Scientific Session of the Division of General Physics and Astronomy and the Division of Nuclear Physics, Academy of Sciences of the USSR (30–31 May 1984)

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A joint scientific session of the Division of General Physics and Astronomy of Sciences was held on May 30 and 31, 1984 at the P. N. Levedev Physics Institute of the USSR Academy of Sciences. The following reports were presented:

May 30

1. *L. M. Dedukh, V. I. Nikitenko, and É. B. Sonin.* Dynamics of Block lines in a domain wall.

2. *A. G. Morozov, M. V. Nezlin, E. N. Snezhkin, and A. M. Fridman.* Laboratory simulation of the generation of the spiral structure of galaxies (theory and experiment).

May 31

3. *I. I. Sobel'man.* Optical experiments on the search for parity nonconservation in bismuth.

4. *Z. G. Berezhiani and Dzh. L. Chkareuli.* Horizontal symmetry: masses and mixing angles of quarks and leptons of different generations; neutrino mass and neutrino oscillation.

The brief contents of three of the reports are published below.

L. M. Dedukh, V. I. Nikitenko, and É. B. Sonin. *Dynamics of Bloch lines in a domian wall.* In the overwhelming majority of real magnetically ordered crystals, domain walls (DW) are necessary elements of the magnetic structure, since the separation of the crystal into domains lowers the free energy of the crystal. The foundations of the quantitative theory of DW were formulated by L. D. Landau and E. M. Lifshitz 50 years ago. Much later it was pointed out that the energy of the crystal can be further lowered by separating the DW into sections, or subdomains, with a different direction of rotation of the magnetic moment **M** on crossing the DW. The boundaries between such subdomains are the Bloch lines (BL). They can also be called magnetic vortices, since when a BL is circumscribed along some path, the magnetic moment **M** in the plane of the DW turns through an angle of 2π. Such a magnetic vortex is a topologically stable linear soliton with very unique dynamics, differing in many respects from the dynamics of vortices in superfluid liquids and superconductors.

Bloch lines play an important role in the process of remagnetization of a magnetic material. Studies of Bloch lines were stimulated by the use of magnetic bubbles (MB) in the development of new types of computer memory elements, since BL radically affect the mass and mobility of the entire domain, playing the role of a carrier of information.[1] However, the study of the laws governing the motion of the BL themselves along DW is only now developing.

In this report, the results of experimental and theoretical studies of oscillations of BL in DW, in which the vortex nature of the BL is manifested, are presented. The experimental studies were performed on single-crystal yttrium iron garnet plates 30–60 μm thick.[2] The direction of easy magnetization was parallel to the plane of the plate. The BL were observed optically by the Faraday effect along the boundary between the dark and light subdomains of the DW, in which the magnetic moment was parallel to the direction of propagation of the polarized light (Fig. 1). The motion of the BL (Fig. 2) and DW was recorded by the concomitant changes in the intensity of the light, measured using a photomultiplier. The oscillations of the BL were excited by magnetic fields parallel to the vectors **M** in both subdomains and domains, though in the latter case the field exerts a pressure only on the DW. Resonance oscillations of BL were observed and their characteristics were studied. It was found that under these conditions resonance oscillations of the entire DW, which in the low-frequency range was characterized by the relaxation spectrum of the oscillations, are also observed.

The totality of the experimental data obtained cannot be described by models which view the BL and DW as one-dimensional topological solitons. In particular, the experimentally measured values of masses of BL and DW exceeded by several orders of magnitude the value of the Düring mass. The unique features of the oscillations of the DW can be explained if the two-dimensional nature of the motion of the BL, which moves not only along the DW, but also has an additional degree of freedom and can move perpendicular to the DW, bending it, is taken into account.[3] It is well known that the displacement of the BL in space (the two-dimensional vector **r** lies in the x, y plane and the BL is parallel to the z axis) satisfies the equation of motion[1,4]

$$2\pi\nu \frac{M}{\gamma} [\hat{\mathbf{z}}\dot{\mathbf{r}}] = -\frac{\partial F}{\partial r},$$

in which the external force—$\partial F/\partial r$ is equal not to the inertial force proportional to the acceleration, but rather to the

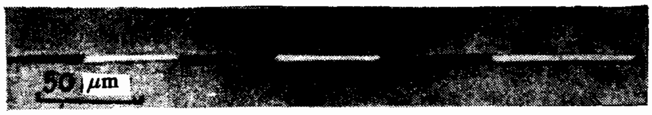

FIG. 1. 180° DW in an yttrium iron garnet plate, observed in polarized light with slightly uncrossed polarizers of the microscope. The Bloch lines separate the black and white subdomains in the DW.

