It must be emphasized that electrons will be effectively accelerated in such a plasma [9]. The spectrum of the accelerated electrons does not contradict the results of observations of the hard x-rays from Sco X - 1 [10], if it is assumed that these rays result from synchrotron radiation of these electrons. We note also that the characteristic polarization-variation time obtained by us are comparable in order of magnitude with the time of slow variation of the x-radiation of Sco X - 1 [6].

The authors thank V.A. Dombrovskii for support of this work, and E.T. Belokon', V.N. Guman, and N.A. Vorob'ev for computer calculation of the periodogram.

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SPIN ECHO ON Mn^{55} NUCLEI IN EASY-PLANE ANTIFERROMAGNETS $CsMnF_3$ AND $MnCO_3$

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Submitted 6 October 1971
ZhETF Pis. Red. 14, No. 9, 511 - 514 (5 November 1971)

The investigation of NMR on Mn^{55} nuclei in antiferromagnets with small anisotropy has been the subject of a large number of papers, for example [1 - 3]. Interest in this research is justified, since effects due to the Shul-Nakamura interaction [4 - 6] become manifest here already at $T \approx 4°K$. There appears in the NMR spectrum an acoustic branch

$$\omega^2 = \omega_{n0}^2 \left[1 - \frac{2H_E A < m_z >}{\omega_e^2}\right] \qquad (1)$$

the line width of which is given by the formula

$$\Delta\omega \approx \left[\frac{I(I+1)}{2\pi S^2}\right]^{1/2} \frac{\omega_{n0}^2}{(\omega_E \omega_e)^{1/2}} . \qquad (2)$$

Here $\omega_{n0} = \gamma_n H_n$ is the frequency of the hyperfine interaction, ω_e is the AFMR frequency, $\omega_E = \gamma_e H_e$ is the exchange frequency, and $<m_z>$ is the mean value of the projection of the nuclear spin on the electron spin.

The experimental spectra are well described by formula (1), but the line widths differ strongly from those predicted theoretically [1]. It becomes necessary to measure directly the relaxation times with the aid of spin echo. So far, however, the possibility of such an experiment in antiferromagnets

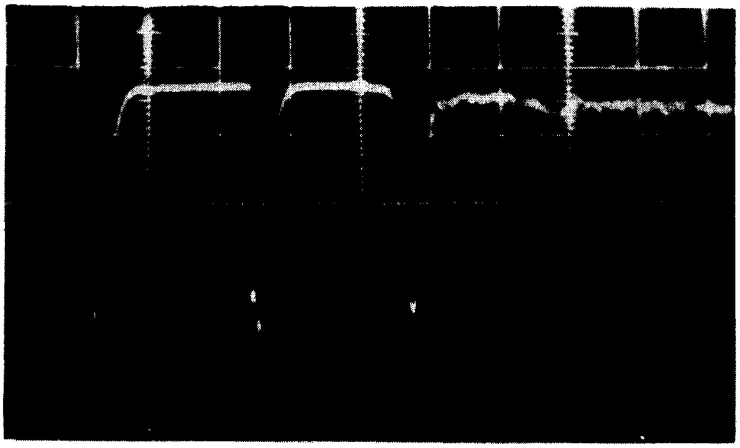

Fig. 1. Oscillogram of spin-echo signal in $CsMnF_3$, $T = 4.2°K$, $H = 5000$ Oe.

with Suhl-Nakamura interaction has remained unanswered. It is shown in [6] that to observe the echo in this case (if at all possible) it is necessary to have radio pulses of exceedingly high power.

The purpose of the present study was to verify this statement experimentally. We chose for the investigation the uniaxial antiferromagnets $CsMnF_3$ and $MnCO_3$. The measurements were performed by the two-pulse "Hahn echo" procedure [7]. The constant and alternating magnetic fields lie in the basal plane of the sample and are mutually perpendicular. At this orientation, an acoustic NMR branch is excited. The power of the radio pulses was ∿1 W, the duration ∿1 μsec, and the distance between pulses ∿10 - 20 μsec.

