The laser output pulse is shown in fig.L.6.5 is measured with pyro-electric detector. The measured output energy was 150mJ/pulse at 100 Hz. Fig.L.6.6 shows the first prototype of this power supply.

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L.7: Development of 300J pulse energy long pulse Nd: YAG Laser

The diode-pumped Nd:YAG and fiber lasers are not easy to operate in high energy, long pulse mode due to switching requirement of pump diodes. Therefore, flash-lamp pumped pulsed Nd:YAG lasers with long pulse duration in the millisecond range are still important for various material processing applications. For deep penetration welding applications, it is desirable to have high energy and long duration pulses. However, beam quality from high power Nd:YAG lasers is limited by strong thermal lensing and stress induced birefringence. Further, power scaling from single Nd:YAG rod is limited due to pump input and available rod length defined by thermal fracture limit of the rod, which is ~ 200 W/cm. Thus, power scaling can be achieved by using multi-rod resonator or master oscillator power amplifier configuration (MOPA). Although, it is easy to design MOPA configuration, but due to variation in thermal focal length of amplifier stage with variation in input pump power, it is difficult to achieve fiber optic beam delivery for the entire range of pump power. Thus, for fiber optic beam delivery, it is a better choice to use multi-rod resonator. It has already been reported that two-rod resonator with plane-parallel configuration has a wide stable range, when the two rods are symmetrically positioned inside the resonator. We have carried out design and development of a pulsed Nd:YAG laser providing 300 J of pulse energy with 40 ms pulse-duration using dual-rod resonator configuration.

There are two identical pump chambers within the laser resonator. Each pump chamber is having a Nd:YAG rod, a lamp, and two halves of gold plated elliptical reflector. Each pump chamber contains 1.1 at.% Nd-doped rod of 10 mm diameter and 150 mm length. In each of the pump chambers, a 10% samarium oxide doped glass plate is inserted between the lamp and rod to absorb the UV radiation from the lamp and convert the UV radiation into the useful visible light, thereby contributing to the laser output power. Both the pump chambers were cooled by closed-loop de-ionized water chillers. Two high voltage power supplies with master-slave configuration and rectangular current pulse profile of variable duration from 2 ms to 40 ms along with capability of pumping both the cavities synchronously has been used. Figure L.7.1 shows the schematic of symmetric dual cavity resonator and Fig. L.7.2 shows a view of the in-house developed. 300 J pulse energy Nd:YAG laser with fiber optic beam delivery. Dual cavity resonator is constructed using a plane-plane

Fig. L.7.1: A schematic of the symmetric dual cavity resonator.

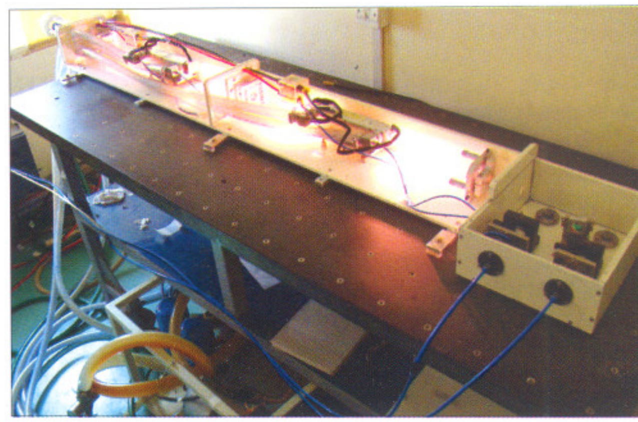

Fig. L.7.2 : A view of the in-house developed 300 J pulse energy Nd:YAG laser with fiber optic beam delivery.

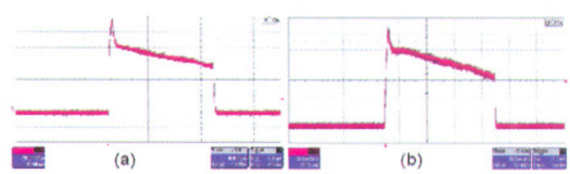

Fig.L.7.3 : (a) Flashlamp pump-pulse, and (b) laser output pulse of 300 J, 40 ms fiber-coupled pulsed Nd:YAG laser.

symmetrical configuration with d: 2d: d configuration, where d is the distance between mirror and the principal plane of the rod.

Figure L.7.3 shows the pump pulse and laser output pulse for 300 J pulsed Nd:YAG laser with fiber optic beam delivery. With dual rod resonator, a maximum average output power of 500 W was achieved with maximum pulse energy of 300 J at 40 ms pulse-duration. Maximum peak power of this laser is 10 kW. Laser pulse duration can be varied from 2-40 ms with variation in pulse frequency from 1-100 Hz. Output pulse energy varies linearly with increase in input pump energy. Electrical to laser conversion efficiency is about 5% with beam quality of better than 20 mm.mrad for the whole range of operation from 0-10 kW. Laser beam has been delivered efficiently through an optical fiber of 400 μm core diameter and 0.22 numerical aperture with 90% transmission at the fiber exit end. There are two fiber ports, which can be used on time sharing basis for different applications. Laser cutting up to a depth of ~ 20 mm and welding in SS up to a depth of ~ 6 mm using this laser system has been carried out. Its further applications in welding of Copper, and Aluminium with variation in pulse duration and pulse energy is underway.

