Enhanced Near-infrared Spectral Performance in Bismuth/erbium Codoped Aluminosilicate Fibers by Energy Transfer for Broadband Application

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1. Introduction

During the last decade, intensive research has been devoted into Bismuth (Bi)-doped devices for the broadband luminescence and lasing in the range 1.1-1.5 μm [1-4]. However, with the increasing demand of data transmission in fiber telecommunication, it's of great significant to extend the transmission capacity of per fiber. Furthermore, the National Fiber Facility from UNSW has pioneered the work in the development of bismuth/erbium codoped silicate fibers (BEDF) for further gain extension. Despite the inspiring progress made on BEDFs for optical transmission, there still remain some challenges, one of which is that interaction between Bi and Er ions in the silica network remains unclear. Hence, in this letter, for further improvement of fiber characteristics, we performed a series of experiments to investigate the impacts of Er^{3+} on the spectral performance of bismuth active centers related to aluminum (BAC-Al) upon 830 and 980 nm pumping, respectively.

2. Experimental results and discussion

Three active fibers (BEDF, BDF and EDF) were fabricated by conventional MCVD method together with in situ solution doping. The optical properties of three samples are summarized in Table 1.

Table 1 Optical Characteristics of Bi/Er doped fibers

Type	Core composition Bi/Er/Al (at%)	λc, nm	Core diameter, μm
BEDF	0.1/0.006/0.1	920	4.5
BDF	0.1/NA/0.1	940	4.6
EDF	0.1/0.006/NA	912	4.5

Seen in Table 1, the concentration of BAC-Al is similar between BEDF and BDF, and the concentration of $Er^{3+}$is the same between BEDF and BDF. In that premise, a series of optical experiments including luminescence, on-off gain, lifetime, have been carried out to explore the underlying energy transfer process between BAC-Al and Er^{3+}. All the results are consistent with each other, indicating that under 980 nm pumping, energy transfer from Er^{3+} to BAC-Al in BEDF, evidenced by the enhanced NIR emission and lifetime when compared with a bismuth doped fiber (BDF). In contrast, Under 830 nm pumping, the spectral performance of Er^{3+} in BEDF is found to benefit from BAC-Al→Er^{3+}, evidenced by the notable increase in NIR emission, lifetime, and gain. The energy transfer diagram concerning with 830 and 980 nm are shown in Fig. 1(a) and (b).

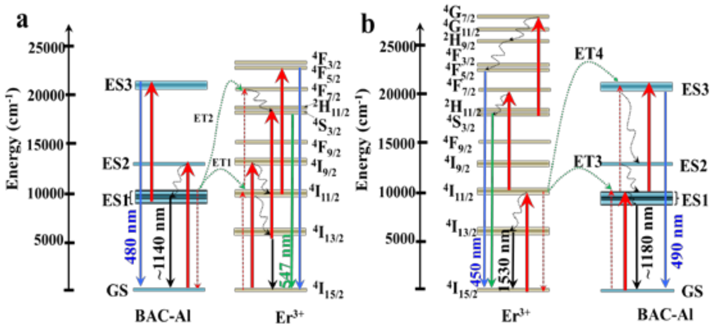

Fig. 1. Energy level diagrams between BAC-Al and Er3+ in terms of dominant energy transfer process depending on (a) 830 nm pumping and (b) 980 nm pumping.

Pumping at 830 nm lifts electrons from ground state to energy level ES2 of BAC-Al and $^4I_{9/2}$ of Er^{3+}. Subsequently, electrons at ES2 quickly relax to ES1 through non-radiative transition, which is partially overlapped with $^4I_{11/2}$. This promotes the Er^{3+} ions for the non-radiative transitions of $^4I_{11/2}$ to $^4F_{7/2}$ and $^4I_{11/2}$ to $^4I_{13/2}$ through ET2 and ET1, enhancing the emission at 547 and 1536 nm. For 980 nm pumping, the energy transfer direction reverses from Er^{3+} to BAC-Al through ET3 and ET4, enhancing the both upconversion and NIR emission for BAC-Al at 490 and 1180 nm.

3. Conclusions

In conclusion, the interaction mechanisms between BACs and Er^{3+} upon 830 and 980 nm pumping have been investigated in BEDF for the first time. Through spectral characterization among BEDF, EDF and BDF, it's revealed that the energy transfer process occurs in opposite ways between 830 and 980 nm pumping. This work shows great potential in advancing the practical application for BEDFs in the optical telecommunication industries such as high power CW laser, super luminescence source, broadband amplifier over ~600 nm

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