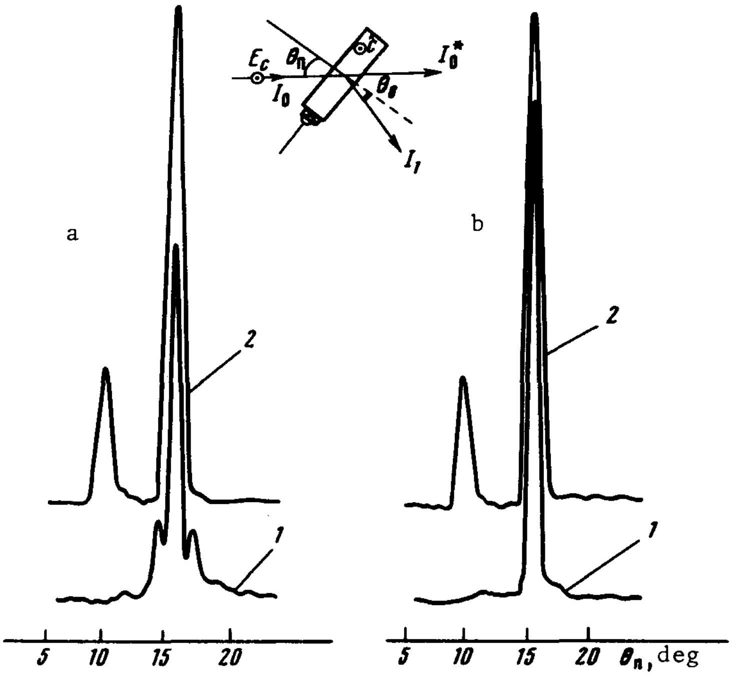
OBSERVATION OF LIGHT DIFFRACTION BY ELECTRON WAVES ACCOMPANYING SOUND IN PIEZOSEMICONDUCTORS

V. V. Proklov, V. I. Mirgorodskii, G. N. Shkerdin, and Yu. V. Gulyaev
Institute of Radio Electronics, USSR Academy of Sciences
Submitted 25 October 1973
ZhETF Pis. Red. 19, No. 1, 13 – 15 (5 January 1974)

The diffraction of light by piezoactive waves in photoconducting CdS crystals was investigated experimentally. The previously predicted diffraction by the electron waves accompanying a sound waves was observed for the first time. Satisfactory agreement between theory and experiment was obtained.

It was shown theoretically in [1, 2], for the first time, that the electron waves accompanying a sound wave in a piezosemiconductor can strongly influence the diffraction of light by this sound wave, especially in the infrared region of the spectrum. In the present paper we report the first experimental observations of this "electronic component" of the diffracted light in a piezosemiconductor.

The experiments were performed in the infrared region of the spectrum at a wavelength 10.6 μ (CO laser of 1 watt power). We used photosensitive piezoelectric n-type crystals with conductivity $\sim 10^{-6}\Omega^{-1}\text{cm}^{-1}$ in darkness and $\sim 10^{-3}\Omega^{-1}\text{cm}^{-1}$ when illuminated with visible light. The samples were parallelepipeds oriented along the principal crystallographic directions in such a way that the hexagonal axis C was perpendicular to their long dimension. A piezoactive ultrasonic shear wave of frequency f_s = 65 MHz was excited by a piezoelectric quartz converter glued to one end of the sample. The maximum wave intensity reached 1 ∿ W/cm^2. The optical system of the setup made it possible to investigate the polarization and spatial characteristics of the diffracted radiation. By using a highly sensitive radiation receiver, we were able to measure very low relative intensities of the diffracted radiation, $I_1/I_0 \simeq 10^{-9}$, where I_0 and I_1 are the intensities of the incident and diffracted radiation, respectively.



Intensity of the diffracted light I_1 vs. the incidence angle θ_i for different electric conductivities of the crystal (a) and for different analyzer positions (b): a – analyzer transmission plane parallel to the polarization plane of the incident light; 1) $\sigma_1 \simeq 1\times10^{-6}\Omega^{-1}\text{cm}^{-1}$, 2) $\sigma_2 \simeq 3\times10^{-3}\Omega^{-1}\text{cm}^{-1}$; b – analyzer transmission plane perpendicular (curve 1) and parallel (curve 2) to the polarization plane of the incident light, $\sigma \simeq 3\times10^{-3}\Omega^{-1}\text{cm}^{-1}$.

The experiment was performed under conditions when the diffraction was of the pure Bragg type, regardless of the light-scattering mechanism, with one first-order diffraction maximum [3]. In addition, at exact orientation of the electric vector of the incident radiation along the hexagonal axis C of the crystal (see the upper part of the figure) the diffraction due to the photoelastic changes of the medium should be "anisotropic," i.e., the incidence and diffraction angles θ_i and θ_d are not equal, and the plane of polarization of the diffracted radiation is rotated 90° relative to the plane of polarization of the incident radiation [4, 5]. At the same time, the "electronic diffraction," according to [1, 2], is isotropic and the polarization plane of the radiation remains unchanged.

