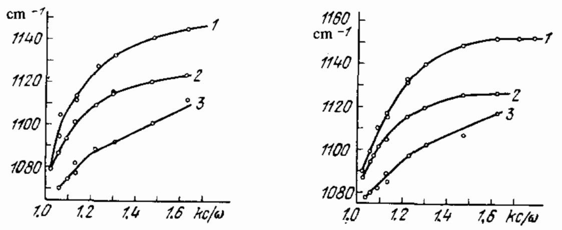
G. N. Zhizhin, O. I. Kapusta, M. A. Moskaleva, V. G. Nazin, and V. A. Yakovlev. Spectroscopy of Surface Waves and the Properties of the Surface. Knowledge of the excited states of dielectric and metal surface layers is important for solution of physical, chemical, and biological problems[1]. For example, they are highly important in analysis of the sandwich model of the superconductor[2].

In both dielectrics and metals, they correspond to the range of negative ϵ. These elementary excitations cannot be investigated by conventional methods of reflection and transmission spectroscopy. They are studied by the disturbed total internal reflection (DTIR) method. Such studies can be carried out comparatively simply at 200-2000 cm^{-1} in the infrared. The frequencies of optically active intramolecular vibrations of the ions lie in this range, along with much of the metal's surface-plasmon branch. Following Mirlin et al.[3], who investigated low-frequency surface polaritons of alkali halide crystals, we concentrated on a search for high-frequency (> 600 cm^{-1}) surface polaritons. We observed such elementary excitations in crystals of sapphire, lithium niobate, yttrium ferrite garnet[4], urotropin[5], apatite, and other single crystal materials. The dispersion relations $\omega(k)$ were determined for these substances for wave vectors from ω/c to $\sim 2\omega/c$. In the range of small wave vectors, where the error in the determination of points of the dispersion curve is large owing to the divergence of the beam in the DTIR cell, and the values of k are therefore uncertain, we registered the spectra at a fixed frequency (with varying k). In some cases (quartz, apatite), these measurements could be made using a CO_2 laser with tuning based on the rotational components.

The trend of the dispersion curves and the widths in the surface-polariton spectrum were the basic characteristics whose variation was studied at contacts between quartz and thin (20-1000 Å) metallic films. Figure 1 shows a series of dispersion curves as a function of the thickness of a tin film. We see that the dispersion range of the surface polariton narrows with increasing thickness of the layer. This effect can be explained with consideration of interference in thin layers with permittivity differing from that of the bulky metal. In those cases when it was possible to obtain thin continuous films (of gold), we observed clearly the abrupt broadening of the surface polaritons that was predicted theoretically in [6] and is due to Joule losses of energy of the electromagnetic wave in the film of metal.

Study of features on the dispersion curves of the surface polaritons indicates the presence of thin layers ($\sim$100 Å) of certain dielectrics even when they cannot be brought out in either transmission or reflection spectra. The appearance of a gap in the surface-polariton curve was predicted theoretically in [7]. We were able to observe it experimentally for an LiF film on the surfaces of sapphire and rutile (Fig. 2). This effect is due to resonant interaction of the longitudinal vibration of the LiF with the surface polariton of the substrate. But it was not possible to detect the presence of the LiF film in the ordinary reflection spectrum. Thus, the sensitivity of methods of detecting superficial adsorbed films of dielectrics can be increased.



a)

b)

FIG. 1. Change in dispersion curves of surface polaritons of α-quartz on an increase in the thickness of a tin film on the quartz surface. (d (Å): 150 (1), 290 (2), and 480 (3)).

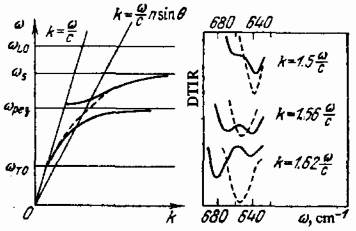


FIG. 2. Formation of a gap in the dispersion curve, and distribution of surface-polariton line in the presence of a thin dielectric film. Spectra obtained for a sapphire crystal without a film and with an LiF film 160 Å thick.

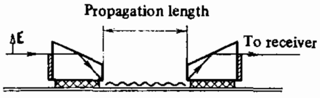


FIG. 3

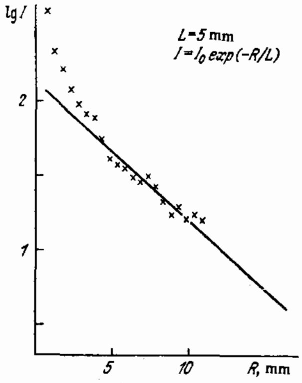


FIG. 4

FIG. 3. Diagram illustrating study of propagation length of surface wave on surface of metal.

FIG. 4. Intensity of light leaving second DTIR prism (see Fig. 3) upon variation of distance between prisms.

Electromagnetic waves corresponding to surface polaritons of dielectrics and plasmons of metals can propagate to macroscopic distances [8]. In our experiment (see diagram in Fig. 3), we observed propagation of a surface wave of a 10.6 μm (CO_2) laser along a copper film with a decrease in intensity by a factor e over a distance of 5 mm (Fig. 4). The surface wave is excited by one DTIR prism and picked up by the other one (which is movable). The fact that the propagation length was shorter than in [8] was perhaps due to poor quality of the film (we deposited the copper film in a vacuum of 10^{-6} Torr). The airgap between the prisms and the copper film (on the glass substrate) was 10 μ. We plan to study the dependence of the surface-wave propagation length on the nature of the metal and on the thickness of a resonantly absorbing dielectric adsorbed on its surface. The described experiment appears to constitute direct observation of the Zenneck-Sommerfeld wave, whose nature in the radio band has been argued about for many years [9]. Investigation of its properties in the optical band may prove highly promising for study of the properties of surfaces and surface-adsorbed molecules.

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