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V. A. KISELEVA and E. I. KONDORSKII

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Abstract

Full Text

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PHYSICS

V. A. KISELEVA and E. I. KONDORSKII

STUDY OF THE TEMPERATURE DEPENDENCES OF CERTAIN PROPERTIES OF FERRITES IN THE CENTIMETER-WAVE RANGE

(Presented by Academician I. K. Kikoin, October 15, 1957)

The rotation of the plane of polarization of ferrites has been investigated in works ($^{1-6}$). However, up to the present time the temperature dependence of the Faraday effect in the region of strong fields has not been studied.

The purpose of the present work was to investigate the rotation of the plane of polarization of a wave of length 3.2 cm in nickel-magnesium ferrites $Ni_{1-x}Mg_xFe_2O_4$ at temperatures from −196 to +220°. The following were measured: the angle of rotation of the plane of polarization, the ellipticity, and the attenuation of the wave passing through a ferrite specimen placed in a longitudinal constant magnetic field. The composition of the ferrite specimens corresponded to values of x equal to: 0.2; 0.3; 0.5; 0.75; 1.

Fig. 1. Block diagram of the experimental setup.
1 —klystron generator; 2 —directional attenuator; 3 —directional coupler; 4 —standing-wave indicator 60-I; 5 —amplifier 28-I; 6 —matching stub; 7 —waveguide system with ferrite, placed in a Dewar vessel; 8 —rotating joint; 9 —detector head

The block diagram of the setup is shown in Fig. 1. The waveguide system was arranged in such a way that the section into which the specimen was placed could be lowered into a Dewar vessel filled with a cooling substance: dry ice or liquid nitrogen. The round waveguide had a diameter of 23 mm. The rectangular waveguide had dimensions $a = 19$ mm and $b = 3$ mm. The dimension a was chosen from the consideration that the wavelength should not be close to the critical one.

The wavelength in the waveguide λ_g was then equal to

$$\lambda_g = \frac{\lambda_0}{\sqrt{1-(\lambda_0/\lambda_{\text{cr}})^2}} = 5.9 \text{ cm} \quad (\lambda_0 = 3.2 \text{ cm}).$$

The reduction of the dimension b for a wave of type H_{10}, as is known, leads to a change in the wave impedance, which in the present case was inessential, since this section of the waveguide was matched to a waveguide of standard cross section by means of an impedance transformer. The dimension $b = 3$ mm was chosen for design reasons.

In order that the monitoring and measuring apparatus should not be subjected to cooling, the part of the waveguide system lowered into the Dewar vessel was isolated from the rest of the waveguide system. The insulating sections of the waveguide were made as follows: the rectangular one from Plexiglas, the round one from textolite. The inner surfaces of these waveguides were silvered. Specimens in the form of rods 50 mm long and 5 mm in diameter were mounted in polystyrene-foam holders. Absorbing plates were arranged so that they absorbed the wave with transverse polarization.

To obtain magnetic fields in the apparatus, a solenoid consisting of separate pancakes was used. The pancakes were made of rectangular copper tubes through which water flowed for cooling. A rheostat system made it possible to vary the current smoothly from 0.06 to 120 A. The solenoid made it possible to obtain fields up to 5500 oersted.

A 51-I generator was used as the power source. The indicator was a 28-I amplifier, to which a detector head was connected. The detector head was connected to the waveguide system by means of a rotating joint, on which a scale was marked. A directional attenuator was used as the klystron decoupler. In order to prevent icing of the specimen and of the inner walls of the waveguide system, compressed air was passed through it. The compressed air was dried beforehand. When working at high temperatures, an analogous apparatus was used. To obtain high temperatures, a nichrome spiral was wound bifilarly on the waveguide section in which the ferrite was placed. To insulate the control-and-measuring apparatus, the heated waveguide section was separated from the rest of the waveguide tract by waveguide sections with water jackets. The temperature was measured with a copper–constantan thermocouple, one end of which was brought into direct contact with the specimen under test. After the specimen temperature had finally become established, the thermocouple was removed from the waveguide, and the temperature during the experiment was monitored by another thermocouple, one end of which was attached to the outer wall of the waveguides at the place where the specimen was located.

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

Fig. 2. Angle of rotation of the plane of polarization θ in a magnetizing field of 1200 oersted, and values of the resonance field H at room temperature for specimens of different composition

The angle of rotation of the plane of polarization was measured by rotating the detector head, which was set in such a position that the 28-I amplifier instrument gave minimum readings. Ellipticity and attenuation were measured with a calibrated attenuator by the substitution method. Attenuation was measured only up to a field of the order of 1200 oersted, since near resonance a large error is introduced into these measurements because of the increase in ellipticity.

Table 1

Value of the ellipticity and attenuation of a specimen of composition $Ni_{0.7}Mg_{0.3}Fe_2O_4$

H, oersted	Ellipticity, dB	Ellipticity, dB	Ellipticity, dB	Ellipticity, dB	Ellipticity, dB	H, oersted	Attenuation, dB	Attenuation, dB	Attenuation, dB
	−196°	−77°	+20°	+120°	+220°		−196°	+20°	+220°
0	24	24	24	25	27	0	1.6	0.3	0.2
1000	22	22	22	25	26	100	0.6	0.25	0.2
2000	9.5	11	11.5	15	17.5	200	1.2	0.25	0.2
3000	9	9.5	10	11	12	500	1.2	0.25	0.2
3700	4.5	5	5	4	0.5	1000	1.2	0.4	0.2
4000	0.5	0.5	0.5	1	6	1200	1	0.5	0.2
4100	0.5	1	1.5	4	14				
4800	22	25	26	30	30				

Figure 2 gives the curve of the dependence of the angle θ of rotation of the plane of polarization in a magnetic field of 1200 oersted, and the values of the resonance field on the quantity x, characterizing the composition of the ferrite. Figure 3 gives the cur-

quantities characterizing the dependence of the angle θ on the magnetic-field strength at different temperatures for the sample with $x = 0.3$. Table 1 gives

Fig. 3. Dependence of the angle of rotation of the plane of polarization θ on the magnitude of the magnetic field H at different temperatures. 1 –at −196°; 2 –at −77°; 3 –at +20°; 4 –at +120°; 5 –at +220°. Sample length 50.2 mm

the values of the ellipticity and attenuation of the same sample at different temperatures. In the study of other samples of the nickel–magnesium system, analogous changes in the angle of rotation of the plane of polarization were

Fig. 4

Figure 4: Fig. 4

observed. The decrease of θ with increasing temperature and as it approaches the Curie temperature is connected with the fact that, in this case, the values μ_- and μ_+ of the real parts of the effective permeability for the negative and positive components of the circularly polarized wave approach one another, and the difference $(\mu_-)^{1/2} - (\mu_+)^{1/2}$, entering the well-known formula for θ, decreases.

Fig. 4. Dependence of the magnitude of the resonance field on temperature. 1 $-x = 0.3$; 2 $-x = 1$

Figure 4 presents curves of the dependence of the magnitude of the resonance field on the temperature of samples with x equal to 0.3 and 1.

From the data given, as well as from data obtained in the study of other samples, it follows that, with an increase in temperature, the resonance region shifts toward lower fields. This shift is apparently connected with a change in the anisotropy field.

Moscow State University
named after M. V. Lomonosov

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