EXPERIMENTAL STUDY OF Nd^{3+} ION CLUSTERS IN Nd^{3+}:LaF_3 CRYSTALS

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Up to now only quantum computing using few quantum bits have been realized [1, 2]. Main obstacles to increase the size of quantum register are fast decoherence and difficulties to control many-qubits entanglement. The clusters of the Nd^{3+} ions formed in the Nd^{3+}: LaF_3 crystal can be candidate for many-qubit CNOT-gate, because of their entangled states, weak electron-phonon coupling and rather long coherence time of the excited states.

It was shown that satellite lines of the main spectral line for single-site optical center in absorption [3, 4] and fluorescence excitation spectra [3] of low doped Nd^{3+}: LaF_3 crystals can be attributed to Nd^{3+} ion pairs. The direct measurement of the fluorescence decay times for various classes of Nd^{3+} pairs was made [3] since the pairs are well selected by fluorescence excitation wavelength. We extended similar activity to 1% Nd^{3+}: LaF_3 crystal at 1.6 K and 4.2 K to study the effects of inhomogeneous splitting. Because of the higher Nd^{3+} concentration the probability of formation of greater number of Nd^{3+} pairs as well as the possibility of formation of larger Nd^{3+} clusters is higher. From the fluorescence excitation spectrum we determined the spectral position of a single-site optical center in Nd^{3+}: LaF_3, which is quite close to that in [4] and spectral positions of new optical centers at the low energy spectral wing of the single-site optical center, which can be considered as pairs. We carried out a double spectral selection of selected Nd^{3+} pairs, as well as possibly larger clusters of Nd^{3+} ions that are spectrally located more closely to the maximum of the spectral line of a single center. For each of the selected centers, the luminescence spectrum was measured, and their lifetimes were determined from the exponential kinetics of spontaneous radiative decay.

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The dynamical splitting (no magnetic field) of Stark levels due to coherent interaction between the ions in the clusters leads to entangled states. Both ground and excited states of rare-earth ions belong to ^4f-states, which are well shielded by the electrons of external $5s^2$ and $5p^6$ shells and, therefore are well isolated from the crystal matrix. This results in the weak electron-phonon coupling and rather long coherence time of the excited states.

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