L.2: Development of ~25 W of eye-safe ytterbium-free erbium-doped fiber laser

Erbium-doped fiber lasers emitting near 1.5 μm radiation have many applications, such as in optical fiber communication, pumping of mid-infrared lasers, medical applications etc. For generation of high powers in these lasers, Er:Yb co-doped fibers are usually employed to enhance the pump absorption using Yb's superior pump absorption at 976 nm (compared to that of Er) and consequent resonant transfer of energy from Yb to Er. However, lasers based on Er:Yb co-doped fibers suffer from parasitic co-lasing at 1 μm along with the desired "eye-safe" radiation at 1550 nm. Special efforts are required to isolate 1 μm radiation from the output of these lasers to qualify them as "eye-safe" lasers in a true sense. In view of this, there has been a spurt of activities on using Yb-free Er-doped fibers (EDFs) for high power generation in eye-safe region.

Erbium-doped fibers can be pumped either by using 980 nm pump band or 1480 nm pump band. Since, pumping at 980 nm pump band leads to a large quantum defect of about 37% and induces a larger heat load on the fiber as compared to 1480 nm, it is difficult to achieve high power and high efficiency by pumping at 980 nm. However, 976 nm diodes are cheaper and easily available as compared to 1480 nm diodes, hence generation of efficient high power output in eye-safe region using 976 nm pump diodes is of significant interest. The generation of high power output from Er-doped fiber oscillator (without an amplifier) is not reported in literature. We report in this communication the generation of output power ~25 W at 1600 nm from Er-doped fiber using 976 nm pump diodes directly from the oscillator stage.

The experimental set-up is shown in Fig.L.2.1. The large mode area Er-doped fiber has a double clad structure with core/ cladding/ coating diameters of 20/125/250 μm, respectively. Numerical apertures (NA) of the core and inner cladding are 0.09 and 0.46, respectively. The absorption of inner cladding at 976 nm is about 1 dB/m. A length of ~12 m of active EDF fiber was used to obtain an efficient pump absorption. Active fiber was pumped from both ends using fiber pig-tailed laser diodes with a rated power of ~60 W coupled out through an optical fiber of core diameter 100 m and NA 0.22. The pump section on one end of the fiber contains an aspheric lens pair and a dichroic mirror at non-normal incidence. The dichroic mirrors (M1) with high reflectivity in 1550 nm region and high transmission in 976 nm region has been kept in between the coupling lens pair, which is used as an output coupler in 1550 nm region. The pump section at the other end of the active fiber is similar, except that the output coupler is replaced with a 100% feedback mirror (M2), with high transmission at pump wavelength. Pump light from the fiber pig-tailed laser diode is coupled into the inner cladding of the fiber with coupling efficiency of ~80%. For effective heat removal from the doped fiber, it was wrapped around a water cooled spool and pump ends were mounted on water cooled V-grooves. Pump light is coupled through 125 μm inner cladding and is guided through inner clad by means of low refractive index of flouroacrylate coating at the outer surface of the doped fiber. As the pump light propagates along the fiber, it gets absorbed in the core. Theoretically, the V number of such a large core diameter fiber is ~3.54, which corresponds to a slightly multi-mode system. A single mode output can be obtained by filtering out the higher order modes by wrapping this fiber around a spool of small diameter.

Laser output was emitted in the eye-safe region with a peak at 1600 nm. Fig.L.2.2 shows variation of output power as a function of input pump power. Output power of ~ 25W was obtained at an absorbed input pump power of 100 W, which corresponds to an optical-to-optical conversion efficiency of 25%. This efficiency is one of the highest reported in this configuration. Major problems faced in the development of high power Er-doped fiber laser are effective heat removal from active fiber and damage of the fiber ends due to high heat load and high power density (~8 MW/cm^2). Further efforts are being made to make all-fiber system using in-built fiber Bragg grating mirrors and fiber pump combiners.

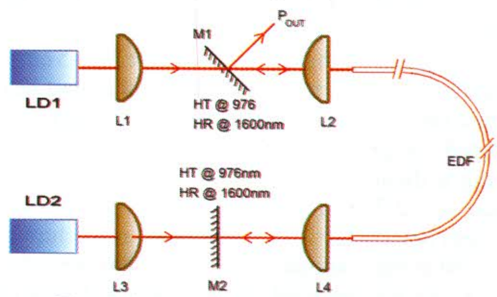

Fig. L.2.1: A schematic of EDFL set-up.

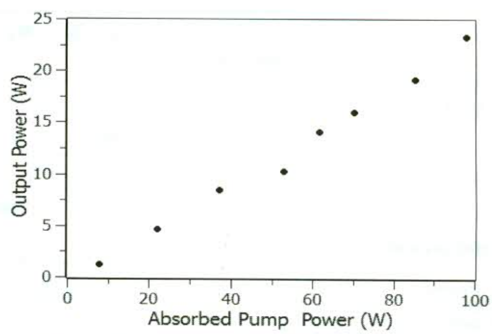

Fig. L.2.2: Output power as a function of absorbed pump power of EDFL.

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