[6] M. Ferro-Luzzi, R. George, Y. Goldschmidt-Clermont, V. P. Henry, B. Jongejens, D. W. G. Leith, G. R. Lynch, F. Muller, and J. M. Perreau, Phys. Lett. 17, 155 (1965).

1) The mass predictions in the model with heavier third quark are approximate, owing to the interaction that violates this model. As a result, the values of Δ (the mass difference between the third and one of the first quarks) differ somewhat from one another in the different multiplets (in mesonic multiplets $\Delta \simeq 100 - 150$ MeV), and splittings also appear in resonances which should have identical masses according to the model.

2) The latter possibility was pointed out By M. Gell-Mann, Erevan, Physics Summer School, May 1965.

SURFACE IMPEDANCE OF Bi AT 1 - 10 Mc IN WEAK MAGNETIC FIELDS

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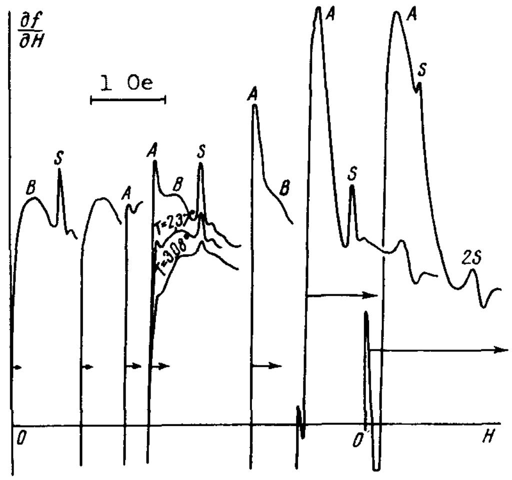
It was pointed out for the first time in [1] that the surface impedance Z of a metal can exhibit a complicated nonmonotonic variation with the magnetic field H in the region of weak magnetic fields at helium temperatures. Khaikin's experiments were carried out at a frequency $f \sim 10^{10}$ cps. It was established somewhat later [2] that nonmonotonic variation, albeit of simpler form, is observed also at lower frequencies ($f \sim 10^6$ cps). The behavior of Z(H) near H = 0 was investigated also in [3,4]. It was indicated in [4] that the function Z(H) changes with varying amplitude of the low-frequency field on the surface of the metal. Inasmuch as there is still no convincing explanation of such strong nonmonotonic variations near H = 0, it is in essence unclear whether the results of [1-4] are different manifestations of the same physical mechanism or not. It is therefore highly desirable to accumulate additional experimental facts.

We have carried out experiments on the behavior of bismuth single crystals in weak fields. Bismuth discs 18 mm in diameter containing $\sim 10^{-4} - 10^{-5}\%$ impurities were grown in dismountable quartz molds. The samples were placed in the coil of a radio-frequency tank circuit and were cooled together with the coil to helium temperatures. The experiments consisted of recording $\partial f/\partial H$ as a function of H with an automatic two-coordinate plotter in the magnetic-field range from 0 to 5 Oe. The measuring apparatus is described in [5]. The earth's field was compensated for accurate to 1%.

The electron mean free path in the metal was such that the radio-frequency size effect [5] could be observed without difficulty on the extremal sections of the electronic "ellipsoids" of samples 1 and 1.2 mm thick. The obtained numerical values of the "ellipsoids" in the C_3 and C_2 directions agree very well with the values obtained by other methods. We were unable to measure the major semiaxis because the line began to diffuse and was eventually

We see from the accompanying figure that the shape of the $\partial f/\partial H$ (H) curve depends on the amplitude of the high-frequency field $H_\omega = H_{\omega 0} \sin\omega t$ on the surface of the metal. The curves obtained can be regarded as consisting of two parts: part A, which depends on $H_{\omega 0}$, and part B, which does not. When $H_{\omega 0} \sim 1$ Oe an additional minimum is observed on the curves near H = 0. In view of the dependence on $H_{\omega 0}$, we had to ensure uniformity of the high-frequency field amplitude over the entire surface of the sample. The length of the coil was made equal to 30 mm; in addition, the sample was placed in a copper mounting to reduce the distortion of the field by the sample itself. The quantity usually measured was $\partial f/\partial H \sim -\partial X/\partial H$, where X = Im Z. The validity of this relation is not obvious, in view of the condition $H \lesssim H_{\omega 0}$ and the concomitant presence of the nonlinear effect. The obtained curves must apparently be considered only from the qualitative point of view, as evidence of some nonlinear processes which occur in the metal. All the experimental facts presented below are qualitative in just this sense.



