Diffraction and anomalous transmission of light in plastically deformed cadmium sulfide

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The diffraction of light by a quasiperiodic system of slip bands in plastically deformed CdS is investigated. An increase of the transmission, which is caused by the appearance of the Bormann effect in the visible spectrum, is observed in the dislocation-absorption region (560 nm).

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When the dislocation structure of plastically deformed CdS crystals was examined by a polarization-optical method,[1] it was noted that a situation can be realized in which the dislocations are grouped in slip bands (SB), whose distribution is close to periodic. In the dynamic theory of x-ray diffraction in a periodic structure,[2] we know of such effects as the formation of a periodic wave field and anomalous transmission (the Bormann effect[3]), which occur when the Wulff-Bragg condition $2d \sin \theta = m\lambda$ is satisfied (d is the period between the reflecting planes, θ is the angle between the propagation direction of the incident wave and the reflecting plane, λ is the wavelength, and m

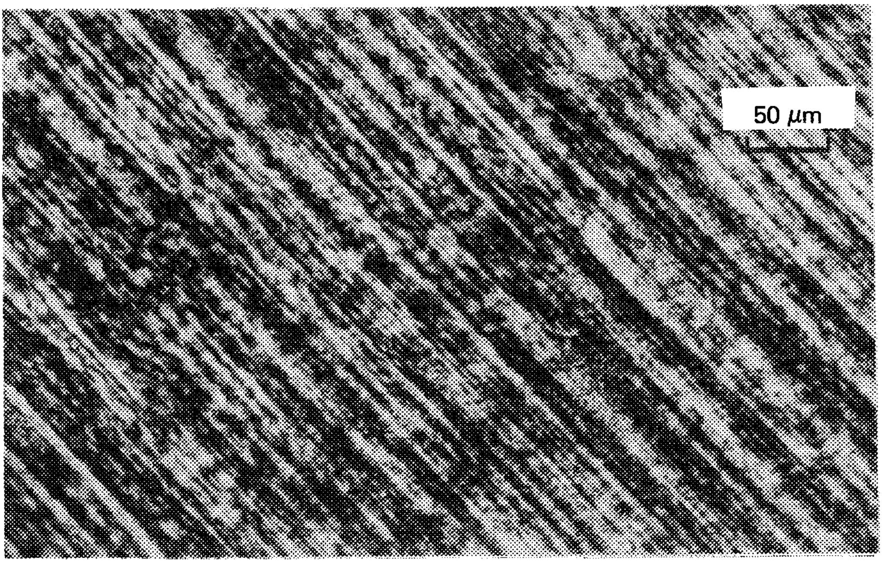

FIG. 1. Small-period intensity modulation at exit face of crystal, observed with the aid of a microscope.

is an integer). The experiments described below show that similar effects are observed when light propagates in plastically deformed CdS crystals.

The CdS samples were subjected to plastic deformation by a several-percent compression along type $\{10\bar{1}0\}$ prismatic slip planes.[4] In this case the characteristic step appeared in the transmission spectrum, which was observable in the 560-nm region for light polarization parallel to the SB.[5] After deformation, the samples were polished mechanically. The slip bands were perpendicular to the faces within a few-degree accuracy.

Light from a monochromator was transformed into a parallel beam and, after passing through a polaroid, was incident on the crystal face. The sample was mounted on the rotating stage of a goniometer; this made it possible to vary continuously the angle between the wave vector of the light and the SB.

The main results of the experiment are as follows. 1) In many samples the light-intensity distribution at the exit face of the crystal had the appearance of bands, parallel to the SB, and the contrast of the pattern depended on the incidence angle ϕ of the light on the face. The photograph (Fig. 1) shows the intensity distribution at the exit face of a 7-mm-thick sample ($\lambda = 633$ nm). A small-period modulation of the light intensity is visible with a period of about 4 μm, on which larger scale beats are superimposed. The small-period modulation was visible at only two angular positions of the crystal; it disappeared with deviations from these angles. These angular positions depended on the wavelength; in particular, they were 0 and 9° at 560 nm. 2) In the 560-nm spectral region for light polarization parallel to the SB we also observed variations in the integrated light transmission of the sample as the angle ϕ was varied. The transmission spectra for four values of the angle ϕ are shown in Fig. 2. The characteristic step, which is missing at angles of 0°10′ and 9°10′, is observed at angles of 3°20′

