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MANIFESTATION OF THE FERMI RESONANCE IN SURFACE POLARITON SPECTRA

G. A. Puchkovskaya, V. L. Strizhevskiy, Y. A. Frolkov, N. M. Chepilko and L. A. Krivodonova

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16. Abstract

The method of disturbed full internal reflection (DFIR) is used to detect and interpret the resonance splitting of the surface polariton. The new effect in the spectra of oscillatory SP which are reflected by the DFIR method in Otto geometry was experimentally recorded. It is concluded that the resonance splitting of the dispersion branch of SP may serve as an effective method for detecting weak oscillations and for measuring their parameters.

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G. A. Puchkovskaya, V. L. Strizhevskiy, Y. A. Frolkov, N. M. Chepilko and L. A. Krivodonova

The method of disturbed full internal reflection (DFIR) was used to detect and interpret the resonance splitting of the surface polariton (SP) associated with the surface of single crystal α-$LiIO_3$ in the range of 790-810 cm^{-1}. The splitting is caused by the resonance interaction of SP with the weak volume polar oscillation of 801.5 cm^{-1} in the contacting medium--a cholesteryl palmitate (CP) crystal.

We experimentally recorded the new effect in the spectra of oscillating SP which are reflected by the DFIR method in Otto geometry [1]. The effect consists of the emergence of a characteristic splitting in the dispersion branch of the SP, which is caused by resonance interaction of the SP genetically tied with one of the contacting media, with the weak polar oscillation of another dielectric medium. This effect is, to a certain degree, analogous to the polariton Fermi resonance--the resonance splitting of the disperse branches of volume polaritons (or anisotropic polar phonons) [2] interacting with weak polar oscillations of one or another medium. However, in our case, we are speaking of SP and the interaction of excitations associated with various contacting media due to the penetration of the SP field from one medium to another. This effect may be called the surface-polariton Fermi resonance. We are speaking, according to [3], of a quasiresonance interaction (in this case by means of an electromagnetic field) of the strong polar oscillation of one medium, caused by the SP, with the weak polar oscillation of another. We will note that work [4] examined the interaction of strong polar oscillations of various media by

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means of the SP field. However, this case differs from the case examined in this work.

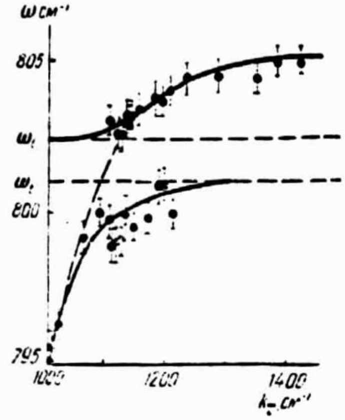

Figure 1

The standard technology for the DFIR method was used for measuring the SP (for more detail see in [5]). Single crystalline hexagonal α-$LiIO_3$ which was cut perpendicular to the optical axis was used as the dielectric in which the SP arose. The spectral interval of 750-850 cm^{-1} was studied, in which, as we know [5], there is an SP branch caused by intensive polar valent oscillations of the crystal with symmetry types A and E (ω_t^A = 795 cm^{-1}, ω_t^E = 769 cm^{-1}, with corresponding electrostatic splitting comprising 22 and 79 cm^{-1}). A CP liquid crystal was introduced into the gap between the α-$LiIO_3$ crystal and the DFIR element (in this case, a half-cylinder made of KRS-5 crystal). The thickness of the CP crystal layer was approximately 1.5 μm. In the IR absorption spectrum for the volume CP, weak polar oscillation is registered without any great difficulty, with ω_t = 801.5 cm^{-1} (the force of the oscillator was s $\approx 10^{-2}$, half-width of the corresponding IR-band was about 3 cm^{-1}).

The figure presents the obtained experimental points corresponding to the course of the dispersion branches of SP. The accuracy of determining ω_p corresponding to the minimum reflection coefficient is ndicated in the figure by vertical segments (spectral width of the spectrophotometer opening amounted to 1 cm^{-1}). The computed dispersion branches are also contained here: the broken line

shows the dispersion branch without consideration for oscillation /692
ω_t, the solid lines--with consideration of the latter. Computations were performed on the study of SP in α-$LiIO_3$ (polar axis of crystal is perpendicular to its surface) in accordance with the formula applicable for this geometry:

$$k_\tau^2 = \frac{\omega_p^2}{c^2} \frac{\varepsilon_\parallel \varepsilon (\varepsilon_\perp - \varepsilon)}{\varepsilon_\parallel \varepsilon_\perp - \varepsilon^2},$$

where ω_p and k_τ are the frequency and wave vector of SP, $\varepsilon_{\parallel,\perp}$ are the main values of the tensor of dielectric permeability of α-$LiIO_3$ in a system of coordinates whose z axis is directed along the polar axis of the crystal (their value is borrowed from [6], ε is the dielectric permeability of the CP). The latter was approximated by the standard expression (for isolated polar oscillation in an isotropic medium):

$$\varepsilon = \varepsilon_\infty [1 + (\omega_l^2 - \omega_t^2)/(\omega_t^2 - \omega^2)],$$

while parameters ε_∞ and ω_l were selected from the condition of the best correspondence with experimental data. It was achieved at ω_l = 803 cm^{-1}, ε_∞ = 2.9, and in this case $s = \varepsilon_{CT} - \varepsilon_\infty \approx 2\varepsilon_\infty (\omega_l - \omega_t)\omega_t \approx 10^{-2}$. The physical sense of parameters ε_∞, ε_{CT} and ω_l is evident.

As we see, the interaction of SP with oscillation ω_t causes a rather large (in our case 2-3 cm^{-1}) characteristic splitting of the disperse branch of the SP, and the experimental results corresponded satisfactorily with the theoretical. We will note that the given effect was theoretically predicted earlier in [7] using the example of isotropic contacting media.

A double structure is observed in the DFIR spectrum, corresponding to the two dispersion branches of the SP. In the range of $\omega_p^r(k_\tau) < \omega_t$ ($\omega_p^-(k_\tau) > \omega_t$) the low frequency (high frequency) component is dominant, while near point $\omega_p = \omega_t$ both components are commensurate in intensity. Consequently, upon passage through the resonance, the components seem to exchange intensities. A single band is observed far from ω_t in the SP spectrum.

The resonance splitting of the dispersion branch of SP may serve as a new effective method for detecting weak oscillations and for measuring their parameters. Here it is significant that it may be used for studying layers or films of the liquid or solid phase.

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Institute of Physics
Academy of Sciences UKSSR, Kiev
Kiev State University
imeni T.G. Shevchenko

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