electrons/outburst. The total energy of the fast electrons in the outburst region can be represented in the form $E_0 = E_{cb} + E_{br} + E_{tb} + E_{cc}$, where E_{cb} and E_{br} are the energy losses to collisions and bremsstrahlung in the outburst region, E_{tb} is the total energy of the electrons leaving the outburst region, and E_{cc} is the energy lost to collisions in the corona. In our case $E_0 = 10^{29}$ erg, $E_{cb} = 8 \times 10^{28}$ erg, $E_{br} = 8 \times 10^{24}$ erg, $E_{tb} = 8 \times 10^{26}$ erg, and $E_{cc} = 2 \times 10^{28}$ erg.

In conclusion we note with gratitide that the short-duration change of counting rate in the energy spectrum in the 20-kV region was noted by V.S. Eletskii. We are grateful to the participants of the seminar, G.E. Kocharov and S.I. Syrovatskii, for useful discussions.

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OBSERVATION OF SPIN ECHO ON CONDUCTION ELECTRONS IN METALLIC LITHIUM

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A study of transient processes, and especially phenomena of the spin-echo type, yields abundant information on the kinetic properties and internal interactions of spin system. Insofar as we know, spin echo has not been observed before on conduction electrons (CE). Two factors acting in opposite directions hinder the registration of the effect: the exceedingly short times of the spin relaxation in metals (usually $\tau \sim 10^{-8}$ sec) and the high CE diffusion rates (the CE diffusion coefficient in bulky metal is $D \simeq 50$ cm^2/sec).

We report here the first observation of CE spin echo in metallic lithium. We succeeded in realizing the necessary experimental conditions for small spherical lithium particles produced in LiF single crystals by neutron bombardment followed by special heat treatment [1]. An estimate of the average diameter of the particles, determined from the asymmetry of the stationary line of paramagnetic resonance with the conduction electrons [2], yielded for our sample $d \simeq 1\ \mu$.

Such a method of obtaining metal particles in alkali-halide single crystals ensures high purity of the samples, and as a result the longest CE spin relaxation times observable in metals; the small particle dimensions on the other hand, limit the diffusion rate. Indeed, the effective diffusion coefficient can be estimated at $D_{eff} \simeq D(d/\ell)^2$, where ℓ is the distance over which the CE diffuses in a bulky metal during the time τ_1 between pulses. In

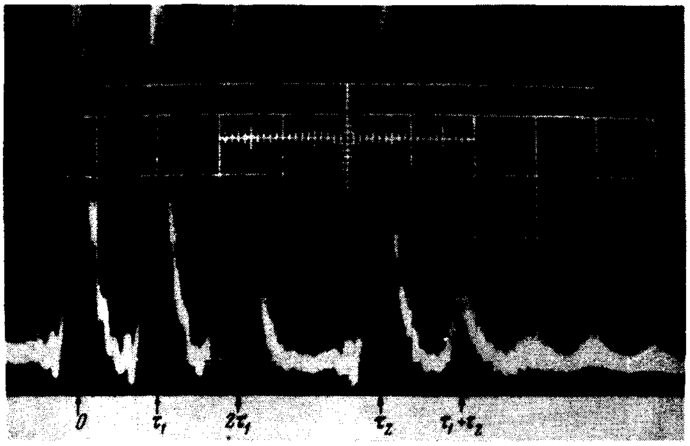

Fig. 1

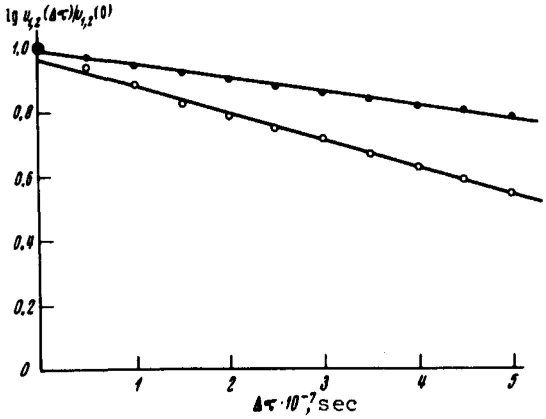

Fig. 2

Fig. 1. Oscillogram of signals of main ($2\tau_1$) and stimulated ($\tau_1 + \tau_2$) CE spin echo in lithium at room temperature. Time scale: 1 division = 0.2 μsec.

Fig. 2. Amplitudes of the main (v_1) and stimulated spin echo (v_2) vs. the change $\Delta\tau$ of the intervals τ_1 and τ_2, respectively: o - $v_1(\tau_1)$, o - $v_2(\tau_2)$.

our experiments $\tau_1 \simeq 5 \times 10^{-7}$ sec, and therefore $D_{\text{eff}}/D \sim 10^{-2} - 10^{-3}$.

