measured value of M^2 was found to be ~1.04, which shows a nearly diffraction-limited output laser beam. During development of high power fiber lasers, it was found that unwanted generation of relaxation oscillations near threshold and consequent generation of high peak power random self-pulsing with pulse duration of the order of a few nanoseconds damages fiber ends or any other fiber laser component, which is irreversible. So, it is extremely important to remove random self-pulsing, if it occurs, before anyone proceeds to generate high power output from Yb-doped fiber lasers. Fiber ends are also prone to damage by dust particles due to emission of high power from very small core size of the fiber and hence due to high power density at the fiber end faces, so it is also important to protect fiber ends by means of end caps.

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L.4: Indigenous development of laser glass

A program to indigenously develop Nd doped phosphate laser glass was funded by Board for Research in Nuclear Sciences (BRNS) with participation of Central Glass and Ceramic Research Institute (CGCRI) Kolkata, Raja Ramanna Centre for Advanced Technology (RRCAT), and Bhabha Atomic Research Centre (BARC) Mumbai, to overcome the problem of non-availability of good quality laser glass rods and discs for high energy, high power (HEHP) lasers. The LHG-8 (M/s Hoya, Japan) glass is currently used in the third generation HEHP lasers like National Ignition Facility (NIF), USA, and Laser Mega-Joule (LMJ), France. Under the MOU, CGCRI will supply 1000 kg of optical quality rectanguloid blocks to RRCAT. The slabs will be machined into laser rods and optically polished in RRCAT. Further, anti-reflection (AR) coating will be deposited at RRCAT on the end faces of the glass rods. The project has successfully passed the first stage of development in which following targets were achieved: a) Optimization of the process parameters for dry route of melting (mainly oxygen bubbling to control OH and Fe impurities); b) Indigenous development of highly pure raw materials like meta-phosphates of Al, Ba, K required for dry route of melting; c) Indigenous development of highly pure Nd_2O_3; d) Validation of Pt crucible and furnace design for glass melting; e) Indigenous sourcing of oxide dispersed Pt crucible; f) Civil, electrical and clean room (with controlled humidity) infrastructure for housing the machines; g) Procurement of annealing and fine annealing furnaces suitable for all the glass sizes; h) Generating infrastructure for transforming laser glass slabs into laser rods; and i) AR coatings of laser glass rods.

The work related to production of pre-cursor raw materials i.e. meta-phosphates of Al, Ba, and K with an impurity of less than 10 ppm (in the glass) of the transition metals like Fe, Cu, Cr and Ni was taken up with a vendor in Indore. Presently, highly pure meta-phosphate raw materials having a batch size 50 kg have been supplied to CGCRI with desired quality. The fluid dynamic calculations for the design and validation of crucible and stirrer had been taken up with IIT- Kanpur, and a five litre platinum crucible was fabricated with this design. The design of 15 litre crucible is ready and will be fabricated after the glass quality in terms of homogeneity is attained in the operational 5 litre crucible. Casting of molten glass using this crucible is shown in Fig.L.4.1. The trials for the turning of glass slabs into laser rods were done at RRCAT with the slabs supplied by CGCRI. The process of the turning of Glass slabs supplied by CGCRI is shown in Fig.L.4.2.The optical polishing of end faces has already been established in RRCAT. The Nd:Glass rods have been coated with a single layer sol-gel silica AR coating at RRCAT.

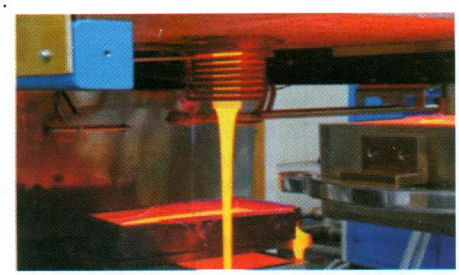

Fig.L.4.1: Casting of laser glass from5 liter bottom pouring furnace.

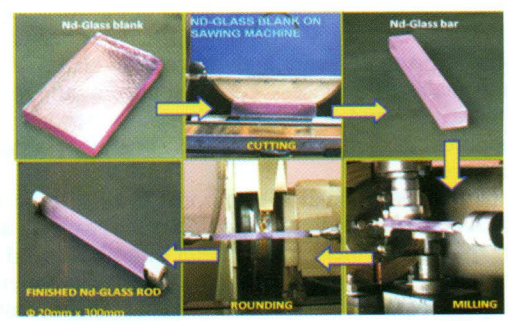

Fig.L.4..2: Optical machining of laser glass at RRCAT from slab to laser rod.

In the second stage of the program, the glass melted in 5 litre bottom pouring Pt crucible was cast, annealed and fine annealed. A slab of size 240 cm x 135 cm x 40 cm with Nd_2O_3 doping of ~ 3 wt% was received from CGCRI for the testing of its optical parameters. The slab surface was polished in the Optical Workshop of RRCAT. The slab was tested for optical homogeneity, birefringence, and for bubbles/inclusions. Presently this glass has total homogeneity (surface + bulk) of better than 6.10^{-5} as measured by the interferometry. This needs to be improved by a factor of two. The stimulated emission cross section (σ) and intensity dependent refractive index (n_2) values were measured using the method of amplification and the Boling's method respectively. These values were found to be comparable to the LHG-8 glass. Efforts are on to further improve the optical quality of the indigenous laser glass.

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