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Highly-sensitive photodetachment spectroscopy in an MR-ToF device

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The electron affinity (EA) reflects the energy released when an electron is attached to a neutral atom. An experimental determination of this quantity serves as an important benchmark for atomic models describing electron-correlation effects [1]. A comprehensive understanding of these effects is also necessary for accurate calculations of the specific mass shift, which is required to extract nuclear charge radii from measurable total isotope shifts. However, isotope shifts in the EA have been experimentally determined only for very few stable nuclides so far, and only with modest precision. As an example, the isotope shift between the two stable chlorine (Cl) isotopes is more precisely predicted in theory [2] than experimentally measured [3].

Exploiting the low-energy version of the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy (MIRACLS) [4], we have initiated a high-precision measurement of the isotope shift in the electron affinity between stable Cl isotopes as well as the long-lived ^{36}Cl isotope. This can be achieved by photodetachment threshold spectroscopy of negative Cl ions. By trapping ion bunches between the two electrostatic mirrors of MIRACLS'multi-reflection time-of-flight (MR-ToF) device, the same ion bunch can be probed by the spectroscopy laser repeatedly. As a result, the photodetachment efficiency can be significantly increased in comparison with single-pass experiments. Thus, instead of conventionally used pulsed high-power lasers with a large linewidth, narrow-bandwidth continuous-wave (CW) lasers can be employed. Consequently, the measurement precision is improved.

By confining the Cl- ions for several 10,000s of revolutions in the MR-ToF device, the residual atoms in the photodetachment process have been experimentally detected. For wavelengths only 3 nm above threshold, a CW laser power as low as 0.8 mW is demonstrably sufficient to observe the process of photodetachment. The first experimental data shows that the signal sensitivity of the new method is 3 to 4 orders of magnitude higher compared to conventional single-pass photodetachment experiments, see e.g. [1]. A first cross section curve of ^{35}Cl was obtained providing confidence in the application of the new technique for high-precision isotope shift measurements between ^{35,37}Cl, which are currently in preparation.

Due to its small floor space of just 2m x 1m, an MR-ToF apparatus can be easily installed at existing radioactive ion beam facilities. Combined with CW lasers operated at higher laser power, the MR-ToF technique will hence allow measurements of EAs and isotope shifts in the EA for various radioactive negative ions for the very first time as well as increasing the precision of existing measurements. Those new measurements will then serve as important benchmarks for theoretical models to e.g. decrease the uncertainty on the specific mass shift, which is often a leading contribution for the extraction of nuclear charge radii from measurable total shifts.

The novel technique will be introduced and the first experimental results will be presented.

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