An 88-nm broadband ASE source with bismuth-based erbium-doped fiber

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A broadband amplified spontaneous emission (ASE) source of 88 nm is demonstrated using novel bismuth-based erbium-doped fiber (EDF) with the length of only 49.2 cm in a bi-direction pumping scheme. The maximum output power of 14.3 dBm is obtained under total pump power of 162 mW. The fiber loop mirror which works as a broadband reflector is responsible for the broadband output spectrum of this source according to the experiments.

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Broadband high power and incoherent light sources are widely used in many applications such as optical sensor systems, fiber optic gyroscopes (FOG), and optical coherence tomography (OCT). Many researches on such sources are made upon rear-earth-doped fibers especially erbium-doped fibers (EDFs)[1−3]. Amplified spontaneous emission (ASE) source with output power as high as 770 mW[4] and linewidth as wide as 80 nm[5,6] have been achieved in recent years using silica-based EDF (Si-EDF). In this letter a new type bismuth-based EDF (Bi-EDF) is used as the gain medium in the broadband ASE source. This non-silica-based EDF was firstly reported by Asahi Glass Company[7]. The superiorities of this new type fiber over ordinary Si-EDF lie in the broad spectral bandwidth and high gains for L-band signals due to its ultra-high erbium concentration. It has been reported that fiber amplifiers based on Bi-EDF have successfully demonstrated their broadband amplification abilities for signals in both C- and L-band[8−10]. Here we report a application of this new type fiber in building a broadband ASE source.

The schematic diagram of the experimental setup is shown in Fig. 1. In order to obtain a high and flat output spectrum, the 49.2-cm Bi-EDF was pumped by a 980-nm laser diode (LD) and a 1480-nm LD backwardly and forwardly. Erbium concentration of this Bi-EDF is 6470 ppm with the core diameter of 3.8 μm and NA of 0.2. The fiber loop mirror (FLM) used at the left end is designed as a broadband high-reflecting mirror, thus the backward ASE generated by 1480-nm LD is reflected back into the Bi-EDF, and the output power of L-band ASE is enhanced. The output is measured by an optical spectrum analyzer (OSA).

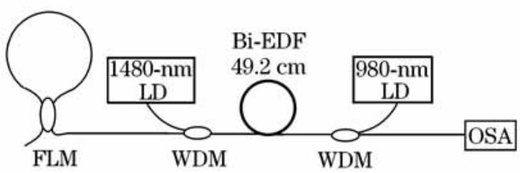

Fig. 1. Scheme of broadband ASE source.

The output broadband ASE spectra under different pump conditions with FLM at the reflecting end are shown in Fig. 2. Both of them have a peak power near 1560 nm. As shown in Fig. 2(a), when 980-nm LD is working at 42 mW and 1480-nm LD at 65 mW, there is a range of about 72 nm (1544 − 1616 nm) above −20 dBm output ASE with the power of 12.4 dBm. A range

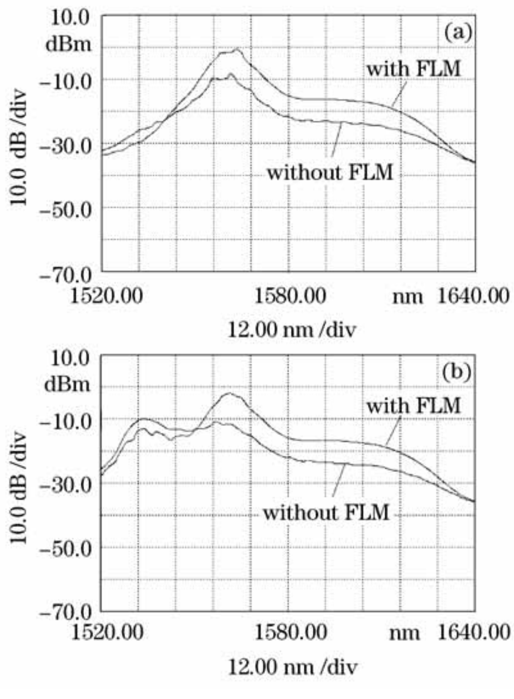

Fig. 2. Output spectra of broadband ASE source under different pump powers with and without FLM. (a) 980-nm LD at 42 mW and 1480-nm LD at 65 mW; (b) 980-nm LD at 138 mW and 1480-nm LD at 24 mW.

of 88 nm (1528 − 1616 nm) is obtained (as shown in Fig. 2(b)) when 980-nm LD is working at 138 mW and 1480-nm LD at 24 mW with the total output power of 14.3 dBm. Increasing 980-nm pump power enhances the C-band ASE power which in turn broadens the line-width of this source, as shown in Fig. 2(b).

In order to demonstrate the function of the FLM, we disconnect it for comparison. The output spectra without FLM are also shown in Fig. 2. Compared with the spectra with FLM, these spectra are about 7 − 8 dB lower in L-band and about 3 − 4 dB higher in C-band. This can be explained as follows: when the FLM is used the backward ASE is reflected back into the Bi-EDF and re-amplified by the 1480-nm LD and 980-nm LD. Because most of the reflected ASE is located in L-band, this process gives a significant rise to the output power of L-band ASE. As the pump energies in the fiber are commonly consumed by C- and L-band ASEs, the power increasing in L-band will lead to power decreasing in C-band.

The reflection properties of the FLM are shown in Fig. 3. The broadband output spectrum of a semiconductor optical amplifier (SOA) is used as the input reference level shown as the upper trace in Fig. 3. The lower trace in Fig. 3 is the FLM reflection spectrum measured with the assistance of a circulator. Because the 3-dB coupler used to form the FLM is designed to work in C-band, the reflections for C-band ASE are 1 − 2 dB higher than L-band ASE. An amplitude difference of about 4 − 5 dB between input and reflection spectra is observed in L-band, after eliminating the 1.5-dB insertion loss induced by the circulator, this FLM gives a reflection of about 45% − 56% for L-band ASE in practice.

In our experiments green light was observed in the

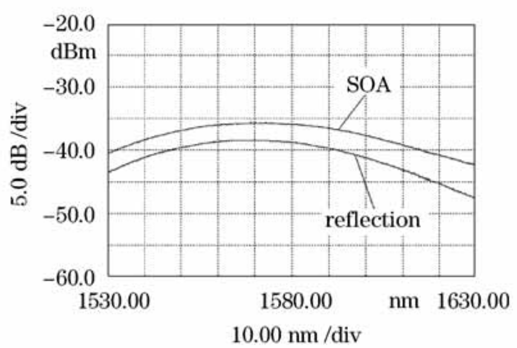

Fig. 3. Reflection properties of FLM.

pumped fiber which was much brighter than commonly pumped Si-EDF. This indicated that the strong excited state absorption (ESA) process was enhanced by the high erbium concentration of this Bi-EDF. Such strong ESA decreased the pump efficiency compared with Si-EDF[6,11]. Fortunately co-doping La ions in Bi-EDFA was proved to be an effective way to solve this problem[10], which made Bi-EDF more practical for further use.

In summary, an 88-nm wide ASE source was presented using only 49.2-cm Bi-EDF with a novel bi-directional pumping scheme where a FLM is used as broadband reflector. The total output power of 14.3 dBm is obtained under a total pump power of 162 mW. When a FLM made of L-band 3-dB couplers was used, the better power conversion efficiency can be achieved while maintaining the same broadband output spectrum.

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