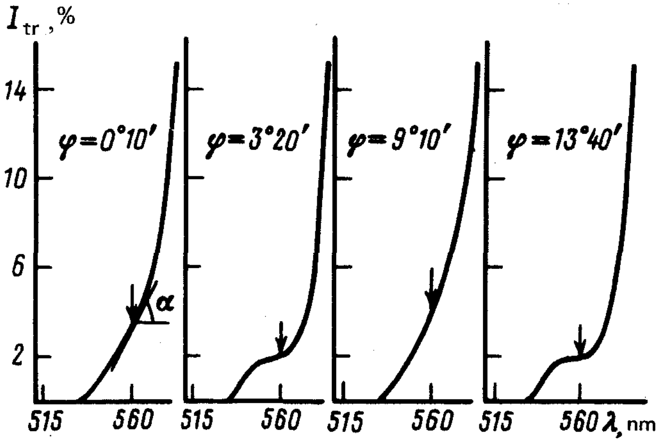

FIG. 2. Variations of transmission spectrum as a function of ϕ. I_{tr} is the transmission in percent.

and 13°40' in the transmission spectrum. A continuous transition from one type of spectrum to the other occurred as ϕ was varied. It is characteristic that the step in the transmission is missing at those angles ϕ for which the small-period intensity modulation appears at the exit face. The slope of the tangent ($\tan \alpha$) at the 560-nm point was chosen as the parameter that characterizes the variations in the transmission spectrum (Fig. 2). Figure 3 shows the dependence of $\tan \alpha$ on ϕ. At the two angular positions $\tan \alpha$ has maxima that correspond to the transmission increase of the sample.

The two crystal positions (separated by an angular distance $\Delta\phi = 9°$), at which the small-period intensity modulation appears, correspond to two first-order symmetrical Bragg reflections. In this case the Bragg angle $\theta = \Delta\phi/2 = \pm 4.5°$ corresponds to the period of the diffraction pattern $d = 4$ μm (for $\lambda = 560$ nm). This correspondence makes it possible to state that in the plastically deformed crystals, analogously to the

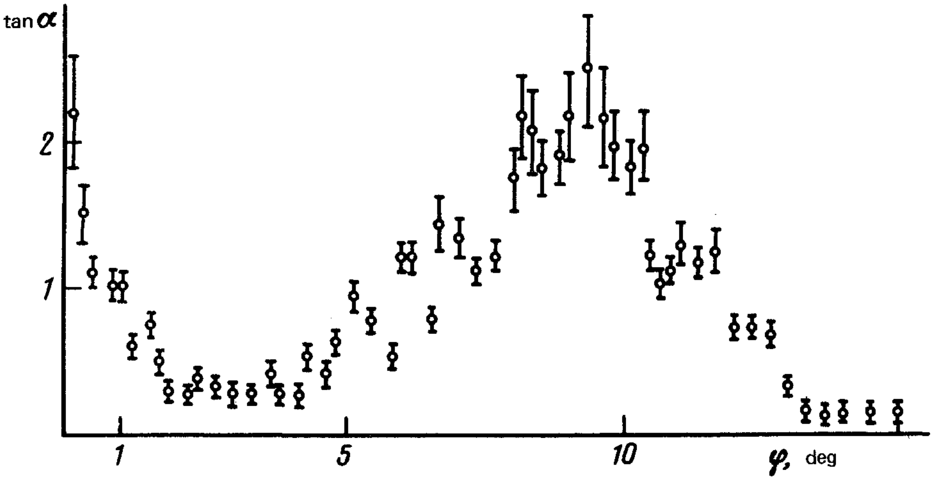

FIG. 3. Dependence of $\tan \alpha$ on ϕ.

case of x-rays, two systems of standing waves, which also give the small-period intensity modulation, are formed because of multiple light scattering by the quasiperiodic SB system when the Bragg condition is satisfied. If the light polarization and wavelength correspond to the dislocation absorption, an anomalous transmission should be observed at the Bragg angles, so that one standing wave has a field antinode between the SB, where the density of dislocations is reduced; this explains the results in Figs. 2 and 3. The analog of the Bormann effect in the optical region has also been observed on holographic gratings.[6,7]

Thus, the dislocation structure of plastically deformed CdS is sufficiently periodic to produce a periodic distribution of the wave field and an anomalous transmission of visible-wavelength electromagnetic waves.

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