DYNAMIC HOLOGRAPHIC GRATINGS IN CADMIUM SULFIDE

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A number of media suitable for the recording of phase holograms in the dynamic regime are known at present. These are ferroelectric crystals, in which the change of the refractive index is due to a redistribution of the space charges [1] and the time constant fluctuates between 0.1 and 10^3 sec, solutions of absorbing media with recorded thermal holograms (10^{-4} – 10^{-6} sec) [2], and silicon crystals ((2 – 3) 10^{-8} sec) [3]. We report here the results of an investigation of dynamic holographic gratings in CdS crystals, with a characteristic lifetime not larger than 5×10^{-9} sec, i.e., the shortest known at present.

To record the holograms we used the beam of a Q-switched ruby laser, operating in a single-transverse mode regime. The Q-spoiler was a solution of cryptocyanine in ethanol. The laser beam was passed through a biprism, and the resultant two beams converged at an angle 20'. A plane-parallel CdS crystal of thickness t = 0.1 cm and with polished faces was placed in the region of maximum overlap of the beam. The light produced in the crystal a priodic distribution of the refractive index, and the light was diffracted by the resultant grating. Besides the two

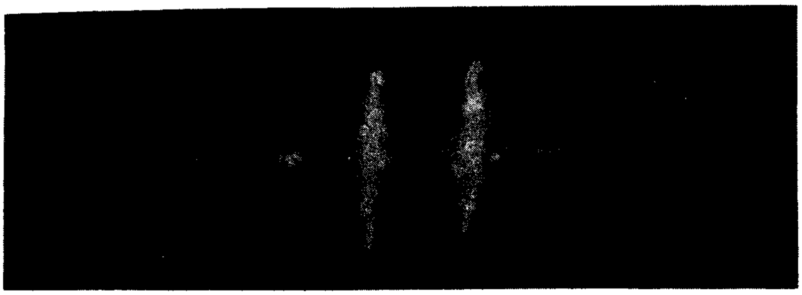

Fig. 1. Self-diffraction of ruby-laser radiation by the recorded grating. The distance between diffraction orders is 20 minutes of arc.

transmitted zero-order beams, the "±1" and higher diffraction orders were also observed past the crystal (Fig. 1).

At a recording-radiation power on the order of 50 MW/cm , the diffraction efficiency, i.e., the ratio of the intensity of the diffraction of order "±1" to the intensity of one of the incident beams was ∿ 4%. Successive recording of holographic gratings in one and the same location in the crystal failed to show any accumulation effects whatever.

The ruby-laser radiation lies in the transparency region of crystalline CdS. The very weak absorption (β = 0.02 cm/MW) [4] is due to two-photon transitions to the conduction band. The sufficiently high diffraction efficiency, the presence of diffraction orders higher than the first, and also the weak initial absorption, all offer evidence that the holographic-grating record is of the phase type.

At a given convergence angle and crystal thickness, we have in accordance with the Kogelnik criterion [5]

$$Q = \frac{8\pi t}{\lambda} \sin^2 \frac{\theta}{2}\ 3 \cdot 10^{-2} << 1$$

and a thin phase hologram should be observed. The presence of many diffraction orders confirms this assumption. The intensity of the "m = 20" order of the diffraction can in this case be determined from the formula

$$I_m = I J_m\left(\frac{2\pi \Delta n t}{\lambda}\right),$$

where $J_m(2\pi\Delta nt/\lambda)$ is the value of the Bessel function of order m when its argument is equal to the phase advance $2\pi\Delta nt/\lambda$ over the grating thickness, and I is the intensity of the recorded pulse. Hence, knowing the efficiency of the hologram we can estimate the order of magnitude of the depth of modulation of the refractive index

$$\Delta n \approx 10^{-5}.$$

The temporal characteristics of the radiation were investigated with the aid of an oscilloscope and a coaxial photocell with a resolution not worse than 10^{-9} sec. The ruby-laser pulse was symmetrical in form and its duration was 15 — 20 nsec. The duration of the diffracted pulse was smaller by a factor 1.5 — 2 than the laser-pulse duration, and its shape varied slightly from sample to sample (Fig. 2). Numerous measurements have shown that the diffracted-radiation pulse had a very steep leading front and a somewhat stretched out trailing edge; the latter, however, was always steeper than the trailing edge of the recording laser pulse.

The sharpening of the diffracted pulse and the large slope of its front indicate that in this case the change in the refractive index of the medium, which leads to the appearance of the phase grating, is indeed nonlinear in character.

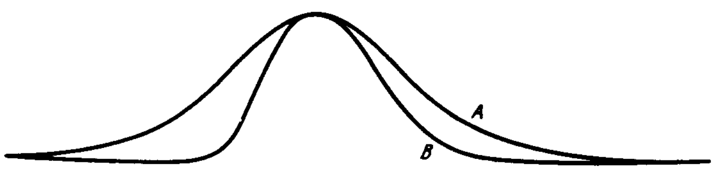

Fig. 2. Oscillograms of recording (A) and diffracted (B) pulses. Total sweep duration 50 nsec.

Earlier investigations [6, 7] have shown that the self-action of ruby-laser emission in crystals such as CdS has a complicated character and is manifest in a competition between positive and negative changes in the dispersion. The mechanism of the positive change of the dispersion is due to a considerable degree to the nonlinear polarizability of the excitons, whereas the negative change of Δn is connected with the excitation of the free carriers. Both nonlinearity mechanisms are inertialess to a considerable degree (at least for times on the order of the duration of the laser pulse). From the performed experiments it is still impossible to determine the sign of the change of dispersion in the recorded phase grating, but from the time variation of the recording and diffracted pulses one can conclude that the induced changes of the refractive index vary with the intensity of the laser pulse, with a time constant that does not exceed half the duration of the diffracted pulse.

CdS crystals of high optical grade can be grown to sufficiently large dimensions. At the given value of Δn, it is possible to record a three-dimensional hologram with a diffraction efficiency up to several dozen per cent in a sample 1 cm thick. Recognizing that the induced changes of Δn depend on the wavelength and increase when the intrinsic absorption edge is approached [8, 9], one can record the grating with ruby-laser emission, and use for the image reconstruction a different spectral region, where the depth of modulation is much higher. Another way of increasing the efficiency is to use mixed crystals, in which one can purposely shift the intrinsic absorption edge towards the working wavelength of the recording laser.

We note in conclusion that in addition to direct applications in holography, the described procedure can be used successfully to investigate the nonlinear characteristics of condensed media.

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