out the generated green beam. For intracavity frequency doubling we have used a 10 mm long type II phase matched KTP crystal operated at 80 °C. The laser was Q-switched with the help of an acousto-optic modulator with 33 kHz of repetition rate. The maximum average green power obtained was 60.1 W at a total emitted diode power of 390 W corresponding to 15.5% optical to optical conversion efficiency. The pulse width was measured to be 350 ns. This is the highest green power achieved with a copper coated flow tube.

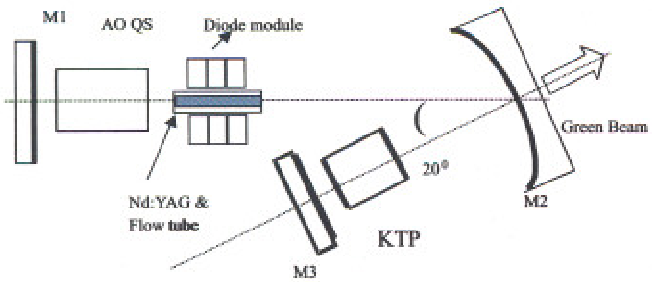

Fig. L.15.1 Schematic of the high average power green laser setup

(Contributed by: P.K. Mukhopadhyay; pkm@cat.ernet.in, Sunil Sharma, T.P.S. Nathan)

L. 16 Conduction cooled edge-pumped slab laser

We have developed a 37 W edge-pumped conduction cooled folded zigzag Nd:YAG slab laser. Edge-pumped conduction cooled geometry offers several advantages over conventional face cooled design. It includes independent optimisation for the pumping and cooling interfaces, simple head design and the coolant does not come in contact with TIR faces. We have used 0.6 at % doped Nd:YAG slab of size 2mm thick, 9mm width and 38mm long with AR/HR coated end faces. Water-cooled microchannel copper heat sinks with indium foils were made to remove the heat.

Pumping was performed by 4 nos. of 50W, 1cm diode bars emitting 808nm at 25 °C. In this pumping scheme, diode bar radiation was first coupled into the 0.5mm thick BK7 waveguide and then launched into the edge of Nd:YAG slab. Moreover, pumping and zigzag path of the laser beam are in the same plane to average the gain distribution and thermal gradients in width dimension. The cooling is perpendicular to the pumping plane. The folded zigzag resonator setup was made with separate cylindrical rear mirror and a plane 80% output coupler. The cylindrical axis of the rear mirror was parallel to the width dimension of the Nd:YAG slab. In width dimension of the slab, the resonator is plane-plane and in the thickness dimension it is plano-concave. The HR coating on the slab served as folding mirror. Fig. L.16.1 shows the photograph of the system. The laser beam makes one diamond pattern with one bounce per surface. Optical-to-optical and slope efficiencies for both the resonator setups are 20% and 26% respectively.

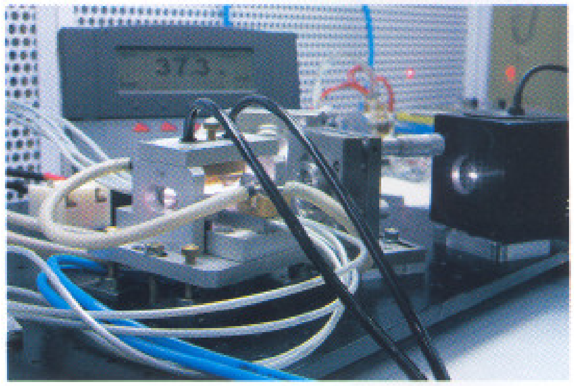

Fig. L.16.1 Photograph of the conduction cooled edge-pumped slab laser

(Contributed by: K. Ranganathan; ranga@cat.ernet.in, P. Mishra, T.P.S. Nathan)

