Light scattering in ferrimagnetic RbNiF$_3$

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Modulation of light by ferromagnetic resonance in the ferrimagnetic crystal RbNiF$_3$ has been observed at $T \approx 2$ K for two directions of the magnetic field relative to the high-order axis C_6: $\mathbf{H} \perp C_6$ and $H \parallel C_6$. The possible contributions of various magneto-optical effects to the intensity of the Stokes and anti-Stokes satellites in the light spectrum modulated by ferromagnetic resonance are analyzed. The velocities of the longitudinal phonons along the C_6 axis and perpendicular to it are determined: $v_\parallel = 5.1 \pm 0.1$ km/s and $v_\perp = 4.82 \pm 0.1$ km/s.

I. INTRODUCTION

The study of light scattering by spin waves excited by magnetic resonance in magnetically ordered media allows us to obtain information on the energy spectrum of magnons (for example, resonance, exchange constants), on relaxation processes that arise in an excited spin system, and on the values of magneto-optic constants of the material.

At the present time, such studies have been carried out on a series of magnetodielectrics: in the ferromagnetic crystals CrBr$_3$ (Ref. 1) and K$_2$CuF$_4$ (Ref. 2), ferromagnetic iron yttrium-garnet (YIG)[3] and antiferromagnetic CoCO$_3$ (Ref. 4). In all the crystals mentioned, modulation of the light by magnetic resonance (ferromagnetic or antiferromagnetic) has been observed or, what amounts to the same thing, the scattering of light by spin waves with $q = 0$. In CoCo$_3$ and K$_2$CuF$_4$, such scattering was observed by spin waves with $q \neq 0$, arising as a result of the relaxation of a uniform precession.[5,2] On the basis of these data, the conclusion has been made that the dominant process of relaxation of magnons with $q = 0$ is a two-magnon process connected with scattering from impurities and leading to the overheating of a certain group of spin waves having a frequency equal to the frequency of magnetic resonance. Thus, the "bottleneck magnon" effect has been observed.[6]

The problem of the relation of the intensities of the Stokes and anti-Stokes satellites in the scattering spectrum has been discussed in a number of works on light scattering by magnons.[7–9] The most general results were obtained by Wettling, Cottam and Sandercock[9] in a study of Mandel'shtam-Brillouin scattering in YIG. It was shown that these intensities are determined by different combinations of magneto-optical constants of the material. In the general case, when all the constants have comparable values, the intensities of the satellites are different. If one of the magneto-optical constants is significantly larger than the others, the intensities of the satellites are the same. In the scattering spectra in CrBr$_3$, K$_2$CuF$_4$, and CoCO$_3$ the intensities of the Stokes and anti-Stokes satellites have the same value. This is connected with the fact that in the case of CrBr$_3$ and K$_2$CuF$_4$ the Faraday effect is dominant for the wavelengths used, while in CoCO$_3$ the anisotropic magnetic birefringence dominates. Ferrimagnetic YIG possesses Faraday rotation and linear magnetic birefringence that are close in value. This fact leads to the result that the intensities of the Stokes and anti-Stokes components in the YIG spectrum are different.

In the present work, we have studied light scattering from spin waves that arise in ferromagnetic resonance in the ferrimagnetic RbNiF$_3$, which possesses Faraday rotation and magnetic birefringence that are close in value. It should be noticed immediately that because of the small values of these magneto-optical effects, we have not succeeded in observing light scattering by thermal magnons. However, it is of interest to study the scattering from excited ferromagnetic resonant magnons for different wavelengths and directions of propagation of the light in the crystal, and also different branches of the low-frequency resonance.

