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Study on pump optimizing for Bi/Er co-doped optical fiber

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ABSTRACT

Bi/Er co-doped optical fiber is one of the solutions for wave band extending technology which is very important for fiber amplifiers, lasers and communication system. Pump option can alter emission band of the Bi/Er co-doped fiber. In this paper, optimization of pump wavelength is proposed. A high Bi concentration co-doped Bi/Er optical fiber is tested as a sample to demonstrate pump wavelength influence to the emission spectrum band. An optical fiber measurement system is provided to measure out characteristics of active optical fibers. And some useful results and parameters of pump optimizing for Bi/Er co-doped optical fiber are discussed in detail. From this research, optimized pump wavelength is suggested around 1350 nm to get a wider continue spectrum covers from 1300 nm to 1600 nm.

1. Introduction

Water-free optical fibers have expanded the accessible telecommunications window across the entire spectrum from 1200 to 1700 nm. The wavelength division multiplexing (WDM) system demands fiber amplifiers with broader and more efficient gain bandwidth in the telecommunication windows. Regarding this, expanding the gain bandwidth of the fiber amplifier has been under continuous research and development [1]. But to date, commercial exploitation of this window has been largely limited to that enabled by erbium (Er)-doped fibers that operating over only 1520–1620 nm (C + L band) – a small portion of the available spectrum. The O – (1260–1360 nm), E – (1360–1440 nm) and S – (1440–1530 nm) bands are not fully utilized as yet [2].

There were several types of fiber to be used, for example, Er^{3+}-doped silica/tellurite-based fiber, Tm^{3+}-doped fluoride fiber and Pr^{3+}-doped fiber [3–6]. However, it was difficult for the gain bandwidth of traditional rare-earth ion doped optical fiber amplifiers to surpass 100 nm due to the forbidden f–f electronic transition nature of rare-earth ions [7]. This has provoked intense research on novel types of amplifier materials with broader emission bandwidth at the best covering of the complete telecom window from 1200 to 1600 nm. Various types of transition and post-transition metal doped materials have been studied for this purpose [8,9].

Recently, broadband near infrared reflection (NIR) emission around 1300 nm, which covered the second communication window, has been intensely investigated in Bi-doped glasses. A wide variety of traditional glass hosts containing Bi were not only investigated so far, mainly silicates [10–12] and germinate [13–15] but also phosphates [16] and borates [17]. According to the above studies, Bi-doped glasses were therefore very promising for creating broadband amplifiers for fiber telecommunication lines and tunable or femtosecond lasers. For ultra-broadband gain from 1100 to 1600 nm, including all the

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O-, E-, S-, C-, and L-bands, Bi/Er co-doping in bulk glasses has been targeted [18–20]. Kuwada et al. reported ultra-broadband fluorescence between 1160 and 1570 nm from a Bi and Er co-doped bulk silica glass mix melted in a crucible [18]. Peng et al. reported ultra-broadband fluorescence between 1160 and 1580 nm, from Bi/Er co-doped germanate glasses [19].

However, unlike Er^{3+} single doped fiber, it is very complex of bismuth active centre (BAC) of Bi/Er co-doped fiber because its valence state and structure haven't studied to be clear so far. This reason makes its luminescence and other Characteristics are also in an uncertain state. In this paper, we focus on Bi/Er co-doped fiber's pump optimizing to do some works to find out which is the best pump for this kind of fiber, and how is its emission spectrum affected by the pump.

2. Scanning pump Bi/Er co-doped fiber luminescence measurement

Experimental setup for scanning pump Bi/Er co-doped fiber luminescence measurement is shown in Fig. 1. It includes two tunable lasers as pump, two broadband coupler, isolator, and an optic spectrum analysis (OSA). N7788B produced by Agilent Company is used to control the tunable lasers to scanning output wavelength and power. TLS81600B-130 (1260–1375 nm) and TLS81600B-140 (1370–1495 nm) work as a tunable pump laser whose wavelength covers from 1260 to 1495 nm. Pump laser reaches to active fiber through broadband couplers. Luminescence is reflected back to OSA.

