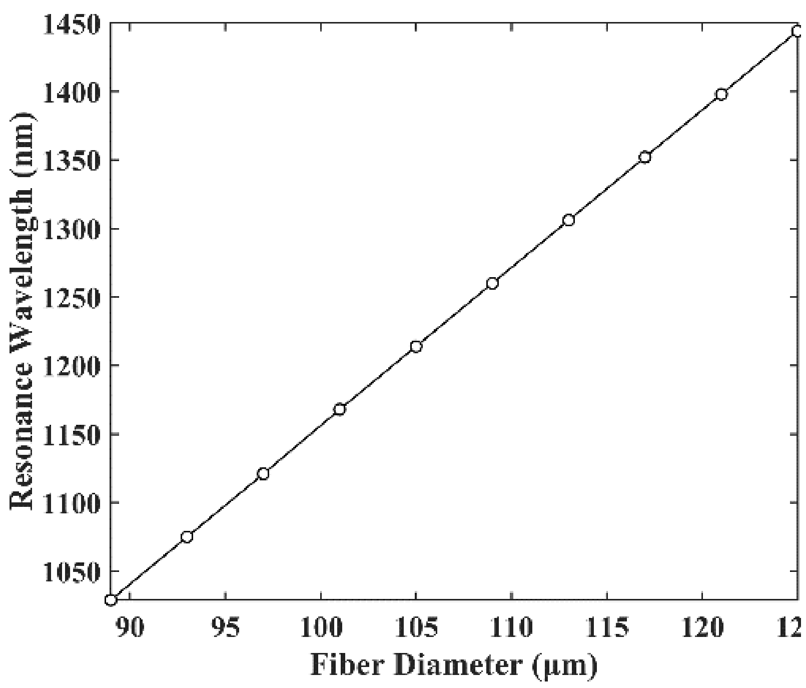

Figure 2. The dual-resonance wavelength of the fiber for different taper diameter.

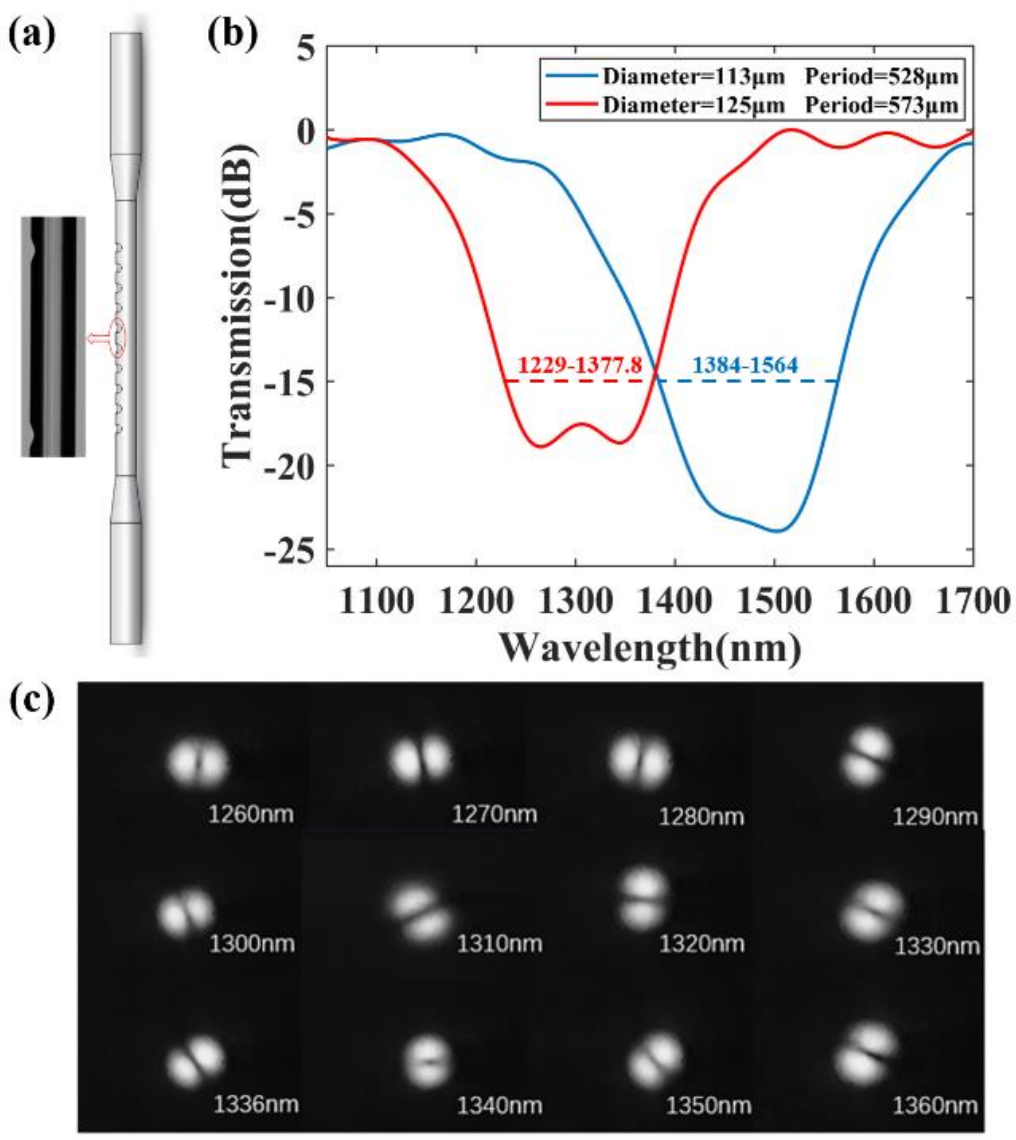

Figure 3. (a) The schematic diagram and micrograph of the fiber grating. (b) The transmission spectrum of the grating when the fiber diameter is $113\mu m$ and $125\mu m$. (c) The output fiber modes of the fiber grating mode converter in its working window.

As shown in Figure 3(b), when the diameter of the optical fiber is 125 µm, the double resonant center wavelength is located at 1474 nm. The 15dB bandwidth is 180 nm from 1384 nm to 1564 nm. The fiber diameter changes from 125 µm to 113 µm after fusing and tapering, the corresponding double resonant center wavelength changes from 1474 nm to 1304 nm, with the 15dB bandwidth 148.8 nm and the wavelength range 1229 nm-1377.8 nm. Thus, the center wavelength of the double resonant center shifts blue when the diameter of the fiber decreases. The experimental results are consistent with the simulation results.

Figure 3(c) shows the mode field of the LP11 mode output by this grating in the working window. It is easy to see that the optical fiber provides good mode conversion in the working window, and the mode purity of the obtained LP11 mode field is very high.

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