Laser program

L.1 Design, development and characterization of a large aperture disk amplifier for high power Nd: glass laser chain

High power, high energy Nd: glass lasers are widely used as pulse power drivers for studies of inertial confinement fusion, generation of intense thermal x-ray radiation, pumping of x-ray lasers etc. These lasers are built using the master oscillator-power amplifier configuration. In the latter case, a master oscillator provides a laser pulse of the desired spatial and temporal profile, which is amplified in a series of power amplifiers of successively increasing apertures, to restrict the laser intensity below the damage threshold. The amplifier stages are coupled by relay systems and with spatial filtering at appropriate locations. However the amplifiers of large size (typ > 75mm, dia) with gain media in rod geometry have higher gain at the edges and poor gain in the center and also suffer from thermo-optic problems. These drawbacks are circumvented using disks in place of the rod as a gain medium. In Laser Plasma Division, we have a 2- beam high power Nd: glass laser chain capable of delivering 50J in 1- 1.5ns giving an intensity of ~ 1GW / cm^2 after 80mm Nd: glass rod amplifier. In order to increase the output energy to 100J, an Nd: glass disk amplifier has been developed and coupled to the laser chain.

The amplifier consists of 3 disks of Nd: Phosphate glass (doping 2.2 wt% of Nd_2O_3), of size 114mm x 214mm x 20mm. The disks are premounted in cassettes and then loaded in a rectangular cross sectional mechanical housing at Brewster angle (~ 57°) and optically pumped using 10 Xe filled flashlamps of 600mm arc length (fig. L.1.1). Drycooled nitrogen gas is circulated to remove the heat formed in the disks during the pumping process. Also it helps in protecting the hygroscopic phosphate glass disk surfaces from degradation. The disc assembly is sealed using AR coated glass windows at the laser entrance and exit faces and with glass blast shields on the flashlamp array side. For this purpose a two stage dry nitrogen cooling system has been set up, which consists of columns of silica gel, and molecular sieves as moisture traps. The thermal recovery of the disk amplifier was found to be 13 minutes.

The disk amplifier system was energized using a bipolar power supply. This consists of two capacitor banks, each of 3000μF, which can be charged to ± 3500V. For each flashlamp the pulse shaping circuit includes capacitance of 150μF (two numbers of 300μF in series) and inductance of 80μH. The flashlamps can be operated from 6kJ up to 36kJ (electrical energy) and the disk amplifier was characterized for gain and its spatial variation along its minor axis. The pump pulse duration was measured to be 450sec. Fig. L.1.2 shows the gain obtained as a function of input pump energy. It is observed that the gain increases linearly with pump energy up to ~20kJ, and thereafter saturates to a value of ~ 6 at a pump energy of 36kJ. This is primarily due to the amplified stimulated emission, parasitic oscillations and also due to the change in the flashlamp spectra. At the pumping of 20kJ, the small signal gain is 5. This corresponds to a stored energy of 930J, which is about 5% conversion of the pump energy. The available gain at the operating intensity of $1GW/cm^2$ is calculated to be 3.65.The spatial gain variation, along the minor axis of the disk aperture was also studied. The variation was found to be from 2.5 to 3.1 (min max). The disk amplifier was coupled to the laser chain and laser pulse output of 105J /1.5ns was obtained at operation at $\sim 1GW/cm^2$.

Fig. L.1.1 *Disk amplifier module of Nd: glass high power laser chain.*

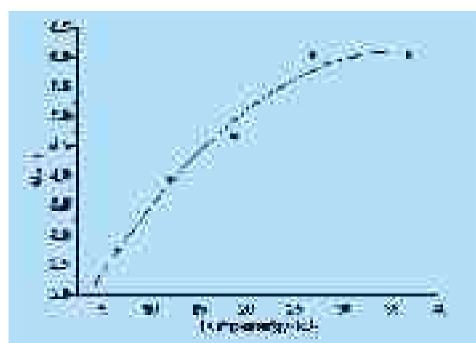

Fig. L.1.2 *Gain characteristics of the Nd:glass laser disk amplifier.*

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L.2 A new method for ultrashort laser pulse characterization

Generation and application of ultrashort laser pulses require reliable characterization techniques to determine various pulse parameters like duration, shape, chirp, spatio-temporal distortions etc. Several diagnostic systems such as simple autocorrelation methods, frequency resolved autocorrelation measurements, temporal or spectral interferometry etc have been developed. Development of simple and inexpensive diagnostic systems capable of real time characterization of ultrashort laser pulses and associated pre-pulses (if any) is highly desirable. The fringe resolved interferometric autocorrelation (FRIAC) signals, which can be recorded in simple, inexpensive and compact setups, are widely used for ultrashort laser pulse measurement, but they are not very sensitive to the pulse chirp and asymmetry.