Responsivity or transmission loss of the pump in different wavelength is not in the same levels after crossing so many devices in this system, which makes big errors for measurement. Hence, normalization is needed to eliminate system error before measuring. Normalized luminescence spectrum can be expressed:

$$\varepsilon(\lambda) = \varepsilon_0(\lambda)/\xi(\lambda) \tag{1}$$

which $\varepsilon(\lambda)$ is luminescence spectrum got from OSA, $\xi(\lambda)$ is correctional function of the system. It also can be accounted as distributed loss of the measurement system under different wavelength pump. $\xi(\lambda)$ can be measured out by scanning TLS's wavelength and to be a fixed inherent parameter. In this system the correctional function $\xi(\lambda)$ is a function of λ. Its drawing line is shown in Fig. 2.

Bi/Er co-doped active fiber is connected to the measurement system. Reflected light from other end of Bi/Er co-doped fiber will influence results got from OSA, especially when luminescence is weak. So that index matching fluid is needed.

3. Results and discussions

Bi/Er co-doped fiber sample is made by University of New South Wales, Australia. And, the compositions and concentration are shown in Table 1. Emission spectrum and intensity in different pump powers are shown in Fig. 3. The pump power grows from 2 mW to 27 mW, and wavelength is 1320 nm. The max intensity of spectrum is located at 1400 nm in such condition. It is obviously that intensity of emission is growing with pump power growing. There is a saturation pump power for the Bi/Er co-doped fiber, shown in Fig. 3(b). Emission intensity will grow quickly at the beginning or low pump injection section. It means that Bi and Er ion absorb pump energy in a high efficiency. But with the pump power increasing, grow rate of emission intensity becomes lower and lower. This explains that Bi and Er ion absorbing efficiency be dropped.

Bi/Er co-doped active fiber send different emission spectrum under different pump wavelength, as Fig. 4 shown. Bi ion emission spectrum located around 1350 nm and distributed from 1300 nm to 1500 nm. Meanwhile, as well known, Er ion emission spectrum located around

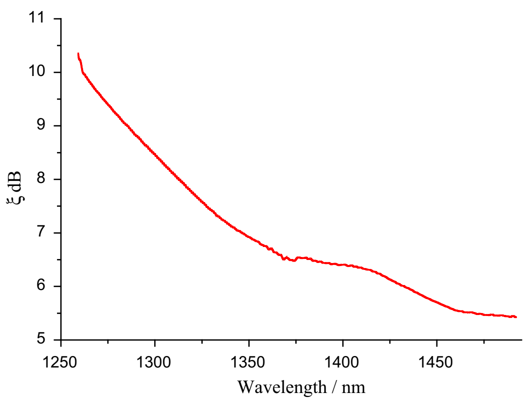

Fig. 2. Correctional function ($\xi(\lambda)$, λ is from 1260 nm to 1495 nm).

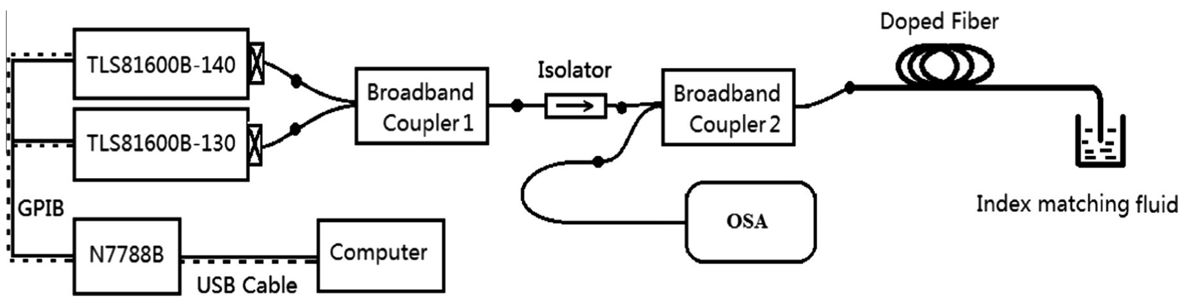

Fig. 1. Experimental setup for scanning pump Bi/Er co-doped fiber luminescence measurement.