We have successfully developed a broadband transverse electrooptic modulator (fig. L.4.2). The element was fabricated using the in-house grown $LiNbO_3$ crystal for this purpose. The dimensions of the crystal element are: $17\times2\times0.8$ mm^3. The half wave voltage of the modulator was 89 volts, measured at 632 nm wavelength (set up shown in fig. L.4.1). The modulator module was tested for analog modulating signals up to 2 MHz frequency range at 632 nm (representative fig. L.4.3). The characteristics of the module are: Type: Broadband EO modulator, Bandwidth: ~ 450 MHz, Insertion loss: ~ 0.9 dB and efficiency ~10%. Some improvements are required in the electroding, electrical contacts, terminal and packaging of the device in order to demonstrate it at higher frequencies.

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L.5 Sol-gel based anti-reflection coatings on Nd: glass laser rods & wedge-shaped optics using spin coater

Sol-gel coatings, due to their high damage threshold and ease of coating of large area substrates with high spatial uniformity at room temperature, are finding increasing applications in fabrication of optics for high power lasers. In high-power pulsed Nd: glass laser systems used for laser plasma interaction studies, a large number of cylindrically shaped laser rods and disks with anti-reflection (AR) coated end surfaces are used to set up master oscillator and power amplifiers. The entrance and exit faces of the laser rods in such systems are usually cut at an angle of a few degrees (typically 3 to 5^o) with respect to the plane normal to the rod axis to avoid depletion of stored energy because of parasitic oscillations. AR coatings are mostly deposited by vacuum dielectric coating technique using either electron beam evaporation or ion beam sputtering. In these coating methodologies, the substrate is required to be heated to a temperature of about 200 ^{0}C to produce a good adhesion of the coating to the substrate to achieve high abrasion resistance, and it has to be simultaneously rotated around its axis to obtain a high spatial uniformity of the coating on the surface. However, for large size laser rods, these simultaneous operations in a vacuum chamber become quite difficult. We have developed and characterized sol-gel AR coatings on wedge-shaped optics [*R. Pareek, A.S. Joshi, P.D. Gupta, P.K. Biswas and S. Das, Optics and Laser Technology 37, 369 (2005)*] and used them to make good quality sol-gel AR coatings on wedged Nd: glass laser rods.

A double layer coating design involving two different materials was used to deposit AR coating. Zirconia and silica sols were chosen for depositing the high and the low refractive index material layers, respectively. Coatings were deposited on flat circular substrates of BK-7 glass and the Nd: phosphate glass laser rods using a spin coater (CONVAC GmbH model 1001). Refractive index of the sol films was measured to be 1.645 and 1.450 for zirconia (2 wt%) and silica (6 wt%) sols, respectively. Calibration curves of physical thickness deposited on BK-7 flat glass substrates versus rotation speed of the spin-coater were obtained for the two sols for the rotation speed in the range of 1000 to 4000 rpm. These were used to select appropriate rotation speeds to deposit the desired thickness of the two sols on flat as well as wedge substrates.

Specular reflection spectra at the centre of the AR coated BK-7 glass substrates of the different wedge angles are shown in the fig L.5.1. It is seen that the reflectivity spectrum from the wedge substrates shifts towards the higher wavelength side for increasing values of the wedge angle. This data was used to decide appropriate rotation speeds for a particular wedge angle to achieve reflectivity minimum at the lasing wavelength of 1054 nm. A 50 mm diameter, 300 mm long Nd: glass laser rod with end surfaces cut at 3^0 was AR coated with a reflectivity of ~0.7% at 1054 nm.

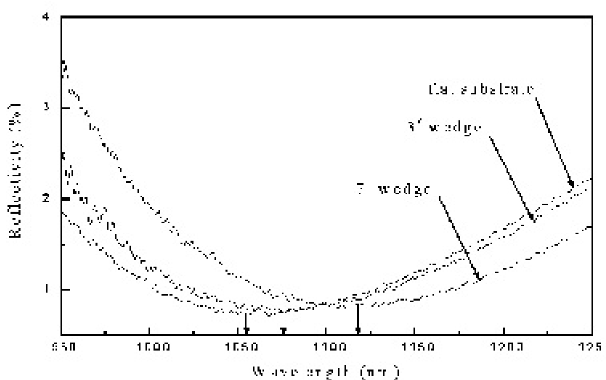

Fig. L.5.1 *Specular reflection spectra obtained at the centre of the AR coated substrates of different wedges angles*

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L.6 Highly stable operation of regenerative amplifier for Table Top Terawatt Nd:glass laser system

Ultra-short laser pulses of energy several orders of magnitudes higher than that available directly from a mode locked oscillator, are required for many investigations and applications. Such pulses are amplified using the Chirped Pulse Amplification technique. In such a system, one stretches a short pulse in time by frequency chirping, amplifies the same and then recompresses it back to get an ultra short, ultrahigh intensity laser pulse. A high gain preamplifier (generally a regenerative amplifier) is required to boost the seed pulse energy from a mode-locked oscillator of a few nJ level to tens of mJ level. A highly stable operation of this large gain amplifier is extremely important for a stable output of the compressed laser pulse. For the Table Top Terawatt Nd:glass laser system built at Laser Plasma Division, a highly stable operation of the Nd:glass regenerative amplifier has been accomplished with a gain of $3x10^7$ in 61 round trips with a shot-to-shot fluctuation in the output less than ± 5%.

