Diode Pumped Bi-doped Fiber Laser Operating at 1360nm

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Abstract: Bi-doped phosphosilicate fibers are fabricated by MCVD-solution doping technique under different oxidation conditions. Fibers are evaluated for unsaturable loss and laser performance. A 22mW all-fiber Bi-laser is demonstrated at 1360nm by LD pumping at 1267nm.

OCIS codes: (060.2280) Fiber design and fabrication; (060.2270) Fiber characterization; (060.3510) Lasers, fiber;

1. Introduction

Exploring fiber lasers and amplifiers in new wavelength bands have been the research interest for decades. The 1150-1500nm wavelength region is one of such bands with demanding applications such as wideband optical fiber communication, medicine, spectroscopy, and astronomy. Bismuth (Bi) doped fibers have paved the way to develop lasers and amplifiers in this wavelength band, thanks to its broad luminescence characteristics. Bi-doped aluminosilicate, phosphosilicate and germanosilicate fibers have shown luminescence around 1150nm, 1300nm and 1450nm respectively [1, 2]. In particular, Bi-doped fibers which exhibit luminescence around 1300nm has specific importance as their operating wavelength region coincide with the second telecommunication window. Bi-doped phosphogermanosilicate fibers have been used to demonstrate lasers from 1280-1360nm with a 30W Raman fiber laser operating at 1230nm as a pump [3]. Among these, the reported efficiency of laser operating at 1360nm was 9.5% and ~18% at low and high pump powers, respectively. Moreover a 100m long Bi-doped fiber was used for laser demonstration. In this paper, we report the fabrication of Bi-doped phosphosilicate fibers (BPSFs) using MCVD-solution doping technique under different atmospheric conditions. The fibers have been characterized for their unsaturable loss (UL) at different pump wavelengths. An all-fiber Bi-doped laser in a ring cavity has been demonstrated by direct diode pumping at 1267nm with a laser output power of 22mW operating at a wavelength of 1360nm. The fiber length used in our experiment was less than 50m.

2. Fiber fabrication and characterization

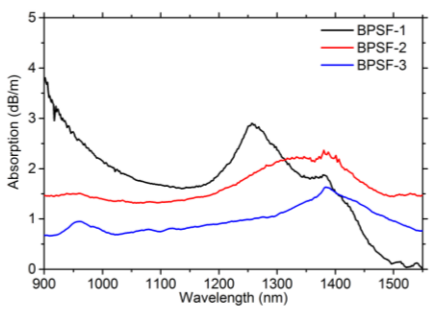

Fig. 1. Absorption spectra of Bi-doped phosphosilicate fibers

Table 1. UL of different BPSFs measured at two pump wavelengths

BPSF fabricated		BPSF-1	BPSF-2	BPSF-3
Preform fabrication condition during sintering and collapsing stages (flow of O_2 to He in SCCM)		250 : 250	400 :100	500 : 0
1210nm pump	UL (dB/m)	0.96	0.3	0.14
	%UL	46	17	13.5
1267nm pump	UL (dB/m)	0.61	0.22	0.08
	%UL	24.5	11	7.2

Bi-doped preforms have been fabricated by depositing phosphosilicate soot under similar fabrication conditions. The soot body was impregnated by the same Bi solution for all the preforms. The only difference between fabricated preforms was the variation of Oxygen (O_2) and Helium (He) flow ratio during the porous layer sintering and the preform collapse stages, while maintaining the total gas flow as constant (see Table 1). The preforms were drawn into fibers (from here onwards named BPSF-1, BPSF-2 and BPSF-3) with a core and clad diameter of 13µm and 100µm, respectively. The index difference (Δn) between the core and clad was found to be 0.004 for all BPSFs. The absorption spectra of all BPSFs were measured by cut-back method using a white light source (WLS) and an optical spectrum analyzer (OSA) and are shown in Fig. 1. The influence of fabrication conditions on absorption characteristics can be seen from Fig. 1. BPSF-1 which was fabricated with 1:1 of O_2 to He ratio has shown an absorption peak around 1255nm accompanying a small water peak at 1380nm. Whereas in BPSF-2, fabricated under excess O_2 (4: 1 ratio of O_2 to He), the 1255nm peak shifted to around 1335nm and it was less pronounced. In BPSF-3, that was fabricated under complete O_2 atmosphere the 1255nm peak disappeared. Also, the absorption in BPSF-3 reduced compared to BPSF-1 and BPSF-2. The UL was measured for all BPSFs at two wavelengths 1210 and 1267nm (see Table 1) using an established method [4]. The UL was around 24.5% (46%), 11% (17%) and 7.2% (13.5%) at pump wavelength 1267nm (1210nm) in BPSF-1, BPSF-2 and BPSF-3, respectively. This indicated that the O_2 rich atmospheric condition during preform fabrication reduces the UL in BPSFs.

