and neodymium (λ = 1.06 μ) free-running lasers. At a sufficiently uniform distribution of the radiation-field amplitude, interference gratings with up to 1000 lines/mm were obtained, comprising alternating sections with different spectral and structural properties. The figure shows an electron-microscope picture of an interference grating with 700 lines/mm, recorded on a GeTe film by neodymium laser radiation. A connection was established between the conditions under which the samples were prepared and the maximum attainable grating line number. There are optimal values of the radiation energy for the production of gratings in the pulsed regime. For example, the energy needed to produce a grating on a GeTe film by a neodymium-laser pulse of $\sim$500 μsec should be $\sim$0.1 J/mm^2.

In the obtained samples, the efficiency (E_{inc}/E_{trans}) was 1 - 4% when an LG-56 He-Ne laser was used. Encouraging results were obtained also at $\lambda \sim$ 10.6 μ. Thus, spatial structures on the order of $\sim$10 lines/mm could be recorded with a CO_2 laser operating in the continuous regime, and this is apparently not the limit. In this case, obviously, an overall heating of the sample takes place and leads to a "blurring" of the image during an exposure time $\sim$1 sec at an energy density $\sim$20 W/cm^2 in the plane of the film.

Depending on the density of the recorded grating, we observed two types of structure changes accompanying the recording of the information in the films. When a grating with $\sim$100 - 200 lines/mm was recorded, the lines were strips of polycrystalline material separated by amorphous film sections. In the case of gratings with $\sim$100 lines/mm an increase of grain was observed in the entire area of the film section processed by the light radiation, but the optical density of the lines of the interference grating was different, making it possible to obtain in this case a grating with sufficient efficiency.

We are continuing further research on the kinetics of the phase transition from the amorphous to the polycrystalline state in the indicated materials and in many others, as well as investigations of the use of these films as carriers for the recording of information in the visible and infrared regions of the spectrum.

In conclusion, we are grateful to V.D. Samoilov for useful discussions.

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PHASE MODULATION OF COHERENT LIGHT WITH THE AID OF LIQUID CRYSTALS

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1. We report here investigations of the effect of phase modulation by means of an electric field, of coherent light passing through a nematic liquid crystal with positive isotropy of the dielectric constant ($\varepsilon_{\parallel} > \varepsilon_{\perp}$). Such a

modulation permits the use of thin transparent liquid-crystal films in controlled phase transparents and makes it possible to increase the speed of optical information processing compared with the speed of other optical switches using liquid crystals.

2. Assume that a thin liquid-crystal film of the indicated type is placed between flat transparent electrodes, and the optical axes of the domains are aligned by rubbing in a definite direction along the planes of the electrodes. In such a case, the liquid-crystal layer is a uniaxial-crystal plate. An external electric field, by orienting the ensemble of molecules along the field [1], changes the direction of the optical axis of the plate domains. For a light wave incident normally to the plane of the liquid-crystal layer, this leads to a change in the refractive index, which is determined from the ellipse produced by the intersection of the optical indicatrix (ellipsoid of revolution) with the plane perpendicular to the propagation of the light wave. Let us consider the simplest case, when the light vector $\vec{E}$, the optical axis of the crystal, and the direction of propagation of the light lie in the same plane. If the directions of the optical axis of the crystal and the vector $\vec{E}$ coincide (angle $\theta = 0°$), then the refractive index is equal to the refractive index of the extraordinary ray n_e. At $\theta = 90°$, i.e., when the domains are oriented under the influence of the electric field along the field (along the direction of light propagation), n is equal to the refractive index for the ordinary ray n_o. When the domains are rotated from $\theta = 0$ to $\theta = 90°$, the phase of the light passing through the liquid crystal changes by an amount

$$\Delta\Phi = 2\pi\delta\lambda^{-1}(n_e - n_o),$$

where λ is the wavelength of the light and δ the thickness of the liquid-crystal layer.

