Ultrasound attenuation on anisotropic Jahn-Teller complex $Cr_{Zn}4Se$ in a magnetic field

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The ground state of the Cr^{2+} center in a cubic ZnSe crystal and the ultrasound attenuation on this center in a magnetic field were studied theoretically. The Cr ion replaces Zn in its position in the tetrahedral surrounding by 4 Se ions and provides an impurity complex $Cr_{Zn}4Se$. The outermost d-shell of the Cr^{2+} ion is occupied by 4 electrons. The tetrahedral crystal field of 4 Se atoms removes the fivefold orbital degeneracy (but spins of all electrons remain codirectional). The manybody ground state of the center is described by fivefold degenerate spin state with total spin S=2 and triply degenerate orbital hole state, which transforms according to the irreducible representation T_2 of the T_d group. Being in the degenerate orbital state, the hole interacts with vibrational modes of the complex $Cr_{Zn}4Se$ that transform under the irreducible representation E of T_d. This results in vibrational and hole states coupling and in spontaneous distortion of the complex along one of the cubic axes <100> (the Jahn-Teller effect). Due to the wave functions overlap of the coupled (vibronic) states corresponded to three equivalent distorted spatial configurations of the complex, there is an exponential suppression of the hole state orbital angular momentum [1]. The interaction with the magnetic field and the spin-orbit interaction are parametrically suppressed in the first order of the perturbation theory. The main contribution to the fine structure levels formation of the center's ground state is made by second-order perturbation theory members. The ground state of the Cr center in ZnSe has the sixfold degeneracy originating from the product of three orbital T_2 states and two spin states with the spin projection on the selected axis equal to ±2. In this study it was shown that the ground state is doubly degenerate at high magnetic fields, but the first excited state is non-degenerate and increases its energy relative to the ground state with the magnetic field increase. The slow shear ultrasonic wave propagating along the <110> axis splits the ground state linearly in amplitude at each time point, and it does not interact with the first excited state. This leads to the ultrasonic wave relaxation attenuation increase with increasing magnetic field that has been previously observed in the experiment [2]. Furthermore, the peak of attenuation in the magnetic field dependency of the ultrasound absorption has been detected in the same experiment [2]. In contrast to the initial theoretical interpretation of the experimental data [3], in this study it was shown theoretically that the peak should not be associated with the resonant absorption of ultrasound at any magnetic field. It is suggested that the non-monotonic magnetic field dependency of the absorption is due to the magnetic field dependency of the relaxation times of the system.

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[1] F.S. Ham, Phys. Rev. A, 138, No.6, 1727 (1965)
[2] V.V. Gudkov et al, Moscow International Symposium on Magnetism, Book of Abstracts, 22PO-J-11, 177 (2011)
[3] K.A. Baryshnikov, Russian Youth Conference on Physics and Astronomy PhysicA.SPb, Book of Abstracts, p. 115 (24-25 October, St.-Petersburg, 2012, in Russian)