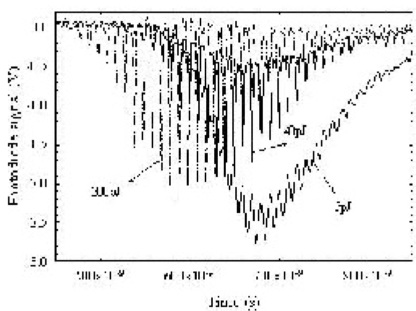

Fig. L.6.1 *Pulse build-up and decay in the regenerative cavity for different seed*

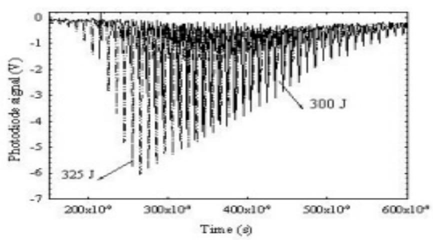

Fig. L.6.2 *Pulse build-up and decay in the regenerative cavity for different pump energies*

The above amplifier is basically a flash lamp pumped cavity dumped injection Q-switched Nd:glass oscillator. It comprises of a pulse injector, a resonator cavity, and a pulse ejector. Two major factors, which affect its output energy stability are: 1) gain fluctuations and 2) seed pulse energy fluctuation. Gain fluctuation changes the peak output energy and its temporal occurrence, and hence affects output energy. Fluctuations in injected pulse energy primarily change the intra-cavity peak pulse timing, which causes output pulse energy variations when the regenerative pulse is switched out at a fixed time. For flash lamp pumped systems (like ours), shot-to-shot output pulse energy is mainly limited by the gain (pump energy) fluctuations in the amplifier cavity. Two techniques for energy stabilization namely, negative feed back system and cavity dumping at a fixed energy rather than at a fixed time, are mostly used. All these techniques have their own limitations. We have therefore studied the stability condition both, theoretically and experimentally, considering various sources of fluctuations in gain and losses in the amplifier. Typical pulse build-up and decay in the regenerative cavity for different seed pulse energies and pump energies are shown in the fig. L.6.1 and fig. L.6.2. The output energy fluctuations are found to be reduced by factor of 10 by ejecting the amplified pulse with delay of 5 round trips after the pulse has built up to its peak level. The experimental results were found to be in close agreement with the simulation results [for details see: *A. K. Sharma, M. Raghuramaiah, K .K. Mishra, P. A. Naik, S. R. Kumbhare, and P. D. Gupta, Opt. Commun. 252, 369, 2005*]. This stable amplification via interplay between the gain and loss of amplifier is advantageous in terms of less complexity and minimum material dispersion in the amplifier compared to using additional control circuitry or active stabilization mechanism.

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L.7 Laser light scattering and x-ray emission from laser heated gas clusters

Interaction of intense laser pulses with atomic clusters of noble gases is of considerable scientific interest and has technological applications, such as, production of high-energy electrons and ions, intense x-ray emission etc. These targets, while retaining the advantages of an overall low-density gas and debris-free operation, offer very high local (solid) density, leading to strong laser heating. The dynamics of laser driven cluster explosion determines the details of laser coupling, which in turn affects the production yield of electrons, ions and x-rays. Optical scattering from these cluster plasmas is an important means of characterizing the dynamics of laser-cluster interaction. Our experimental study on scattering of laser light from argon gas clusters irradiated by multi-picosecond Nd: glass laser pulses at a laser intensity of 10^{15} W/cm^2, and the x-ray emission from these clusters have yielded some interesting results and provided a better insight in to the dynamics of intense laser-cluster interaction.

Contrary to the expectation, the space-resolved side-scattered laser light was observed to have only a blue-shifted and broadened spectrum with no red component. Scattered signal intensity and average blue-shift exhibited marked dependence on backing pressure of the gas. At a backing pressure of 70 bar, the maximum blue shift is as large as 6 nm (see fig. L.7.1). The occurrence of large blue shift and absence of any red shift are explained from self-phase modulation accumulated by the laser radiation in its passage through the cluster plasma during resonance interaction phase in the