In-trap production of highly charged ions at ARTEMIS

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We are currently setting up a laser-microwave double-resonance spectroscopy experiment with highly charged ions in a Penning trap, which combines precise spectroscopy both of optical transitions and microwave Zeeman splittings [1, 2, 3]. The experiment aims at spectroscopic precision measurements of such energy level splittings and magnetic moments of bound electrons on the ppb level of accuracy and better. For first tests, the $^{40}Ar^{13+}$ ion has been chosen. It has a spinless nucleus, such that only a fine structure is present. Similar measurements in hyperfine structures are to be performed with ions of higher charge states such as for example $^{207}Pb^{81+}$ and $^{209}Bi^{82+}$ as available to ARTEMIS within the framework of the HITRAP facility.

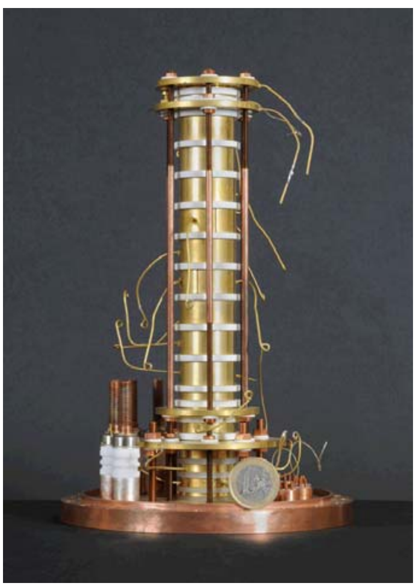

Figure 1: Photography of the ARTEMIS Penning trap, in which the ions are created and confined for spectroscopy.

In an external magnetic field, the Zeeman effect lifts the degeneracy of energies within fine- and hyperfine-structure levels. For highly charged ions in magnetic fields of a few Tesla strength, the Zeeman splitting is well within the microwave domain and thus accessible for precision spectroscopy. In addition, in case of fine- and hyperfine-structure transitions, the strong scaling with Z eventually shifts the corresponding energies into the laser-accessible region and thus makes them available for precision optical spectroscopy [1]. Figure 1 shows the Penning trap of the ARTEMIS experiment, in which the ions of interest are created and confined for spectroscopy. Creation takes place by electron impact ionization in close similarity to the charge breeding processes used in electron beam ion sources (EBIS). We have installed this trap arrangement in the superconducting magnet of the ARTEMIS experiment, and have used an EMCCD-camera to detect photons emitted during the charge breeding process of highly-charged argon ions. Figure 2 shows a false-colour image from this camera looking into the cylindrical trap along its symmetry axis from above. This optical tracking of the ion creation

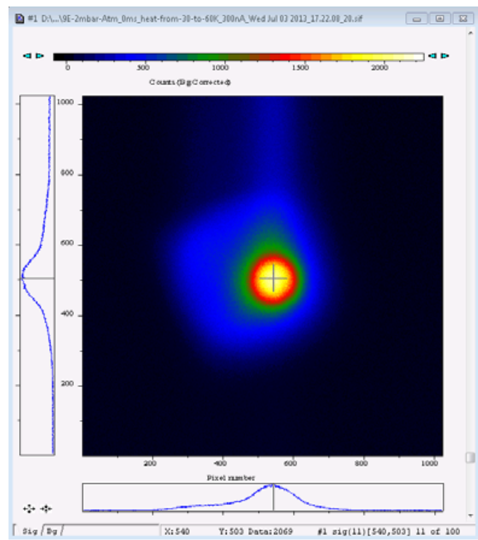

Figure 2: EMCCD-image of photons emitted during creation of highly-charged ions in the trap.

process is a powerful diagnostic tool to control and optimize the charge breeding process in real-time. In a next step, it will be combined with non-destructive electronic detection able to yield mass spectra of produced ion distributions, thus providing optimal control.

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References

[1] W. Quint, D. Moskovkin, V.M. Shabaev and M. Vogel, Phys. Rev. A **78** (2008) 032517.

[2] D. von Lindenfels, N. Brantjes, G. Birkl, W. Quint, V. Shabaev and M. Vogel, Can. J. Phys. **89**, 79 (2011).

[3] D. von Lindenfels, G. Birkl, D.A. Glazov, A. Martin, G. Plunien, W. Quint, V.M. Shabaev, M.M. Sokolov, M. Vogel, A.V. Volotka, and M. Wiesel, Phys. Rev. A **87** 023412 (2013).

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