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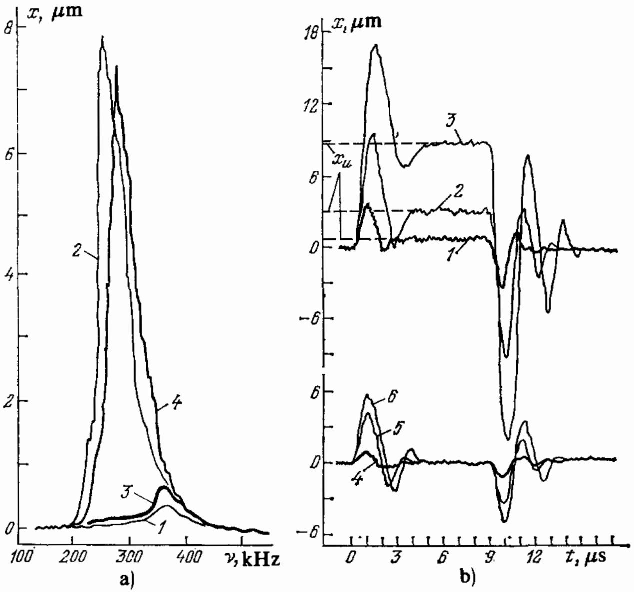

a) b)

FIG. 2. a) Spectra of the amplitudes of oscillations of BL, initiated by magnetic fields perpendicular (1, 2) and parallel (3, 4) to the vectors **M** in the domains ($H_z = 75$ mOe (1), $H_z = 150$ (2), $H_x = 6$ (3) and $H_x = 7.5$ (4); b) free oscillations of BL excited by rectangular pulses of fields H_z (1–3) and H_x (4–6) with a duration of 9 μs ($H_z = 300$ mOe (1), $H_z = 500$ (2), $H_z = 700$ (3), $H_x = 8$ (4), $H_z = 15$ (5), and $H_z = 20$ (6)).

gyrotropic force proportional to the rate of displacement $\dot{\mathbf{r}}$ of the BL. Here γ is the gyromagnetic ratio, $\hat{\mathbf{z}}$ is a unit vector lying along the z axis, and $\nu = \pm 1$ is a topological invariant, which depends on the structure of the core of the BL. The free energy F of the BL includes the energy which depends on the displacement along the DW and the energy which depends on the displacement perpendicular to the DW, leading to bending of the DW. The latter is determined by the energy expended on bending the DW.

Thus the BL is located in a two-dimensional potential well. A particle in this well would have two linearly polarized oscillatory modes. For the BL, appearing as a mangetic vortex, there exists only one mode of the elliptically polarized oscillations, analogous, to the Thompson oscillations of a vortex in hydrodynamics. These vibrations are accompanied by the bending oscillations of the DW and in the language of fields represent magnons localized on the BL.

If the length over which the oscillating BL bends the DW becomes greater than the distance between neighboring BL, then all BL oscillate synchronously with the DW.

The characteristic features of the observed resonance oscillations are as a whole described quite well by the studied model of the two-dimensional elliptically polarized oscillations of BL in DW. We note also that the displacements of the BL, accompanying the oscillations of the DW, can determine not only its inertial properties, but also the viscous losses accompanying the motion of the DW in the process of magnetization of the entire crystal.

[1] A. P. Malozemoff and J. C. Slonczewski, Magnetic Domain Walls in Bubble Materials, Academic Press, N. Y. (1979) [Russ. Transl., Mir. M., 1982].

[2] V. I. Nikitenko, L. M. Dedukh, V. S. Gornakov, and Yu. P. Kabanov, Pis'ma Zh. Eksp. Teor. Fiz. **32**, 152 (1980) [JETP Lett. **32**, 140 (1980)]; Zh. Eksp. Teor. Fiz. **82**, 2007 (1982) [Sov. Phys. JETP **55**, 1154 (1982)].

[3] A. V. Nikiforov and E. B. Sonin, Pis'ma Zh. Eksp. Teor. Fiz. **40**, 325 (1984) [JETP Lett. **40**, 1119 (1984)].

[4] A. V. Nikiforov and E. B. Sonin, Zh. Eksp. Teor. Fiz. **85**, 642 (1983) [Sov. Phys. JETP **58**, 373 (1983)].