Qualitatively, the collision process is considered in the following manner. As the atomic particles come closer together ($R \to 0$), the ground-state term of the Na^+Ne system intersects two terms of the quasimolecule $(Na^+Ne)^*$ in the region $R = R_0$. The ordinate of this pseudo-intersection, U_0, is determined by the position of the threshold for the process (1), and lies at $U_0 < E = 100$ eV. Following the population process at the point $R = R_0$, which is described by the Landau-Zener theory, the two molecular terms vary adiabatically up to a certain internuclear distance $R_1 \gg R_0$, at which the close approach leads to a nonadiabatic interaction that causes mixing of the wave functions of the molecular states under consideration. Two stationary states, corresponding to two inelastic channels (1) and (2) of the reaction $Na^+ + Ne$ are then formed in the region $R > R_1$.

The regular oscillations of the total cross section in process (1), according to the foregoing hypothesis, are the results of the fact that the time spent by the system in the region $R < R_0$, where integration with respect to the impact parameter ρ is significant, is much lower than the time of stay in the region $\Delta R = R_1 - R_0$.

The fact that the maxima are equidistant with respect to v^{-1} (see the table) in a wide range of relative-motion velocity v shows that the quantity determining the period of the oscillation is the phase difference in the section from R_0 to R_1, which does not depend on ρ.

An inevitable consequence of the considered collision mechanism are oscillations in the total cross section of the reaction (2), in counterphase with the oscillations observed in this investigation for the reaction (1).

Similar qualitative considerations were advanced by Rosenthal [2] to explain the structure of the excitation functions of two helium lines emitted in the visible region of the spectrum in $He^+ + He$ collisions [3].

We plan to publish in the nearest future a theoretical analysis that would make it possible to describe quantitatively certain features of the behavior of the measured excitation functions of the resonant lines of the Ne atom.

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[1] V.B. Matveev, S.V. Bobashev, and V.M. Dukel'skii, Zh. Eksp. Teor. Fiz. 55, 781 (1968) [Sov. Phys.-JETP 28, 404 (1969)].
[2] H. Rosenthal, Abstracts of Papers of Sixth International Conference of the Physics of Electronic and Atomic Collisions, p. 302 (1969).
[3] S. Dworetsny, R. Novick, W.W. Smith, and N. Tolk, Phys. Rev. Lett. 18, 939 (1967).

INCOHERENT REFLECTION OF LIGHT BY A METAL

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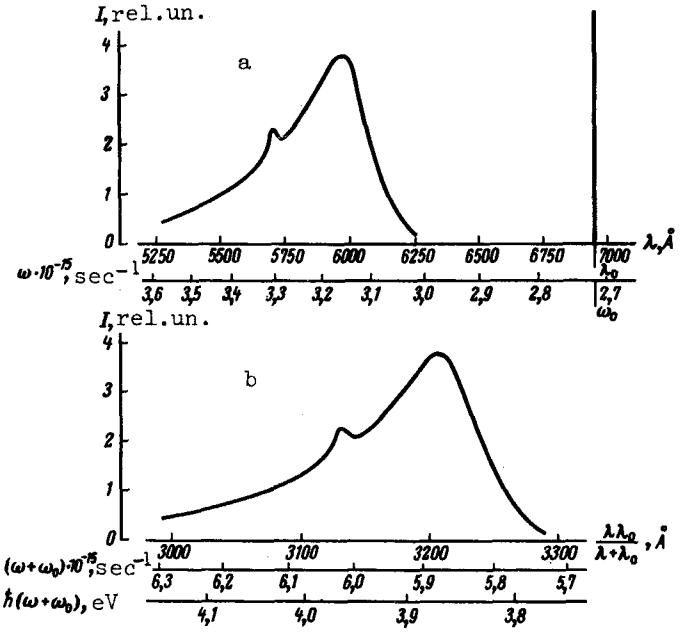
In metals, just as in a plasma, there exist fluctuations of the free-electron density, owing to the presence of fluctuation Langmuir oscillations and surface waves. Because of the nonlinear interaction between the incident waves and the fluctuations of the electron density, reflection of the electromagnetic wave from the metal surface should produce emission at the combination

frequencies $\omega_{1,2} = |\omega_0 \pm \omega_L|$ and $\omega'_{1,2} = |\omega_0 + \omega_S|$, where ω_0 is the frequency of the incident wave, and ω_L and ω_S are the frequencies of the Langmuir and surface oscillations [1, 2]. When $\omega_0 \sim \omega_L$, the incoherent reflection coefficient is $R \sim \delta\Sigma \sim hne^4/m^{*3}c^5$, where $\delta \sim c/\omega_L$ is the depth of the skin layer, Σ the cross section of the incoherent scattering, n the free-electron density, and m* their effective mass. For good metals $R \sim 10^{-12}$ and is thus observable.

We have observed the Raman scattering of light reflected from the surface of silver, corresponding to the frequencies $\omega_2 = \omega_L - \omega_0$ and $\omega'_2 = \omega_S - \omega_0$. We used a plate of silver with purity better than 99.99%, mechanically polished and then annealed in a vacuum of 1×10^{-5} Torr at 500°C for three hours. The radiation source was a GOR-100 ruby laser ($\lambda_0 = 6943$ Å) with a pulse energy ~30 J. The laser radiation was almost normally incident on the silver sample. The light beam indicent on the sample was not focused additionally, to prevent damage to the metal surface. The radiation reflected from the surface at angles close to 90° was focused on the slit of an ISP-28 spectrograph and photographed on RF-3 film. The apparatus width in the region of the observed combination frequencies was much smaller than the widths of the registered spectral distributions. To obtain a film density suitable for photometry, the energy of the radiation incident on the sample had to exceed ~1 kJ.



