Improved large-mode-area Bragg fiber

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A novel large-mode-area Bragg fiber (BF) is proposed for selectively suppressing the amplified spontaneous emission (ASE) of Yb. Confinement loss can be effectively lowered by adding a layer of F-doped glass near the core of this fiber. The BF can achieve effective suppression of ASE of Yb when the bend radius is 0.15 m at wavelength lower than 1.13 µm in theory, and eliminate LP11 mode in mode competition in wavelength range of 1.15–1.2 µm.

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Two-dimensional (2D) solid-core photonic bandgap fibers (SC-PBGFs) have attracted much attention over the past few years because of their unusual dispersion and modal properties [1–4]. Moreover, such fibers can be used as wavelength-dependent distributed filters owing to the band gap principle. By filtering the amplified spontaneous emission (ASE) of Yb in the high-gain region (∼1.03–1.11 µm), the frequency-shifted fiber laser (FSFL) can achieve high output power (∼0.98 or 1.15 µm) [5–9], which provides a new means of blue or yellow light generation by direct frequency-doubling FSFL. In 2009, Shirakawa et al. obtained 30-W laser at a wavelength of 1178 nm with a double-clad Yb-doped SC-PBGF, and pointed out two main problems in such fibers [9]. Firstly, the Ge-doped lattice in the clad absorbed an amount of pump power. Second, with the Yb-doped SC-PBGF, it was difficult to achieve large-mode-area (LMA) design. Both factors impede further improvement of the output power of FSFL.

Bragg fibers (BFs) consist of a core with low refractive index, surrounded by alternating layers with high and low refractive indices [10]. Light confinement in the core is due to the coherent Fresnel reflection from the boundaries between the high-index and low-index layers. BFs are promising candidates for designing LMA structures owing to their high bend immunity [11]. Continuous wave and mode-locking oscillations have recently been demonstrated around ∼1.06 µm in the Yb-doped BF lasers [12,13]. Thus, the LMA BF with a core diameter of 30 µm is a candidate for high-power FSFL, and is compatible with common Yb-doped active fiber and optical devices. In this study, we propose a novel bend-resistant LMA BF for filtering the high-gain region of Yb ASE. The low-index F-doped layer added near the core can enhance the light confinement. In theory, the BF can effectively suppress the ASE of Yb at wavelength lower than 1.13 µm at a bend radius of 0.15 m. The large difference in confinement loss (CL) between LP10 and LP11 modes is beneficial for achieving single-mode oscillation in laser cavity.

The cross section and refractive index profiles of the improved BF are shown in Fig. 1. Unlike common BFs, this BF has a thin F-doped layer added adjacent to the fiber core to decrease the bending loss. The fiber core has a diameter (Dco) of 30 µm, and its refractive index difference is ∆nco=3×10−4. By adding a thin F-doped layer with a thickness of 3 µm and its refractive index difference is ∆nF=4×10−3. Three coaxial high-index Ge-doped rings compose the Bragg mirror. The thickness and pitch of these rings are 1.5 and 12 µm, respectively. Each ring has an index difference of ∆nGe=4.5×10−3 higher than that of pure silica.

Fig. 1. (a) Cross section and (b) refractive index profiles of improved BF.

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Fig. 2. Calculated CL curves of improved and common BFs.

Fig. 3. Calculated CL curves of LP_{01} and LP_{11} modes of the improved BF. The inset is LP_{11} mode distribution at 1.13 \mu m.

Fig. 4. Dependence of CLs on bend radius.

Fig. 5. LP_{01} mode distribution at (a) 1.13 and (b) 1.2 \mu m.

Fig. 6. CLs of LP_{01} and LP_{11} modes at \( R_c = 0.15 \) m.
layer can lower the CL. Our calculation shows that the CL is very low in the wavelength range of $1.15-1.2 \mu m$ at $R_c = 0.15 \text{ m}$. The novel fiber design is of great significance for the high-power FSFL and the highly efficient yellow laser light generation.

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