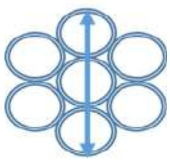
L.3: Development of 7x1 pump combiner for high power fiber laser pumping

Fiber lasers are the state-of-the-art solid-state lasers having all fiber integration and compact foot print with lower thermal problems and single mode output. It consists of rare earth doped double-clad fiber as the gain medium, which is end pumped by fiber coupled laser diodes and in-line fiber Bragg grating mirrors form laser resonator. As gain fiber has two free ends, it can be end pumped from both sides. However, pumping is limited by available pump power from single diode laser. Thus, for power scaling of fiber lasers, output power from several fiber coupled diode lasers is combined using Nx1 or (N+1)x1 pump and signal combiner. Thus, pump combiners are important passive fiber optic components for high power fiber laser development. In this direction, a fiber optic pump and signal combiner fabrication facility has been created and using this facility 7x1 pump combiners having 7 No. of pump input ports and one output port has been developed.

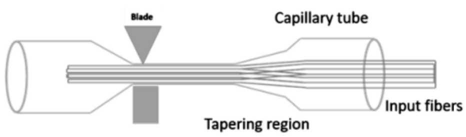
Fabrication of fiber optic pump combiner involves following steps: 1) Fiber preparation, 2) Bundle formation/fiber stacking, 3) Tapering of bundle, 4) Cleaving of tapered bundle, 5) Splicing with output fiber, and finally 6) Recoating and thermal packaging of the combiner for integration with fiber laser. For achieving higher transmission efficiency from pump combiner, brightness needs to be conserved during evolution from N input beams to single output beam. The brightness conservation is described by the ratio of integrated brightness of the total input of a pump combiner to the total integrated brightness of the output beam and is given by:

$$D_{out}^2 . NA_{out}^2 \geq N . D_{in}^2 . NA_{in}^2$$

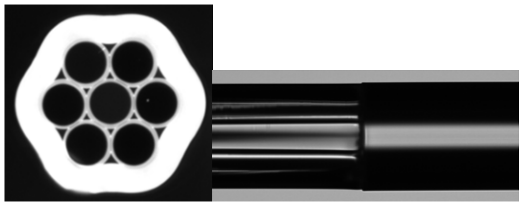
where, D_{in} and D_{out} are core diameters of input and output fibers; NA_{in} and NA_{out} are numerical aperture of input and output fibers; and N is the number of input fibers. Figure L.8.1(a), (b), (c) and (d) show cross-section of 7x1 fiber bundle, schematic of fiber tapering and cleaving, 7x1 combiner cross-section after tapering and cleaving and splicing of cleaved tapered bundle with output fiber.



(a)



(b)



(c) (d)

Fig. L.3.1: (a) Cross-section of 7x1 fiber bundle, (b) schematic of fiber tapering and cleaving, (c) 7x1 combiner cross-section after tapering and cleaving, and (d) splicing of cleaved tapered bundle with output fiber.

Fabrication of a 7x1 pump combiner having 7 input pump input fibers each of 100/125 µm core/clad diameter and 0.22 NA and 20/400 µm double clad fiber with NA of 0.46 as the combined output port has been carried out using in-house fiber optic pump and signal combiner fabrication workstation facility for high power fiber laser activity. Process parameters such as taper ratio, taper length, fusion power, etc. were optimized for tapering of fluoride glass tube containing fiber bundle. Further, this pump combiner has been thermally packaged (Fig. L.3.2) for utilization in high power fiber laser. Laser diodes at 915 nm wavelength were spliced at the pump input ports of pump combiner and pump combiner was tested up to combined output power of 500 W (~70 W per pump port) with a pump combining efficiency of ~99.2%, which is close to reported in literature. Figure L.3.3 shows testing of pump combining efficiency of the fabricated pump combiner. Further optimization of pump combiner fabrication process for enhancement in number of pump input ports and pump power handling capability per port is underway.

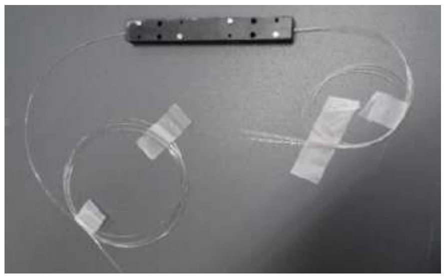


Fig. L.3.2: In-house fabricated thermally packaged 7x1 fiber optic pump combiner.

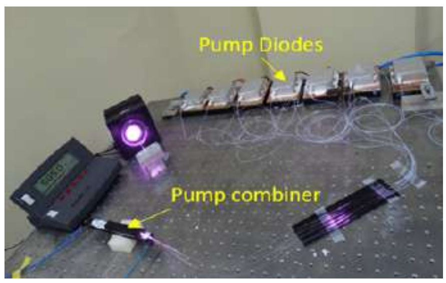


Fig. L.3.3: Testing of 7x1 pump combiner at 500 W of input pump power from 7 diodes.

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