High resolution measurement of isotopic shift in singly charged argon ions

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Synopsis The isotopic shift between ^{40}Ar and ^{36}Ar for the $3s^2 3p^5$ $(^2P_{3/2} \rightarrow {}^2P_{1/2})$ transition is measured.

High precision measurements of isotopic shifts in the energy levels of noble gases can provide a very good test of relativistic and QED effects. An accurate and straightforward technique which enables the measurement of such a small shift in the energy levels of two isotopes is therefore necessary. It is the goal of this work to present a novel spectroscopic method that is based on the beating of coherently excited states and its observation in real-time. The states are populated by strong field ionization.

In our experiment, we measured the *IS* between ^{36}Ar and ^{40}Ar for the $3s^2 3p^5$ $(^2P_{3/2} \rightarrow {}^2P_{1/2})$ transition for singly charged argon ions. We measure it by implementing a Ramsey-like scheme using two ultrashort ($\sim$ 6fs) laser pulses. The first laser pulse ionizes the atom and excites the system in a coherent superposition of the aforementioned states by removing an electron from the atomic p-shell (Fig. 1). This superposition leads to a spin-orbit wave packet, which oscillates with a period of $T = 23.3fs$, for relatively long times ($\sim ns$). The system evolves for $\sim$ 10.000 cycles which effectively increases the accuracy of our measurement. Its dynamics can be investigated by applying a second delayed pulse, after $\tau_0 = 3.97ns$, which further ionizes the system [1].

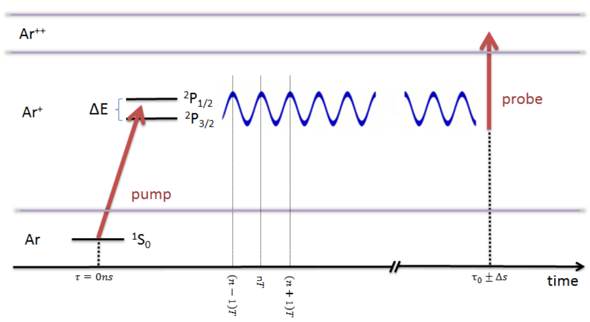

Figure 1. Ramsey-like scheme for the creation and the investigation of the SOWP in singly charged argon ions

A Mach-Zehnder interferometer is used to introduce the long time delay between the two pulses. To detect the ions of different argon isotopes we used a reaction microscope spectrometer (REMI). From the data analysis the phase of each isotope is extracted and plotted versus counts (Fig. 2). The *IS* is found to be $(1.22 \pm 0.10) \cdot 10^{-7}$eV.

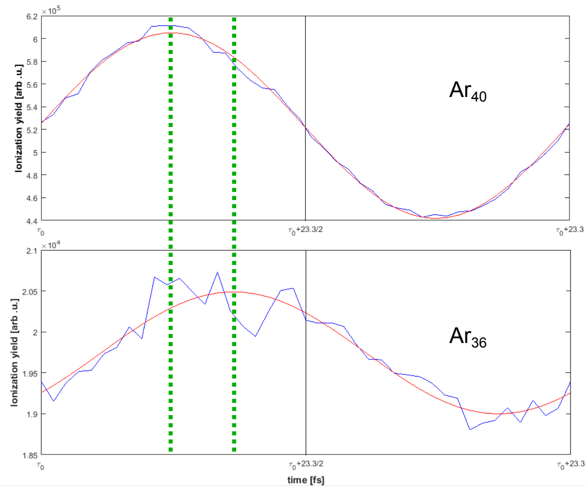

Figure 2. Isotopic shift between ^{40}Ar and ^{36}Ar

The major contribution to the error arises from the statistical determination of the shift itself whilst a smaller contribution comes from the error on the delay we introduce between the two laser pulses. The experimental relative shift was calculated (i.e. the value of the *IS* divided by the energy of the studied transition for ^{40}Ar) and found to be half of the relative shift coming from the contribution of the normal mass shift (*NMS*) to the total *IS*. The *NMS* is directly proportional to the reduced mass of the system. However, the contributions from the spesific mass shift *SMS* (due to electron momenta correlations), the field shift *FS* (due to the finite volume of the nucleus), the relativistic *NMS* and the relativistic *SMS* must be also theoretically calculated [2]. This novel and precise spectroscopic method in the time domain can be utilized as a test of relativistic and QED effects and may reveal information about the nucleus which would otherwise be hard to obtain by conventional spectroscopy.

References

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