L.17 Temperature tuned, birefringent filter based 500 mW SLM IR laser

We have developed a diode end pumped solid state (DEPSS) single longitudinal mode (SLM) IR laser with more than 500 mW of output power by end pumping a 1 at% doped semi-monolithic Nd:YVO_4 crystal with a fiber coupled laser diode operating at 809nm. The SLM operation was confirmed with a scanning plane-plane FPI. The cavity configuration was V-shaped with the HR coated Nd:YVO_4 crystal at one end and a 5% transmission rated output coupler at the other end with a 100mm radius of curvature folding mirror. A 2mm thick good quality Brewster plate (BP) was kept with its transmission axis parallel to the c-axis of the Nd:YVO_4 crystal. A temperature controlled AR/AR coated Nd:YVO_4 crystal was also used inside the cavity in between the BP and the output coupler and it acted as a temperature tunable wave plate. Fig. L.17.1 shows the experimental setup. The combination of this wave plate along with the BP act as temperature controlled birefringent filter. When the temperature of this crystal was adjusted to 35.1 °C, it act as full wave plate. The estimated FSR of the birefringent filter was 240 GHz at 1064nm and it was comparable to the gain bandwidth of the Nd:YVO_4 crystal, which is ~257 GHz. The slope efficiency of the laser was 33.4% and the maximum

SLM output power was 535mW corresponding to an optical-to-optical efficiency of 30% with respect to the absorbed pump power.

Fig. L.17.1 Experimental setup of DEPSS laser operating with 535mW of SLM output power at 1064nm

(Contributed by: Jogy George; jogy@cat.ernet.in, V. Agnihotri, T.P.S. Nathan)

L.18 Development of laser based system for cutting and welding of bellow lip of a coolant channel in a pressurized heavy water reactor

It is generally necessary to replace pressure tubes in a pressurized heavy water reactor (PHWR) after a life of around 15 years. This replacement is performed en masse on all channels with in the permissible MANREM dose. There are about 306 coolant channels in Indian PHWR which are bounded to the core of the reactor by means of two shrink fit welded bellow attachment rings, one on each face of reactor core located at a distance of about 945mm from E-face of end fittings. These coolant channels can be replaced, if the welded bellow rings are detached at the welding point on each end. This requires grooving at the welding point up to the depth of welding and then pulling the channel. Although, single point mechanical cutters, are utilized for this operation, such cutters suffer from bulkiness and entail large time consumption.

To speed up this process, a multi-port fiber coupled industrial Nd:YAG laser with 250 W average power has been developed along with fixture and tooling for coolant channel replacement in Indian PHWR in collaboration with NPCIL. The fixture for cutting of bellow lip consists of a motorized circumferential rotary arrangement, which can be mounted on E-face of coolant channel and can be fixed on E-face just by tightening of a single screw. A miniature fiber coupled laser cutting head with 0.5 inch diameter is mounted on the fixture in such a way that it takes care of position tolerance of bellow lip and diameter of coolant channel. Fig. L.18.1 shows the fixture mounted on coolant channel for cutting of bellow lip. The time required for cutting of one bellow lip is typically 5 minutes. Using the multi-port fiber optic beam delivery, time-sharing can be utilized to further reduce cutting time. This laser based bellow lip-cutting tool has been field tested by NPCIL and found to be very satisfactory. The same fixture with a fiber optic beam delivery and welding nozzle can also be utilized for welding. The time required for welding one of the bellow lips is about 8 minutes.

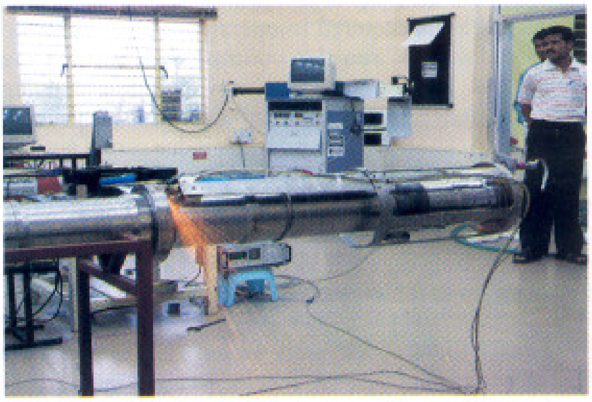

Fig. 18.L.1 Bellow lip cutting demonstration

The fixing of tool on any of the coolant channel requires about one minute and the cutting process can be controlled remotely. With this laser based cutting and welding tool, there is an enormous scope for time reduction, for en-masse coolant channel replacement (EMCCR) operations of our PHWR's. This system is being made ready for deployment for EMCCR at NAPS in 2005-06.

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