Section 1
LASER SYSTEM REPORT

1.A OMEGA Facility Report

Initial steps were undertaken at LLE to characterize the uniformity of illumination on the target surface. The theoretical modeling of target illumination as well as preliminary beam propagation tests were reported in Volume 4 of the LLE Review. During this quarter the OMEGA laser system was used to provide laser system code normalization data as well as study the pointing and focusing of the laser on laser fusion targets.

The pointing and focusing of OMEGA beams was studied by photographing the x-ray emission of targets irradiated by two or six OMEGA beams. Several target shots studying these effects were taken during this period. The x-ray photographs were digitized and compared with an expected x-ray emission distribution. Figure 1(c) shows a result of a six beam shot on an empty glass microballoon 231 μm in diameter with 2.5 μm wall thickness. The laser was operated with a pulse width of 257 psec and an energy of 228 J on target. Figure 1(a) shows the six beam geometry as viewed by the x-ray pinhole camera; Fig. 1(b) shows the x-ray contours of constant intensity calculated from the photograph in Fig. 1(c). This result shows the OMEGA beams to be pointed to better than 8 μrad on target. This has provided initial verification of the ability to conduct target experiments on OMEGA with a high degree of confidence in the system alignment. More extensive calibration shots will be performed on OMEGA during the next quarter.

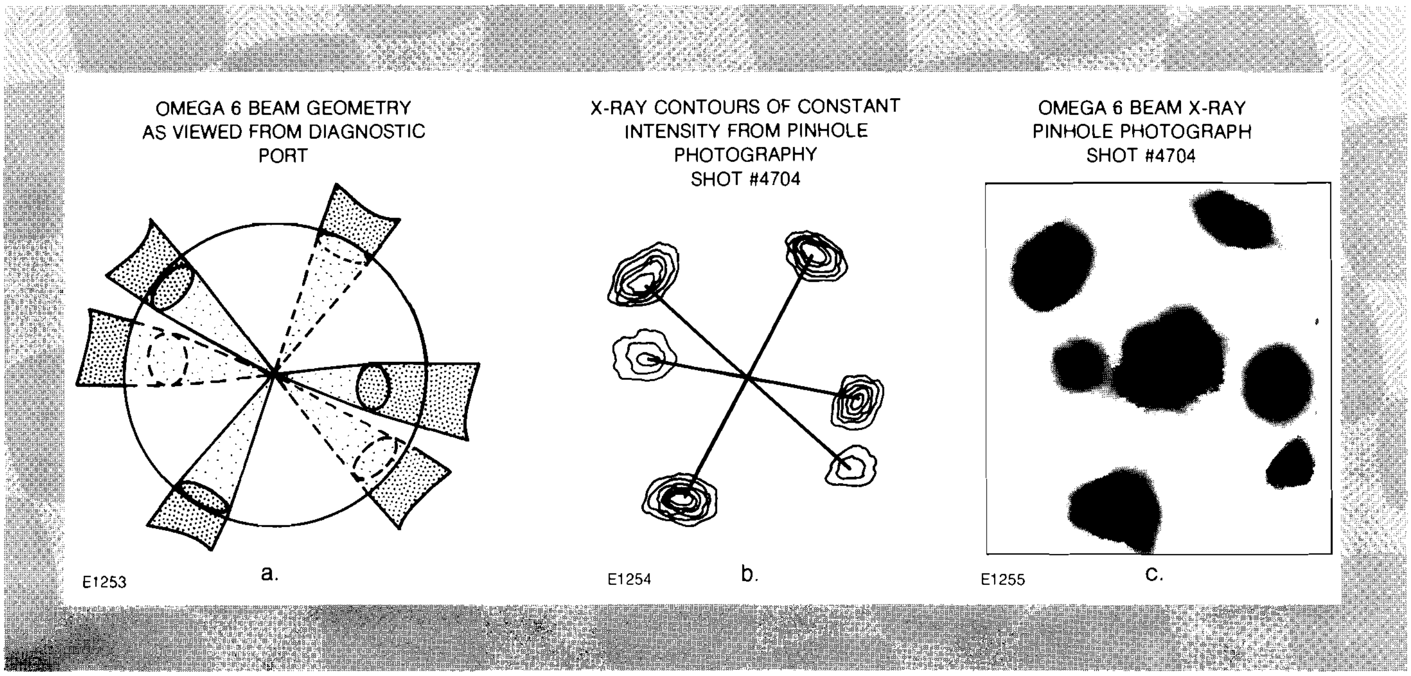

Fig. 1
The geometry of irradiation on the surface of an OMEGA target as viewed from the pinhole camera diagnostic port (a), a sample x-ray pinhole photograph (c), and a plot of equal intensity contours from the pinhole photograph (b), show that the OMEGA laser beams are pointed to better than 8 μrad.