At $T = 4.2°K$, an echo signal was observed in both substances in a wide range of frequencies (Fig. 1)[1]. We investigated the frequency dependence of the spectra of the acoustic NMR branches (Figs. 2 and 3). Good agreement was obtained with the data of [1, 2]. We measured the spin-spin relaxation $T_2 = 20$ μsec for $CsMnF_3$ ($H = 5000$ Oe) and $T_2 = 15$ μsec for $MnCO_3$ ($H = 4000$ Oe). For $CsMnF_3$, the value obtained in [1], in the same field, is $T_2 \simeq \Delta\omega^{-1} \simeq 30$ μsec,

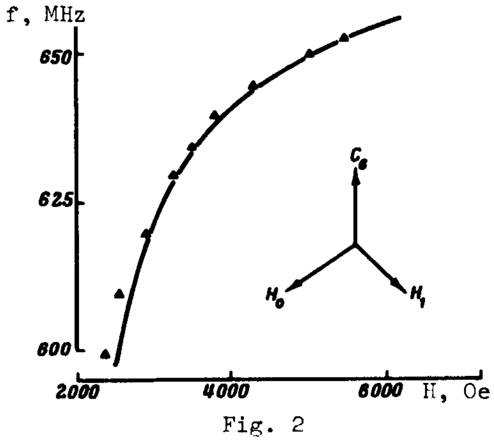

Fig. 2

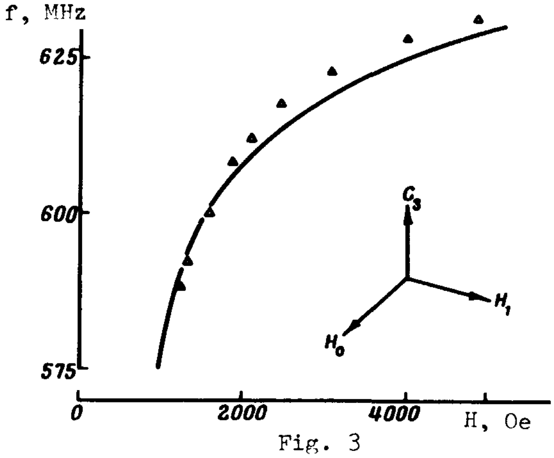

Fig. 3

Fig. 2. Spectrum of acoustic NMR branch in $CsMnF_3$; the continuous curve is taken from [1].

Fig. 3. Spectrum of acoustic NMR branch in $MnCO_3$; the continuous curve was obtained from [2].

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[1] Additional echo signals were observed at $H = 5000$ Oe and lagged the first signal by a time equal to a multiple of the delay between pulses.

whereas theory (formula (2)) gives $T_2 \approx 1$ μsec for both substances.

The following considerations can be advanced regarding the observed phenomenon. The authors of [6] started from the premise that since $\langle m_z \rangle$ changes when a high-frequency pulse is applied. The resonant frequency of the system should change (formula (1)). This causes violation of the condition for resonance with the external field, and the spin system ceases to absorb energy. As a result it is impossible to take the spins out of the equilibrium position at a rate sufficient to observe the echo signal.

In the quasi-classical analysis, the dependence of the echo-signal amplitude on the initial spin-rotation angle is given by the formula [7]

$$I \sim \sin \xi \sin \frac{\xi}{2}, \tag{3}$$

where $\xi = \eta \gamma_n H_1 t_\omega$ is the angle of rotation of the spins in a rotating coordinate system. According to the estimates, a frequency shift $\Delta\omega \approx 1$ MHz (the spectral width of the working pulses) corresponds to $\Delta\langle m_z \rangle / \langle m_z \rangle \sim 0.05$ ($H \approx 5000$ Oe). If it is assumed that this change is determined by the spin rotation angle[2], then the signal intensity will be smaller by three orders of magnitude than the maximum possible value. However, the presence of a large gain for the acoustic NMR branch causes the effect to become perfectly observable.

An exact solution of the problem is made difficult by the fact that in this case it is impossible to use either the methods used in the theory of ordinary spin echo (it is necessary to take into account the motion of the electron spins) or methods based on the concept of spin temperature (the nuclear spin system is essentially not in equilibrium).

In conclusion, the author is deeply grateful to A.S. Borovik-Romanov for guidance and interest in the work, and to M.P. Petrov and A.A. Petrov for valuable consultations.

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[2] The superheating of the nuclear spin system is negligibly small in this case.