The measurements were performed with a pulsed relaxometer for the 3-cm band [3] at room temperature. A typical response of the CE spin system to three identical microwave pulses of 4×10^{-8} sec duration, applied at the instants of time $t = 0$, τ_1, and τ_2, is shown in Fig. 1. As seen from the figure, a spin-echo signal is produced at $t = 2\tau_1$, and a stimulated echo signal, followed by three secondary echoes, is produced at $t = \tau_1 + \tau_2$.

The lithium particle dimensions are smaller than the skin-layer depth δ at the working frequency of the measurements ($\delta = 1.6$ μ), and it can therefore be assumed that the alternating field in the sample is uniform. Then the amplitudes of the main and stimulated echo, as in a dielectric, are proportional to the quantities [4]

$$v_1(t = 2\tau_1) = \exp\left\{-\frac{2\tau_1}{T_2} - \frac{5}{3}k\tau_1^3\right\},$$

$$v_2(t = \tau_1 + \tau_2) = \exp\left\{-\frac{\tau_1 + \tau_2}{T_2} - (\tau_2 - \tau_1)\left(\frac{1}{T_1} - \frac{1}{T_2}\right) - k\tau_1 \times \right.$$
$$\left. \times \left[\tau_2^2 + \tau_2\tau_1 - \frac{\tau_1^2}{3}\right]\right\},$$

where T_1 and T_2 are the relaxation times of the longitudinal and transverse spin-magnetization components, $k = (\gamma G)^2 D_{\text{eff}}$, γ the gyromagnetic ratio of the CE and G is the gradient of the constant magnetic field (in our experiments $G \sim 70$ Oe/cm). Determination of $v_1(\tau_1)$ and $v_2(\tau_2)$ makes it possible, in principle, to obtain the parameters T_1, T_2, and k.

Figure 2 shows the experimental dependence of the amplitudes of the main and stimulated echoes on the intervals τ_1 and τ_2, respectively. Within the limits of errors, the experimental points lie on straight lines, indicating that diffusion processes do not make a noticeable contribution to the damping of the echo signals. This confirms the assumption made above that the diffusion is effectively limited by the small dimensions of the metal particles. Neglecting the diffusion terms in the expressions for $v_1(\tau_1)$ and $v_2(\tau_2)$, we obtain from the experimental plots of Fig. 2 $T_1 = (1.06 \pm 0.15)$ μsec and $T_2 = (1.03 \pm 0.10)$ μsec. Together with the value $T_2^* = (1.13 \pm 0.10)$ μsec obtained from the measurements of the width of the stationary absorption line (the peak width of the resonance line of our sample is $\delta H = 58 \pm 5$ mG), these data indicate that $T_1 = T_2 = T_2^*$, and are thus a direct experimental confirmation of the validity of an important premise of the theory of [5], that the relaxation times of the longitudinal and transverse components of the spin magnetization of CE are equal.

We note in conclusion that for bulky metals the diffusion of CE leads to an exceedingly rapid damping of the echo signals. This is probably why they observed in [6] only the free-induction signals that follow directly the microwave pulses, and could not measure the echo signals in bulky samples of lithium and sodium. At the same time, further research on the spin echo of CE in samples of intermediate dimensions, $d \simeq 5 - 10$ μ, affords a direct method of measuring the diffusion velocity of CE.

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CONNECTION BETWEEN THE WAVE FRONTS OF THE REFLECTED AND EXCITING LIGHT IN STIMULATED MANDEL'SHTAM-BRILLOUIN SCATTERING

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In stimulated Mandel'shtam-Brillouin scattering (SMBS) the back-scattered light propagates usually in the same solid angle as the exciting radiation [1]. It has never been ascertained whether this fact is connected only with the geometry of the experiment or whether it has a deeper meaning. To answer this question, we have compared the wave fronts of the reflected and exciting light.

The experimental setup is shown in Fig. 1. The wave front of the ruby-laser radiation is distorted by the plate P, made by etching polished glass in fluoric acid. The laser beam has a divergence 0.14 × 1.3 mrad. The divergence of the light passing through the plate is 3.5 mrad. This light enters a hollow glass light pipe of square cross section, placed in a cell with methane gas[1].

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[1] The methane is at room temperature and 125 atm pressure. Under these conditions, the gain due to the SMBS is approximately 0.09 cm/MW and the gain line width is $\sim$20 MHz [3].