A program was formulated this quarter to further pursue the evaluation of the present performance of OMEGA to provide an understanding of the intensity profile on-target and to allow normalization of several propagation codes.

The first four laser amplifiers in the OMEGA system (called the driverline) are the most critical for affecting the laser output spatial intensity profile because of the large magnification (60X), the high gain (4×10^6) and the nonuniform radial gain profiles. These four laser amplifiers were removed from the system and their small signal radial gain profiles were measured to improve our existing data, which was for a different laser glass composition and neodymium doping. The details of the measurements are reported in LLE Report #110. This data will be used to model the performance of this important section of the laser. This capability will allow us to evaluate various driverline configurations in order to optimize the output intensity profile of OMEGA.

Near field photos were taken at the locations shown in Fig. 2 to provide additional data for normalizing the propagation codes. Digitization and processing of these images will proceed through the next quarter. Each piece of film was individually calibrated with a series of spots which vary by a known intensity ratio. This will allow accurate calculation of the beam intensity from the photo density. These photos were taken with a pulse width of 600 psec. Additional short pulse photos will be taken in the future.

Additional testing of the quality of an OMEGA beam at the target will be conducted in the next quarter.

The Laboratory for Laser Energetics is proceeding on a program to do direct-driven implosions at short wavelength (around 350 nm) on OMEGA. These experiments require nanosecond pulse widths, so a second oscillator was brought on-line on OMEGA to produce pulses of 600-700 psec. This oscillator, and the existing short pulse oscillator, provide OMEGA with the flexibility to operate at the 100 psec and 700 psec regimes with a minimal change-over time. This longer pulse oscillator is an active-passive cavity similar to the short pulse oscillator which has been running on OMEGA for several years.[1] A more flexible oscillator similar to the Kuizenga oscillator of LLNL[2] will be put on-line on OMEGA during the third or fourth quarter.

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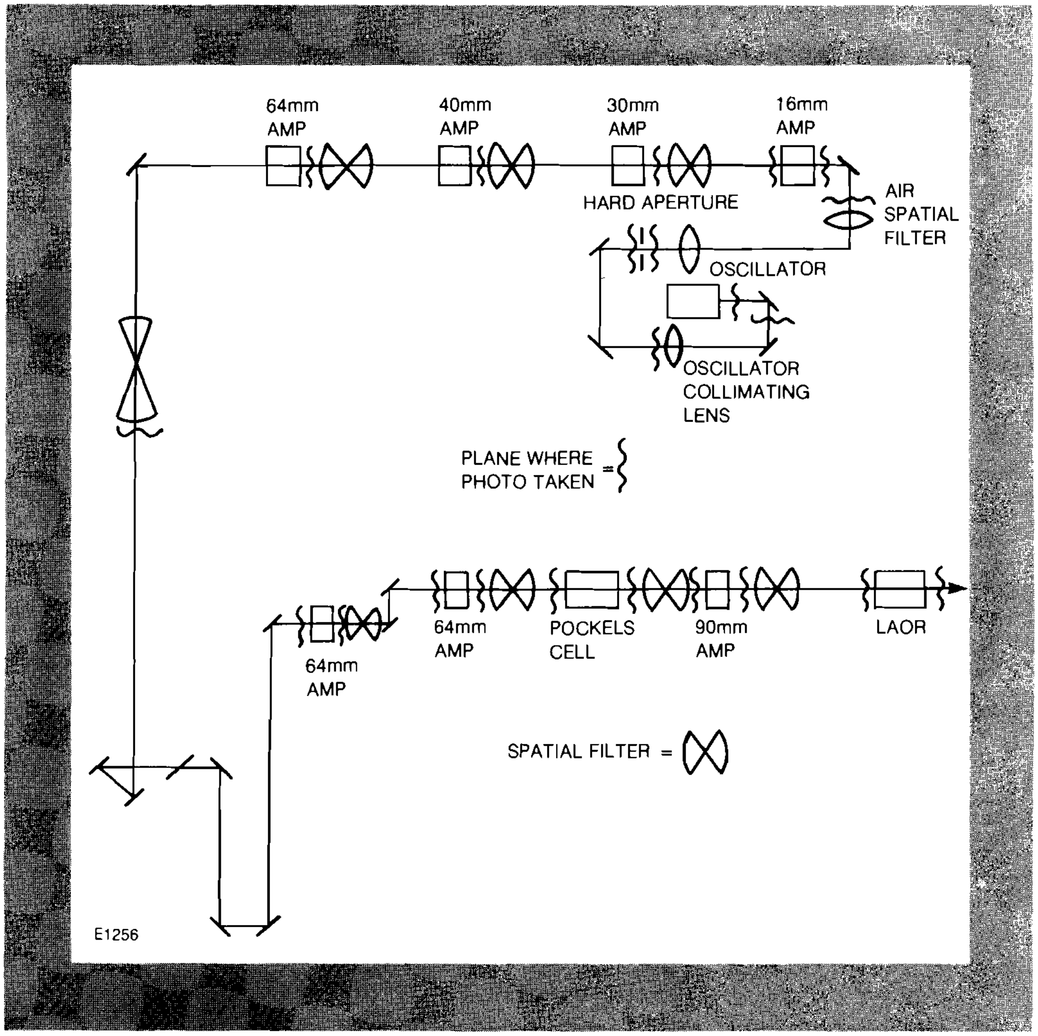

