This number agrees with that given in the literature.[3] Other characteristics also give the possibility of determining the relaxation rate. Figure 3 shows the dependence of output power of the maser on resonator tuning (curve 1). Curve 2 (on a different scale) is the resonance curve of the resonator. The power of the generated signal falls by a half when the frequency of the resonator is detuned from the frequency of the line by about 15 kcs. At the same time the maser frequency changes by not more than 0.4—0.6 cps. Using the well-known formula for the pulling of the maser frequency by the resonator[3] we find that $\gamma_0 = \Delta\omega/2 \approx 2\ \mathrm{sec}^{-1}$, which is in approximate agreement with the results obtained from the oscillograms (Fig. 1).

[1] Goldenberg, Kleppner, and Ramsey, Phys. Rev. Letters **5**, 361 (1960).

[2] Kleppner, Goldenberg, and Ramsey, Appl. Optics **1**, 55 (1962).

[3] Kleppner, Goldenberg, and Ramsey, Phys. Rev. **126**, 603 (1962).

Translated by L. M. Matarrese
333

NEUTRON SCATTERING BY SPIN WAVES IN IRON

G. M. DRABKIN, E. I. ZABIDAROV, Ya. A. KASMAN, A. I. OKOROKOV, and V. A. TRUNOV

A. F. Ioffe Physico-technical Institute, Academy of Sciences, U.S.S.R.

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THE authors of [1,2] did not connect neutron scattering by spin waves with measurement of the polarization of the scattered neutrons, although the most characteristic feature of neutron scattering by spin waves is the neutron spin flip following excitation or absorption of the spin wave. In the present communication we present results of experiments on the scattering of polarized neutrons by single-crystal iron. We have investigated the excitation and absorption of spin waves for small-angle neutron scattering.

Since the energy of the spin wave excited in a ferromagnet placed in a magnetic field is equal to

$$\hbar\omega_k = Ak^2 + 2\mu_0 H$$

(where ω_k—frequency of the spin wave, μ_0—Bohr magneton, and A—constant determined by the exchange interaction), the following relation is satisfied in the case of small-angle neutron scattering

$$\hbar^2 \mathbf{p}_i^2 / 2m - \hbar^2 \mathbf{p}_f^2 / 2m = A(\mathbf{p}_i - \mathbf{p}_f)^2 + 2\mu_0 H,$$

where $\mathbf{p}_i$—neutron momentum prior to scattering and $\mathbf{p}_f$—neutron momentum after scattering. It follows from this relation that the scattering of neutrons by spin waves terminates at angles $\theta_0 \sim 1/\alpha$, where $\alpha = 2mA/\hbar^2$ (m—neutron mass).

The experiments were made with the equipment illustrated in Fig. 1. A quasi-monochromatic neutron beam ($\lambda \approx 2.9$ Å) is shaped by mirror 1, which limits the spectrum of neutrons from a reactor on the long-wave side, and a mirror-polarizer 2, which limits the spectrum on the short-wave side. The mirror 1 is produced by sputtering nickel on a plate of single-crystal quartz 0.4 mm thick. The total length of the mirror is 600 mm. The polarizer and analyzer were mirrors made by sputtering iron on TF-4 glass. The length of each mirror was 800 mm.

Such a mirror system makes it possible to obtain intense beams of quasi-monochromatic neutrons with polarization larger than 80% without beam broadening. The spin flip of the neutrons was with the aid of radio frequency coils 3 placed in a homogeneous magnetic field. By interconnecting these coils in different combinations it was possible to determine the polarization of the incident and scattered neutrons. The horizontal divergence of the incident and scattered beams was ± 2′, and the vertical divergence ± 20′. The sample was placed in a 26 kG field.

Figure 2 shows the measurement results. The data are given only for scattering through an angle larger than 6′, for at smaller angles the introduc-

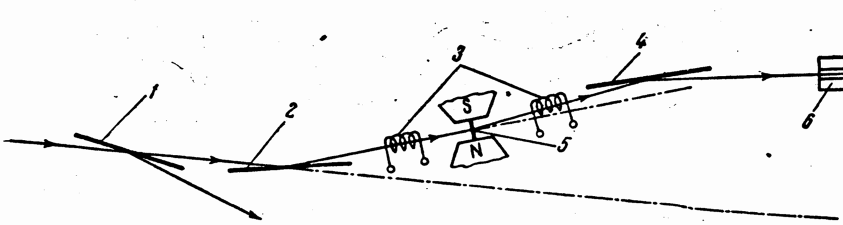

FIG. 1. Diagram of set-up: 1 – Nickel mirror on a quartz substrate, 2 – polarizer, 3 – radio-frequency coils for neutron spin flip, 4 – analyzer, 5 – sample, 6 – detector.

