L.1: Development of 1.5 kW average power long pulse lamp pumped Nd:YAG laser

High average power and high peak power long pulse Nd:YAG lasers have found potential applications in large depth cutting and welding of metals and alloys with minimum heat affected zone, shrinkage and distortion. As the output power from a single rod is limited due to thermal fracture limit, multi-rod and oscillator-amplifier configurations are normally used for power scaling. In case of oscillator-amplifier system, mode matching telescopes and spatial filters are required in laser set up, which results in a complicated structure with low electrical to optical conversion efficiency. As compared to oscillator-amplifier system, multi-rod resonator design consists of a number of rods kept in a single resonator in rod imaging configuration, which is simple and more efficient. But, the length of resonator becomes very long, so, precise alignment of Nd:YAG rods is necessarily required to achieve safe and stable operation. Further, discrete unstable regions, which result in a sudden drop in output power in a particular range of input pump power may also exist in the resonator, if identical pump chambers are not used and the resonator is not optimally designed. Thus, it is important to select identical rods, pump chambers and cooling units to have similar thermal lensing from all the rods used in the resonator. In high average power long pulse lamp pumped Nd:YAG lasers, maximum electrical to laser conversion efficiency in the range of 3-4% and maximum pulse energy of ~100 J is reported in literature. In view of increased requirement in thickness of cutting and welding, development of 1.5 kW average output power with 5% electrical to laser conversion efficiency and a maximum pulse energy of 680 J at 40 ms pulse duration has been carried out.

Figure L.1.1 shows schematic arrangement of three rod resonator. There are three pump chambers, which have the same geometry and each pump chamber consists of an Nd:YAG rod of 8 mm diameter, 160 mm length, [111] orientation, and 1.1 at.% Nd^{3+}- doping concentration. An Nd:YAG rod and two Kr-filled flashlamps have been placed in a close coupled yellow glazed diffuse ceramic reflector in each pump chamber. A maximum of 10 kW average electrical power is pumped in each pump chamber and 5 kW in each flashlamp. Lamp and rod are separated by 10% samarium doped glass filter plates, so that unwanted UV radiation from flashlamp is absorbed by the samarium filter, which then emits in the pump band of Nd:YAG rod and results in lower thermal load and enhancement in optical conversion efficiency. Three number of 10 kW power supplies have been used to separately trigger and pump the six flashlamps. However, a single power supply controller has been used to operate all the six power supplies in synchronization to simultaneously pump all the rods in the resonator. Identical water cooling units operating at 22 °C have been used for all the three pump chambers to achieve similar thermal lensing for each rod. A plane-plane U-shape laser resonator has been designed in rod imaging configuration with d:2d:2d:d separation of principal planes of the rod.

The rear mirror M1 is plane with high reflection (HR) coating at 1064 nm (R>99.7%) for normal incidence and mirrors M2 and M3 are also plane mirrors with HR coating at 1064 nm for 45° angle of incidence. The output coupler mirror M4 is a plane mirror with 20% reflectivity at 1064 nm to have feedback and couple out laser beam. U-shaped resonator design was selected to accommodate laser resonator on optical table of 1.5 m length. The total physical length of the resonator was optimized to be 230 cm with d=35 cm. Laser output characteristics were studied for different values of d in the range of 20 cm to 40 cm. However, a distance of 35 cm was found to be optimum to achieve good beam quality with M^2~69 at the maximum pump power and efficient operation over the whole range of average input pump power from 0 to 30 kW. Figure L.1.2 shows a table-top view of 1.5 kW average power Nd:YAG laser. A maximum average output power of 1550 W was achieved with maximum pulse energy of 680 J at 40 ms pulse duration, leading to a peak power of 17 kW. However, at lower pulse duration of 4 ms, a maximum pulse energy of 121 J was achieved leading to a peak power of ~30 kW. Laser pulse duration can be varied in the range of 4 ms to 40 ms and repetition rate in the range of 1 Hz to 100 Hz. Now, development of laser beam delivery system through optical fiber is underway for remote cutting of more than 30 mm thick sections of stainless steel.

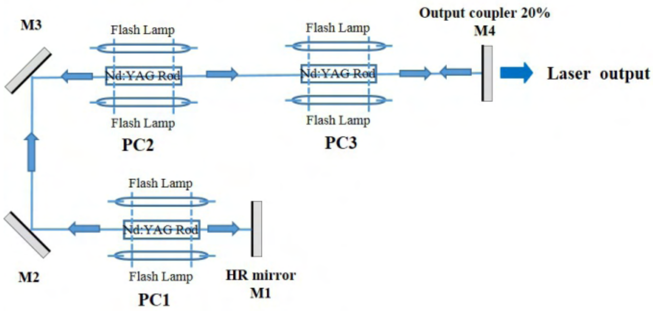

Fig. L.1.1: Schematic of 1.5 kW average power long pulse Nd:YAG laser.

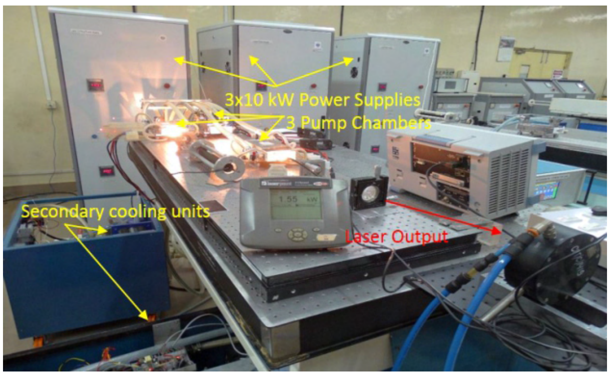

Fig. L.1.2: Table-top view of 1.5 kW average power long pulse lamp pumped Nd:YAG laser.

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