Scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the Academy of Sciences of the USSR (18–19 January 1984)

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On January 18 and 19, 1984, at the P. N. Lebedev Physics Institute, USSR Academy of Sciences, the Joint Scientific Session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the USSR Academy of Sciences was held. The following papers were given at the session:

January 18

1. *A. I. Akhiezer, V. G. Bar'yakhtar, K. B. Vlasov, and S. V. Peletminskiĭ.* Rotational invariance, coupled magnetoelastic waves, and magnetoacoustic resonance.
2. *A. S. Borovik-Romanov, E. G. Rudashevskiĭ, E. A. Turov, and V. G. Shavrov.* Magnetoelastic effects of spontaneously broken symmetry and soft modes in magnetic phase transitions.
3. *V. I. Ozhogin and M. A. Savchenko.* Exchange-enhanced linear and nonlinear magnetoacoustic effects in antiferromagnets.

January 19

4. *I. D. Novikov.* Electrodynamics of black holes and its astrophysical applications.
5. *V. P. Frolov.* Quantum effects in black holes.

A brief summary of four of the reports is given below.

A. I. Akhiezer, V. G. Bar'yakhtar, K. B. Vlasov, and S. V. Peletminskiĭ. *Rotational invariance, coupled magnetoelastic waves, and magnetoacoustic resonance.* It is well known that, as a result of the dependence of the exchange and relativistic interactions on the distance between atoms, an interaction arises between the deformations of a crystal and its magnetic subsystem—the magnetoelastic interaction. In the static case it leads to a well studied phenomenon—magnetostriction, and in the dynamic case it leads to processes of mutual scattering and conversion of magnons into phonons.[1,2]

The role of these processes in establishment of equilibrium between the lattice and the magnetization was investigated by one of us long ago.[1] That study proposed a general method of discussion of relaxation processes in magnetically ordered crystals. The interaction between the magnetic subsystem and the lattice is characterized by a dimensionless constant $\zeta = \lambda M_0^2/\rho s^2$, where M_0 is the magnetization (the moment of the magnetic sublattice), ρ is the density of the material, s is the velocity of sound, and λ is the dimensionless constant of magnetostriction. Usually $\lambda \approx 1$ and $\zeta \ll 1$, and therefore magnons and phonons are usually considered to be quasiparticles which do not interact with each other. However, when the frequencies and wave vectors of a magnon and a phonon are close together, the interaction between them becomes strong in spite of the fact that $\zeta \ll 1$. In this case magnons and phonons lose their individuality and instead of elastic waves and magnons, hybrid magnon-phonon excitations become the normal waves.[2–5]

In the figure we have shown schematically the dependence of the frequencies of the hybrid waves, and the thin lines show the dispersion laws of the initial magnons and phonons: $\omega_m = \omega_0 + \omega_E (ak)^2$, $\omega_p = \omega_D ak$ where $\omega_0 = \gamma H_0$ is the frequency of uniform precession of the magnetization in an external field H_0, and ω_D and ω_E are respectively the Debye and exchange frequencies; a is the interatomic distance. The neighborhood of the point O is the region of magnetoacoustic resonance. In this region, excitation of oscillations of the magnetization Δm is accompanied by excitation of oscillations of the displacement Δu, and vice versa, which provides the possibility of resonance generation of sound by a variable microwave field, and of spin waves by variable applied stresses.

Far from the point O there is essentially no magnetoelastic interaction, so that in the upper part (the point A) curve I represents purely spin oscillations, and in the lower part (the point A') it represents purely elastic oscillations. Depending on the strength of the external magnetic field H_0, the point O may be either below or above the frequency ω of the wave introduced into the crystal. Therefore a wave of a given frequency ω can be continuously converted from a spin

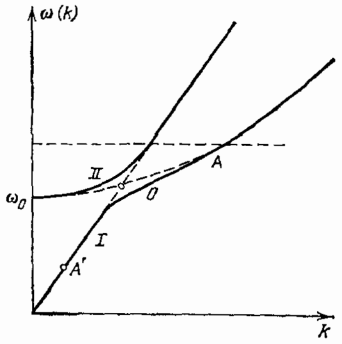

FIG. 1.

wave to an elastic wave and vice versa, by an appropriate change of H. This phenomenon is used in microwave electronics to create delay lines controlled by a magnetic field.

The magnetoelastic interaction appears not only in a change of the spectrum of quasiparticles, but also in the nature of the polarization of elastic waves.[6] Spontaneous magnetization of the medium results in the appearance of additional antisymmetric components of the dynamic elasticity modulus tensor of the type $c_{yzxz} = -c_{xzyz}$ (the z axis is chosen along the direction of magnetization). These components are responsible for acoustic gyromagnetic phenomena: rotation of the plane of polarization and appearance of ellipticity of an initially plane-polarized transverse elastic wave during its propagation along the magnetization. The two effects increase rapidly (in a resonance manner) on approach to the region of magnetoacoustic resonance, which is observed experimentally.

The study of magnetoacoustic phenomena has led to a review of the basic concepts of the mechanics of continuous media. It is well known that the equations of the mechanics of continuous media are constructed on the basis of the laws of conservation of momentum, energy, and angular momentum. Related to the conservation of angular momentum is the fact that the symmetric deformation tensor enters into the free energy of an elastic medium and into the equations of motion. Since neither orbital nor spin angular momenta are conserved individually in magnetic materials, for description of the magnetoelastic state of a material it is necessary to introduce (in addition to the symmetric part) also an antisymmetric part of the deformation tensor. Accordingly the stress tensor in magnetized media has an antisymmetric part, in contrast to ordinary media where it is equal to zero. Vlasov[7] showed that the antisymmetric part of the stress tensor determines an additional moment of the forces, which arises in local rotation of crystallographic axes and the axes of magnetic anisotropy of the relative magnetization associated with them. These ideas have led to the discovery of new effects. For example, an observed effect is nonmutuality, which consists of the fact that the velocities of two transverse sound waves in which the directions of the wave vectors and the polarizations are mutually changed, turn out to be different.

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[2] A. I. Akhiezer, in: Conference on Physics of Magnetic Phenomena, Acad. Sci. USSR, Moscow, May 1956.

[3] E. A. Turov and Yu. P. Irkhin, Fiz. Met. i Metallov. **3**, 15 (1956) [Phys. Met. Metallogr.].

[4] E. A. Turov, cited in Ref. 2.

[5] A. I. Akhiezer, V. G. Bar'yakhtar, and S. V. Peletminskiĭ, Zh. Eksp. Teor. Fiz. **35**, 228 (1958) [Sov. Phys. JETP **8**, 157 (1959)]. Spinovye volny (Spin Waves), Nauka, Moscow, 1967, pp. 136–169.

[6] K. B. Vlasov, Fiz. Met. i Metallov. **4**, 542 (1957) [Phys. Met. Metallogr.].

[7] K. B. Vlasov, Zh. Eksp. Teor. Fiz. **43**, 2128 (1962) [Sov. Phys. JETP **16**, 1505 (1963)].