Bismuth Doped Fiber Laser Performance on Effective Fiber Cooling

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In the past, bismuth doped fiber (BiDF) lasers, operating in the 1160 – 1300 nm wavelength range, have gained much attention as they are promising for many applications; including medical and astronomy. However, the poor lasing efficiency of BiDF laser, compared to the widely used rare-earth doped fiber lasers, requires further investigations. One possible reason that can impair the BiDF laser efficiency is the presence of high unsaturable loss in the fiber, which is temperature dependent [1, 2]. Thus, temperature rise in the BiDF under strong pumping can be a limiting factor for such laser systems. Here, we report the dependence of BiDF laser efficiency on effective cooling of the fiber.

The fiber laser was constructed with a 30 m long BiDF in a 100%-4% linear cavity, where a 15 W Yb doped fiber laser at 1090 nm served as the pump source. We used a broadband mirror in the high reflection end of the fiber to reflect back both pump and signal. The fiber had an absorption coefficient of 1.04 dB/m at 1090 nm and 0.23 dB/m at 1178 nm; measured by the cut-back method. The fiber core was 8 μm with a NA of 0.18, and the outer diameter was 125 μm.

Figure 1(a) shows the BiDF laser output power in various heat sink arrangements. We found that at high pump powers the laser efficiency decreased when the fiber was cooled by natural convection. The rollover in output power was prominent at approximately 6 W of pump power at 24^{0}C. An increase in fiber temperature was also observed during the experiment. To verify our results, the fiber temperature was further increased to 40^{o}C in air. A similar behaviour was observed and the efficiency dropped down to 2%. To provide more effective heat removal from the fiber, the fiber spool was then placed in a water tank at room temperature. An increase in efficiency, compared to that measured at room temperature, was observed with the water cooling. Moreover, no rollover in the output power was noticed. On further cooling the fiber to 10^{o}C in water, an increase in efficiency upto 10% was observed. We also raised the water temperature to 40^{o}C, and the efficiency dropped down to 4.8%, but no rollover was observed in the output power even at the maximum pump power.

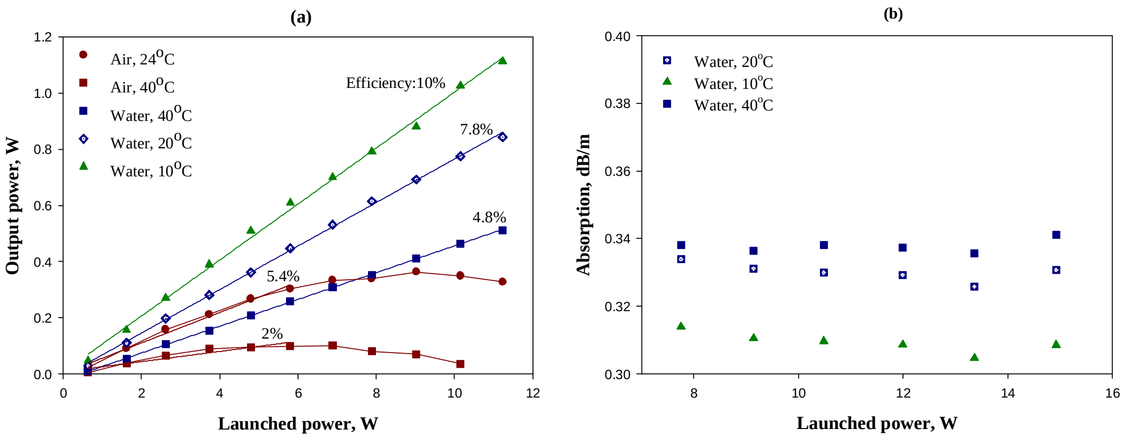

Fig. 1 (a) BiDF laser performance at different heat sink arrangements, and **(b)** Unsaturable loss in BiDF at different temperatures.

We further measured the unsaturable loss in our BiDF at the pump wavelength of 1090 nm, and at different temperatures [Fig.1 (b)]. The fiber was dipped in water, so as to maintain the same temperature during the entire experiment. The ratio of unsaturable absorption to small signal absorption was 33, 30 and 28% at 40^{o}C, 20^{o}C and 10^{o}C respectively.

It seems to indicate that, the gradual increase in fiber temperature with the pump power, in absence of forced cooling [Air- 24^{0}C and Air- 40^{0}C; both in Fig 1(a)], leads to a continuous rise in unsaturable loss in the BiDF, resulting in rollover in the 1178 nm output power. Thus, with effective cooling the BiDF laser performance can be significantly improved.

References

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[2] V. V. Dvoyrin, V. M. Mashinsky, and E. M. Dianov,"Efficient Bismuth-Doped Fiber Lasers," IEEE J. Quantum Electron. **44**, 834-840 (2008).