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Towards precision tests of fundamental physics using a highly-charged-ion optical clock

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Precision measurements of isotope shifts could reveal new physics beyond the Standard Model. Measurements of these shifts for two transitions in at least three pairs of isotopes for a given element allows the construction of a so-called King plot, where deviations from linear behaviour could point to a previously unknown boson mediating a fifth fundamental force that couples electrons to neutrons. Adding more transitions to the analysis allows suppression of nuclear effects which could themselves lead to nonlinearity, and also the uncertainties in the experimentally-determined isotope masses. Unfortunately, singly-charged and neutral atoms generally do not offer enough additional narrow electronic transitions that can be measured with the required precision and accuracy.

Interest in highly charged ions (HCI) has intensified over recent years due to their high sensitivity to fundamental physical effects, but a reduced sensitivity to the kinds of external electric fields that cause some of the leading systematic uncertainties for modern optical atomic clocks. Recently, we demonstrated the first quantum logic spectroscopy of an HCI, namely boron-like Ar13+ (Ar XIV). Using novel laser cooling techniques, the equivalent temperature of the HCI can be reduced to less than 200 μK in each of its motional modes. These breakthroughs finally unleashed the full potential of HCI for ultra-high precision spectroscopy at the level of state-of-the-art optical atomic clocks.

We will present a brief overview of our experiment, along with an overview of our progress towards spectroscopy of highly charged calcium ions, with expected relative frequency uncertainties below the 1e-15 level. As this clock transition has a very different character to those already measured in singly-charged calcium, this has the potential to improve the bounds on the coupling strength of any potential fifth force by several orders of magnitude.

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