II. SAMPLES AND METHODS OF MEASUREMENT

The RbNiF$_3$ crystal has a hexagonal structure, and its symmetry is described by the space group D^4_{6h}. In the unit cell, the nickel ions occupy two nonequivalent positions NiA and NiB, in which the NiA ions are twice as numerous as the NiB. Below $T_c = 139$ K, the RbNiF$_3$ crystal transforms into a magnetically ordered ferrimagnetic state of the "easy plane" type; here the NiA and NiB ions form two nonequivalent sublattices with oppositely directed spins. The saturation magnetic moment per unit formula amounts to one third the total saturation moment for the Ni^{++} ion.[10–12] In a magnetic field $\mathbf{H}$ parallel to the hexagonal axis C_6, the ferromagnetic moment departs from the plane and at $H \approx 20$–30 kOe it is directed along C_6.[10–12]

The conditions for excitation of ferromagnetic resonance in RbNiF$_3$ have been studied theoretically and experimentally at $T \geqslant 77$ K by Golovenchits, Gurevich, and Sanina.[13,14] They showed[13] that the experimental results obtained at low temperatures are described in first approximation by the model of a uniaxial ferromagnet with anisotropy of the easy plane type. The resonance frequencies ν for the two directions of the magnetic field $\mathbf{H}$ in this model are, as is well known (see, for example, Ref. 15), described by the equations

$$\mathbf{H} \perp C_6: \left(\frac{\nu_\perp}{\gamma}\right)^2 = [H + H_A + (N_z - N_x) M_s][H + (N_y - N_x) M_s], \tag{1}$$

$$\mathbf{H} \parallel C_6: \left(\frac{\nu_\parallel}{\gamma}\right)^2 = [H - H_A + (N_x - N_z) M_s] \times [H - H_A + (N_y - N_z) M_s]. \tag{2}$$

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Equations (1) and (2) were obtained for an ellipsoidal sample under the approximation that the coordinate axes coincided with the principal axes of the ellipsoid. Here the axis $z \parallel C_6$, while the x axis lies in the basal plane and in the case $\mathbf{H} \perp C_6$ is identical with the direction $\mathbf{H}$; N_x, N_y, N_z are the principal values of the coefficients of the demagnetization tensor, M_s is the saturation magnetization, H_A is the field of the anisotropy.

A more detailed experimental investigation of the dependence of the frequency of the ferromagnetic resonance, on the magnetic field H, on the angle between $\mathbf{H}$ and C_6, and on the temperature (77–180 K) in $RbNiF_3$ showed that it is necessary, for the description of the results, to go over to the following approximation, which takes into account the anisotropy of the g factor and the presence of a second anisotropy constant at $T \geqslant 77$ K.[14]

$RbNiF_3$ crystals are transparent in the green portion of the spectrum.[16] They are optically uniaxial in the paramagnetic state. In the ferrimagnetic state, magnetic birefringence appears in them[17] as well as the Faraday effect.[18] The Faraday rotation has been measured along the C_6 axis (in Ref. 18), when the light wave vector $\mathbf{k} \parallel \mathbf{H} \parallel C_6$, at $T = 77$ K. Magnetic birefringence has been studied in the basal plane, at $\mathbf{k} \parallel C_6$ and $\mathbf{H} \perp C$. Several parameters of $RbNiF_3$ are shown in Table I.

The $RbNiF_3$ crystals that we used were grown by the Bridgman method in the Institute of Physical Problems, Academy of Sciences USSR. The modulation studies were made on two samples having the shapes of discs with diameter 2 mm and thickness ≈ 0.3 mm. The C_6 axis in one of them lay in the plane of the disc and was perpendicular to it in the other. In the study of light scattering from phonons, the sample of $RbNiF_3$ used by us had the shape of a parallelepiped with dimensions $1 \times 2 \times 3$ mm. The precision of the orientation of the samples amounted to 1–2°. The surfaces of the samples were subjected to optical polishing.

For the study of Mandel'shtam-Brillouin scattering by magnons excited by ferromagnetic resonance at low temperatures, apparatus was used consisting of a high-contrast optical system, a microwave spectrometer, and an optical helium cryostat. As the spectral instrument we used a scanning multipass Fabry-Perot interferometer of the American firm "Burleigh." The contrast of the interferometer in our experiments was greater than 10^7; the sharpness of the bands amounted to ≈ 60. As light sources, we used an argon laser ILA-120 (of the firm C. Zeiss, Jena) and a helium-neon laser LG-38.

The optical scheme of the apparatus allowed us to illuminate three scattering geometries: at small angles, at 90° and back (180°) scattering.

As a source of microwave power, we used a ≈ 36-GHz magnetron. The sample was placed at the end of a shorted waveguide. All the experiments were conducted in superfluid helium at $T \approx 1.7$–2 K.

