We propose to perform off-line experiments on $^{226}$Ra$^+$ ions using existing Paul- and Penning-traps at the University of Mainz. Ra$^+$ is considered as possible candidate in the search for parity violating effects in atomic physics. Experiments on parity non-conservation (PNC) in atoms have been performed in the past on systems such as Cs, Pb, Bi, and Tl. The most advanced experiment on Cs, performed by C. Wieman and coworkers at Boulder/Co, has led to a definite measurement of the nuclear anapole moment in Cs and sets limits on physics beyond the standard model[1].

Parity violating effects in atomic physics scale with the third power of the nuclear charge. Therefore attempts are under way to use high-Z atoms for similar experiments in the past. Since the interpretation of any experimental result requires a good knowledge of atomic wavefunctions, the proposed new experiments focus on Francium (Z=87) [2,3] since alkali atoms offer the simplest level configuration to perform atomic physics calculation.

Iso-electronic to the Francium atom is the Radium ion. A parity experiment on an ion suspended in an ion trap is under way at the University of Washington/Seattle, using Ba$^+$ as the highest-Z stable alkali-like ion [4]. It has been proposed to replace Ba$^+$ by Ra$^+$ [5], since the higher Z would increase the parity violating effects by a factor of 20. In contrast to Ba$^+$, however, the atomic physics of Ra$^+$ is not yet considered in detail. In order to start related calculations, data on atomic properties are required. The aim of our proposed experiments is to obtain data relevant to atomic physics calculation on Ra$^+$ using existing apparatus and established techniques.

The quantities of interest are lifetimes of metastable states and the ground state $g_J$ Factor.

Ra$^+$ has two metastable 6D-states which decay by electric quadrupole radiation into the 7S$_{1/2}$ ground state. The lifetime has not been calculated or measured but can be expected to be in the range of several hundred ms to several s. To measure this lifetime the ions shall be stored in a radio-frequency (Paul) trap. The metastable states are populated by decay from the laser-
excited $7P_{1/2}$ or $7P_{3/2}$ states. The decay from the metastable states can either be directly observed by counting of decay photons on the $6D - 7S_{1/2}$ transitions or by measuring the D-state population using time-delayed excitation of the D-states by an additional laser. These techniques have been successfully employed in our Laboratory on ions like Ba$^+$, Sr$^+$, and Ca$^+$ [6,7,8].

The ground state $g_J$-factor can be determined with high precision in a Penning ion trap using a strong superimposed magnetic field. One of the two Zeeman levels of the ground state can be selectively excited by a laser and depleted by optical pumping. A microwave transition to the other Zeeman level repopulates the empty state. This can be monitored by an increase of the fluorescence intensity from the stored ions. The magnetic field is calibrated by the cyclotron frequencies of electrons stored in the same field. This method has been successfully used in our laboratory on Ba$^+$ and Ca$^+$ where the $g_J$ factor has been obtained with $10^{-8}$ precision [9,10].

In both cases of Paul- and Penning-trap experiments the traps can be loaded from ions released by surface ionisation from a rhenium or tungsten filament near one of the trap electrodes. Previous similar experiments on radioactive isotopes of Ba and Eu [11,12], collected at the ISOLDE facility, have shown that the total quantity of atoms required to fill the trap several times, should be of the order of $10^{13}$. Ionisation of Ra by the same method should not be a problem because of its low ionisation energy. It is critical to avoid the collection of isobares which may be ionised and stored simultaneously with Ra$^+$. They might create a space charge which would reduce the number of stored Ra$^+$ ions. We plan to perform the measurements on the isotope of mass 226 since its long lifetime of 1600 y allows off-line operation at our laboratory at Mainz and reduces the safety measures.

The required Paul- and Penning traps are available at our laboratory as well as the lasers, fluorescence detection systems, and radio-frequency and microwave equipment.

**Beam request:**
Element: Ra
Isotope 226
Intensity $> 10^8$ s$^{-1}$
Number of shifts: 4, preferentially 2 times 2 shifts
References

  Determination of the nuclear magnetic anapole moment in Cs
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  Magneto-optical trapping of $^{210}$Fr

  Efficient collection of $^{221}$Fr into a vapour cell magneto-optical trap

[4] E.N. Fortson

  Nuclear Spin-Dependent Parity Nonconserving Transitions in Ba$^+$ and Ra$^+$

  Experimental Lifetime of the metastable 5D$_{3/2}$ state in Ba$^+$

  Lifetime of the 4D$_{5/2}$ and 4D$_{3/2}$ metastable states in Sr$^+$

  Precise lifetime measurements of the metastable 3D$_{5/2}$ level in Ca$^+$

  Bound and excited state g-factors of Ba$^+$

  Precise g$_J$ factor of the ground state of Ca$^+$
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  and the ISOLDE collaboration
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