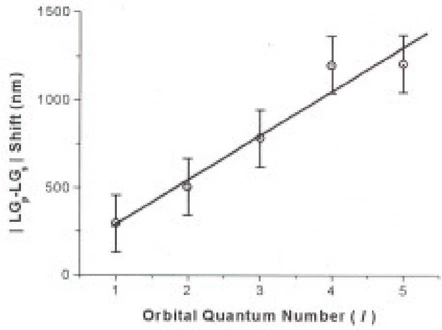

***Fig. L.3.2** The variation of absolute value of relative transverse shift with changing orbital quantum number.*

In fig. L.3.1 we show the measured differential transverse shift of the reflected LG beams for a range of angle of incidence (~ 20° to 80°). Measurements could not be carried out in the vicinity of Brewster angle (~ 56°) because of the low reflection coefficient. The measured differential LTS is in good agreement with the theoretical predictions (shown by solid line in fig. L.3.1). The dependence of the measured LTS on azimuthal index of LG beam for a fixed angle of incidence (81°) is shown in fig. L.3.2. The linear dependence of the shift on orbital quantum number of the beam can provide an attractive non-interferrometric method for measurement of OAM [*R Dasgupta and P K Gupta, to appear in Optics Communications*].

(Contributed by: P. K. Gupta; pkgupta@cat.ernet.in)

L.4 Design and fabrication of electro-optic modulator based on $LiNbO_3$

Light waves can be made to carry information, by modulating their intensity, phase, frequency or polarization. Among these, the intensity modulation is the most popular for optical fibre communication systems, primarily due to the simplicity of envelope photo detection. The intensity modulation can be implemented simply by direct modulation of the laser sources. Due to the requirements of bandwidth and efficiency, only semiconductor lasers are of practical interest for direct modulation. Several types of modulators have been developed over the past several decades for optical fibre communication applications. These include lithium niobate ($LiNbO_3$) modulator, semiconductor electro absorption modulators (EAMs), semiconductor Mach-Zehnder modulator and polymer modulators.

Electro-optic modulators use an electric field to alter the characteristics (band gap, index of refraction) of a material through which light is travelling, thus changing the characteristics of the light itself. The $LiNbO_3$ has always been preferred over other comparative materials due to its high electro-optic (EO) coefficient, non-hygroscopic nature, hardness and mechanical strength. Moreover as the optical communication wavelengths fall in the ranges 1.3 μm and 1.55 μm and optical distortion for $LiNbO_3$ is negligible for wavelength $\lambda > 1 \mu m$, its figure of merit is highest for these applications. The change in index of refraction of the material can be used to modify light passing through the material. Modulators are key components for high-speed optical transport systems. They modulate laser output into high-speed light pulses that transmit voice, data and video signals over fibre-optic cables. The electro-optic modulator based on lithium niobate presently operate at 40 gigabits per second (Gbps) which is the highest speed commercially available in optoelectronic devices. This is four times faster than current-generation based modulator products.

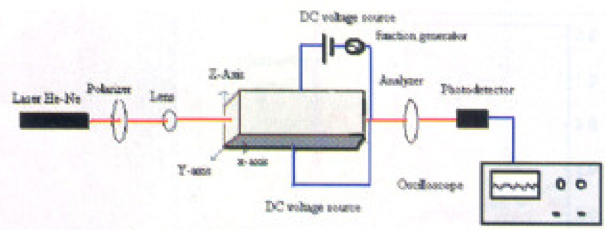

***Fig. L.4.1** Schematic of experimental set up used for modulation*

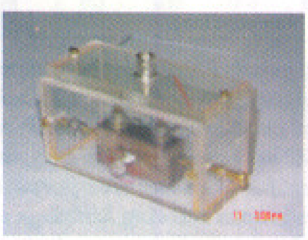

***Fig. L.4.2** $LiNbO_3$ Modulator module*

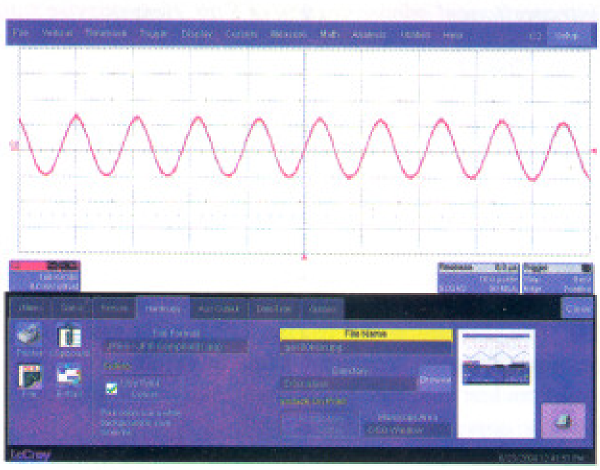

***Fig. L.4.3** Modulated out put signal at 100 kHz*

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.

(Contributed by: S. Kar, R. Bhatt, K.S. Bartwal; bartwal@cat.ernet.in and T.P.S.Nathan)

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°) 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.

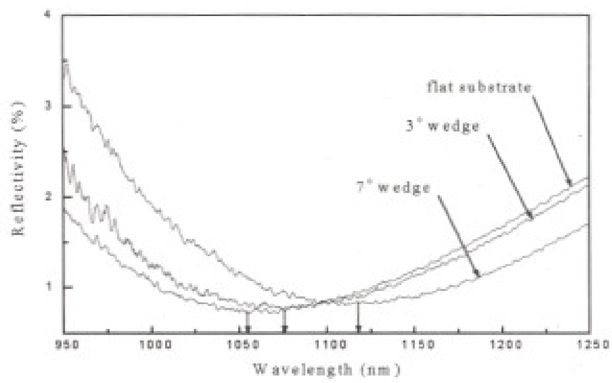

Fig. L.5.1 *Specular reflection spectra obtained at the centre of the AR coated substrates of different wedges angles*

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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