Fig. 2
Near field photograph locations for propagation code normalization. Comparison of actual intensity distribution are made with calculated intensity distribution at these locations.

1.B GDL Facility Report

During the first quarter of FY 1981, GDL began operations as a 0.35 μm irradiation facility. The basis of this facility is the Glass Development Laser system originally constructed as a prototype of an OMEGA beam line.[1] With the addition of frequency conversion crystals, ultraviolet optics and an ultraviolet alignment and beam diagnostics system, the facility is now one of the most powerful ultraviolet irradiation systems in the world. The current capabilities of the GDL 0.35 μm facility are listed in Table 1. Later in the year the capabilities of this system will be enhanced with the addition of faster optics (f/3) and crystals optimized for longer pulse operation.

ON TARGET POWER:	200 GW (100 psec) @ 0.35 μm
ON TARGET ENERGY:	50J (450 psec) @ 0.35 μm 25J (100 psec) @ 0.35 μm
ON TARGET INTENSITY:	10^{12} to 5×10^{15} W/cm^2
FOCUSING OPTICS:	f/12 Quartz Lens
SPOT SIZE:	80 - 800 μm Diameter
FUNDAMENTAL AND SECOND HARMONIC SUPPRESSION:	10^4 in Intensity 10^2 in Energy

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Table 1
Current capabilities of GDL, 0.35 μm irradiation facility.

The design of the frequency conversion system used on the GDL 0.35 μm irradiation facility was based on the development work conducted on GDL in 1980.[2,3] Design details of the system are presented elsewhere in this report. During the first quarter of FY 81, the system was operated in short pulse mode (100 psec FWHM at 0.35 μm) for frequency conversion tests, coating damage tests, and initial interaction experiments.

The facility delivered a total of 409 shots during this time. The shot distribution was as follows:

3ω Conversion Tests	171 Shots
3ω Diagnostics C/O	63
3ω Target Experiments	48
Damage Test Facility	106
Beam Alignment	11
Failed Shots	10
TOTAL	409 Shots

Figure 3 illustrated the excellent stability of both the GDL driver and the frequency conversion system.

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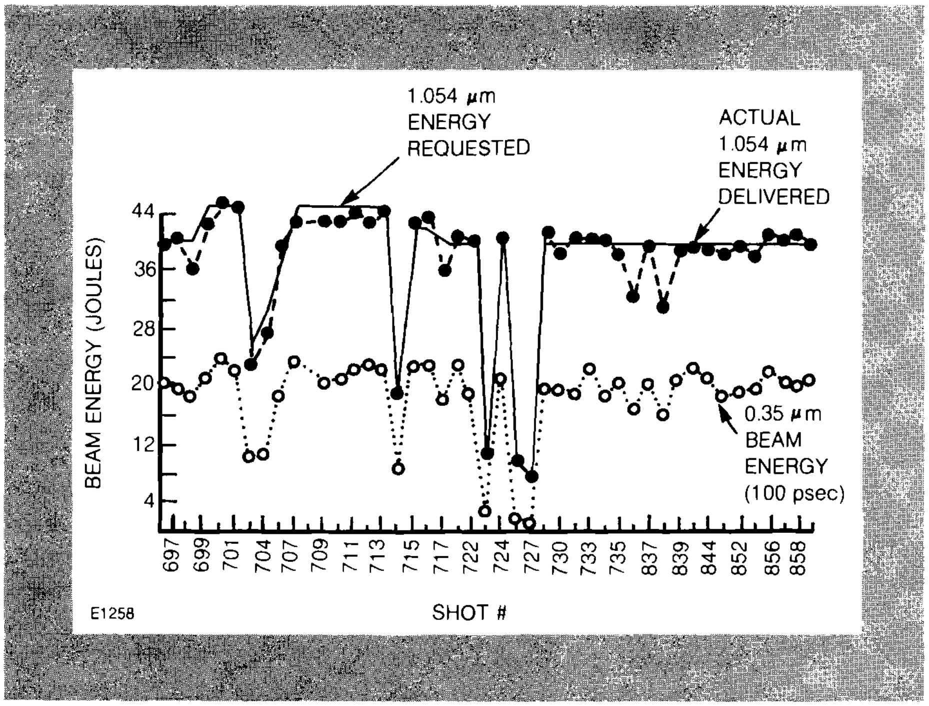

