L.2: Development of Erbium:Ytterbium co-doped fiber laser emitting 10 Watts near 1.55 μm in eye-safe region

Erbium:Ytterbium co-doped fiber (EYDF) lasers emitting 1.55 μm radiation have applications indermatology as part of fractional laser treatment for pigmentation and texture improvement of skin. Fiber lasers typically use cladding-pumping for efficient coupling of pump light from fiber pigtailed laser diodes to the core of doped fiber. However, the absorption of Erbium (Er) doped fibers at 976 nm (wavelength of laser diodes) is not sufficient to achieve large amount of output power. Ytterbium (Yb) has an absorption cross-section of ~1.8 pm^2 at 976nm, which is an order of magnitude more than that of Er. This, coupled with the resonant energy transfer between Yb's $^2F_{5/2}$ level to Er's $^4I_{11/2}$ level, makes Yb a co-dopant of choice in Er doped fibers to increase the output power in 1550 nm region. Up to ~300 W power in 1550 nm region has been achieved using Er:Yb co-doped fibers. However, to qualify as "an eye-safe radiation source", such lasers require some additional means to suppressthe parasitic emission at 1 micron regiongenerated due to Yb dopant.

Work on EYDFLs was initiated at SSLD with a target of achieving 10 watts of power in 1550 nm region.In the experimental set-up (Fig.L.2.1), a large mode area EYDF in double-end pumping configuration has been used.The pump section in one end of the fiber contains an aspheric lens pair and two dichroic mirrors at non-normal incidence. One of the dichroic mirrors (M_1) with high reflectivity in 1550 nm region and high transmission in 976 nm region, kept between the coupling lens pair, is used as an output coupler. Two dichroic mirrors (M_3&M_4) with high transmission for pump wavelength and high reflectivity in 1 μm region are used to prevent 1 μm radiation from entering the pump diodes,to prevent irreversible damage to the laser diodes. 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 (M_2), which has high transmission for pump radiation. Pump light from fiber pig-tailed laser diodes is coupled into the inner cladding of the fiber with ~85% coupling efficiency. The initial lengths of the active fiber at both ends were kept in water cooled V-grooves to remove heat generated by the absorption of large amounts of pump power in these regions. The fiber-pig tailed laser diodes have a rated power of ~30 Watts, which can be increased to upto~40 watts for short durationsat the expense of slight reduction in lifetime. The active fiber has a double clad structure with core/ inner cladding/ outer cladding diameters of 25/300/450 μm respectively. Pump light is coupled through 300 μm inner cladding and is guided through inner clad by means of low refractive index flouro-acrylic outer cladding. As the pump light propagates along the inner cladding, it is coupled to the core and is absorbed. The absorption of the pump beam at 976 nm is at a rate of ~ 2.5 dB/m. Numerical apertures of the core and inner claddingare 0.1 and 0.46, respectively. Hence, theoretically, this fiber can support about 12 higher order modes at 1550 nm resulting in a M^2 of ~ 6. However, single mode operation can be achieved by coiling it on a mandrel of suitable diameter.

It was found that suppressing parasitic oscillations at 1 μm region enhances power at 1550 nm region. Hence, one-end (M_2 side) of the EYDF was angle cleaved to suppress the feedback from that fiber end to reduce the output at 1 μm region. Emission wavelength of laser diodes was also tuned by tuning laser diode temperature using TEC controllers to optimize the absorption in the EYDF. Fig.L.2.2 shows the variation of output power at 1564 nm Vs input pump power. Reliable operation was achieved up to 10 W of output power. Catastrophic damage of active fiber was observed at higher powers (~14 W) after a few minutes of operation, which is likely to be due to either self-pulsing phenomenon or due to insufficient heat removal from the EYDF. Few more investigations have been planned to achieve reliable operation at power levels greater than10W.

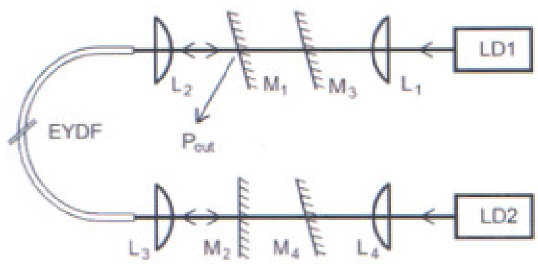

Fig. L.2.1: Schematic of EYDF Laser System.

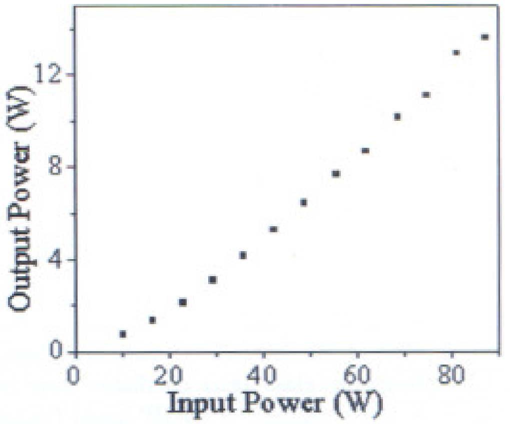

Fig. L.2.2: Output power at 1550 nm vs Pump Power.

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