Our apparatus has been described in more detail in Refs. 4, 5, and 19.

III. LIGHT MODULATION BY FERROMAGNETIC RESONANCE

1. Experimental results

a. An investigation of ferromagnetic resonance in $RbNiF_3$ by the microwave method was carried out at $T \leqslant 2$K. The results that were obtained showed that the basic features of this phenomenon, which were observed in Refs. 13 and 14 at $T = 77$ K, are preserved at low temperatures. In a magnetic field $\mathbf{H}$ perpendicular to the C_6 axis, the resonance is observed in small fields $H_{\text{res}} = 4.70 \pm 0.05$ kOe (low-field resonance), and in another geometry, in which $\mathbf{H} \parallel C_6$, the field H_{res} is large and amounts to 32.8 ± 0.3 kOe (high-field resonance) at a frequency of ferromagnetic resonance $\nu_{\text{FMR}} = 35.8$ GHz.

At a low value of applied microwave power, an intense absorption line is observed in low-field resonance, of width ≈ 50 Oe, and a number of satellites with lesser intensity, distributed on both sides of the principal line. The presence of the satellites is evidently connected with the excitation of magnetostatic modes in the disc. Upon increase in the applied [1)] power P to 50 mW, the shape of the line and the value of the relative absorption of microwave power do not change. Further increase in P is accompanied by a transition to a nonlinear regime, and a broadening of the absorption lines and disappearance of the satellites are observed. In the high- frequency resonance, the absorption line has the width ≈ 400 Oe.

b. For observation and study of the modulation of light by ferromagnetic resonance in $RbNiF_3$ we used an optical-apparatus variant corresponding to direct scattering of light (or scattering at small angles). The optical expermients were conducted in the three geometries shown in Fig. 1: the geometries 1 and 2 corespond to excitation of the low-field resonance (1), in which $\mathbf{M} \parallel \mathbf{H} \perp C_6$. They differ in the direction of propagation of the light: $\mathbf{k} \parallel C_6$ in case 1 and $\mathbf{k} \perp C_6$ in case 2. The geometry 3 corresponds to excitation of the high-field

TABLE I

T_c, K	$4\pi M_s$, kOe $T=$ 4,2 K	H_A, kOe		g- factor	$T=77$ K, $\lambda=514,5$ nm		T 300 K, $\lambda=500$ nm	
		$T=77$ K	$T=4,2$ K		Faraday effect, deg/cm	magnetic birefringence, deg/cm	n_0	n_e
139	1,25 [10]	25 [10]	30 [11]	$g_{\parallel}=2,33$ [14]	140 [17]	135 [16]	1,5 [11]	1,5 [11]
(10, 11)	1,33 [11]	17 [12] 17 [14]	15 [12] 21,5 current work	$g_{\perp}=2,26$				

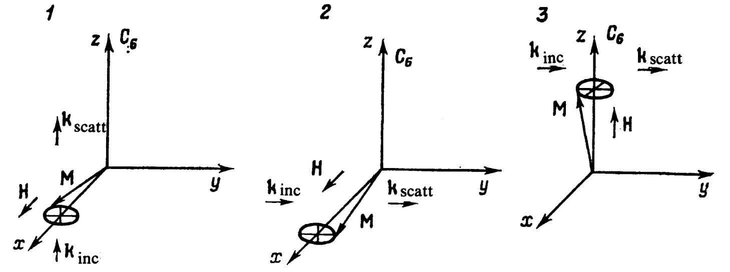

FIG. 1. Geometry of the experiments used in the observation of the modulation of light by ferromagnetic resonance in $RbNiF_3$: 1—$H \perp C_6, k \parallel C_6$; 2—$H \perp C_6, k \perp C_6, H \perp k$; 3—$H \parallel C_6$, $k \perp C_6$.

resonance (2), in which $M \parallel H \parallel C_6$. Here the light is directed perpendicular to the C_6 axis.

The onset of light modulation corresponds to the appearance in the spectrum of the light passing through the crystal of additional satellites with a shift in frequency equal to the frequency of the excited magnetic resonance ν_{FMR}.

