L.2 : Development of 215 W of all-fiber single transverse mode Yb-doped CW fiber laser

High power double clad CW fiber lasers have recently attracted considerable attention due to their advantages such as single-mode operation, all-fiber integration, high efficiency, compactness, no misalignment sensitivity, robustness, and efficient heat dissipation due to large surface area to volume ratio. Due to the significant compactness and robustness compared to the solid state high power lasers the CW fiber lasers are increasingly being used in the industry. Further, these lasers are also attractive for defence applications as a directed energy weapon source. Although, up to 2 kW single transverse mode fiber lasers are commercially available, in view of the above, it is of vital importance to study and develop single transverse mode, all-fiber, Yb-doped fiber lasers in Indian context. Major obstacles in the development of all-fiber fiber lasers is the selection of compatible fibers for pump, combiner, and gratings along with minimization of splice loss at each joint and efficient removal of heat load from thin polymer coated double-clad fibers. We have recently developed an all-fiber single transverse mode narrow linewidth all-fiber Yb-doped CW fiber laser of 215 W output power at 1090 nm in master oscillator power amplifier (MOPA) configuration.

Figure L.2.1 shows schematic of experimental set-up and Fig. L.2.2 shows table-top view of high power all-fiber Yb-doped CW fiber laser. A Yb-doped double-clad fiber with a core diameter of 20 μm and an inner-clad diameter of 400 μm has been used as the gain medium. For efficient absorption of the pump beam, 10 m length of the active fiber has been used, which provides total pump absorption of ~17 dB. Two diode pump modules with three fiber coupled diodes in each were made for the pumping of active fiber. Each fiber coupled diode provides an output power of 35 W at 975 nm. The pump modules were spliced to (6+1) x1 fiber optic signal and pump combiner. The core diameter of the fiber optic pump combiner at the output end is 400 μm with a NA of 0.46. Further, the output end of the fiber optic pump combiner was spliced to a fiber Bragg grating (FBG) of ~98% reflectivity. The fiber Bragg grating is written in a compatible double-clad fiber and has a peak reflectivity at 1090 nm with a bandwidth of 0.2 nm. One end of the Yb-doped fiber has been spliced to the other end of the high reflectivity FBG. Another FBG of ~7% reflectivity at 1090 nm was spliced at the other end of Yb-doped fiber to make an all-fiber fiber laser oscillator. The output of the oscillator was amplified by using another (6+1)x1 fiber optic pump and signal combiner. From the oscillator stage, 115 W of output was achieved, which was further amplified to obtain an output power of 215 W at the amplifier stage. As the laser 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 amplifier an end cap of 400 m diameter was spliced to sustain higher damage thresholds. An optical-to-optical conversion efficiency of 55% and a slope efficiency of 57% has been achieved in this all-fiber Yb-doped fiber laser MOPA configuration. Output signal was peaked at 1089.7 nm having a 3 dB line-width of 0.64 nm.

Major problems faced in this development were self-pulsing, optimization of splice joints, and heat removal. Self-pulsing, that is the generation of high peak power ns-pulses even with CW pumping, results in catastrophic damage of fiber components and diode laser. The self-pulsing was removed by considerably reducing the intra-cavity losses primarily by minimizing the losses in the splice joints in the cavity including the splice joints of fiber Bragg gratings with Yb-doped fiber. The splice joint loss was minimized by varying splice parameters such as fusion power, hot push, rate of fusion, argon flow rate etc., using a fusion splicing work station. Heat load from Yb-doped fiber was efficiently removed by tightly winding it on a copper spool, so that the heat from fiber is conducted through copper spool. Further power scaling to achieve kW-level fiber laser output is in progress.

Using this laser, micro-cutting of 2 mm thick stainless steel sheets and tubes were also carried out with a kerf width of less than 200 μm.

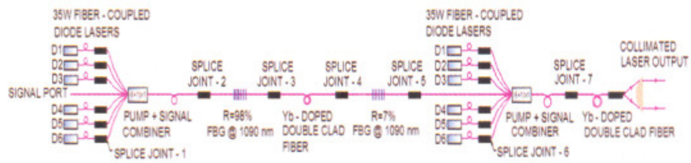

Fig.L.2.1 : Schematic layout of the all-fiber Yb-doped laser

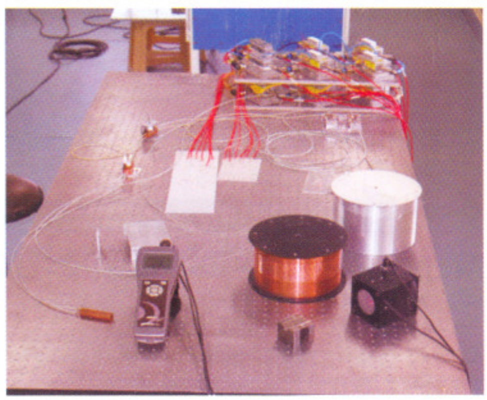

Fig. L.2.2: Table-top view of 200 W of all-fiber Yb-doped fiber laser..

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