Thermally stimulated emission by surface oscillations of zinc selenide crystal-lattice atoms

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(Submitted June 14, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **24**, No. 2, 84–86 (20 July 1976)

A new method of investigating surface polaritons is proposed, using the spectra of thermally stimulated infrared (IR) radiation of a system consisting of a crystal and a disturbed total internal reflection prism.

PACS numbers: 78.45.+h, 73.90.+f

The experimental study of surface polaritons of single crystals is presently carried out mainly with the aid of the method of disturbed total internal reflection (DITR) (see, e.g., [1,2]. If the crystal temperature differs from 0 °K, then obviously volume and surface polaritons are excited in it. The electromagnetic component of the volume polariton can easily pass through the crystal boundary and can be registered as temperature radiation by means of a photoreceiver.[3] Under ordinary conditions a surface polariton cannot emit a light wave, since the polariton branch of the surface phonon lies outside the radiation region.[1] The polariton wave vector k_x is parallel to the crystal surface and $k_x > k_0$ (k_0 is the wave vector of light in vacuum). This is precisely why surface waves are excited by light through a DITR prism, which has a sufficiently large refractive index, such that the projection of the wave vector of the light inside the prism, parallel to the crystal surface, is comparable with the polariton wave vector, i.e., $k_x = nk_0 \sin\theta$, where θ is the angle of incidence of the light on the crystal. If this condition for the matching of the two waves is satisfied then, it might appear, a wave propagating along the surface could leave the crystal-prism system [3] regardless of the method used to excite the surface polariton. The present paper is devoted to the investigation of emission from a system consisting of a crystal, air gap, and a prism, all heated to 150 °C. To this end the globar of the FIS-21 spectrometer was replaced by a DITR prism of silicon and a ZnSe single crystal (symmetry group T_d). The surface polariton in ZnSe ($T = 300$ °K) exists between the frequencies $\omega_{TO} = 205$ cm^{-1} of the transverse phonon and $\omega_{LO} = 252$ cm^{-1} of the phonons. The gap between the prism and the crystal was determined by the thickness of a washer of polyethylene-terephthalate film and was equal to 15 or 25 μ. Since the silicon prism heated to 150 °C is itself a good radiator in the wavelength band of interest to us, we measured the difference between the emission E_1 of the prism + crystal system and the emission E_2 of prism + mirror system.$^{1)}$ To eliminate the spectral transmission coefficient of the instrument, we registered also the irradiation E_3 of a "black" body with known emissivity.[4] The end result was assumed to be the ratio

$$\frac{E_1 - E_2}{E_3} \approx \frac{\epsilon_1(\omega)}{\epsilon_2(\omega)}, \qquad (1)$$

where ϵ_1 is the emissivity of the crystal in the inverted DITR regime, and ϵ_2 is the emissivity of the "black" body. Relation (1) is qualitative in character, since the wave radiated by the crystal surface is partially absorbed in the prism material.

Figure 1 shows the emission spectrum obtained in this manner for the crystal + prism system under two measurement conditions: at fixed emission angles with frequency scanning (Fig. 1a) and at fixed frequency with emission-angle scanning (Fig. 1b). The positions of the maxima of the emission bands correspond to the polariton frequency at a given polariton wave vector $k_x = 2\pi\nu n \sin\theta$. The band half-width is determined by the error in the measurement of the emission angle θ, which is connected with the non-parallelism of the light beam inside the DITR prism and amounts to approximately 2°. Figure 2 shows the dispersion of the surface polariton of zinc selenide, reconstructed from the emission spectra. The theoretical curve was obtained from the expression

$$k_x = \frac{\omega}{c}\sqrt{\frac{\epsilon(\omega)}{1 + \epsilon(\omega)}}$$

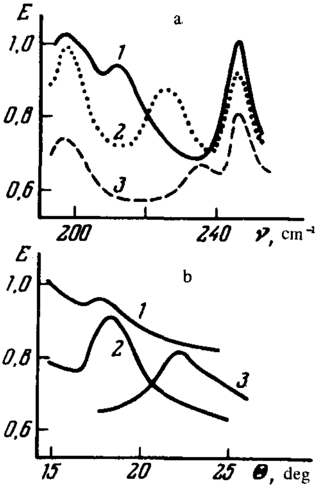

FIG. 1. Emissivity of a crystal—DITR prism system: a—frequency scanning at fixed emission angles: 1) 17°, 2) 19°, 3) 24°; b—scanning of emission angle at fixed frequencies: 1) 208 cm^{-1}, 2) 220 cm^{-1}, 3) 234 cm^{-1}.

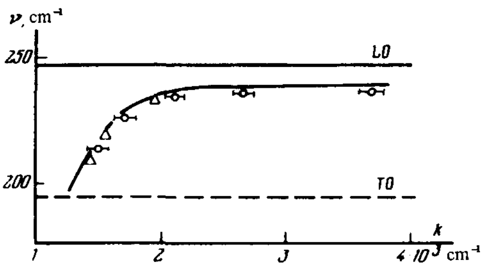

FIG. 2. Dispersion of infrared surface polariton: triangles—maxima of bands in angle scanning, circles—maxima of bands in frequency scanning.

where

$$\epsilon(\omega) = \epsilon_\infty + \frac{(\epsilon_0 - \epsilon_\infty)\,\omega_{TO}^2}{\omega_{TO}^2 - \omega^2}$$

is the dielectric constant of the zinc-selenide crystal with $\epsilon_\infty = 5.8$; $\epsilon_0 - \epsilon_\infty = 3$ and $\omega_{\text{TO}} = 196\ \text{cm}^{-1}$.[4]

Thus, our investigations have shown that under certain conditions the surface polariton can emit thermally-stimulated electromagnetic (light) waves, and the IR emission procedure can be useful for the study of the physics of surface states of crystals.

1)The mirror is needed to exclude the radiation of the holder of the sample with the prism.

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