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Multiquantum Spin Echoes from Quadrupole Nuclei in Ferromagnetic Materials

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The natural inhomogeneous broadening determine the basic peculiarities of the NMR in magnetically ordered materials. If there are the quadrupole interactions, the traditional Hahn echo is observed as well as multiquantum nuclear echo signals. For quadrupole nuclei with spin I = 3/2 the multiquantum 4τ echo (τ is the time interval between the pulses) appears if both magnetic and/or quadrupole inhomogeneities are present. The formation of this echo is possible at the frequencies corresponding to the pure magnetic spectroscopic transition $(\pm 1/2 \leftrightarrow \mp 1/2)$ only [1].

In order to study the relaxation properties of multiquantum echoes, we investigated the dependences of the 4τ echo amplitude on the time interval τ for both copper and chromium nuclei in ferromagnetic chromium chalcogenide spinels. We have found the exponential echo decay, which is described by expression $V(\tau)=V(0)\exp(-\tau/T_2)$, for both 2τ and 4τ echo signals.

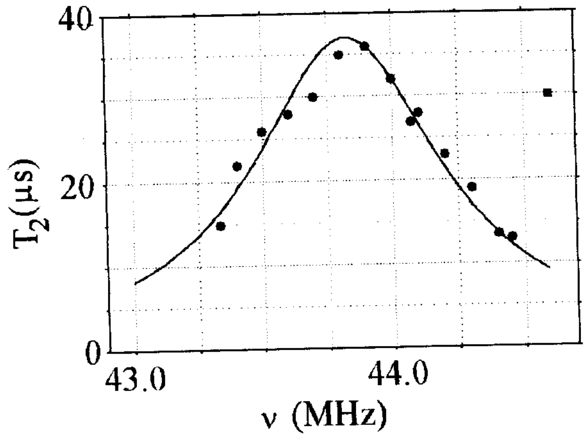
The Theory

The spin echoes attenuation, which is caused by fluctuations in secular part of spin hamiltonian, was analysed in the theoretical work [2] for quadrupole nuclei. It follows from this work, that exponential decay is possible both for the fast Lorentzian and for the fast Gaussian processes. We have analysed the influence of nonsecular fluctuations also. We have revealed that a parameter, which is determined as the ratio of the T_2^{-1} for the 4τ echo to the T_2^{-1} for the 2τ echo at same frequency, has deferent values, if different relaxation mechanismes are used. We denote this parameter as R and its numerical values are: for the fast Lorentzian process: R = 3; for the fast Gaussian process: R = 11/2; for nonsecular fluctuations: R = 2.

The ^{53}Cr NMR in $CdCr_2Se_4$:Ag

The spin echo signals from ^{53}Cr nuclei in multidomain polycrystalline samples of $Cd_{0.985}Ag_{0.015}Cr_2Se_4$ have been investigated at the temperature T = 4.2 K. Based on an analyses of relaxation data, we divide all chromium nuclei into two types.

The 2τ echo decay from the first type nuclei depends on a frequency. A reason for that are the fluctuations of the electron magnetization direction and nuclear relaxation is described in terms of Gaussian process [3]. The 4τ echo from these nuclei is observed at the frequency 44.6 MHz. The value of R = 5.5 ± 1.5 is obtained for nuclei of first type, that demonstrates a good agreement with assumption about the Gaussian process. The 4τ echo from these nuclei is not observed at other frequences because (i) the transverse relaxation time T_2 is very short, or (ii) **rf** field amplitude is not sufficient for multiquantum echo appearance [1].



The chromium nuclei of second type give the 4τ echo into wide frequency range (points in the figure) and an echo decay depends on a frequency also. Assuming that the fluctuations of the magnetization direction cause the nonsecular fluctuations, we give an explanation for experiment (solid line in figure).

The ^{63}Cu and ^{65}Cu NMR in $CuCr_2S_4$:Sb

The copper iones occupy tetrahedral sites in spinel structure. The local symmetry of these sites is cubic, what provides the absence of quadrupole splitting in ideal lattice. However, we have experimentally observed the 4τ echo from both copper isotopes. The Sb impurities produce the nonzero quadrupole splitting, which is responsible for an appearance of multiquantum echo.

We have obtained experimentally the values of R = 3.5 ± 0.5 for both isotopes. These values indicates the predominant influence of Gaussian process on nuclear magnetic relaxation of copper nuclei.

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