L.1: Development of engineered 500 W Yb-doped CW fiber laser

High power Yb-doped CW fiber lasers have been demonstrated to provide multi-kilowatt output with nearly diffraction limited beam quality. These lasers provide single-mode operation, high efficiency, compactness, no misalignment sensitivity, robustness, and efficient heat dissipation due to large surface area to volume ratio along with all-fiber integration. It is possible to undertake different kind of laser material processing applications using high power fiber lasers such as, rock and concrete drilling for gas and oil well exploration, deep penetration welding in the range of ~10-30 mm for industry, laser additive manufacturing, cutting of thick components (~100 mm) for shipyard industry, and reactor decommissioning. CW fiber lasers can also be utilized as directed energy weapons in defense applications. Thus, it is pertinent to work on indigenous development of compact kW class CW fiber lasers. Normally, high power fiber lasers are generated either directly from the oscillator or using master oscillator power amplifier and seed amplification. Major challenges in the development of all-fiber fiber laser systems are the selection of compatible fibers for pump diodes, pump combiner, and gratings along with minimization of splice loss, reliable defect free recoating at each splice joint without any hotspot and efficient removal of heat load from thin polymer coated double-clad fibers and fiber components. Further to this, self-pulsing, fiber fuse effect, transverse mode instabilities, and nonlinear effects such as stimulated Raman scattering and stimulated Brillouin scattering have to be carefully controlled or eliminated for high power laser generation. In this direction, development of an engineered version of 500 W all-fiber single transverse mode Yb-doped CW fiber laser at 1080 nm has been carried out with an optical-to-optical conversion efficiency of ~70%.

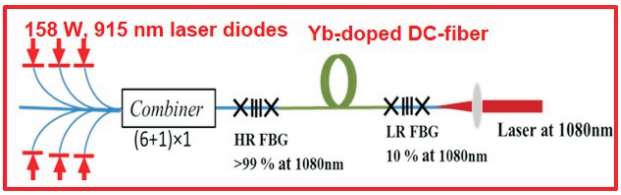

Fig. L.1.1: Schematic of 500 W Yb-doped CW fiber laser oscillator.

Figure L.1.1 shows a schematic of 500 W Yb-doped CW fiber laser oscillator. In this all-fiber laser set-up, a Yb-doped double-clad fiber has been used as the gain medium having a core diameter of 20 µm and an inner-clad diameter of 400 µm with numerical apertures of the core and inner clad as 0.075 and 0.46, respectively. Inner clad has an octagonal shape to avoid excitation of skew modes. A diode pump module of six fiber-coupled diodes is used for pumping of Yb-doped double-clad fiber. Each fiber coupled diode provides an output power of 158 W at 915 nm. Pumping wavelength of 915 nm was selected to minimize effect of variation in pump wavelength with change in diode temperature and diode pump current, since absorption peak of Yb-doped fiber at 915 nm is very broad as compared to sharp absorption peak at 975 nm. This diode-pump module has been spliced with a (6+1)x1 fiber optic signal and pump combiner. Further, the output end of the fiber optic pump combiner has been spliced to a fiber Bragg grating (FBG) mirror of ~99% reflectivity. The other end of this high reflectivity FBG has been spliced to one end of Yb-doped fiber. Another FBG of ~10% reflectivity at 1080 nm has been spliced at the other end of Yb-doped fiber. The laser output is emitted from the fiber end of 10% reflectivity FBG mirror and output spectrum has a peak at 1080 nm with a full width and half maximum (FWHM) linewidth of ~1 nm. Laser output is emitted through 20 µm core diameter of a matched passive fiber with measured value of beam quality factor M^2~1.26, which shows that laser output is nearly single mode. However, for material processing applications, output has been delivered through a 20 m long quartz block head connectorized 50/360 µm fiber optic cable. For development of packaged engineered version, a compact water cooled heat sink structure for spooling and packaging of fiber laser components has been designed and fabricated. Active fiber, splice joints and fiber laser components have been mounted on top of this water cooled heat sink structure for efficient heat removal. This water cooled heat sink structure has played important role in heat removal and compact packaging of 500 W fiber laser. This opto-mechanical assembly will act as a driving engine for development of future multi-kW CW fiber lasers. Laser output was found to be stable within 1.5% over 1 hr. of continuous operation and will now be utilized for material processing applications. Figure L.1.2 shows in-house developed engineered 500 W Yb-doped CW fiber laser.

Fig. L.1.2: In-house developed engineered 500 W Yb-doped CW fiber laser.

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