Performance of optical amplifier employing silica host magnesium-aluminum-germanium co-doped erbium-doped fiber

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Two silica host magnesium(Mg)-aluminum(Al)-germanium(Ge) co-doped erbium-doped fibers (EDFs) have been fabricated, which have different Mg concentrations. The concentration of all the compositions in the preform is measured through electronics probe micro analysis (EPMA). The maximum Mg concentrations of fibers A and B are 3.98 and 1.28 mol%, respectively. The performance characteristics including absorption spectrum and gain are measured and analyzed. The absorption coefficients of fibers A and B are 13.3 and 14.3 dB/m respectively at wavelength of 1532 nm. The max gains of these two erbium-doped fiber amplifiers (EDFAs) are 30.1 and 35.9 dB with input signal power of −30 dBm and pump power of 100 mW at 980 nm. Fiber B with maximum Mg concentration 1.28 mol% has better performance than fiber A. Fiber B has high absorption coefficient and high gain characteristics. The optimum fiber B length of C-band EDFA is 7 m and that of L-Band EDFA is about 30 m, which is much shorter than standard commercial EDFAs. The result of experiments showed that a few Mg added to silica host EDF can increase the concentration of erbium ions, which will shorten the EDF length much, but not degrade the performance characteristics.

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Erbium-doped fiber amplifiers (EDFAs) are commonly used in telecommunications systems. Because high doped erbium devices show degraded performance when compared with low concentration standard erbium-doped fibers (EDFs). This is because at high concentration of erbium ions, upconversion processes including pair-induced quenching (PIQ) and homogenous upconversion are activated. So at present, most of EDFs used in optical amplifiers are low erbium ions concentration. For a C-band EDFA, the EDF length is about 20 m, and for a L-band EDFA, which is often about 100 m. Now the EDFs are even expensive, which result that the price of EDFAs are expensive especially for L-band EDFA. To overcome upconversion processes mainly the PIQ upconversion, some technique have been reported. La co-doping[1] and Yb co-doping[2] are two mainly methods to fabricate high concentration EDF.

Performance of high concentration EDFA is not good like low concentration EDFA; the gain of high concentration C-band EDFA is only 22 dB small signal gain[3]. Conventional EDF with Al_2O_3-GeO_2-SiO_2 glass has low Er ions concentration, and these EDFAs have very good performance, which have very low upconversion processes. In Ref. [4], we have found that increasing aluminum concentration can increase the Er ions concentration and flatter the gain spectrum. In this letter, we found the Mg addition to Al_2O_3-GeO_2-SiO_2 glass, and more erbium ions can incorporate to the glass network. A few Mg concentrations can help increase the Er ions and shorten the EDF length, and then will keep the good performance of low concentration EDFAs.

The two Mg co-doped Al_2O_3-GeO_2-SiO_2 EDFs are fabricated through modified chemical vapor deposition (MCVD) combined with solution doping method. Mg, Al, and Er are doped with solution, and the Er ions concentration in solution is the same as the front two fibers. Fibers A and B have different Mg and Al ions concentrations in solution. The concentration of all the compositions in the preform is measured through electronics probe micro analysis (EPMA). The radial concentration distributions of Mg, Al, and Er of fibers A and B are shown in Figs. 1 and 2. The magnesium concentration of fiber A is higher than that of fiber B, and the aluminum concentration of fiber A is lower than that of fiber B.

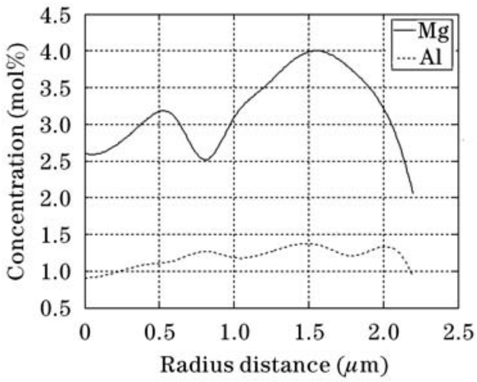

Fig. 1. The Mg and Al concentration distribution of fiber A.

