L.2: Development of a compact high energy Nd:phosphate glass laser system

High energy pulsed Nd:phosphate glass based laser systems delivering pulse energies of sub-100 J are widely used for a variety of investigations and applications such as direct amplifiers for chirped laser pulses, pump source for optical parametric amplifiers and Ti:Sapphire based amplifiers, laser-plasma interaction, and developing secondary source of radiations etc. Such laser systems mainly consist of a master oscillator providing a low energy beam of well-defined beam quality and pulse width, and a number of power amplifiers of successively increasing cross-section in a master oscillator power amplification scheme. Laser Plasma Division at RRCAT has indigenously developed a highly efficient oscillator-amplifier Nd:phosphate glass laser system (λ = 1054 nm) to deliver laser pulses with pulse energy of ~50 J in 9 ns duration (~75 mm beam diameter) at a total electrical pump pulse energy of 48 kJ with a worst case background pulse energy contrast ratio of 1: 200. The key design aspect of this laser is to incorporate multiple pass pulse amplification in each amplifiers and use of circular polarization at amplifier stages to improve extraction efficiency of laser amplifier, to reduce optical non-linearity and to avoid limitations of capacitor bank of pulse forming network.

The laser system (Fig.L2.1) mainly consists of a Q-switched and cavity dumped laser oscillator (also acts as regenerative amplifier for 1 ns duration chirped laser pulses) followed by three stage multiple pass Nd:phosphate glass amplifiers (first 4-pass, second 2-pass and other one is four-pass), one Galilean beam expander, and one vacuum spatial filter cum beam expander cum image relay system to match beam cross section at successive laser amplifiers. Multiple pass pulse amplification in the first two amplifiers (using 25 mm and 50 mm diameter laser rods) has been achieved using passive polarizing switching devices, the last amplifier (using 80 mm diameter laser rod) utilizes far field injection technique to achieve four-passes. The product of Nd_2O_3 concentration (in % wt) and diameter (in cm) of glass rods is chosen to be ~3-3.5. The last amplifier is designed to have beam expander cum image relay system (using lenses each having focal length of +5 m), injection beam line with another image relay system (using lens with focal length of +5 m and +3 m, longer focal length lens being common to both the systems), and a 2x2 pin hole array kept inside an evacuated chamber and at focus point of unit magnification relay system. All amplifiers are pumped by air-cooled Xenon flash lamps (6, 12 and 16 lamps in first, second and third amplifier respectively) in a circular reflector design and the laser rods are cooled by circulating a mixture of glycol-distilled water (50% by volume). To minimize the operation and maintenance time, CCD based on-line diagnostics have been set up to monitor the leakage laser light through various bending mirrors, and four pass geometry of the last amplifier of the laser system. In particular, the leakage light was focused on to a single CCD camera coupled to display monitor to allow detection of all four passes of last amplifier.

The laser performance has been characterized for various parameters in space and time domain. The variation of pulse energy with seed pulse energy at constant electrical pump pulse energy and with electrical pump pulse energy at a constant seed pulse energy was recorded and found to vary linearly. Depolarization measurements were carried out for both linear and circular polarization at pulse repetition rate of 1 pulse in ~ 3 minutes and depicted in Fig.L.2.2.

Fig.L.2.1: Compact 50 J Nd:phosphate glass laser system at Laser Plasma Division. Inset also show typical beam profiles at low and high pulse energy regimes.

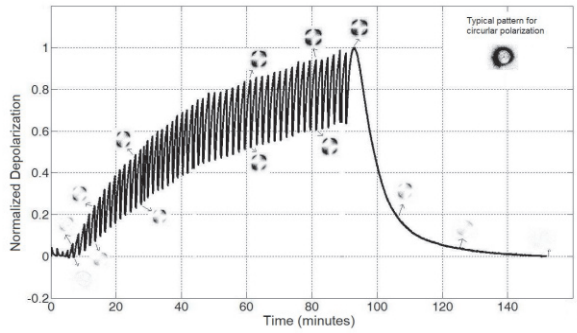

Fig.L.2.2: Normalized depolarization and typical pattern as function of shot number (time). Inset also show typical pattern for circular polarization.

Next, the ratio of pulse energy fluence to saturation fluence of phosphate glass (4.5 J/cm^2), responsible for extraction efficiency of the amplifiers was estimated to ~ 0.22 at last amplifier stage. At such an operational level, the extraction efficiency (electrical to optical) of laser system is estimated to be ~ 0.1% and gain medium utilization factor (defined as ratio of laser energy to total weight of glass rods in kilograms) is estimated to be ~7.7 J/Kg.

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