In Laser Plasma Laboratory, a new technique for sensitive detection and estimation of chirp and pulse asymmetry of ultrashort laser pulses has been worked out and implemented experimentally using 200fs laser pulses from cw mode-locked Nd:glass laser oscillator. This technique is based on unbalanced fringe resolved interferometric autocorrelation (UFRIAC) signals and uses a procedure of unbalanced fringe resolved interferometric autocorrelation envelope function difference (UFRIACED) to generate spectrally modified signals, which are sensitive to pulse chirp and asymmetry [*A.K. Sharma, P.A. Naik, P.D. Gupta, Opt. Exp. 12, 1389, 2004; ibid, Opt. Commun. 246,195,2005*]. For any new diagnostics, it is very important to carryout noise analysis for its performance in real laboratory environment. It was found, both theoretically and experimentally, that the UFRIACED method works very well even for noisy FRIAC signals [*A.K. Sharma, P.A. Naik, P.D. Gupta, Opt. Commun. 259, 350, 2006*].

The second order UFRIAC signals have been recorded using simple, low cost real time interferometric autocorrelator with extended temporal scan range, in which a commercial grade light emitting diode and audio speakers have been used as a quadratic detector and optical delay line respectively [*A.K. Sharma, P.A. Naik, P.D. Gupta, Appl. Phys. B 82, 407, 2006; ibid, Opt. & Laser Technol. 2006 In press*]. The UFRIAC and UFRIACED signals are displayed on a digital storage oscilloscope interfaced with a personal computer either via GPIB card or standard USB port. A computer program has been written to analyze these signals, which generates various spectrally modified signals for visual detection of pulse chirp and asymmetry. A typical UFRIAC signal and corresponding UFRIACED signals are given in fig. L.2.1. The pulse duration is derived from the number of interference fringes in the UFRIAC signal. This technique is superior to the modified spectrum auto-interferometric correlation technique, as the latter does not provide any information about pulse asymmetry. Moreover, it is twice more sensitive towards the chirp and much less sensitive to various perturbations.

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L.3 Intense coherent XUV radiation produced through higher order harmonic generation in plasma plumes

Higher order harmonic generation using ultrashort pulse lasers is an attractive means of producing coherent radiation in the extreme ultraviolet (XUV) spectral range, which may serve as a much simpler alternative to the soft x-ray lasers. It can also have the additional advantage of having ultrashort sub-femtosecond duration pulses. Mostly gas jets are used for high order harmonic generation. However, they provide a low conversion efficiency. Alternatively, one can use plasma plumes produced from low intensity laser pulse irradiation of solid targets as the medium for harmonic generation. This may be much more advantageous compared to the use of gas jets since the availability of a much wider range of target materials for plasma production increases the possibility of resonant enhancement of some particular harmonic orders.

At the Laser Plasma Laboratory, higher order harmonic generation has been studied in plasma plumes and resonant enhancement of some single harmonics has been observed. The laser used in the study was 100mJ, 48fs Ti:sapphire laser. A 300ps prepulse (a portion of the uncompressed laser beam) was used to produce the plasma from different solid targets. The high intensity ultrashort laser traversed the plasma plume, parallel to the target surface and produced higher harmonics. Figure L.3.1 shows harmonic spectrum obtained from silver plasma. Harmonics as high as 63^{rd} order were observed.

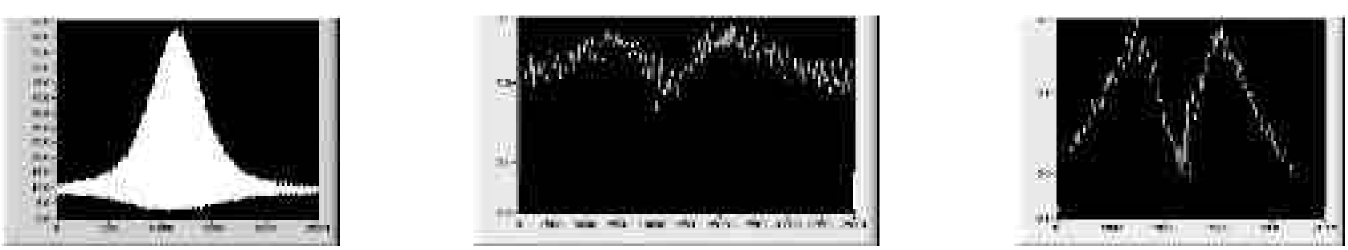

Fig. L.2.1 Typical UFRIAC signal of 200fs laser pulse (left), corresponding UFRIACED signals for sensitive detection of chirp (middle) and for pulse asymmetry (right).