The experiments have revealed that diffracted radiation is observed only at a scattering angle $\theta_{sc} \equiv \theta_i + \theta_d \simeq 21°$, corresponding to diffraction by the periodic lattice produced by the piezoactive shear wave propagating with velocity 1.7 10 cm/sec. The intensity I of the diffracted radiation depends in this case strongly on the angle of incidence of the light on the crystal. At low electric conductivity of the crystal, $\sigma_1 \simeq 1\times10^{-6}\Omega^{-1}\mathrm{cm}^{-1}$ (sample in darkness), the diffraction is accompanied by a 90° rotation of the polarization plane, and occurs only at $\theta_i \simeq 16°$ (curve 1 of Fig. a); this is in good agreement with the calculated values of the angles for anisotropic diffraction due to the lattice photoelasticity of the material.

At sufficiently strong illumination of the crystal ($\sigma_2 \simeq 3\times10^{-3}\Omega^{-1}\mathrm{cm}^{-1}$), effective diffraction is produced also at $\theta_i^* \simeq 10.5°$ (curve 2 of Fig. a). The polarization plane of the diffracted light coincides then with the polarization plane of the in-ident light (see Fig. b), and the intensity of the diffracted light is smaller by a factor 50 — 100 than the intensity of the diffraction maximum for anisotropic lattice diffraction at $\theta_i \simeq 16°$. The equality of the angles θ_i and θ_d^*, their close agreement with the Bragg angle $\theta_B = \sin^{-1}(1/2)(\lambda_0/\lambda_s)$ (estimates yield $\theta_B \simeq 10°36'$), and the polarization of the diffracted radiation, all indicate that the resultant diffraction is of the isotropic Bragg type. Estimates, based on [1, 2], of the intensity ratios of the diffraction maxima following scattering by electron waves and following anisotropic lattice diffraction yield $(I_1)_{lat}/(I_1)_e \simeq 50$, in satisfactory agreement with experiment.

These data give grounds for assuming that the diffraction observed at the incidence angle $\theta_i^* \simeq 10.5°$ is due to scattering of light by electronic waves accompanying the transverse piezoactive wave in the CdS. Additional evidence indicating that the observed isotropic is by electrons rather than by the lattice is seen also in the differences between the behaviors of the "anisotropic," "lattice," and "electronic" components when an electronic nonlinearity sets in with increasing wave intensity. This agrees qualitatively with [6], where it is shown that at high sound-wave intensities the anharmonicity in the electron wave sets in much earlier than in the elastic wave.

The authors thank Professor L. N. Korbatov for help with developing the high-sensitivity IR recording system used in the present experiments.

[1] V. V. Proklov, G. N. Shkerdin, and Yu. V. Gulyaev, Solid State Comm. 10, 1145 (1972).
[2] V. V. Proklov, G. N. Shkerdin, and Yu. V. Gulyaev, Fiz. Tekh. Poluprov. 6, 1915 (1972) [Sov. Phys.-Semicond. 6, 1646 (1973)].
[3] W. R. Klein and B. D. Cook, IEEE Transactions SU-14, 123 (1967).
[4] R. W. Dixon, IEEE J, QE-3, 85 (1967).
[5] W. T. Maloney and H. R. Carleton, IEEE Transactions SU-14, 135 (1967).
[6] Yu. V. Gulyaev, IEEE Transactions SU-17, 111 (1970).

IDENTIFICATION OF TRANSITIONS FROM DOUBLY EXCITED LEVELS OF LITHIUM-LIKE Ti AND V IONS CONTAINED IN A LASER PLASMA

E. V. Aglitskii, V. A. Boiko, S. M. Zakharov, S. A. Pikuz, and A. Ya. Faenov
P. N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 2 November 1973
ZhETF Pis. Red. 19, No. 1, 16 — 18 (5 January 1974)

Results are presented of observation of the helium-like ions Ti-XXI and V-XXII (with ionization potentials 6.250 and 6.825 keV, respectively). Identification of transitions of the type $1s2pn\ell \rightarrow 1s^2n\ell$ of Li-like Ti-XX and V-XXI (altogether 19 lines) is also reported (measurement accuracy 0.0005 Å).

We report here the results of observation of the spectral lines of the helium-like ions Ti-XXI and V-XXII (ionization potentials 6.250 and 6.852 keV, respectively), and the identification of the transitions of the type $1s2pn \rightarrow 1s^2n\ell$ of the lithium-like ions Ti-XX and V-XXI. The excitation source, just as in the earlier investigation of the doubly-excited levels of the ions Mg-X, Mg-XI, Al-XI, and Al-XII [1, 2], was a laser plasma produced by sharp focusing of laser beam of flux density 5×10^{14} W/cm^2. Spectrograms suitable for the study were obtained with a mica x-ray spectrograph [3] on type UF-VR films after 10 - 15 flashes of the laser. The wavelengths were measured in the third and fifth orders. The references were the wavelengths of the