Measurement of the 5D level polarizabilities in laser cooled Rb atoms

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Synopsis We report on accurate measurements of the scalar $\alpha_S$ and tensor $\alpha_T$ polarizabilities of the 5D fine structure levels $5D_{3/2}$ and $5D_{5/2}$ in Rb.

Study of atomic and molecular polarizabilities remains an important task in atomic physics. Accurate measurements of polarizability facilitate progress in sophisticated atomic structure calculations and the theory of heavy atoms, which results in more precise predictions for other important atomic parameters (see, e.g., [1]). Measurements of polarizabilities become even more crucial in applications for modern optical atomic clocks. Predictions of the magic wavelength in optical lattice clocks [2] and accurate estimation of the blackbody radiation shift require precise knowledge of static and dynamic polarizabilities [3].

Polarizabilities of ground and highly excited states of alkali atoms are known quite accurately. In case of Rb, the polarizabilities of $5S$ and $5P$ levels have been measured long ago with high precision while being in agreement with theory [4]. However, considering intermediate states there are some difficulties both theoretically and experimentally. For example, 5D level in Rb. There are several theoretical predictions which differ up to 20% [5, 6].

We report on accurate measurements of the scalar $\alpha_S$ and tensor $\alpha_T$ polarizabilities of the 5D fine structure levels $5D_{3/2}$ and $5D_{5/2}$ in Rb-87 [7]. $\alpha_S$ and $\alpha_T$ describe the dependance of $\alpha$ on total angular momentum $F$ and its projection $m_F$:

$$\alpha = \alpha_S + \alpha_T P(F, m_F)$$ (1)

Rb atoms were laser cooled in a regular six-beam magneto-optical trap, forming a cloud at the center of a plane capacitor. Excitation to 5D level was performed in a cascade mode, the population was measured by spontaneous emission.

Optical pumping of atoms to a specific magnetic sublevel allowed us to measure the tensor polarizability component with relatively high precision. In order to perform optical pumping we applied a circularly $\sigma^+$-polarized pump pulse to transfer atoms to the $5F_{3/2}(F = 3, m_F = +3)$ magnetic sublevel. Using the probe $5P \rightarrow 5D$ pulse with certain polarization ($\sigma^+$ or $\sigma^-$) we defined both scalar and tensor polarizabilities.

The measured values (in atomic units) $\alpha_S(5D_{3/2}) = 18400(75)$, $\alpha_T(5D_{3/2}) = 750(30)$, $\alpha_S(5D_{5/2}) = 18600(76)$ and $\alpha_T(5D_{5/2}) = 1440(60)$ show reasonable correspondence to previously published theoretical predictions, but are more accurate. We demonstrated a relative uncertainty of 4% for the tensor polarizability and 0.4% for the scalar polarizability, which is comparable to accurate measurements in ground-state alkali atoms. Our result is close to the theoretical prediction [5].

References

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