MAGNETOOPTICAL EFFECT OF CHANGE OF ELECTRONIC STRUCTURE OF A FERROMAGNETIC METAL FOLLOWING ROTATION OF THE MAGNETIZATION VECTOR

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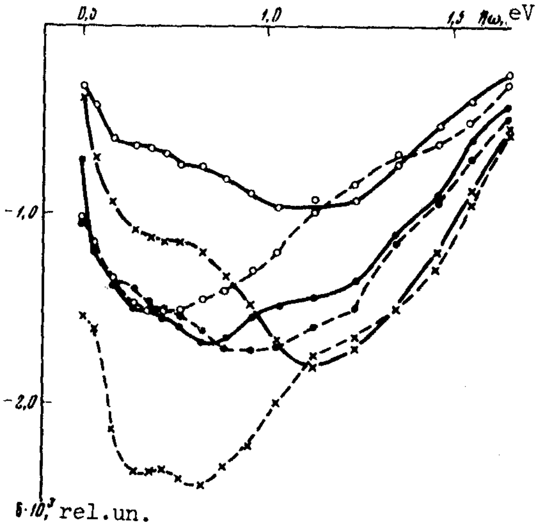
Recently Hodges et al. [1] (see also [2]) observed, in an investigation of the Fermi surface of ferromagnetic nickel, a change in the form of the hole pockets at the X_5 point following rotation of the magnetization vector, and attributed this change to the influence of the spin-orbit interaction. Falicov and Ruvalds [3] made a group-theoretical analysis of this effect for various points of the Brillouin zone and explained the experimentally observed [2] change of the de Haas - van Alphen amplitudes following rotation of $\vec{I}$.

It is important to emphasize that the spin-orbit interaction should influence, in the sense indicated above, not only the energy levels located on the Fermi surface, but also the entire electronic energy spectrum of the ferromagnetic metal, and this influence should be particularly strong in the vicinity of the symmetry points of the Brillouin zone, where the degeneracy of the energy levels is lifted by the spin-orbit interaction. It thus becomes possible in principle to observe the indicated change of the electron structure of the ferromagnetic metal, following rotation of $\vec{I}$, by an optical method at the frequencies of the interband transitions, and the "localization" of this change in definite regions of the Brillouin zone offers promise of a reliable identification of the interband transitions. We describe below a magnetooptic experiment aimed at observing this effect in ferromagnetic single-crystal Ni. We started from the premise that the sought effect shoudl not depend on the sign of $\vec{I}$ (in particular, the discussed influence of the orientation of $\vec{I}$ on the Fermi surface [1 - 3] has an even character), and can be easily separated against the background of the usual odd ferromagnetic Kerr effect.

The measurements were made with the sensitive magnetooptic setup used to measure the equatorial Kerr effect [4] in a nickel single crystal measuring 5 x 5 x 1 mm, cut in the (110) plane. Periodic reorientation of the vector $\vec{I}$ from one crystallographic axis to another, needed for the modulation technique employed for the measurement [4], was effected in the following manner. An extraneous component $i_=$, corresponding to a field of 1000 Oe, was applied to the magnetizing winding of the electromagnet, besides the alternating component $i_=$, wuch that $i_= = i^{\text{ampl}}$. Thus, the magnetizing field changed from 0 to +2000 Oe (case a) when $i_=$ was positive, and from -2000 to 0 at negative values (case b). At a field orientation along any crystal axis, a field H = ± 2000 Oe should correspond to a magnetization $I = \pm I_s$ with orientation along this axis, and a field H = 0, obtained after turning off the field H = ±2000 Oe, to a magnetization $I = \pm I_r$, with a predominant orientation of individual domains along easy magnetization axes of the [111] type. The signals obtained as a result of the equatorial Kerr effect (odd component) should be the same in cases a and b, and should equal $\delta_s(I_s - I_r)/I_s$, where δ_s is the magnitude of the equatorial Kerr effect, corresponding to I_s. The presence of the sought even component shoudl lead to the inequality δ_a and δ_b.



