Inconel-625 is a nonmagnetic, corrosion- and oxidation-resistant, nickel-based alloy, which is used widely in heat shields, furnace hardware, gas turbine engine ducting, combustion liners and spray bars, chemical plant hardware and special seawater applications. Using indigenously developed LRM facility, the LRM process for the Inconel-625 component fabrication has been established. The tensile and impact resistance properties of the LRM material have been evaluated for various directions of deposition. LRM fabricated machined tensile test specimen are shown in fig. L.14.1

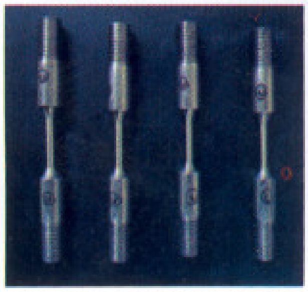

Fig. L.14.1 *LRM fabricated machined tensile specimen*

The results of tensile testing are summarized in Table L.14.1. It is found that LRM material has superior tensile strength without sacrificing percentage elongation as compared to that of wrought material, while the impact resistance of the material is at par with that of conventionally processed material.

The microstructure examinations revealed that there were finely intermixed dendritic and cellular microstructures with high dislocation density. Fig. L.14.2 presents the microstructure of LRM fabricated Inconel-625 specimen.

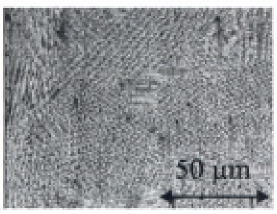

Fig. L.14.2 *Microstructure of LRM fabricated Inconel-625 specimen*

The direction of dendrite growth was along the direction of deposition. The fine dendrite formation was due to inherent rapid cooling rate during LRM, while cellular microstructure is attributed to relatively reduced cooling rate during multi-layer deposition. The fine dendritic formation with high dislocation density are responsible for higher mechanical strength, while formation of cellular microstructure has helped in keeping ductility intact. Using the established process parameters, several components like- impeller, cage, multi-layer walls etc. have been successfully fabricated.

(Contributed by: C P Paul; paulcp@cat.ernet.in, P. Ganesh and A.K. Nath)

L.15 Efficient 60 W green beam generation by use of an intracavity frequency-doubled diode side-pumped Q switched Nd:YAG rod laser

We have achieved 60 W of average green power by using copper coated pump beam reflector and 80 °C phase-matched KTP crystal. The schematic of the laser set up is shown in fig. L.15.1. The laser set up consists of a pump head, a resonator, an acousto-optic Q-switch and a KTP crystal for intracavity frequency doubling. The pump head consists of a 0.6 at.% doped 100 mm long (4 mm diameter) Nd:YAG crystal placed within a copper-coated flow tube. Nine numbers of 1cm laser diode bars were grouped in 3-fold symmetry for transverse pumping of the rod.

The cavity was V-shaped in order to provide proper spot sizes at the rod and at the KTP crystal. The rear flat mirror (M1) was highly reflecting (R> 99.7%) at the fundamental wavelength. The flat end mirror (M3) is highly reflecting (R> 99.7%) at the fundamental wavelength as well as at the second harmonic wavelength at 532 nm in order to retro-reflect the green beam generated in the backward direction. The folding mirror M2 was a concave mirror with 200 mm radius of curvature and was coated for high reflection at the fundamental wavelength and high transmission at the second harmonic wavelength in order to provide a means to couple

Table L.14.1 Tensile and impact properties of differently processed Inconel-625

Material	Direction of deposition	0.2% yield stress	Ultimate tensile stress	Elongation	Impact resistance
LRM fabricated	0°	572±25 MPa	920±15 MPa	48±2 %	104±2 J
	90°	568±20 MPa	925±12 MPa	46±2 %	102±1 J
	Mixed	571±15 MPa	915±20 MPa	49±3 %	103±1 J
Hot finished & annealed	-	395±15 MPa	824±25 MPa	51±4 %	110±5 J

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.

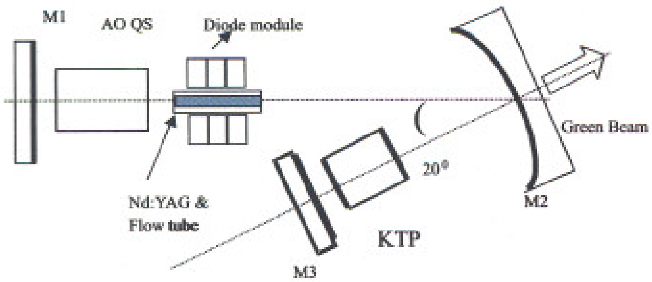

Fig. L.15.1 Schematic of the high average power green laser setup

(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.

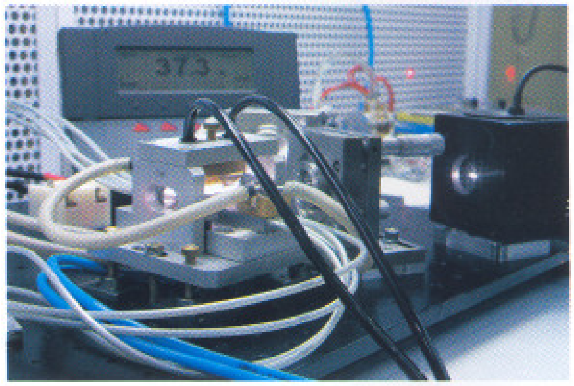

Fig. L.16.1 Photograph of the conduction cooled edge-pumped slab laser

(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