Fig. 3
GDL 0.35 µm irradiation facility performance on 0.35µm target shots during the period 3-20 November, 1980. The solid lines shows the 1.054 µm energy requested by the experimentalists, the filled dots show the actual 1.054 µm energy delivered to the conversion crystals and the open dots show the 0.35 µm energy delivered to the target. All of the shots were at a pulse width of 100 psec at 0.35 µm.

1.C Liquid Crystal Devices for High Power Lasers – Part I: Optical Isolators

Liquid crystals constitute a unique state of matter. They can flow over surfaces as easily as liquids, and yet they possess a long range structural order characteristic of crystalline solids. Liquid crystal compounds are not rare. Over 20,000 compounds have been found or synthesized since their discovery in 1888.[1,2] These substances have found a wide range of applications and are commonly used as numerical displays in calculators and watches, as thermometers, in computer information displays,[3] in electronic games, and even as an artistic medium for paintings.[4]

There are three recognized classes of liquid crystals: smectic, namatic and cholesteric. Each class is distinguished by the way its individual molecules align. This article describes cholesteric liquid crystal compounds and how they might be used as large aperture optical isolators (or one way light valves) in the laser systems at LLE. Nematic compounds and their possible uses at LLE will be discussed in LLE Review #6.

All laser systems used to investigate inertial confinement fusion must focus their optical radiation onto small targets. Infrared glass lasers like LLE's OMEGA risk damage to their optical components if infrared radiation reflected off a target surface is allowed to propagate back onto the laser system. Optical isolators are therefore placed at the output of each laser beamline. These devices permit light propagation only in a forward (to the target) going direction, acting as optical light valves to stop the propagation of any back reflected radiation. Three technologies capable of providing isolation are the Faraday rotator[5] (used on Shiva[6] at LLNL, Gekko IV[7] at Osaka, and on numerous other systems) the plasma shutter[8] (being developed for Nova at LLNL[9]), and the large aperture optical retarder (LAOR) currently used on OMEGA at LLE. The liquid crystal isolator[10] offers an attractive fourth alternative.

Unlike the Faraday rotator or plasma shutter, the liquid crystal isolator (LCI) is a passive device that requires no electronics, electric or magnetic fields, or synchronization with the firing of the laser system. It consists simply of a glass cell filled with a thin layer of liquid crystal material. Figure 4 shows schematically how the LCI works. Right-hand circularly (RHC) polarized infrared radiation generated from a laser system passes unattenuated through the LCI and propagates to the target. A portion of the light not absorbed by the target is specularly reflected and undergoes a 180° shift in its phase of vibration. The polarization sense of this retroreflected light is now left-hand circular (LHC), and the liquid crystal cell will not permit this state of polarization to pass.