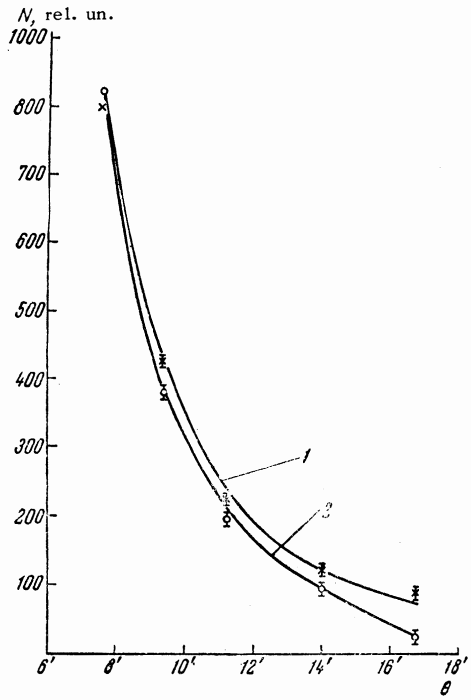

FIG. 2. Number of neutrons (per second) scattered with spin flip: 1 – Direction of the spin of the incident neutrons coincides with the direction of the magnetic field, 2 – direction of the incident-neutron spin opposite the direction of the magnetic field. When $\theta = 5.6'$ we get $N_1 = 4200$ and $N_2 = 3285$.

tion of corrections for the transmitted beam greatly reduces the accuracy of the results. The measurements were made up to angles 20′: at larger angles the low counting rate makes it practically impossible to determine the polarization.

It follows from the experimental results that the cross section for the scattering of neutrons with excitation of spin waves is not equal to the cross section for scattering with absorption of spin waves, and that with increasing scattering angle the absorption predominates over the excitation. These data are in agreement with calculations made by S. V. Maleev.

Calculations have shown that for a sample situated in a magnetic field H, scattering of neutrons with excitation of a spin wave should terminate at angles $\theta_+ < \theta_0$, while scattering with absorption of a spin wave at angles $\theta_- > \theta_0$. The parameter determining the angles θ_+ and θ_- is the quantity $2\mu_0 H/E$, where E—energy of the incident neutrons. Polarization on the order of 20% was observed when the samples scattered an unpolarized neutron beam at angles 10′–20′.

We have thus been able to show that neutron scattering by spin waves is actually accompanied by spin flip of the neutron and that the character of the scattering depends on the parameter $2\mu_0 H/E$.

S. V. Maleev participated in a discussion of the work during all of its stages, and we are most grateful to him for valuable advice. The authors are thankful to D. M. Kaminker for continuous interest in the work and for a discussion.

[1] R. D. Lowde and N. Umakantha, Phys. Rev. Lett. **4**, 452 (1960).
[2] Samuelsen, Riste, and Steinsvoll, Phys. Lett. **6**, 47 (1963).

Translated by J. G. Adashko
334

CONCERNING SURFACE SUPERCONDUCTIVITY

V. L. GINZBURG

P. N. Lebedev Physics Institute, Academy of Sciences, U.S.S.R.

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In an earlier communication[1] we called attention to the possible existence of surface superconductivity. We dealt primarily with the transition into the superconducting state of electrons on non-localized surface levels of the crystal (one can also conceive, however, of other types of surface superconductivity and of surface ordering in general[1,2]) 1). It was indicated in[1] that interaction with surface phonons can lead to additional attraction between the electrons located either near or on the surface. On the whole, however, the question of the sign of the interaction of energy between the surface electrons remained open.

The purpose of the present paper is to discuss one seemingly promising way of obtaining surface superconductors, which may even have a high critical transition temperature T_c. Namely, additional attraction between the surface electrons can be produced by depositing on the surface a dielectric film or a monomolecular layer of neutral atoms. This conclusion can be easily arrived at by an analysis similar to that used by Little[5] for organic chains.

Formal use of the BCS scheme[3] leads not only to three- and two-dimensional systems, but