L.5: Development of 50 W Er-doped CW fiber laser at 1600 nm

The emission of laser radiation from Er-doped fiber (EDF) lasers in the spectral range of 1500-1700 nm is attractive for many applications since it falls in the eye-safe region. The maximal tolerable exposure to human eye near 1550 nm wavelength region is about three to four orders of magnitude higher than that for 1000 nm wavelength region. Important applications include free space communication, LIDAR, sensing, target illumination, directed energy, etc. For these applications, highly used ~1000 nm infrared wavelength region is not suitable as propagation loss in the atmosphere is substantially higher and is also not eye-safe. Generation of high output power from EDF laser is challenging due to higher quantum defect and lower allowable Er^{3+}-ion concentration in EDF to avoid clustering effects, which results in manufacturing of less efficient double-clad fibers. Several approaches have been used worldwide to increase the laser efficiency near 1550 nm wavelength. One of the approaches is co-doping of EDF with Yb^{3+}-ions, but, efficient generation of 1550 nm wavelength from Er:Yb co-doped fibers is inhibited by co-lasing near 1000 nm wavelength. Another approach to achieve high output power near 1550 nm is core-pumping of EDF with a 1480 nm Raman fiber laser, which is more complex. Now a days, diode lasers at 1480 nm for in-band pumping have become available, but are very expensive. The simplest and the most efficient approach is clad-pumping of Yb-free EDFs with commercially available low cost 976 nm pump diodes. In this direction, development of 50 W of CW output power from an all-fiber Yb-free EDF laser using master oscillator power amplifier (MOPA) configuration by pumping with 976 nm pump diodes with a slope efficiency of 24% has been carried out.

The experimental set-up consists of two stages, as shown in Figure L.5.1. The first stage is a master oscillator, which consists of a large mode area (LMA) Er-doped double-clad active fiber with core/inner clad/outer clad diameters of 20/125/250 μm, respectively. Numerical apertures (NA) of core and inner cladding are 0.09 and 0.46, respectively. The absorption of the pump beam at 975 nm for inner clad launching is 1 dB/m. A length of 10 m of EDF was selected as the gain medium to have an effective pump absorption of ~10 dB. The Er-doped fiber has been spooled on a water cooled aluminium mandrel to increase heat conductivity from the active fiber surface. A diode of 70 W output power at 976 nm with pigtail fiber core/clad diameter of 100/125 μm and 0.22 NA was selected to pump the EDF using a multimode fiber optic pump combiner. This diode is mounted on water cooled heat sink to maintain its temperature at 20 °C for the entire range of pump operation. Fiber pigtail of the pump diode has been fusion spliced with one of the pump input ports of multimode pump combiner. Output signal port of the pump combiner has a core/inner clad diameter of 20/125 μm and an NA of 0.15/0.46. This port has been spliced with the EDF and a high reflectivity (HR) (~99%) fiber Bragg grating (FBG) mirror in series.

The FBG mirror written in a compatible double-clad fiber has a peak reflectivity at 1600 nm with a linewidth of 0.2 nm. A low reflectivity (LR) (10%) FBG mirror has been spliced at the signal input port of the pump combiner to form resonator in backward pumping configuration. In this configuration, the residual pump is automatically removed. A maximum output power of 5 W at 1599.9 nm has been achieved from the oscillator at an input pump power of 50 W.

Further, the output power from oscillator was fed to the amplifier stage. In the amplifier stage, four pump diodes of 70 W output power at 976 nm were spliced with four pump input ports of a (6+1)x1 multimode pump combiner. The output of the pump combiner was then spliced with another 20 m long EDF having core/inner clad diameter of 25/125 μm and an NA of 0.08/0.46. The total combined pump input to the amplifier stage is 220 W. A broadband dichroic mirror with high transmission from 960-980 nm and high reflectivity from 1500-1600 nm at 45° angle of incidence has been used to filter out the unabsorbed pump power. A maximum output power of 53 W has been achieved with a slope efficiency of 24%. The output spectrum has a peak at 1599.9 nm with FWHM linewidth of ~1.7 nm. Figure L.5.2 shows a table top view of 50 W Er-doped CW fiber laser at 1600 nm. Now, developement of an engineered version of this laser is in progress for different applications.

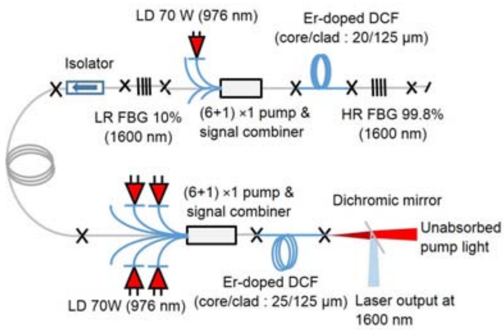

Fig. L.5.1: Schematic of 50 W Er-doped CW fiber laser at 1600 nm.

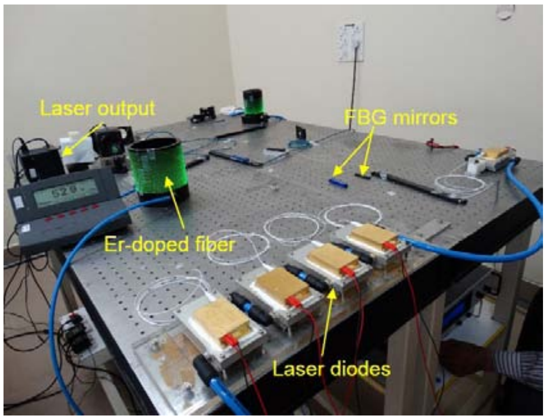

Fig. L.5.2: A view of 50 W Er-doped CW fiber laser at 1600 nm.

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