Dependence of the oscillation frequency on the constant magnetic field at different amplitudes of the hf field. The curves are displaced relative to one another along the abscissa axis. The arrows denote the amplitudes $H_{\omega 0}$; for the first curve $H_{\omega 0} \simeq 0.06$ Oe, and for the others it is larger by 2, 3, 4, 6, 15, and 30 times, respectively. The normal to the sample is $\vec{n} \parallel C_3$, $\vec{H} \parallel \vec{H}_{\omega 0} \parallel C_2$, sample thickness d = 1.2 mm, f = 4.1 Mc, T = 1.57° (except for the two marked curves). S and 2S are the lines of the single and double size effects.

The field amplitudes $H_{\omega 0}$ indicated in the figure were calculated from the formula

$$H_{\omega 0}\ (\text{Oe}) = \sqrt{2} \times 0.4\pi I n = \sqrt{2} \times 0.4\pi\omega C U n$$

where n is the number of turns per cm, C the tank-circuit capacitance, and I and U the hf current and voltage in the tank circuit. The latter was measured directly with a vacuum-tube voltmeter connected to the circuit.

To clarify the nature of this phenomenon, we performed several experiments aimed at establishing the roles of different factors. The experiments were made in the 1 - 10 Mc range. No appreciable influence of frequency on the shape of the curves was observed. The occurrence of the maximum A and its position are apparently determined only by the amplitude of the high-frequency field, and not by its frequency. The width of the maximum A, the value of $H_{\omega 0}$ at which the maximum appears, and the ratio of the maxima A and B depend strongly on the evenness of the sample surface (for a fixed amplitude of the size effect). This was established by etching the sample, first lightly and then deeply, so as to reduce the thickness by 10%. Cold working the sample eliminates completely the field dependence of $\partial f/\partial H$. The influence of the surface quality is at any rate stronger than the influence of the crystallographic orientations (we investigated only four samples with normal $\vec{n} \parallel C_3$, one with $\vec{n} \parallel C_2$, and one with $\vec{n}$

lying in the (C_3, C_2) plane and making an angle 24° with C_3).

If the constant magnetic field remains in the plane of the sample, then a picture similar to that shown in the figure is obtained also for a different polarization, when $\vec{H} \perp \vec{H}_{\omega 0}$, although the peak A shifts somewhat towards larger fields. On samples with normal $\vec{n} \parallel C_3$ the influence of the polarization is best investigated by rotating the constant field by 60°; such a rotation from $\vec{H} \parallel \vec{H}_{\omega 0}$ to $(\vec{H} \hat{} \vec{H}_{\omega 0}) = 60°$ does not shift the maximum A. If the constant field H is perpendicular to the surface of the sample, then the nonlinear effect disappears. The temperature dependence of the value of the maximum A is approximately the same as that of the amplitude of the size effect (see the figure). The possible occurrence of nonlinearities as a result of some size effect was eliminated by using a wedge-shaped sample in which the thickness varied along the disc from 1 to 0.1 mm. The behavior of this sample did not differ from that of the others.

The results of these experiments give grounds for assuming that the observed dependence on the amplitude of the hf field is connected with the quasistatic distribution of the magnetic field inside the skin layer. In the theory of [6] where account is taken of the effect produced on the impedance Z by the bending of the trajectories in a constant magnetic field, but H_ω is neglected in comparison with H, it is shown that $|\Delta Z/Z| \sim (H/H_1)^2$, where H_1 is determined by the condition $l^2 = r\delta$ (l = electron mean free path, r = radius of the electron trajectories in the magnetic field, and δ = thickness of the skin layer). Since in our conditions l is of the order of 1 mm and $\delta \sim 10^{-3}$ cm, we have for bismuth $H_1 \sim 10^{-2} - 10^{-1}$ Oe (for good metals H_1 is larger by one order of magnitude). It is clear therefore that H_ω cannot be neglected in any case. The inhomogeneity of the magnetic field in the skin layer greatly complicates the integral relation between the current and the electric field in the skin layer. Application of a small constant field shifts the picture of the instantaneous field distribution in the skin layer, and this naturally should lead to a decrease in the impedance.