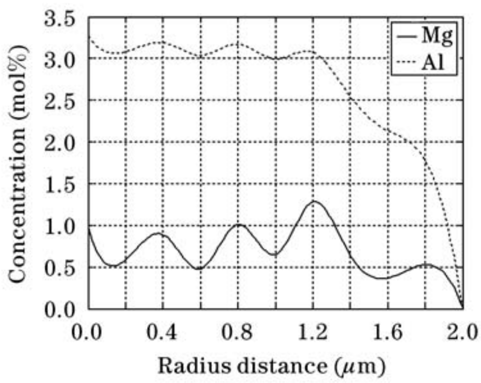

Fig. 2. The Mg and Al concentration distribution of fiber B.

The absorption spectra of these two EDFs at around 1550 nm are measured, which is shown in Fig. 3. The absorption coefficients at 1532 nm are 13.3 and 14.3 dB/m, and the absorption coefficients at 978 nm are 7.2 and 6.4 dB/m for fibers A and B, respectively. The absorption coefficients (the commercial conventional EDF of Fibercore Corporation) are 6.5 dB/m at 1532 nm and 4.6 dB/m at 978 nm, respectively.

We explored the fluorescence characteristics and gain performance of these two EDFs. We use the 980-nm pump laser to measure the C-band fluorescence characteristics and gain performance of these two EDFAs made with fiber A and B. The maximum output pump power is 100 mW, and the input signal power is −30 dBm. The fluorescence characteristic of C-band EDFA is shown in Fig. 4, and the C-band gain spectra of these two EDFAs are shown in Fig. 5.

The optimal EDF lengths of C-band EDFA are 5 and 7 m for fibers A and B, respectively, which have optimal

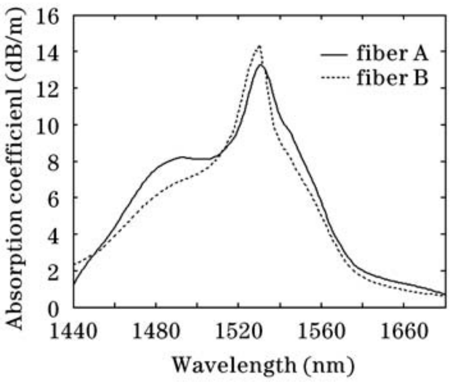

Fig. 3. The absorption spectra of fibers A and B.

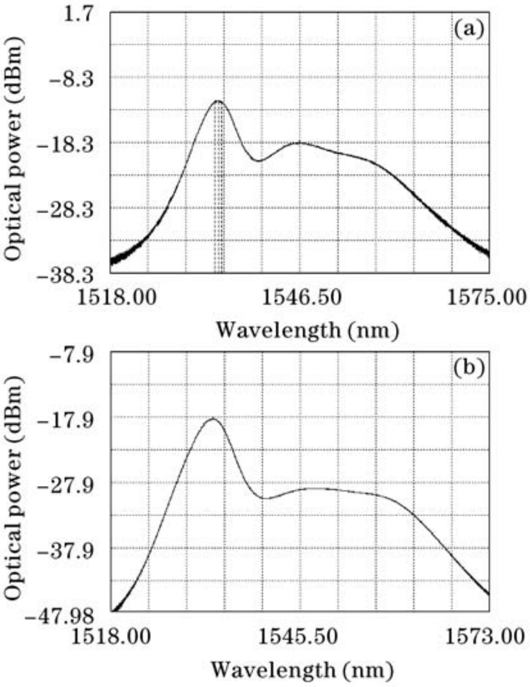

Fig. 4. Fluorescence spectra of (a) fiber A (5 m), (b) fiber B (7 m).

