Isotopic Shifts of Atomic States Measured Through Strong Field Interaction

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Figure 1: Phase of the wavepacket for different isotopes after a delay of 3.97 ns

High-precision measurements of isotopic shifts in the energy levels of atoms can provide sensitive tests of our understanding of relativistic and QED effects [1].

In this work we present a novel spectroscopic method to measure small isotopic shifts utilizing the coherent population of different states arising from strong field ionization. In our experiment, we measured the isotope shift between 36Ar, 38Ar and 40Ar for the 3s²3p⁵(2P₃/₂ → 2P₁/₂) transition in singly charged argon ions. We measure it by implementing a Ramsey-like scheme using two ultrashort (6 fs) laser pulses. The first laser pulse excites the system into a coherent superposition of the aforementioned states by removing an electron from the atomic p-shell of the neutral atom. This superposition leads to a spin-orbit wave packet (SOWP) oscillating with a period of \( T = \frac{2\pi}{E(P_{3/2} - P_{1/2})} = 23.3 \text{ fs} \) that lasts for very long times (tens of ns). The second delayed pulse probes the wavepacket dynamics of the system by further ionization [2].

A Mach-Zehnder interferometer is used to adjust the delay between the two pulses of \( \tau_0 = 3.97 \text{ ns} \), which effectively corresponds to \( \approx 170 \) 000 cycles of the SOWP and allows us to obtain a high accuracy on the energy levels of the different isotopes.

To detect the ions of different argon isotopes we used a reaction microscope spectrometer. From the data analysis the phase of each isotope wavepacket is extracted and plotted versus counts (Fig. 1). 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.

References
