Highly charged ions at SpecTrap*

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The SpecTrap collaboration aims at high precision laser spectroscopy of forbidden transitions in highly charged ions (HCIs). Similar experiments performed to date with ions stored in an EBIT or in a storage ring still suffer from Doppler broadening or the difficulties in wavelength conversion between the laboratory frame and the rest frame [1, 2]. Therefore, the SpecTrap experiment employs a cryogenic Penning trap suitable for trapping externally produced ions and sympathetically cooling them with laser cooled Mg^+ ions [3]. Cooling of HCI to the mK-regime will dramatically reduce the Doppler broadening of the fluorescence signal and allow the measurement of the hyperfine splitting of the HCI with an expected relative accuracy of 10^{-8} for a stringent test of bound state QED.

In 2013, a new beamline was installed at the HITRAP platform to connect a commercial EBIT with the SpecTrap Penning trap [4]. This EBIT can be used to produce argon ions with any desired charge state up to bare Ar. Since Ar^{13+} is a suitable candidate for a laser-accessible, forbidden transition in a HCI, the beamline has been optimised for maximum transmission of this charge state. Several 10^4 Ar^{13+} ions have been transported with a kinetic energy of 4 keV/q to the SpecTrap experiment. Because of the maximum voltage that can be applied to the trap electrodes only low energy ions with kinetic energies of a few hundreds eV/q can be trapped in the SpecTrap-Penning trap whereas much lower transport energies would be desirable. Unfortunately, intra-beam scattering and electron capture sets constraints to the minimum transport energy of the beam and further reduction of the current value of 4 keV/q would lead to much lower transport efficiency from the EBIT to the trap. Therefore, a pulsed drift tube has been installed close to the trap and used to decelerate several 10^4 Ar^{13+} ions in a single bunch to energies as low as 600 eV/q. Ions with this energy can be easily trapped with the Penning trap's electrodes and the number of Ar^{13+} ions even in one single bunch is now sufficient for the designated spectroscopy experiments at SpecTrap.

Prior to the installation of the HITRAP beamline, the experiment had been connected to two different ion sources simultaneously. The first source supplied the experiment with singly charged magnesium, the second one with Ar^+ and Ar^{2+}. With this setup, alternating trapping of Mg^+ and Ar^+ was demonstrated, being the first step for simultaneous storage and sympathetic cooling of HCI. Ar^+ transported with a kinetic energy of 600 eV has been trapped and electronically detected with the resonant circuit attached to the endcaps of the SpecTrap Penning trap. Furthermore, resistive cooling of Ar^+ with the resonant circuit has been demonstrated as well. Different ion species and charge states were identified via their axial and radial oscillation frequencies. To this end, the trap parameters that influence the axial oscillation frequency have been determined with the species Mg^+ and Ar^+. Resonant excitation of different ion species has been performed and detected by changes in the fluorescence signal of $^{24}Mg^+$ (see Fig. 1). This demonstrates the potential for non-destructive detection and identification of arbitrary ion species.

With these tools at hand, the SpecTrap experiment is ready for trapping and detection of HCI like Ar^{13+}. In a first step the storage time, resistive, and sympathetic cooling and the interaction between Ar^{13+} and Mg^+ will be investigated. As soon as a cold and dense ion cloud of Ar^{13+} is available, the forbidden transition of Ar^{13+} will be measured in a high precision laser spectroscopy experiment, followed by experiments with different ion species like Ca^{14+} and Bi^{82+} once HITRAP is fully operational.

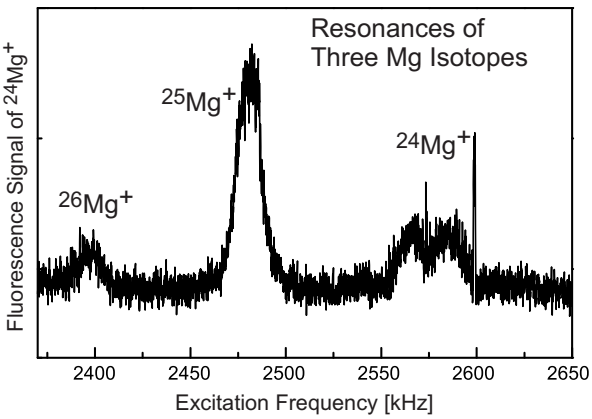

Figure 1: Reduced cyclotron frequencies ν_c of $^{24-26}Mg^+$ isotopes. Excitation of ν_c changes the state of the ion cloud and therefore increases the fluorescence signal received from ^{24}Mg isotopes.

References

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