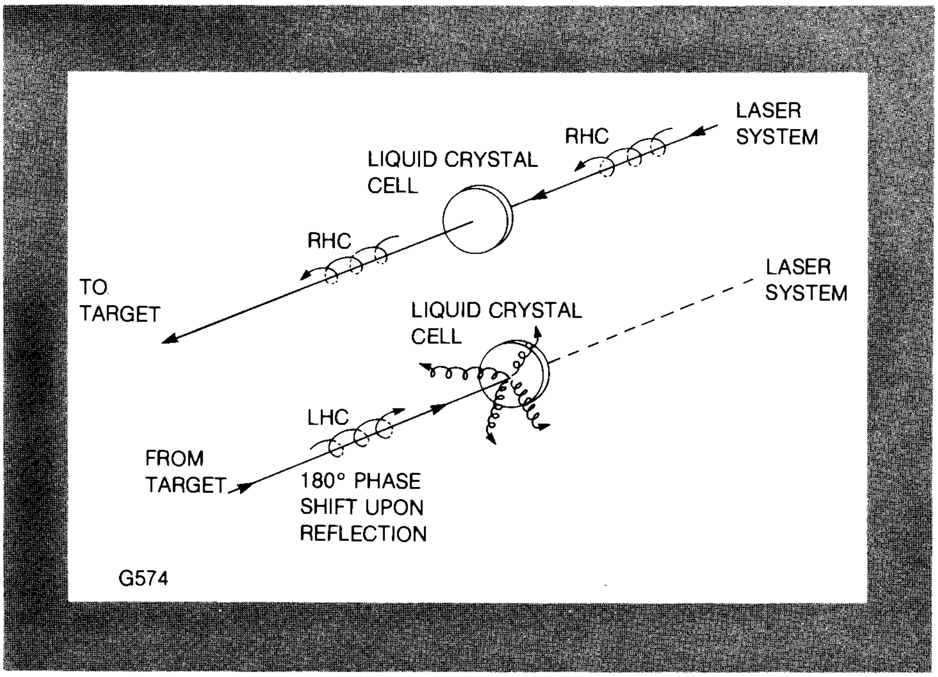

Fig. 4
Schematic diagram of liquid crystal isolator. Liquid crystal cells may be used to provide protection of the laser system from back reflections from the target. In this illustration the liquid crystal cell is shown to pass right-hand circularly polarized (RHC) light to the target but will block the reflected left-hand circularly polarized (LHC) light.

Advantages of the LCI include its large aperture capability; low optical loss for light propagating in the forward direction; high contrast ratio or blocking ability for backward propagating light; simplicity of fabrication, installation and operation; and low cost.

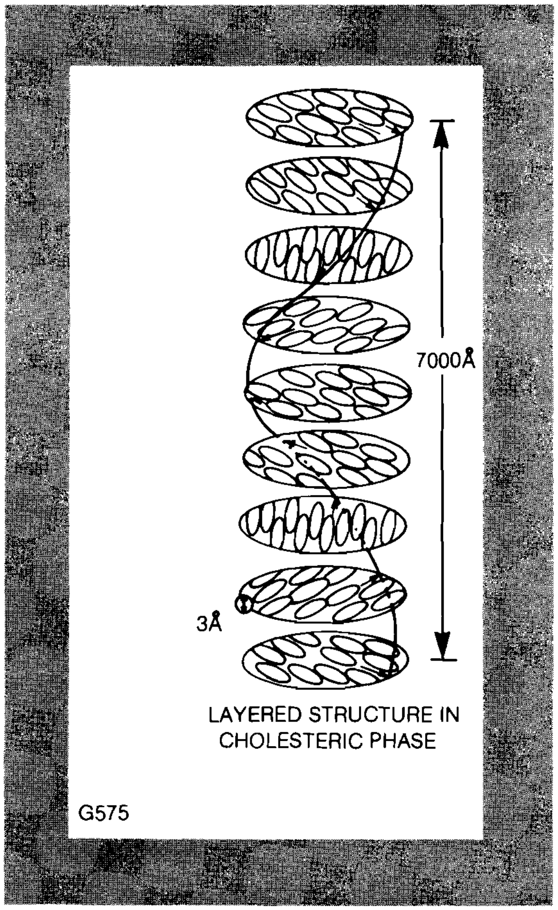

Fig. 5
Layered structure of cholesteric molecules. Cholesteric molecules are arranged with their molecular dipole moments oriented from layer to layer in a helical screw sense. The helix pitch will vary depending on composition, temperature, and mechanical stress.

The circularly polarized output characteristic of LLE laser systems[11] is ideally suited for input to a LCI.

The principle of operation within the liquid crystal itself can be described by referring to Fig. 5. The cholesteric class of liquid crystals consists of long chains of carbon and hydrogen atoms, bonded together in a manner characteristic of the substance cholesterol[1] (hence their name). Additional side chains give each cholesteric molecule a rod-like shape roughly 0.3 nm in diameter and 3 nm long. Cholesteric liquid crystals form a layered structure when placed between flat glass plates. Within a given layer (see Fig. 5) all molecules preferentially align with the direction of their long axes (directors) parallel to each other. In the next layer, spaced some 0.5 nm away the molcules are likewise aligned with long axes parallel, but the protrusion of side groups forces the directors to be rotated some 10-30 minutes of arc away from that of the previous layer. Figure 5 shows that the directors (indicated every 150 layers within the cholesteric) trace out a helical path. The distance required for the directors to rotate 360° is called the pitch, *p*, of the cholesteric liquid crystal.

