Towards high precision optical spectroscopy of trapped radioactive ions

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Since the invention of ion and atom traps, they have been a widely used tool for high precision optical measurements. Despite extensive developments in ion trapping, an ion trap for high precision optical spectroscopy of short-lived radioactive isotopes has not yet been installed at an ISOL (Isotope Separator On-Line) facility.[1] One possible application of such a device is high precision isotope shift (IS) spectroscopy. To first order, the IS (difference in transition energy in two isotopes) of two atomic transitions in an isotopic chain lie on a straight line, which can be fit using a King plot method. Probing the nonlinearities of this King plot allows searching for higher-order nuclear effects (e.g. the quartic nuclear charge moment $\langle r^4 \rangle$), as well as intermediate mass range dark-matter candidates.[2] To probe these nonlinearities, it is advantageous to have as many IS as possible. Currently, the method is limited by the number of stable isotopes of one element.

This motivated the building of two ion trapping setups at KU Leuven aimed at high precision optical spectroscopy of trapped radioactive ions. Currently, both ion traps, BICEPS (Bespoke Ion Cooling Experiment for Precision Spectroscopy) and the ultra-cold cooler buncher have been commissioned. I will discuss the ongoing developments of BICEPS as well as a plan towards future experiments at an ISOL facility. Presently, we are performing a lifetime measurement of the $D_{5/2}$ state in (Sr^+) using BICEPS. Combining both ion traps, we will perform the first high precision IS spectroscopy on trapped radioactive ions (Sr^+), specifically extracting $\langle r^4 \rangle$, currently not directly possible on radioactive isotopes.[3] This opens up new opportunities to study the nuclear charge distribution more accurately. With this device we will significantly improve the ability to probe higher-order nuclear effects using a King plot method and expand the field of high precision optical spectroscopy to radioactive ions.

[1] Takamine, A. et al., Phys. Rev. Lett., 112, 162502 (2024).

[2] Door, M., et al., Phys. Rev. Lett., 134, 063002 (2025).

[3] Reinhard, P. G., Nazarewicz, W., Garcia Ruiz, R. F., Phys. Rev. C, 101 (2020).