Alignment – Orientation Conversion of Rb^{85} in a Magnetic Field Caused by a Hyperfine Structure

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An effect has been studied, where an external magnetic field breaks the symmetry of the initially created angular momentum spatial distribution. As a result, circularly polarized fluorescence is detected during linearly polarized laser excitation of atoms. This effect arises due to non-equidistant hyperfine structure (HFS) level M_F energy splitting in an external magnetic field. The appearance of fluorescence circularity indicates a partial alignment – orientation conversion (AOC) of the excited state angular momentum distribution [1]. This is transversal orientation, perpendicular to the external field. Similar AOC effects, but caused by other reasons, were studied previously in atoms (for a review see [2]) and in diatomic molecules by our group [3-5]. In Te_2 transversal AOC was observed due to non-linear Zeeman effect [3] and in NaK due to quadratic Stark effect [4] and *e-f* sublevel mixing in electric field [5].

The effect where AOC was caused by non-linear HFS level splitting in intermediate strength external magnetic field was recently theoretically predicted for molecules [6], but no measurements on molecules were performed, yet. Calculations showed that the effect vanishes rapidly with increasing angular momentum values. For example, in NaK excited $D^1\Pi$ state the circularity signal could be measurable only for J' = 0, 1 and 2, i.e., when the angular momentum is comparable to the nuclear momentum $I = 1/2$.

In this contribution we report that the work done in [6] is extended with both calculations and measurements on Rb^{85} atoms having a relatively large nuclear spin $I = 5/2$. An excited state $5P_{3/2}$ with total angular momentum $J = 3/2$ is exploited. We calculate the excited state HFS level energies in external magnetic field by Hamiltonian matrix diagonalization and the fluorescence intensities using quantum density matrix formalism. First we reproduce well-known level-crossing signals [7] in linearly polarized fluorescence to test the experimental set-up as well as computer code, and then we both calculate and measure the AOC effects causing appearance of fluorescence circularity signals.

Rb^{85} vapour is kept at room temperature in a glass cell placed between Helmholz coils to produce a magnetic field, while the Earth magnetic field is compensated. The transition $5S_{1/2} \rightarrow 5P_{3/2}$ at 780.2 nm is excited with a diode laser. In absorption two spectrally resolved lines are observed. One corresponds to the absorption from a ground state hyperfine level with quantum number $F = 3$ and another from a level with $F = 2$, see Fig. 1. The hyperfine splitting of the excited state is not spectrally resolved in absorption. The laser radiation is locked to one of these absorption peaks. The fluorescence at 780.2 nm is detected by a photodiode. A rotating polarizer together with a lock-in amplifier is used to measure the difference of two orthogonal linearly polarised fluorescence components. A λ/4 plate is added in front of the polarizer to measure circularly polarized light components I_+ and I_-. The geometry for circularly polarised fluorescence measurements is presented in Fig. 1. As seen from Fig. 1, experimentally recorded circularity signals show good agreement with the calculated ones. The maximum circularity rate is about 3.5 percent. Circularity signals have resonant maximums corresponding to the excited state hyperfine level crossings with $\Delta M_F = 1$. Observation of circularly polarised fluorescence allows the measurement of the level crossing position in a weak field region, where the traditionally observed $\Delta M_F = 2$ crossings in linearly polarised fluorescence are hidden under a strong zero-field level crossing signal. This fact can be useful for precise atomic constant determinations.

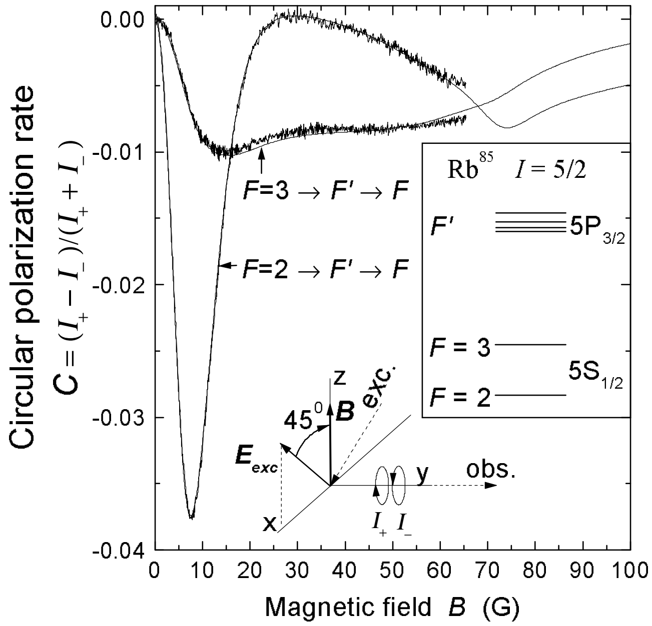

Figure 1. Calculated and experimentally recorded fluorescence circularity signals for Rb^{85}, experimental geometry and a schematic HFS energy level diagram.

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