3. Bi-doped fiber laser: Experimental set up and Results

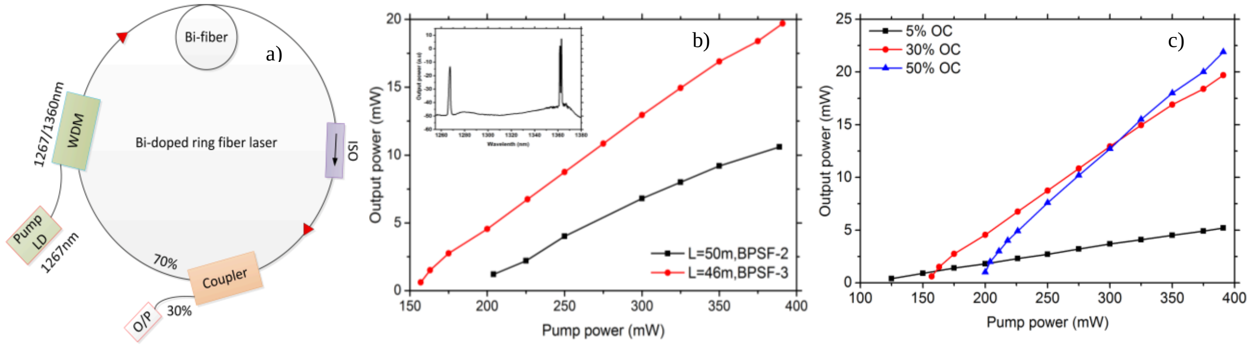

Fig. 2. a) Schematic experimental set up of Bi-doped fiber laser, b) Output power vs launched pump power for optimum lengths of BPSF-2, BPSF-3 (Inset shows the laser spectrum at 1360nm of BPSF-3), c) Output power vs launched pump power with different output coupling (OC) for 46m long BPSF-3.

The experimental set up of Bi-doped fiber laser in a ring cavity is shown in Fig. 2 (a). It consists of a fiber pigtailed pump LD operating at 1267nm, a 1267/1360nm wavelength division multiplexer (WDM), an Isolator, and an optical coupler for cavity feedback. An additional WDM was used to separate pump from signal in the output port of the coupler. The maximum available pump power from the LD is 390mW. The 1267nm pumping wavelength was chosen due to lower UL in BPSF among the available pump LDs. The absorption values at 1267nm pump wavelength measured by WLS were found to be 2.8dB/m,1.95dB/m and 1dB/m in BPSF-1, BPSF-2 and BPSF-3, respectively. At first, a coupler with an input/output coupling ratio of 70/30 was used for BPSF-1. No lasing action was obtained in this fiber at any fiber length despite being highest absorption at the pump wavelength. Next, BPSF-2 was tested using the same coupling ratio and it shows lasing at a wavelength of 1360nm. The length of the fiber was optimized to achieve maximum laser efficiency. The optimum fiber length was found to be 50m with laser efficiency of 5% and the maximum output power was 10mW as shown in Fig. 2 (b). Subsequently, BPSF-3 was tested which exhibited a laser efficiency of 8% with an output power of 20mW for a fiber length of 46m. The threshold pump power was 157mW. The laser spectrum of BPSF-3 taken by an OSA is shown in the inset of Fig. 2 (b). We then varied the output coupling ratio in the ring cavity. The laser efficiency in BPSF-3 was increased to 11% with an output power of 22mW for the 50/50 coupling ratio as shown in Fig. 2 (c). The performance of BPSF laser can be improved further by optimizing the preform fabrication conditions. From this study, it is evident that an absorption peak around 1255nm leads to higher UL and thereby impairing the laser performance.

4. Conclusions

In conclusion, we fabricated BPSFs under different oxidation conditions by standard MCVD-solution doping technique. Absorption, UL and laser efficiency have been measured in all BPSFs and found to be strongly correlated with the fabrication conditions. The UL was found to be low at 1267nm in comparison with 1210nm pump wavelength. A Bi-doped fiber laser operating at 1360nm has been demonstrated with a laser efficiency of 11% by direct diode pumping at 1267nm.

5. Acknowledgement

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6. References

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