An All-Permanent Magnet 10 GHz "Multi-Mode" ECR Ion Source for the Production of Metallic Ions

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Abstract

An all-permanent magnet ECR ion source has been designed and built with respect to the use on a high voltage platform of the Giessen ion-ion experiment. The performance of the ion source in the production of ions from gaseous elements was investigated. The metal ions were produced by evaporating atoms from an oven which is integrated into the coaxial microwave coupling. The source was operated with both an excellent reproducibility and a very good stability.

1. Introduction

In order to measure cross sections for charge-changing processes in collisions between ions in our ion-ion [1] experiment one ion beam has to be produced on a high voltage terminal. Since there are restrictions concerning the available space and electrical power an all-permanent magnet 10 ECR ion source has been built earlier [2]. This ion source is in operation and produces multiply charged ions from gaseous elements with sufficient intensities. Now there is a growing interest in the use of ions from metallic elements. For this purpose a new all-permanent magnet 10 GHz ECR ion source has been constructed and tested.

2. Source Description

One feature of the new ion source is a stepped plasma chamber which leads to a bigger plasma volume and therefore to higher extracted ion currents. Furthermore, this allows the propagation of higher microwave modes together with the ground then coupled to the plasma via a coaxial line. Here a miniature evaporation oven for the metallic ion production can be integrated. The plasma chamber has a length of 250 mm and the three different inner diameters are 28 mm at the injection side, 60 mm in the hexapole region and 33 mm at the extraction side. The ions are extracted through a spherical extraction electrode with voltages of typically 10-20 kV. The grounded puller electrode with an integrated electrostatic Einzel lens is movable to allow the optimization on different charge states. During the test measurements a residual gas pressure of $9 \cdot 10^{-7}$ mbar was obtained.

Fig. 1 shows a schematic drawing of the ion source.

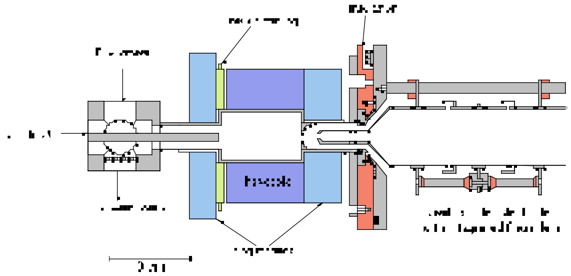

Fig. 1: Schematic set-up of the 10 GHz

The magnetic field is produced by permanent magnets from NdFeB only. In the radial direction the plasma electrons are confined by the magnetic field of a Halbach-type hexapole [3] with a magnetic field strength of 11.5 kG at the inner wall of the plasma chamber. The axial confinement is achieved by two radially magnetized ring magnets. This structure leads to an axial magnetic field strength of 6.5 kG at the injection side and 5.5 kG at the extraction side with 3 kG at the minimum of the magnetic field. The optimum performance of the ion source was obtained at a microwave frequency of 8.5 GHz where the corresponding magnetic resonance field strength is equal to the minimum of the mirror field. Therefore the mirror ratios are 2.2 and 1.8, respectively. The magnetic field configuration is shown in fig. 2.

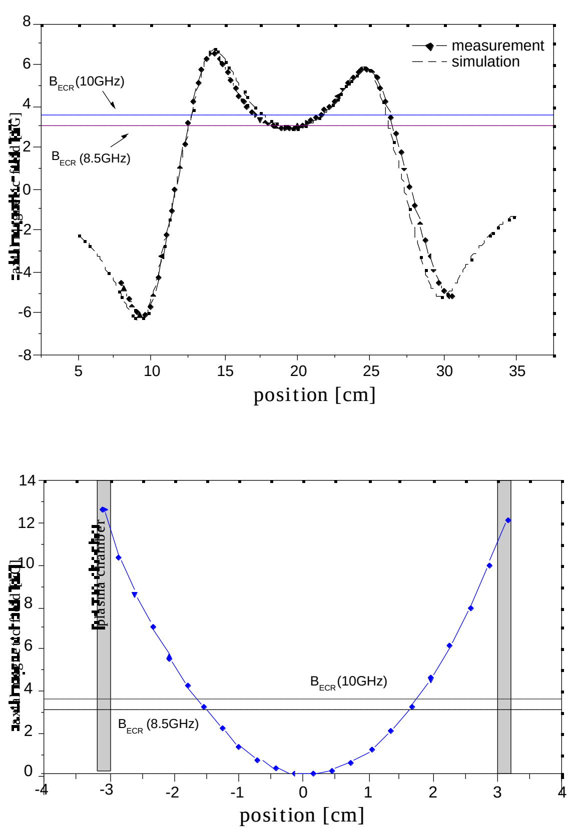

Fig.2: Axial and radial magnetic field plot of the 10 GHz ECRIS

The microwave is produced in a frequency-tunable magnetron (8.5-10.5 GHz, 250 Watts cw max.) and coupled to the plasma via a coaxial line. The plasma chamber represents the outer conductor and a 12 mm stainless steel rod the inner conductor. An evaporation oven can be integrated into this coaxial line and the position with respect to the plasma can be varied by a movable linear feedthrough. Fig. 3 shows a schematic set-up of the microwave system.

