**Spin Relaxation and optically detected magnetic resonance
of** $Cr^{3+}$**in** $Al\_{2}O\_{3}$ **(Ruby)**

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**Introduction**

In addition to being a popular gemstone, ruby ($Cr^{3+}$ in $Al\_{2}O\_{3}$)is also a well-explored material for its optical and spin properties, and has played an important role in the history of lasers and masers. However, despite decades of research, it has rarely been measured at temperatures below 1 K (Wiemann *et al.* 2015), and fundamental properties, like its spin relaxation, remain uninvestigated.

Using photoluminescence excitation (PLE) spectroscopy, we measure the spin dynamics of an ensemble of $Cr^{3+}$ ions at temperatures between 18 mK and 4 K and observe a maximum spin relaxation time of $T\_{1}$=3.4 s. Furthermore, we are able to conduct optically detected magnetic resonance (ODMR) with contrasts up to 340 %.

**Methods and Results**

The sample consists of an ensemble of $Cr^{3+}$ ions in $Al\_{2}O\_{3}$with a concentration of 0.005-0.01%, andis mounted on the cold-finger of a dilution refrigerator. A home-built confocal microscope allows us to resonantly excite the sample with a narrow-linewidth, tunable laser at $\~$692 nm and collect the emission of the phonon sideband in a photoluminescence excitation (PLE) spectroscopy experiment.

We measure the PLE spectrum as a function of external magnetic field and are able to assign the peaks to the states of the S=3/2 ground state Hamiltonian of the defect. At zero magnetic field, the ground state of the $Cr^{3+}$ issplit into two Kramers doublets with a splitting of 11.4 GHz. When increasing the magnetic field the spin states Zeeman-split according to the C3-axis being perpendicular to the external magnetic field (Chang *et al.* 1978).

We measure the electron spin relaxation $T\_{1}$ between the two Kramers doublets for MXC temperatures between 18 mK and 4 K at zero magnetic field. Above 1.2 K, $T\_{1}$ scales indirect proportional with temperature, consistent with previous studies (Standley *et al.* 1965), indicating that spin relaxation is dominated by direct or one-phonon processes. Below 255 mK, $T\_{1}$ is constant up to the measurement error, with an average of $T\_{1}$=3.2 s. The turning point is near 547 mK, where $k\_{B}T≈$11.4 GHz.

Furthermore, we measure continuous-wave ODMR at zero magnetic field, initializing the spins via optical cycling. Resonant laser excitation of the $m\_{s}$=1/2 states, whilst magnetically driving the $m\_{s}$=1/2$\leftrightarrow $3/2 transition at 11.4 GHz, yields an ODMR contrast of 340 %. Laser excitation of the $m\_{s}$=3/2 states yields a contrast of 107 %. In both cases, we measure an ODMR linewidth of $\~$90 MHz.

**References**

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