The helical screw-sense of the cholesteric liquid crystal phase is the key to the LCI's principle of operation. Light propagating up through the layers depicted in Fig. 5 with a sense of circular

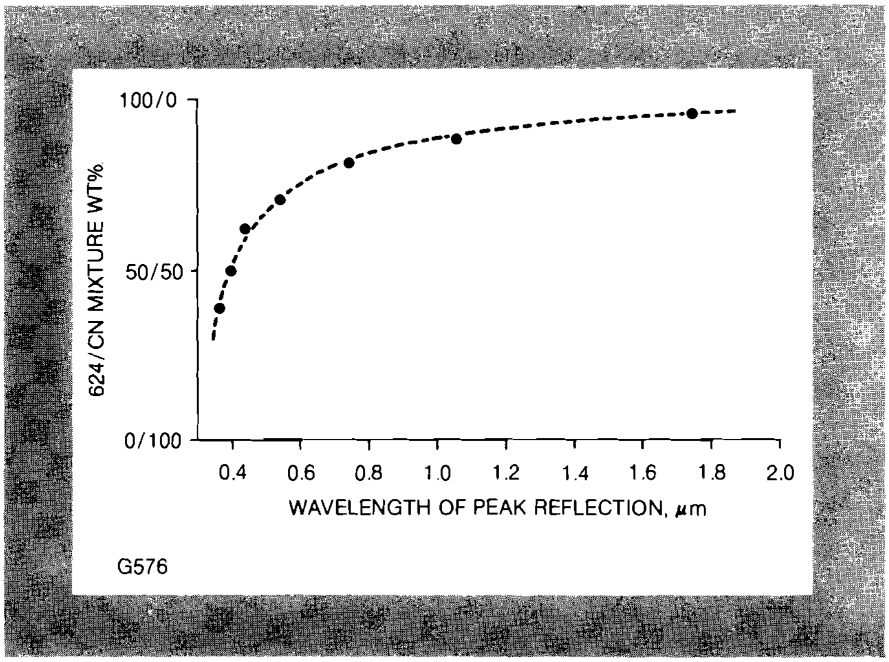

Fig. 6
Wavelength of peak reflection for different 624/CN mixtures. The wavelength for peak reflection from a cholesteric liquid crystal combination can be varied by adjusting the ratio of the mixture.

polarization opposite to that of the molecular helix will be transmitted unattenuated through the material. Light circularly polarized with the same screw-sense of the molecular helix will encounter constructive interference as it propagates from layer to layer,[4] eventually being totally reflected. This difference in transmittance for LHC versus RHC polarized light (called circular dichroism) is exhibited by the cholesteric only at a wavelength that satisifies the equation[12]

$$\lambda_{max} = n \text{ (index) } p \text{ (pitch)}$$

where n is the average refractive index of the liquid crystal. The wavelength of maximum selective reflection can be controlled easily by varying the pitch, p, through changes in liquid crystal composition.

Chemical stability with aging and temperature insensitivity are desirable for cholesteric compounds used in LCI cells. Figure 6 shows how, by varying the proportions of two commercially available left-handed cholesterics, one can tune the selective reflection peak into the infrared. A stable mixture tuned to $\lambda = 1.05\ \mu m$ has been used to fabricate a number of LCI cells for on-line tests at LLE.

A typical cell consists of a 12 μm thick layer of cholesteric liquid crystal material sealed between two externally AR coated 100 mm diameter optical glass windows. Measurements with the 64 mm rod output of the GDL laser system have found such cells to transmit 97% in RHC polarized light and 0.7% in LHC polarized light, thus providing a contrast ratio of better than 130:1. Separate tests have determined the 1.054 μm laser damage threshold of the cholesteric combination (see Fig. 6) to be greater than 20 GW/cm^2 at 700 psec. Cells have exhibited no degradation of optical properties over the past fourteen months.

In summary, the liquid crystal isolator offers an attractive alternative to presently used devices. LCI's are readily scalable to apertures larger than 100 mm, possess low insertion loss and good optical isolation, show minimal temperature sensitivity, and exhibit good long-term chemical stability. LCI's are passive devices, whose design simplicity could offer considerable cost advantages if implemented on a large aperture multiple beamline laser system.

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