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L.8. Long distance axial trapping with Laguerre-Gaussian beams

Optical tweezers require tight focusing of laser light through a high numerical aperture (NA) microscope objective lens to produce the strong gradient forces necessary to overcome axial scattering forces and thus achieve stable three-dimensional trapping. The short working distance associated with a high NA (NA>1) objective limits the axial trapping range to a typical value of ~ 200 µm. Further, because the particles to be trapped are often suspended in an aqueous medium the trap beam suffers significant spherical aberration at the glass-water interface leading to an increased axial spread of the focal volume with increasing distances from the substrate. The resulting reduction in the power density at focus leads to a reduction in the gradient forces and consequently a limited axial trapping range that is significantly shorter (often under 100 µm) than the available working distance of the objective lens. Longer axial trapping range is however required for optical manipulation of objects at free liquid surface.

Studies performed in Laser Biomedical Applications and Instrumentation Division (LBAID), have shown that since the *LG* mode traverses the glass-water interface with a narrower angular range of rays vis a vis the TEM_{00} mode, the spherical aberration gets reduced for the *LG* mode. The resulting smaller axial spread of focal volume for *LG* mode enables longer axial trapping range compared to the TEM_{00} mode.

With ~10 mW of trapping laser power, with LG_{01} trap beam human colon adenocarcinoma (Colo-205) cells could be moved over an axial distance of ~ 240 µm whereas with the same power in the TEM_{00} mode the cells could be moved only up to a distance of ~ 145 µm (fig. L.8. 1). This ability of LG_{01} was used to transport a human colon adenocarcinoma (Colo-205) cell from the bottom layer of the medium to the top surface layer (thickness of the fluid ~200 µm) exposing it to a higher atmospheric oxygen concentration. By tagging the cell with a fluorescent membrane probe (laurdan), the difference in the extent of oxygen mediated fluorescence quenching between the two cases was used to estimate the oxygen diffusion rate in the membrane.

The relative fluorescence intensity for the cells at the air-liquid interface with respect to the cells trapped deep inside the medium is shown in fig.L.8.2. The data shown is the mean value taken over ten cells. The ratio of mean unquenched fluorescence intensity at bottom (F_0) to reduced fluorescence intensity at top surface (F_{eq}) ratio was measured to be ~ 1.23 yielding an oxygen diffusion rate of ~ 5.2 x10^{-5} cm^2s^{-1}. The value is in reasonable agreement with the value for biological membranes. To further validate these results measurements were also made on cells kept at higher temperature (55°C for 1 hr. The measured values for F_0 and F_{eq} for cells heat treated for ~ 1 hour at a temperature of 55 °C are consistent with the expected increase the membrane permeability of the cells.

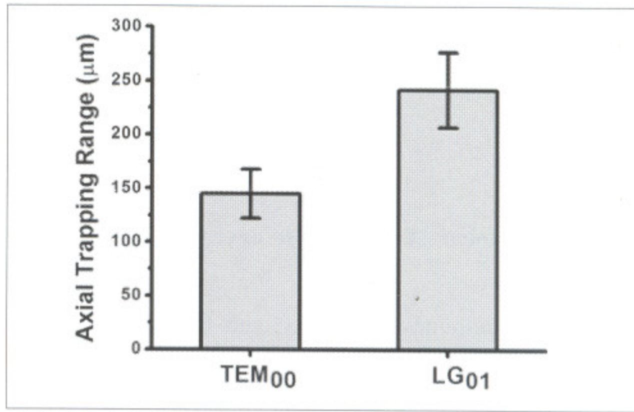

Fig.L.8.1: The axial trapping range observed for colo cells with TEM_{00} and LG_{01} modes. The data shown are the mean over five experiments.

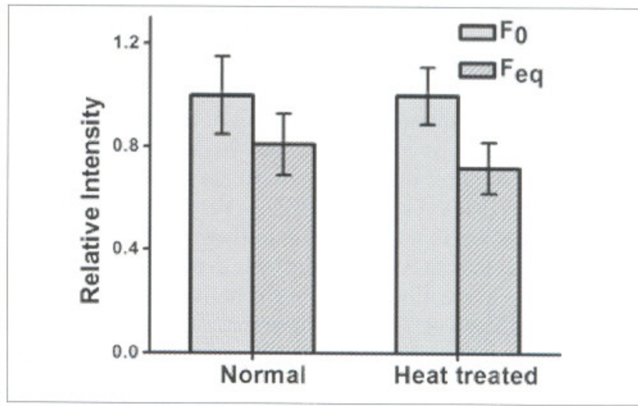

Fig.L.8.2: Observed mean relative fluorescence intensities of cells when trapped at the bottom (F_0) and at the top surface (F_{eq}). The data for cells althrough kept at room temperature (25°C) and cells heat treated for ~1hr at an elevated temperature of ~ 55 °C are shown.

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