We observed light modulation by ferromagnetic resonance in $RbNiF_3$ for the geometries 1 and 3 of the experiment at the wavelengths of the incident light $\lambda = 488.0$, 514.5, and 632.8 nm.

In the case of geometry 2, light modulation was not observed.

The ratio of the intensities of the Stokes (P_S) and anti-Stokes (P_{AS}) satellites in the scattering spectrum depends on the geometry of the experiment and the wavelength of the incident light. For $\lambda = 488.0$ and 514.5 nm in geometry 1, the ratio P_S/P_{AS} amounts to 2.8 while in geometry 3, $P_S/P_{AS} \approx 1$. In the case $\lambda = 632.8$ nm, and geometry 1, we have $P_S/P_{AS} \approx 1.3$. The accuracy of the measurement of the intensities of the satellites amounted to 10%. Upon rotation of the plane of polarization of the incident light by 90°, the ratio of the intensities of the satellites was inverted in all cases. Typical plots of the obtained scattering spectra for $\lambda = 514.5$ nm in the geometry 1 of the experiment, in the case of two polarizations of the incident light, are shown in Fig. 2. Satellites are observed in the scattering spectrum in the range of magnetic fields corresponding to the linewidth of the ferromagnetic resonance. At a specific intensity of the incident light, the intensity of the satellites is determined by the power absorbed at resonance, i.e., the intensity of the satellites approximately repeats the line shape of the UHF absorption. At constant UHF power, the intensity of the satellites is proportional to the intensity of the incident light.

2. Theoretical consideration and discussion of results

The results of the previous section show that the essential feature of the light modulation by ferromagnetic resonance, discovered by us in $RbNiF_3$, is the difference in the intensities of the Stokes and anti-Stokes components of the scattering spectrum. As was shown above, a similar phenomenon has already been observed in ferrimagnetic YIG[3,9] and has found its explanation in the works cited above. It is interesting to carry out a detailed consideration also for the $RbNiF_3$ case that we have investigated. For this purpose, it is first necessary to determine the parameters of the ferromagnetic resonance H_A and γ at $T \leqslant 2$ K and the amplitudes of the oscillations of the magnetization in homogeneous precession for different directions of the magnetic field (1) and (2). As has already been shown above, Eqs. (1) and (2) were derived in the approximation of isotropic g-factor and with account of only the first anisotropy constant K_1. However, the data of Ref. 20, where the first (K_1) and the second (K_2) anisotropy constants were measured, show that K_2 is smaller than K_1 only by a factor of 7. Such a ratio of constants can lead to different values of the effective field of the anisotropy H_A entering into (1) and (2). Since the measurements of the ferromagnetic resonance have been made by us at one frequency only, we cannot determine γ, H_{A1} and H_{A2} independently from our experimental data. Therefore, taking the value of γ from Ref. 14 (assuming that γ changes little with temperature) and using our experimental values of H_{res} we find the values of H_{A1} and H_{A2} from Eqs. (1) and (2). It turns out that they differ by at most 2%. Therefore, in what follows, we shall assume that γ is isotropic and equal to 3.30

