Highly-sensitive photodetachment spectroscopy in an MR-ToF device

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The electron affinity (EA) reflects the released energy when an electron is attached to a neutral atom. An experimental determination of this quantity can serve 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. By measuring small differences in the EA between different isotopes of the same chemical element, the isotope shifts of the EA, atomic models can be further constrained. 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 to 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 will be improved.

By confining the Cl^- ions for a few 10,000s of revolutions in the MR-ToF device, neutralised atoms produced by photodetachment have been experimentally detected. For wavelengths only 3 nm above threshold, a CW laser power as low as 0.8 mW has been demonstrated to be sufficient to observe the process of photodetachment. The first experimental data indicates that the new method is 3 to 4 orders of magnitude more sensitive than conventional single-pass photodetachment experiments, see e.g. [1]. Thus, our novel measurement scheme paves the way for precision measurements of isotope shifts in the electron affinity between stable and ultimately radioactive Cl isotopes.
As such, the MR-ToF technique can become complementary to recently reported high-precision photodetachment measurements at storage rings such as DESIREE [5] and, furthermore, extend the range of isotopes beyond the stable ones.

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 higher power lasers, the MR-ToF technique will hence allow measuring EAs and isotope shifts in the EA for various radioactive negative ions for the very first time.

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

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