Recent Advances in Bi-doped Fiber Lasers and Amplifiers

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ABSTRACT

This paper will review the influence of fiber fabrication and selection of pump wavelength on the performance of Bismuth (Bi)-doped fiber lasers and amplifiers operating in the near-IR region.

***PACS Keywords*:** 42.70.Hj Laser materials, 42.81.Bm Fabrication, cladding, and splicing, 42.81.Cn Fiber testing and measurement of fiber parameters, 42.55.Wd Fiber lasers, 42.60.Da Resonators, cavities, amplifiers, arrays, and rings

Bi-doped fiber lasers and amplifiers is a burgeoning research area in the field of fiber optics. The interest stems from the large variety of applications such as medicine, astronomy and material processing as well as optical fiber communication. Bi has shown promising results as an active fiber dopant in various glass hosts for the development of lasers and amplifiers in the wavelength range 1150-1800nm [1, 2]. However, some of the challenges need to be addressed to achieve efficiencies comparable to rare earth (RE)-doped fiber lasers and amplifiers. These are unwanted losses caused by the unsaturable absorption, excited state absorption (ESA), and the unknown Bi-state that leads to NIR emission [1-6]. In this paper we present some of our recent results in Bi-doped aluminosilicate (BASF) and phosphosilicate (BPSF) fibers. The Bi-doped fiber preforms were fabricated by the modified chemical vapor deposition (MCVD)-solution doping technique. The resultant fibers have the core diameter of 8 and 13µm, with an index difference (Δn) of 0.008 and 0.004, for BASF and BPSF respectively. The cladding diameter of these fibers was 100µm [7, 8]. The pump wavelength was chosen by measuring the absorption spectra and unsaturable loss (UL). In BASF, the absorption was 0.35 and 0.7dB/m, whereas UL was found to be 35% and 65% at 1120 and 1047nm pump wavelengths, respectively. The availability of laser diode (LD) at 1120nm in combination with low UL made us to explore 1120nm pumping of the BASF. The experimental setup and the corresponding gain characteristics of the BASF amplifier are shown in Fig.1. An 1120nm LD having an output power of 350mW was used and we obtained a maximum gain of 8dB at 1180nm with a fiber length of 100m for an input signal power of -4dBm. It was observed that use of 1120nm pump wavelength provided a gain enhancement of 70% compared to 1047nm pumping. A maximum gain of 11.5dB was obtained via simultaneous pumping at both 1120 and 1047nm as shown in Fig 1. A comparatively low gain enhancement under dual pumping conditions can be explained by an increase in UL which was observed in a separate experiment while pumping the fiber together at 1120 and 1047nm wavelengths [7].

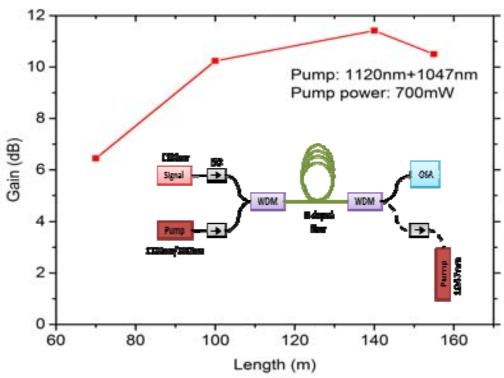

Fig. 1 BASF gain at 1180nm with fiber length for bi-directional pumping

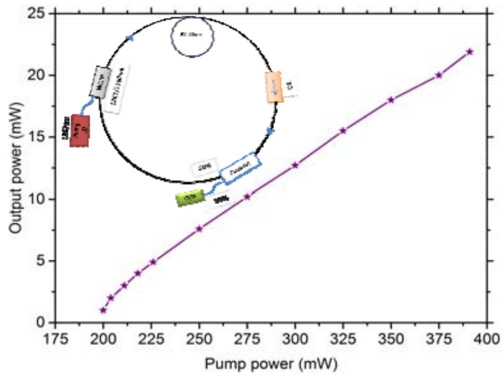

Fig.2 Output power vs launched pump power with 50% output coupling (OC) for 46m long BPSF (Pump and laser wavelengths: 1267 and 1360nm)

In the case of BPSF, a 1267nm LD pumped all-fiber laser in a ring cavity has been developed as shown in Fig.2. The absorption at 1267nm pump wavelength was found to be 1dB/m. The ULs measured for 1267 and 1210nm pump wavelengths were 7.2% and 13.5% respectively. Due to its lower UL in BPSF, the 1267nm pumping wavelength was chosen from among the available LDs. The laser efficiency was 11% for an optimum output coupling ratio of 50/50 with a fiber length less than 50m. The BPSF laser has an output power of 22mW and operating at 1360nm [8].

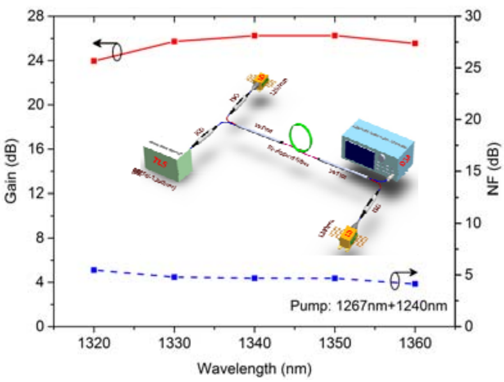

Fig.3 Flat gain characteristics of the amplifier from 1320-1360nm

In addition to the aforementioned demonstrations, a Bi-doped phosphosilicate amplifier was constructed as shown Fig. 3. Here, we used single-mode bismuth doped fiber with cutoff around 1100nm. Initially, the Bi-doped fiber was individually pumped by 1267 and 1240nm LDs with pump powers of 360 and 400mW, respectively to evaluate the gain and NF. The input signal was -10dBm. The 1267nm pumping provided a maximum gain of 15dB and a NF of 5dB at a wavelength of 1350nm for 100m long fiber while the gain at 1300nm was only 5dB. In the case of 1240nm pump, a maximum gain of 14dB and a NF of 6dB were obtained at 1330nm for 75m long fiber. Here the gain at 1300nm was 10dB, which is double the gain of the 1267nm pumping. Thus the 1267nm pump can shift the gain toward the longer wavelength whereas the 1240nm pump allows the gain to operate at a shorter wavelength. In order to obtain a flat gain, the Bi-doped fiber was pumped using both diodes (1267 and 1240nm) simultaneously as shown in Fig. 3. The total pump power of the LDs amounted to 760mW. A flat gain of 25±1dB with a NF of <6dB was achieved over a 40nm bandwidth (1320-1360nm), for the 150m long BPSF. Furthermore, a maximum gain of 29dB and a NF of 4.5dB were obtained at 1340nm for an input signal power of -30dBm, which, to the best of our knowledge, is the maximum gain, reported from a BDFA operating in the second telecommunication window [9].

The present work leads to further investigations on Bi-doped fiber technology to obtain the similar laser and amplifier performance currently offered by the RE-doped fibers. Besides power scaling of Bi-doped fiber lasers is an interesting aspect which requires significant increase of Bi concentration in fiber, suitable for cladding pumping. Research leading to better understanding of the Bi active centers in BASFs and BPSFs would greatly assist the optimization of fiber fabrication.

Acknowledgement: This work was supported by the UK Engineering and Physical Sciences Research Council grant EP/I01196X/1(Hyperhighway).

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