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ANTIFERROMAGNETIC RESONANCE IN ORTHORHOMBIC WEAK FERROMAGNET YCrO₃

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Résumé. — On a étudié la résonance antiferromagnétique dans des monocristaux de YCrO₃ avec des champs pulsés et dans la gamme de longueur d'onde 1-6 mm. La dépendance en champ de la fréquence a été mesurée avec un champ H_0 dirigé selon les axes a et c. Pour parallèle à l'axe a, le basculement des spins se produit pour 33 kOe. On calcule les paramètres de l'énergie libre comme dans NaNiF₃ qui avait été précédemment étudié et on en fait la comparaison.

Abstract. — Antiferromagnetic resonance in YCrO₃ single crystals was studied in pulse magnetic fields in 1-6 mm wave-length range. The frequency vs field dependences were measured with magnetic field H_0 directed along a and c axes. For the H_0 directed along the a-axis at $H_0 = 33$ kOe the spin-flop takes place. As in the earlier investigated orthorhombic NaNiF₃ the parameters of the free energy were calculated. The obtained values of the parameters are compared with the values of the same parameters for NaNiF₃.

According to [1] YCrO₃ has the perovskite structure with orthorhombic distortions (space group D_{2h}^{16}). Below the Néel temperature $T_N = 141$ °K this crystal is antiferromagnetically ordered with weak spontaneous moment directed along the c axis (G_x -type magnetic structure).

Assuming the two-sublattice model the magnetic free energy of such crystal may be written in the form :

$$F = EI_1 \cdot I_2 + E_{xx} I_{1x} I_{2x} + E_{zz} I_{1z} I_{2z} - A_{xx}(I_{1x}^2 + I_{2x}^2) - A_{zz}(I_{1z}^2 + I_{2z}^2) - D(I_{1x} I_{2z} - I_{2x} I_{1z}) - A(I_{1x} I_{1z} - I_{2x} I_{2z}) - (\gamma_1 I_1 + \gamma_2 I_2) \cdot H_0, \tag{1}$$

where $I_{1,2}$ are the mechanical moments of the sublattices, connected with the magnetic moments $M_{1,2}$ by the expressions :

$$M_{1,2} = \gamma_{1,2} J_{1,2} \tag{2}$$

The magneto-mechanical ratio tensors in this case have the form [2]

$$\gamma_{1,2} = \begin{vmatrix} \gamma_{xx} & 0 & \pm \gamma_{xz} \\ 0 & \gamma_{yy} & 0 \\ \pm \gamma_{zx} & 0 & \gamma_{zz} \end{vmatrix}. \tag{3}$$

The plus and minus signs in eq. (3) correspond to γ_1 and γ_2 accordingly. In order to determine the values of parameters in eq. (1) and (3) we have measured the AFMR field vs frequency dependences for YCrO₃ single crystals.

The measurements were performed in the wave-length range 1-6 mm. Pulse magnetic fields up to 150 kOe were used. The magnetic field was directed along all three main axes of the crystal. But with magnetic field along the « b » axis no AFMR signals were found. The AFMR frequency vs field dependences (AFMR spectra) for two other orientations of the magnetic field H_0 are shown in figure 1. One can see from this figure, that in the case $H_0 // a$ a sharp

change of the spectrum originated in the spin-flop occurs at $H_0 = H_f \equiv (33 \pm 3)$ kOe.

We suppose that all the AFMR signals we have seen correspond to the excitation of transverse AEMR

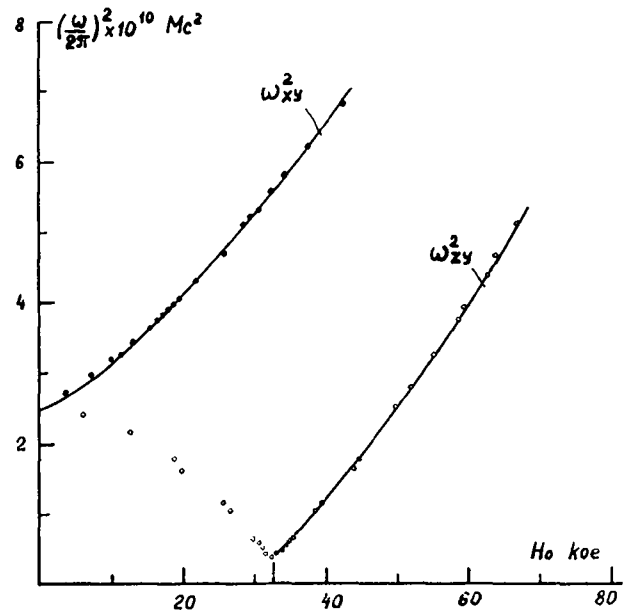


FIG. 1. — Resonance frequencies vs magnetic field for YCrO₃ at 77 °K. Open circles and full circles correspond to $H_0 // a$ and $H_0 // c$ accordingly.