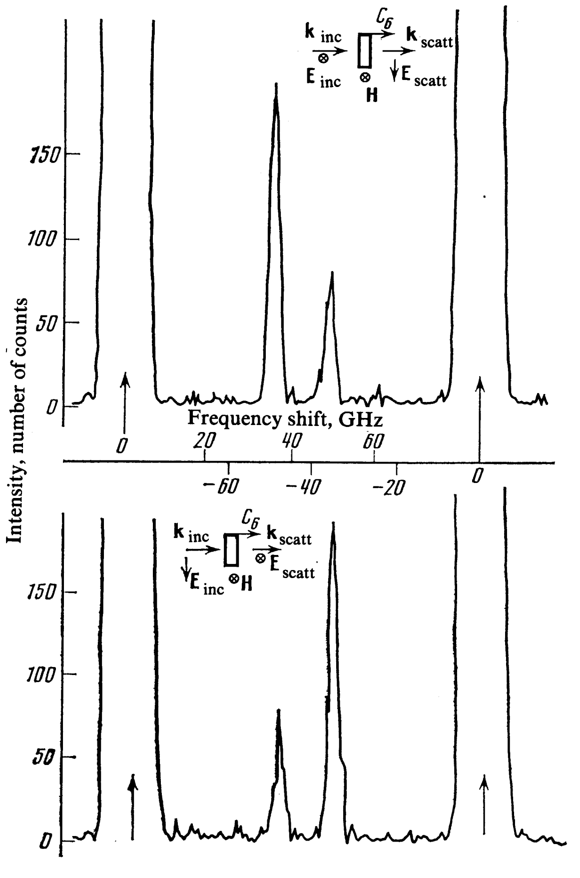

FIG. 2. Spectra of light passing through an $RbNiF_3$ crystal in the excitation of ferrromagnetic resonance for two mutually perpendicular polarizations of the incident light $\lambda = 514.5$ nm.

(Ref. 20) and $H_{A1} = H_{A2} = H_A$. The calculated value of H_A under these conditions amounts to 21.5 ± 0.5 kOe. There is a rather large scatter in the values of H_A determined from different experiments, as is seen from Table I.

The amplitudes m_j of the oscillations of the magnetization in homogeneous precession ($M_j = m_j \exp(2\pi i\nu t)$, $j = x, y, z$) can be determined from the solution of the corresponding equations of motion. We obtained the following results for the components of the spins in low- and high-field resonances:

$$\mathbf{H}\perp C_6:\quad \frac{m_y}{m_z}=\left[\frac{H+H_A+(N_z-N_x)M_s}{H+(N_y-N_x)M_s}\right]^{1/2}, \tag{3}$$

$$\mathbf{H}\|C_6:\quad \frac{m_y}{m_x}=\left[\frac{H-H_A+(N_x-N_z)M_s}{H-H_A+(N_y-N_z)M_s}\right]^{1/2}. \tag{4}$$

After determining the necessary parameters of ferromagnetic resonance, we return to the problem of finding the intensities of the satellites in the scattering spetrum in $\mathrm{RbNiF_3}$ in the case of ferromagnetic resonance. This problem has been solved by us in manner similar to what was done in Refs. 3 and 7.

We write out the magnetic part of the permittivity tensor $\Delta\varepsilon_{ij}$ of the $\mathrm{RbNiF_3}$ crystal for the case corresponding to geometry 1 (see Fig. 1), i.e., when low-field resonance is excited in the material:

$$\mathbf{H}\|x,\quad M_y=m_ye^{2\pi i\nu t},\quad M_z=m_ze^{2\pi i\nu t},\quad M_x=\mathrm{const}=M_s$$

(ν is the frequency of ferromagnetic resonance), and $\mathbf{k} \parallel z$. Here we shall take into consideration only the contributions to the tensor components that are linear in M_y and M_z, since it is just these that are responsible for the appearance of satellites in the light scattering spectrum at the frequencies $\nu_0 \pm \nu$, where ν_0 is the frequency of the incident light:

$$\Delta\varepsilon_{ij}=\begin{pmatrix} 0 & if_{123}M_z+g_{66}M_sM_y & if_{321}M_y+g_{44}M_sM_z \\ -if_{123}M_z+g_{66}M_sM_y & 0 & 0 \\ -if_{321}M_z+g_{44}M_sM_z & 0 & 0 \end{pmatrix}. \tag{5}$$

Here, as is usually the case, the coefficients f_{ijk} and g_{ij} describe the contributions to $\Delta\varepsilon$ from the Faraday rotation and the magnetic linear birefringence, respectively. Using the obtained value of $\Delta\varepsilon_{ij}$ (5), we find the intensity of the light, following Refs. 3 and 7, for the case in which the incident light is polarized along the x axis: $\mathbf{E}_{\rm inc} \to (E \sin 2\pi\nu_0 t, 0, 0)$. Here the light scattering will be polarized along the y axis. If we denote the intensity of the Stokes satellite of frequency ν_0-ν by $P_{\rm S}$ and the anti-Stokes value by $P_{\rm AS}$ then the results of the calculation can be represented in the form

$$\frac{P_{\rm C}}{P_{\rm AC}}=\left(\frac{f_{123}m_z+g_{66}M_sm_y}{f_{123}m_z-g_{66}M_sm_y}\right)^2. \tag{6}$$