The only experimental fact which fits poorly in the proposed scheme is the weak dependence of the effect on the angle between $\vec{H}$ and $\vec{H}_{\omega 0}$. It must be borne in mind, however, that in an anisotropic crystal the plane of polarization of $\vec{H}_\omega$ can generally speaking rotate.

We must note one more circumstance. In the first approximation we probably can assume that the relation $\partial f/\partial H \sim -\partial X/\partial H$ is valid and that when $H \gg H_{\omega 0}$ the impedance Z is independent of $H_{\omega 0}$. Then an analysis of the experimental data shows readily that when H = 0 an increase in $H_{\omega 0}$ leads to an increase in X, whereas an increase in H with $H_{\omega 0}$ constant causes a decrease in X. (The theory of [6] predicts an opposite sign for the variation of X with the field H. Thus, the very theory from which the estimate for $H_{\omega 0}$ is taken turns out to be inapplicable even in the case of small $H_{\omega 0}$.)

If the proposed explanation of the observed nonlinearity is correct in principle, then the development of similar investigations can yield information on the structure of the field in the skin layer.

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[1] M. S. Khaikin, JETP 39, 212 (1960), Soviet Phys. JETP 12, 152 (1961).
[2] V. F. Gantmakher and Yu. V. Sharvin, ibid. p. 512, transl. p. 358.
[3] J. F. Koch and A. F. Kip, Bull. Amer. Soc. 10, 326 (1965).
[4] J. F. Cochran and C. A. Shiffman, ibid. p. 110.
[5] V. F. Gantmakher, JETP 44, 811 (1963), Soviet Phys. JETP 17, 549 (1963).
[6] M. Ya. Azbel' and E. A. Kaner, ibid. 33, 1461 (1957), transl. 6, 1126 (1958); J. Phys. Chem. Solids 6, 113 (1958).

INDUCED MANDEL'SHTAM-BRILLOUIN SCATTERING IN GASES

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We report in this letter on induced Mandel'shtam-Brillouin scattering (IMBS) observed by us in several compressed gases 1).

No discrete Mandel'shtam-Brillouin components (MBC) were observed in the only experimental investigation of the Rayleigh lines in thermal scattering of light in hydrogen at 100 atm, in nitrogen and oxygen at 80 atm, and in carbon dioxide at 50 atm [4].

In [5,6] it was shown, on the basis of a classical calculation and data on sound absorption in gases, that under the experimental conditions of [4] the discrete fine-structure components should be observed in all cases. The conditions for the existence of discrete MBC are determined by the inequality [6]

$$\alpha\Lambda \ll 1.$$

As shown by calculation [5,6], for gases $\alpha\Lambda = A(\bar{l}/\Lambda)$ (α, Λ, and $\bar{l}$ are the amplitude coefficient of sound absorption, the hypersound wavelength, and the mean free path of the molecule, respectively, and A is a constant, ≈ 25 for a diatomic gas).

At atmospheric pressure ($\bar{l} \sim 10^{-5}$, $\Lambda \sim 3 \times 10^{-5}$) there can be no discrete fine structure in thermal scattering of light ($\alpha\Lambda > 1$), but $\alpha\Lambda < 1$ already at 20 - 30 atm and the fine structure should be observable.

The disparity between the experiment [4] and the deduction of the theory [5,6] has remained unexplained until recently.

If the deductions of the theory are correct, then in compressed gases (P > 20 atm) we should observe a discrete fine structure of the Rayleigh line and, consequently, IMBS should be observable in principle. Whether it will be observed in reality depends on the magnitude of its threshold and on the experimental capabilities. When the condition $\bar{l} \ll \Lambda$ is satisfied, the expression for the threshold of IMBS in gases coincides formally with the expression for the threshold in liquids [6]. However, the magnitude of the threshold in gases at pressures