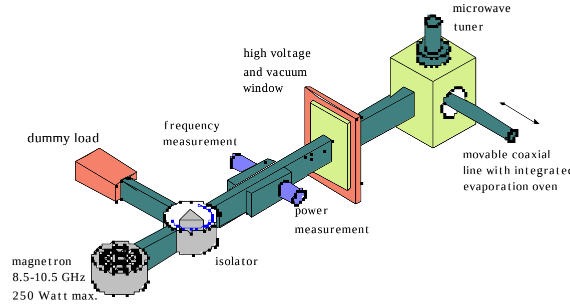

Fig. 3: Microwave system

3. Experimental Results

After the assembly the ion source was installed on a test bench and the performance was investigated using different gaseous elements. As a first test we used oxygen with helium as a mixing gas. Fig. 4 shows one of the first spectra extracted from the ion source at an acceleration voltage of 10 kV through an extraction aperture of 3.5 mm diameter. Although there are still many contaminations from residual gas ions in the spectrum, an ion current of about 10 eμA for O^{6+} could be identified.

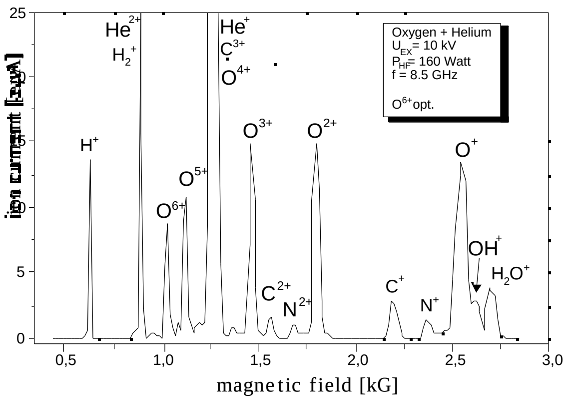

Fig. 4: Charge state distribution for Oxygen

After the first successful operation on the test bench the ion source was installed on the high voltage terminal of the Giessen ion-ion experiment. Here, the ion source delivered Ar^{5+} ions for collision experiments. A typical charge state distribution for argon is shown in fig. 5. The ion current was measured at a distance of about 6 m from the extraction aperture after collimation of the ion beam to typically 1x1 mm^2.

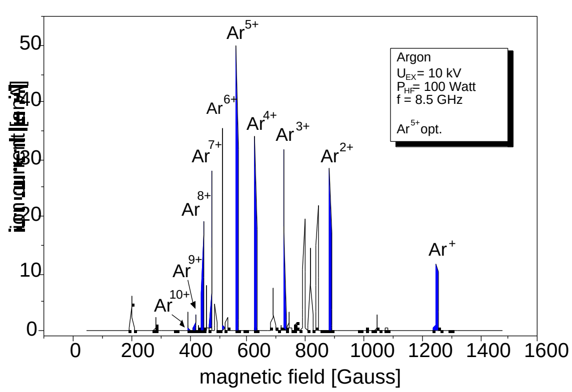

Fig. 5: Charge state distribution for argon

In order to produce ions from metallic elements a miniature evaporation oven was installed into the coaxial line for the microwave coupling. In order to satisfy the demands of the ion-ion experiment, bismuth was used as the first metal to become ionized. Bismuth has a relatively low melting point of 273°C and therefore only about 500°C are needed to get a Bismuth gas pressure in the range of 10^{-5} for Bismuth is shown as it is obtained when optimizing the ion source on Bi^{19+}. This spectrum was also measured after tight collimation of the ion beam.

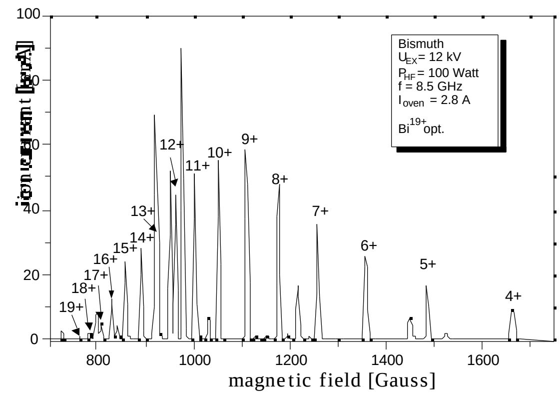

Fig.6: Charge state distribution for Bismuth

During all measurements the ion source showed an extremely stable performance, e.g. we obtained a stable Bi^{4+} beam used for an ion-ion experiment for a period of about 100 h until the evaporation oven had to be refilled. Also the reproducibility of the source is exceptionally good.

4. Conclusion

A new all-permanent magnet 10 GHz ECR ion source with a “multi-mode” plasma chamber and a coaxial microwave coupling has been built and tested. The new source produces sufficient intensities for our ion-ion experiment for both gaseous and metallic elements. The ion source shows an excellent reproducibility as well as a very good stability.

5. Outlook

In first emittance measurements the emittance of the ion source was determined to be about 100 π mm mrad. Work is in progress to improve that value by testing different extraction geometries.

At the moment the temperature of the

1000°C. Soon we will install a water-cooling into the oven and with that we hope to be able to produce also metallic ions from high-melting elements.

6. References

[1] S. Meuser et al., Rev. Sci. Instr. **67** (1996) 2752-2759

[2] R. Trassl et al., Physica Scripta **T73** (1997) 380-381

[3] K. Halbach, Nucl. Instr. Meth. **169** (1980) 1