Upon rotation of the plane of polarization of the incident light by 90°, $\mathbf{E}_{\rm inc} \to (0, E \sin 2\pi\nu_0 t, 0)$, Eq. (6) transforms into

$$\frac{P_{\rm C}}{P_{\rm AC}}=\left(\frac{f_{123}m_z-g_{66}M_sm_y}{f_{123}m_z+g_{66}M_sm_y}\right)^2. \tag{7}$$

A similar consideration has been carried out by us for the geometries 2 and 3 (see Fig. 1) of the experiment. Here it has been assumed in both cases that the polarization of the incident light is either parallel to the magnetization [the upper sign in Eqs. (8) and (9)] or perpendicular to it [the lower sign in (8) and (9)]. For $\mathbf{k} \parallel y$, $\mathbf{H} \parallel \mathbf{M} \parallel x$ (geometry 2):

$$\frac{P_{\rm C}}{P_{\rm AC}}=\left(\frac{f_{321}m_y\pm g_{44}M_sm_z}{f_{321}m_y\mp g_{44}M_sm_z}\right)^2. \tag{8}$$

For $\mathbf{k} \parallel y$, $\mathbf{H} \parallel \mathbf{M} \parallel z$ (geometry 3),

$$\frac{P_{\rm C}}{P_{\rm AC}}=\left(\frac{f_{321}m_y\pm g_{44}M_sm_x}{f_{321}m_y\mp g_{44}M_sm_x}\right)^2. \tag{9}$$

Thus, calculation shows that in the general case the intensities of the Stokes and anti-Stokes satellites in the light scattering spectrum are different and their ratio changes to its reciprocal upon rotation of the polarization of the incident light by 90°.

We now carry out a comparison of the existing experimental data with the equations that we have obtained. From measurements of the Faraday effect and the magnetic birefringence in $\mathrm{RbNiF_3}$, given in Refs. 17 and 18, we can estimate the ratio of the constants f_{123}/g_{66} for $\lambda = 514.5$ nm at 77 K. Taking it into account that at this temperature, $M = 0.79M_s$,[11] we obtain

$$f_{123}/g_{66}M_s=0{,}75. \tag{10}$$

The quantity m_y/m_z can be determined from Eq. (3) of the present paper if we substitute the parameters of ferromagnetic resonance of the geometry 1 in it–$H = 4.7$ kOe, $H_A = 21.5$ kOe, and $4\pi M_s = 1.25$ kOe:

$$m_y/m_z=2{,}4. \tag{11}$$

Using (10) and (11), we obtain an estimate of the value of $P_{\rm S}/P_{\rm AS}$ [see Eq. (6)] for geometry 1 of the experiment

$$P_{\rm C}/P_{\rm AC}=3.6 \tag{12}$$

under the assumption that the constants f_{123} and g_{66} change little with decrease in temperature. This value is found in good agreement with our experimental result $P_{\rm S}/p_{\rm AS} = 2.8$. In correspondence with theory, this value changed to its reciprocal upon rotation of the polarization of the incident light by 90° (see Fig. 2).

In the geometries 2 and 3, the ratio of the intensities of the Stokes and anti-Stokes satellites is determined by the same constants f_{321} and g_{44} [see (8) and (9)]. Actually, $m_y/m_z = 2.4$ from (11), while $m_x/m_y = 1$, as follows from Eqs. (4) (if we substitute the values $H = 32.8$ kOe, $H_A = 21.5$ kOe and $4\pi M_s = 1.25$ kOe in it.

A comparison with the experimental data allow us to make some estimates of the quantities f_{321} and g_{44} for light of wavelength $\lambda = 514.5$ nm. Since $P_{\rm S}/P_{\rm AS} = 1.0 \pm 0.1$ in ge-