modes — with the frequencies $\omega_{xy}(H_0 // c)$ and $\omega_{zy}(H_0 // a)$. The experimental dependences of these frequencies on H_0 can be approximated by polynomials :

$$\begin{aligned} \omega_{xy}^2 &= a_0 + a_1 H_0 + a_2 H_0^2, \\ \omega_{zy}^2 &= b_0 + b_1 H_0 + b_2 H_0^2. \end{aligned} \tag{4}$$

The values of the coefficients in eq. (4) calculated by least squares method are :

$$\begin{aligned}
 a_0 &= (2.36 \pm 0.07) \times 10^{10} (\text{Mc})^2, \\
 a_1 &= (0.71 \pm 0.07) \times 10^6 \frac{(\text{Mc})^2}{\text{Oe}}, \\
 a_2 &= (8.4 \pm 0.9) \left(\frac{\text{Mc}}{\text{Oe}} \right)^2, \\
 b_0 &= - (2.27 \pm 0.20) \times 10^{10} (\text{Mc})^2, \\
 b_1 &= (0.54 \pm 0.05) \times 10^6 \frac{(\text{Mc})^2}{\text{Oe}}, \\
 b_2 &= (8.4 \pm 0.7) \left(\frac{\text{Mc}}{\text{Oe}} \right)^2.
 \end{aligned} \tag{5}$$

Solid lines in figure 1 are the curves calculated using eq. (4) with the values (5) of the coefficients.

According to [3] the ω^2 vs H_0 dependencies for transverse AFMR modes have the following form:

$$\begin{aligned}
 \omega_{xy}^2 &= 2EI_0 A_{x-z} I_0 + 4A(D+A)I_0^2 + \\
 &\quad + \gamma_{zz}(D+5A+2E\tau_2)I_0 H_0 + \gamma_{zz}^2 H_0^2, \\
 \omega_{zy}^2 &= -2EI_0 A_{x-z} I_0 - 4A(D-A)I_0^2 + \\
 &\quad + \gamma_{xx}(D-5A-2E\tau_1)I_0 H_0 + \gamma_{xx}^2 H_0^2,
 \end{aligned} \tag{6}$$

where

$$\begin{aligned}
 A_{x-z} &= (E_{xx} + 2A_{xx}) - (E_{zz} + 2A_{zz}), \\
 \tau_1 &= \frac{\gamma_{xz}}{\gamma_{xx}}, \quad \tau_2 = \frac{\gamma_{zx}}{\gamma_{zz}}.
 \end{aligned}$$

The frequencies (6) were calculated by solving equations of motion in the form

$$\frac{d\mathbf{I}_{1,2}}{dt} = -\mathbf{I}_{1,2} \times \frac{\partial F}{\partial \mathbf{I}_{1,2}}. \tag{7}$$

The free energy expression (1) and eq. (7) have been written with suggestion

$$I_{1,2}^2 = \text{const}. \tag{8}$$

This condition generally speaking is not correct if anisotropy of g -factors takes place. However, for such ions as Ni^{2+} , Cr^{3+} or V^{2+} the orbital angular moments in ground state are quenched, and a small addition of orbital moments to spin ones appears only because of the admixture of excited states in second order of perturbation theory. In such case the condition (8) is approximately valid.

Using eq. (4) and (6) together with expressions for the spin-flop field H_f and the spontaneous moment (see Ref. [4]), we have obtained the parameters in eq. (1) and (3). The values of these parameters are listed in Table I.

TABLE I

The values of effective fields and g -factor components for YCrO_3

$H_D = \frac{DI_0}{\gamma}$	$H_A = \frac{AI_0}{\gamma}$	$H_t = \frac{E\tau I_0}{\gamma}$	$H_{x-z}^A = \frac{A_{x-z} I_0}{\gamma}$	$g_{xx} \cong g_{zz} = g$	$\tau_1 = \tau_2 = \tau$
kOe	kOe	kOe	kOe		
74 ± 3	3.8 ± 0.5	$-(4 \pm 2)$	0.5 ± 0.1	2.07 ± 0.02	(-2×10^{-3})

One can see from this table that in the case of YCrO_3 , as well as in the case of isomorphous crystal NaNiF_3 investigated previously [3], it is necessary to take into account all three origins of weak moment. These origins are the anisotropic exchange interactions (effective field H_D), the one-ion anisotropic interactions (effective field H_A) and the off-diagonal components ($g\tau$) of the g -factor tensors. But as in the case of NaNiF_3 the largest contribution is that of the anisotropic exchange effective field. According to Moriya [5] the following estimates for the effective fields H_D and H_A must be valid

$$H_D \cong \left(\frac{\Delta g}{g} \right) H_E, \quad H_A \cong \left(\frac{\Delta g}{g} \right)^2 H_E. \tag{9}$$

The experimental values of these effective fields for YCrO_3 as well as for earlier investigated isomorphous NaNiF_3 are listed in the table II. One can see from this table that the experimental values for both crystals correspond rather well with the theoretical estimates.

TABLE II

The values of parameters for YCrO_3 and NaNiF_3 crystals

	$\Delta g/g$	H_D/H_E	$(\Delta g/g)^2$	H_A/H_E
YCrO_3	0.03	0.05	0.001	0.002
NaNiF_3	0.07	0.08	0.005	0.006

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