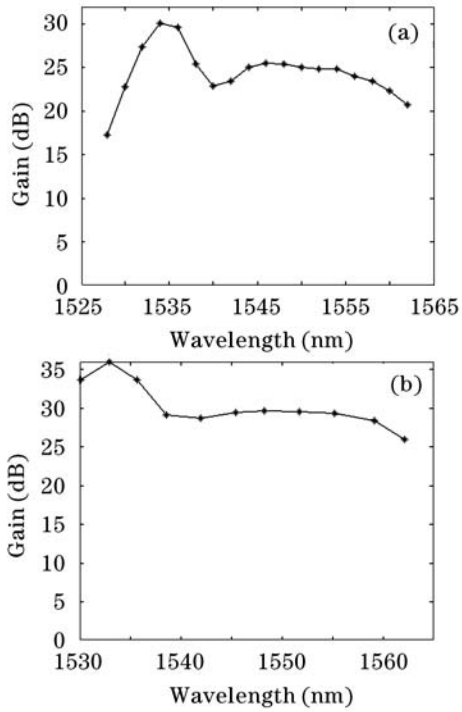

Fig. 5. C-band Gain spectra of (a) fiber A, (b) fiber B. Input signal power = −30 dBm, pump power = 100 mW, optimal fiber length = 5 m.

gain spectra and flatter fluorescences. The C-band gain spectrum of EDFA-2 (with 7-m fiber B) is higher and flatter than that of EDFA-1 (with 5-m fiber A). The maximum gain at wavelength 1534 nm is 30.1 dB for the EDFA-1, and the maximum gain of the EDFA-2 is 35.9 dB at 1532.9 nm. The gain fluctuation is 2.5 dB for EDFA-1 and 1.2 dB for EDFA-2. The mean gain of EDFA-2 is over 5 dB larger than that of EDFA-1. From these results, we can obtain that the EDF co-doped with fewer Mg and more Al has better performance, which can reduce the length of EDFA and keep good performance of low Er concentration.

L-band fluorescence spectrum of fiber B is shown in Fig. 6, and the L-band gain spectrum of EDFA with fiber B is shown in Fig. 7. The 1480-nm diode laser was used as pump source for L-band EDFA, whose maximum output power is 200 mW. The signal input power is

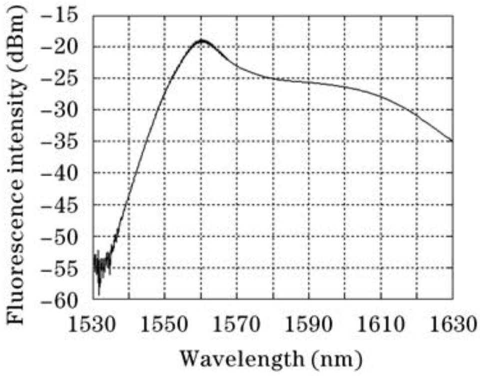

Fig. 6. Fluorescence spectrum of L-band EDFA with 30-m fiber B.

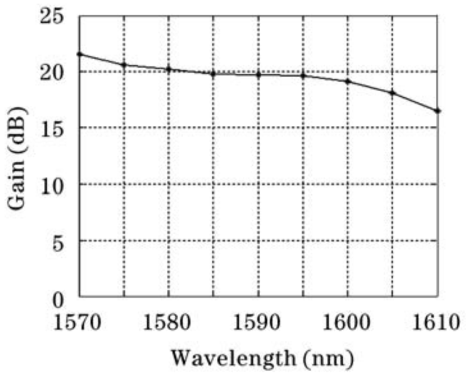

Fig. 7. Gain spectrum of L-band EDFA with 30-m fiber B.

−30 dBm, and the length of the fiber B for L-band EDFA is 30 m.

A few Mg added to the Al_2O_3-GeO_2-SiO_2 host EDF can increase the concentration of erbium doped, and then increase the absorption coefficient. At the same time, the EDF with Mg as addition will not degrade the performance of EDFA, and keep the good performance of low concentration EDF. This EDF can be used in C-band EDFA and L-band EDFA, which can decrease the price of EDFAs much.

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