TABLE II

	geometry of scattering, φ	λ, nm	q_{ph}, $10^5 cm^{-1}$	ν, GHz	v, km/s
$\mathbf{q}_{ph} \parallel C_6$	90°	488,0	2,75	22,3	5,10
	180°	632,8	2,98	24,4	
	180°	514,5	3,68	30,3	
	180°	488,0	3,89	31,4	
$\mathbf{q}_{ph} \perp C_6$	90°	488,0	2,76	21,4	4,82
	180°	514,5	3,71	28,6	
	180°	488,0	3,91	29,5	

ometry 3 of the experiment, then, in accord with (9), one of the mentioned constants should be significantly less than the other. In geometry 2, the light modulation was not observed. This fact, with account of the fact that the constants f_{321} and g_{44} enter in Eqs. (8) and (9) with different weights, leads to the conclusion that the quantity f_{321} is small. The following estimate is obtained for these quantities:

$$f_{321}/g_{44}M_s<2\cdot10^{-2}. \tag{13}$$

Thus, the analysis that has been made of the experimental data for $\lambda = 514.5$ nm shows that the modulation of light in geometry 1 of the experiment is due both to magnetic birefringence and to the Faraday effect. In geometry 3, the dominant role in the light modulation is played by the magnetic birefringence.

The value of the ratio P_S/P_{AS} for $\lambda = 488$ nm is identical with the value obtained from $\lambda = 514.5$ nm. With the use of $\lambda = 632.8$ nm, this characteristic changes. It is known that $RbNiF_3$ absorbs light strongly in the red region of the spectrum. The effects of linear and circular dichroism appear in this connection, and the Faraday constants and the magnetic birefringence are also changed. All this leads to a change in the ratio of the intensities of the Stokes and anti-Stokes satellites in the light scattering spectrum. However, our experimental data are insufficient for any quantitative estimates for the magneto-optical constants at $\lambda = 632.8$ nm.

3. Determination of the angle of inclination of the spins in homogeneous precession

The ratio of the intensity of the satellites in the spectrum of light scattered forward to the intensity of the incident light is characterized by the angle of inclination of the spins (measured from the equilibrium position) in the excitation of homogeneous precession or the number of spin waves with $q = 0$. We have estimated this angle for geometry 1 of the experiment with a power of the microwave pump corresponding to the transition to the nonlinear regime. It turned out that

$$\varphi_1{}^M = \frac{m_z}{M_s} \approx 0{,}2\pm0{,}1^\circ, \quad \varphi_2{}^M = \frac{m_y}{M_s} \approx 0{,}5\pm0{,}25^\circ.$$

These same values can be obtained independently of the values of the high-frequency susceptibility at resonance and the value of the microwave field in which the sample is found. Under the condition that the line width of the ferromagnetic resonance ΔH_{res} is equal to 50 Oe, we found, for the same power as in the previous case, that $\varphi_1^{micro} \approx 0.05 \pm 0.03°$ and $\varphi_2^{micro} \approx 0.12 \pm 0.06°$. It noted that the homogeneity of the constant field in the solid that we used was no greater than $\sim 1\%$. This means that the real picture of the line of ferromagnetic resonance at $H_{res} = 4.7$ kOe can be less than the observed $\Delta H_{res} = 50$ Oe. The decrease of ΔH_{res} leads to an increase in the angles φ_1^{micro} and φ_2^{micro}.

Taking into account everything that has been said above, we can conclude that the values of the angles of inclination of the spins in ferromagnetic resonance, obtained by two different methods, do not contradict one another.

IV. SCATTERING OF LIGHT BY PHONONS

We investigated the Mandel'shtam-Brillouin scattering of light by phonons in $RbNiF_3$ at room temperature. The study was carried out at different scattering geometries (90° and 180° geometries) and at different light wavelengths.

Light scattering from longitudinal phonons was observed. These phonons were propagating along the C_6 axis and in the basal plane. The experimentally determined values of the frequencies of the phonons for different waves vectors $\mathbf{q}_{ph}$ are given in Table II.

The propagation velocities of the phonons were calculated from the obtained values of $\nu_{ph}(q_{ph})$ according to the usual formula.[21] The velocities of the longitudinal phonons along the C_6 axis were calculated by the method of least squares: $v_{\parallel} = 5.1 \pm 0.1$ km/s, and of phonons traveling perpendicular to it, $v_{\perp} = 4.82 \pm 0.1$ km/s.

In conclusion, the authors express their gratitude to P. L. Kapitza for interest in the work, to Yu. F. Frekhov for orientation of the crystals and to E. K. Zhdanov for polishing the samples.

[1)] The sample absorbs $\sim 15\%$ of the applied power.

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