L.6: Development of 400 W of all-fiber Yb-doped cw fiber laser

High power Yb-doped fiber lasers have shown tremendous progress in terms of power scaling by achieving multi-kilowatt output with near diffraction limited beams. These high power Yb-doped continuous wave (cw) fiber 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 for fiber optic beam delivery. A 2 kW near single mode all-fiber Yb-doped double-clad fiber laser with an optical-to-optical conversion efficiency of 78.5 % at 1080 nm using master oscillator power amplifier (MOPA) configuration has recently been reported in literature. Major challenges in the development of all-fiber fiber laser systems is the selection and availability of compatible fibers for pump, pump combiner, and gratings along with minimization of splice loss and reliable recoating at each splice joint, and efficient removal of heat load from thin polymer coated double-clad fibers. In view of the advantageous features of fiber lasers, Solid State Laser Division at RRCAT has taken up the task of indigenous development of high power CW fiber lasers for potential material processing applications. In this direction, development of a 405 W of all-fiber Yb-doped cw fiber laser with single transverse mode output at 1080 nm using single end pumping oscillator configuration has been carried out.

Fig. l.6.1 shows schematic of experimental set-up for single-end pumping configuration of 400 W Yb-doped fiber laser. In this all-fiber fiber laser set-up, a 20 m length of Yb-doped double-clad fiber has been used as the gain medium, which has a core diameter of 20 µm and an inner-clad diameter of 400 µm with inner clad pump absorption of 1.2 dB/m at 975 nm. Numerical apertures of the core & inner clad were 0.075 and 0.46, respectively. A diode pump module of six fiber-coupled diodes has been made for pumping of Yb-doped double-clad fiber. Each fiber coupled diode provides an output power of 150 W at 975 nm. This diode-pump module has been spliced to 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) of ~99% reflectivity. This fiber Bragg grating is written in a compatible double-clad fiber and it has a peak reflectivity at 1080 nm with a bandwidth of 0.2 nm. 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 and bandwidth of 1.5 nm has been spliced at the other end of Yb-doped fiber. Yb-doped double-clad fiber was tightly wrapped on a water-cooled copper spool of 200 mm diameter to achieve single mode operation as higher order modes are leaked out due to bending loss on spool. As the laser beam is emitted from a very small (20 µm) core diameter of Yb-doped fiber, it is prone to damage by dust particles. Thus, at the exit end of fiber, an end cap of 400 µm diameter and 1.5 mm length was spliced to increase laser beam diameter at the fiber end face. Fig. L.6.2 shows a bench top view of 405 W of single transverse mode all-fiber Yb-doped CW fiber laser. Using this set-up, an optical-to-optical conversion efficiency of 71% has been achieved with a beam quality factor (M^2) of ~1.04. Laser output signal was peaked at 1080.19 nm with a 3 dB linewidth of ~ 0.5 nm at the maximum output power.

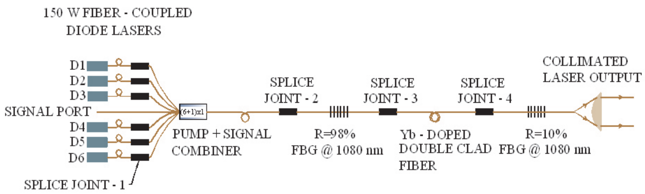

Fig. L.6.1: Schematic of experimental set up

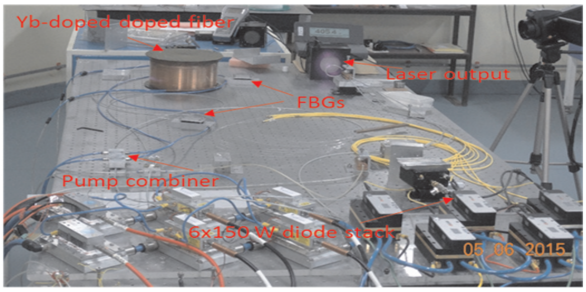

Fig. L.6.2: Table-top view of 400 W of all-fiber Yb-doped fiber laser

Various problems faced during the high power fiber laser development were fiber-fuse effect, self-pulsing, optimization of splice joints, and efficient heat removal. Fiber-fuse effect is a destructive mechanism, which results in the self-damage of the core of fiber components by backward propagation of signal due to inhomogeneity or absorption in the fiber at high powers, which abruptly increases the temperature beyond 1000°C at some point along fiber length. In order to avoid fiber-fuse effect, temperature of various fiber components and splice joints were monitored continuously using a thermal camera while increasing pump power. Further, high peak power self-pulses were removed by minimization of intra-cavity losses at the splice joints of fiber Bragg grating mirrors with Yb-doped fiber. The losses at splice joints were minimized by controlling splice parameters such as fusion power, hot push, rate of fusion, fiber core alignment, etc. This development will provide a foundation for development of kW class all-fiber fiber laser.

Reported by:
B.N. Upadhyay (bnand@rrcat. gov.in), K.S. Bindra