The spectral distribution of the scattered-radiation intensity is shown in Fig. a. Two maxima are observed at wavelengths $\lambda \approx 5975$ Å and $\lambda \approx 5700$ Å, corresponding to frequencies $\omega \approx 3.16 \times 10^{15}$ sec^{-1} and 3.31×10^{15} sec^{-1}. The observed distribution of the intensity $I(\omega)$ is a sum of spectral distributions at the frequencies $\omega_L - \omega_0$ and $\omega_S - \omega_0$; since the half-width of $I(\omega)$ is comparable with the recorded distance between the maxima, the value of the frequency $\omega_L - \omega_0$ is somewhat higher, and that of $\omega_S - \omega_0$ somewhat lower than the frequencies of the experimentally observed maxima of $I(\omega)$.

The frequency of the Langmuir oscillations ω_L is determined from the dispersion equation $\varepsilon(\omega) = \varepsilon_0(\omega) + \varepsilon_f(\omega) = 0$, where $\varepsilon_0(\omega)$ is the dielectric constant of the lattice, $\varepsilon_f(\omega) = -\omega_P^2/\omega^2$ is the contribution of the free electrons to the dielectric constant, and $\omega_P = (4\pi ne^2/m^*)^{1/2}$ is the plasma frequency. The surface-wave frequency ω_S is determined from the equation $\varepsilon(\omega) + 1 = 0$. Thus, $\omega_L = \omega_P/\sqrt{\varepsilon_0(\omega_L)}$ and $\omega_S = \omega_P/\sqrt{\varepsilon_0(\omega_S) + 1}$.

The dependence of the intensity of the scattered radiation on the quantities $\lambda\lambda_0/(\lambda + \lambda_0)$, $(\omega + \omega_0)$, and $\hbar(\omega + \omega_0)$ is shown in Fig. b; the curve has a maximum at the frequencies $\omega + \omega_0 = \omega_S \approx 5.88 \times 10^{15}$ sec^{-1} and $\omega_L \approx 6.02 \times 10^{15}$ sec^{-1}.

For silver we have $\omega_P \approx 1.39 \times 10^{16}$ sec^{-1} [3]; the frequencies ω_L and ω_S lie in the region of the long-wave edge of quantum absorption, where the function $\varepsilon_0(\omega)$ is large. According to the data of [4], $\varepsilon_0(\omega_L) \approx \varepsilon_0(\omega_S) \approx 6$, $\omega_L = \omega_P/\sqrt{\varepsilon_0} \approx 5.7 \times 10^{15}$ sec^{-1}, and $(\omega_L - \omega_S)/\omega_L \approx 7 \times 10^{-2}$. The experimentally observed values are sufficiently close to these calculated ones.

The obtained value $\hbar\omega_L \approx 3.96$ eV agrees well with the results of the measurements of the characteristic electron energy losses in silver. These data lie in the interval from 3.9 to 4.6 eV [5 - 7]. The experimental data on the transformation of the plasma oscillations into electromagnetic radiation [8] also yield the close value $\hbar\omega_L = 3.75$ eV.

As shown by the experimental results, the incident wave interacts with the surface oscillations more effectively than with the Langmuir oscillations.

The observed effect of incoherent scattering of light can be used for the investigation of the spectra of elementary excitations of electrons in metals.

[1] I.A. Akhiezer, Zh. Tekh. Fiz. 33, 935 (1963) [Sov. Phys.-Tech. Phys. 8, 699 (1963)].
[2] N.Ya. Koparenko and A.M. Fedorchenko, ibid. 39, 42 (1969) [14, 27 (1969)].
[3] V.G. Padalka and I.N. Shklyarevskii, Opt. Spektrosk. 11, 527 (1961).
[4] V.K. Miloslavskii and R.G. Yarovaya, ibid. 21, 708 (1966).
[5] J.C. Turnbull and H.E. Farnsworth, Phys. Rev. 54, 509 (1938).
[6] E. Rudberg, Proc. Roy. Soc. A127, 111 (1930); Phys. Rev. 50, 138 (1936).
[7] W. Kleinn, Optik 11, 226 (1954).
[8] W. Steinmann, Phys. Rev. Lett. 5, 470 (1960).

TWO-MAGNON SCATTERING OF LIGHT IN ANTIFERROMAGNETIC $KMnF_3$

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An experimental study of Raman scatterings of light in magnetically ordered substances, first considered theoretically by Bass and Kaganov in 1959 [1], has been made possible only following the development of quantum electronics and the appearance of powerful sources of monochromatic radiation, namely lasers. In spite of the fact that only four years have elapsed since the performance of the first experiment [2], the light-scattering method has found extensive use in the study of the energy spectra of magnetic crystals. It suffices to mention the observation of light scattering with excitation of two magnons of limiting energy [2, 3], the investigation of localized magnetic states in impurity antiferromagnets [4, 5], and the proof of existence of magnon-magnon interactions in magnetodielectrics [6]. Just as in the study of the phonon spectrum of a substance, the method of Raman scattering by spin waves supplements successfully the infrared and submillimeter measurements, and in many cases it is the only one possible. Thus, for example, owing to the high symmetry in antiferromagnetic crystals with perovskite structure, the two-magnon absorption is greatly attenuated and is not observed [7], and the intensity of the analogous process in Raman scattering is the same as in crystals of lower symmetry [6].

We report in this paper the results of an investigation of the scattering of light in the antiferromagnetic crystal $KMnF_3$ ($T_N = 88°K$). The measurements