3. In the present investigation, the change of the phase of light passing through the liquid crystal was registered by observing interference of light reflected from the rear and front electrodes. We used the liquid crystal 4'-ethoxybenzylidene-4-aminobenzonitrile, in which the temperature interval of the existence of the nematic phase was 106 - 120°C. A layer thickness $\delta \simeq 10$ μ was produced with the aid of teflon liners. The refractive indices n_e and n_o, measured in a thin layer of liquid crystal by an interferometric procedure, were respectively 1.84 and 1.47 for $\lambda = 0.63$ μ at t = 120°C. For these data, at an electric field intensity ensuring complete orientation of the domains along the field direction, with the laser beam ($\lambda = 0.63$ μ) normally incident on the plane of the electrodes, the intensity of the transmitted light should vary between zero and the maximum m times, where m is determined from the condition $2\Delta\Phi = 2\pi m$ and is almost equal to 10. The coefficient 2 appears here as a result of allowance for the double passage of light through the crystal.

A similar picture of the variation of the light intensity, but in inverse order, should be observed also when the crystal relaxes to the initial state. This is confirmed by the oscillogram of Fig. 1a. Rapid orientation of the crystal in the direction of the electric field was effected by a field pulse of duration $\tau_p = 2$ msec. The oscilloscope sweep is comparable with the relaxation time of the crystal and we see therefore that when the crystal returns to the initial state with $\theta = 0°$ the intensity of the transmitted light is modulated ten times. The number of maxima will obviously decrease if the initial orientation of the molecule is changed so as to increase the angle θ by the dc component of the electric field. Figures 1b and 1c show the influence of the increase of the dc component, and in Fig. 1b the change of the light intensity was registered within a time equal to the duration of the voltage pulse τ_p.

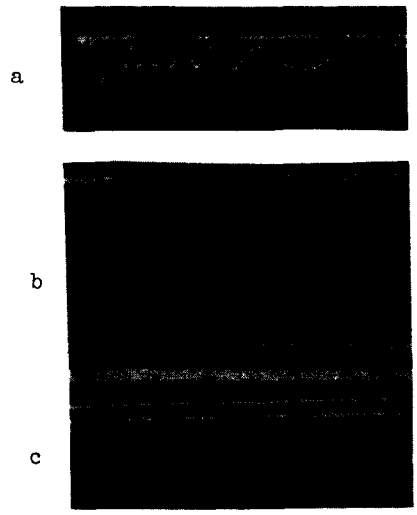

Fig. 1

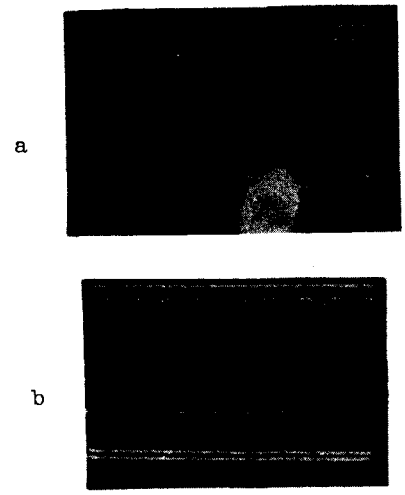

Fig. 2

Fig. 1. Change of light intensity I_L for different values U of the dc component of the electric field. Field pulse duration 2 msec, amplitude 75 V, repetition frequency 2.2 Hz. The upper straight line marks the level $I_L = 1$: a - E = 0, b - E = 3.2 V, the time sweep rate is increased 20 times compared with the other frames. The lowest straight line marks the level U = 0, c - U = 7 × 4 V.

Fig. 2. Modulation of light intensity I_L by electric pulses (duration 60 μsec, amplitude 50 V) with repetition frequency 200 (a) and 2000 Hz (b). The upper and lower straight lines mark the zero level of I_L and of the dc component of the electric field, respectively.

In estimating the frequency characteristics of the phase modulation of the light in a liquid crystal, we assumed the change in the phase under the influence of the electric-field pulse not to exceed π. The dc component of the field was chosen in this case such that the intensity of the transmitted light was minimal in the absence of the pulse. Figure 2 shows oscillograms obtained at electric-field pulse repetition frequencies 200 and 2000 Hz (at equal oscilloscope sweep rates). It is seen that for the given pulses, if the total relaxation of the domains to the initial orientation is maintained, the frequency can be increased approximately to 4 kHz. Such a rate, obtained in the preliminary experiments, is already 80 times larger than the limiting frequency given in [2] for optical switching in a liquid crystal.

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