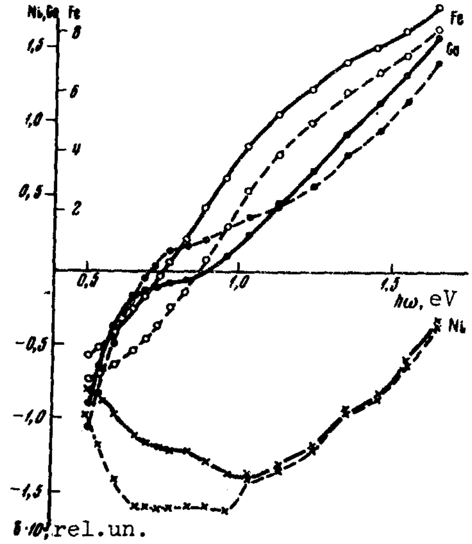


Fig. 1. Relative change of intensity of p-component of linearly-polarized light reflected from single-crystal Ni; δ_a - solid curves, H changes from 0 to 2000 Oe; δ_b - dashed curves, H changes from -2000 to 0, light incidence angle $\phi = 70^\circ$; ○○ - H parallel to [110], ●● - H parallel to [111], ΔΔ - H parallel to [100].

Fig. 2. The same as Fig. 1 for polycrystalline samples of Fe, Co, and Ni.

Figure 1 shows the relative change of the reflected-light intensity, obtained for the p-component of linearly polarized light by the method described above, with H oriented along the three principal crystallographic directions of the single crystal. The sharp difference between δ_a and δ_b in the case of reorientation of the magnetization vector from the axes [100] and [110] to the [111] axis in the region 0.5 - 1.1 eV shows that the even component exists and its order of magnitude is comparable with the usual odd equatorial Kerr effect. The equality, within the limits of error, of the measured δ_a and δ_b curves for the [111] axis (when only a reorientation of $\vec{I}$ takes place in several domains from one type [111] axis to another confirms the correctness of the proposed interpretation of the experimental results. The "localization" of the observed even effect in the region 0.5 - 1.1 eV makes it possible to attribute it to the electronic transition $L_2' \downarrow \rightarrow L_{32}' \downarrow$, since the lifting of the degeneracy of the L_{32} band in the region of the indicated frequencies is due to the spin-orbit distribution (see [4,5]).

We have thus observed experimentally, for the first time, an even magnetooptic effect wherein the intensity of reflected light is changed following rotation of the spontaneous-magnetization vector, with a value comparable to that of the ordinary Kerr effect. We propose that it is due to the influence of the rotation of $\vec{I}$ on the electronic structure of the ferromagnet, owing to the presence of spin-orbit interaction. Naturally, this effect is not the consequence of the usual odd magnetooptic Faraday and Kerr effect, and cannot be reduced to the even magnetooptic Voigt effect [6] (with the change of the diagonal component of the dielectric tensor in the second approximation in I), since the absolute magnitude of the observed effect is larger than that of the Voigt effect by twothree orders of magnitude.

Figure 2 shows plots of δ_a and δ_b obtained for polycrystalline Ni, Co, and Fe samples. The magnitude of the even effect for polycrystalline Ni in the region 0.5 - 1.1 eV is smaller than in the single crystal, corresponding to averaging over various orientation of the crystallites. The results obtained for polycrystalline Co and Fe show that the effect observed in nickel can be investigated using single-crystals of various ferromagnetic d-metals and alloys. We note that the differences $\delta_a - \delta_b$ reverses sign in the region of the interband transition that leads to a sharp magnetooptic anomaly 0.7 - 1.0 eV in cobalt [4].

It can be assumed that the influence of the orientation of I on the electronic spectrum of the ferromagnet affects directly its optical characteristics. However, our preliminary experiments in this direction (measurements made at normal incidence of light), yielded for the time being a negative result. The fact that the magnetooptic characteristics of the metal are much more strongly affected by this influence is apparently connected with the circumstance that both the magnetooptical effects in ferromagnets and the influence of the orientation of I on the electronic structure of the metal have a common spin-orbit origin.

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INVESTIGATION OF HIGHLY EXCITED LEVELS OF NUCLEI WITH THE AID OF NEUTRON-CAPTURE GAMMA RAYS

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A new method of investigating the nature of highly excited nuclear levels [1] was first used by us to determine the radiative level widths near the neutron binding energy for the nuclei listed in the table.

The high-energy states of the nuclei were excited with gamma rays emitted by the nuclei excited upon capture of thermal neutrons. Capture gamma rays have a high monochromaticity compared with gamma-ray sources having a continuous spectrum, such as bremsstrahlung from electron accelerators. This property of the capture gamma rays permits their use for the study of individual high-lying nuclear levels by the method of resonance scattering by the nuclei.

Our experimental setup [2] ensured high gamma-ray intensity and a low background, and made it possible to measure the resonance scattering intensities as functions of the scatterer and absorber temperatures.