Status of the Frankfurt 14GHz-ECRIS-(ve)RFQ-Facility

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Abstract

The accelerator facility installed at the Institut für Kernphysik (IKF) combines a 14 GHz electron cyclotron resonance ion source (ECRIS) and a variable energy radio frequency quadrupole accelerator (ve-RFQ)[1,5]. The installation provides highly charged ions in an energy range between a few keV - using only the beam delivered from the ECRIS - and 200 keV/u using the post acceleration by the ve-RFQ. The setup delivers a variety of ions in well defined high charged states for basic atomic physics and materials research. Besides this, the ion source is also used for studies of the basic production processes of highly charged ions in ECR ion sources with the intention to continuously improve quality and intensity of the available ion beams. The present status and further plans and activities at the facility are reviewed. (See also the contributions to this workshop by V. Mironov et. al [2], S. Runkel et al. [6] and L. Schächter et al.[10])

Introduction

The Frankfurt 14 GHz-ECRIS-(ve)RFQ facility is designed for experiments for basic atomic physics and materials research, where highly charged ions from different elements are subject of investigation [1]. A sketch of the present (solid lines) and projected (dashed lines) outline of the facility is given in Fig.1

Up to now mainly highly charged ions from lighter gaseous elements (He, Oxygen, Neon, Argon) have been produced in the Frankfurt ECRIS to be delivered to various types of experiments. First tests with heavier elements like Krypton and Xenon as well as with metallic ions, produced via laser ablation technique[2], have been carried out successfully. Additionally the production of metal ions from volatile compounds (MIVOC) [3] has been tested within the frame of the collaboration with Hungary at the ATOMKI ECRIS [4].

The range of ion velocities delivered by the ECRIS (ECRIS-beam) depends on the charge state of the ion and on the extraction voltage. Actually, extraction voltages up to 50kV have been used. An extension to 100kV is principally possible. This velocity range can be extended for ions with sufficiently high charge states by means of the variable-energy (ve)RFQ [5]. This RFQ structure allows a variation of operation frequency between 80–110 MHz, which corresponds to an energy variation of a factor 2. The structure is designed for a minimum specific input charge of q/A=0.15 and delivers ion energies between 100 and 200 keV/u (RFQ-beam).

The 120° ECRIS-beam line is now permanently used for dedicated experiments using the method of Cold Target Recoil Ion Momentum Spectroscopy (COLTRIMS). A series of experiments performed at the faraday cup in the 90° ECRIS-beam line in front of the RFQ is devoted to plasma diagnostics [6, 7] and to investigate and optimize the conditions of injection into the RFQ structure. For the final design of the RFQ-beam-line sections the beam was characterized directly at the exit of the RFQ for different operational frequencies and charge states. This part of the facility consists of three beam lines with different requirements for the beam profile [8]. For ‘in-situ’ double beam experiments there is a crossing between the ECRIS-beam and the RFQ-beam. The beam transport to the 45°-RFQ-beam line after the second analyzing magnet (AM2) has been optimized for well collimated beams for angular differential measurements. The building-up of both, the 0° and the 45° RFQ-beam lines is finished. First experiments with the postaccelerated ions are in preparation and energy-calibration measurements are presently performed in the 45° beam line.

Several mechanical and technical improvements of the experimental setup have been tested and installed. In this paper a review on some of these developments is given.

Microwave stabilization

For time resolved measurements of the ion current the present diagnostics D3 and D4 were replaced by coaxial faraday cups with an impedance of 50 Ω. One coaxial faraday cup is installed in the 90° beam line behind the first analyzing magnet (AM1). It serves to investigate the time structure of the ion currents emitted from the ECRIS. Another cup behind the RFQ-accelerator is used for measurements of the beam structure induced by the bunching capability of the RFQ.

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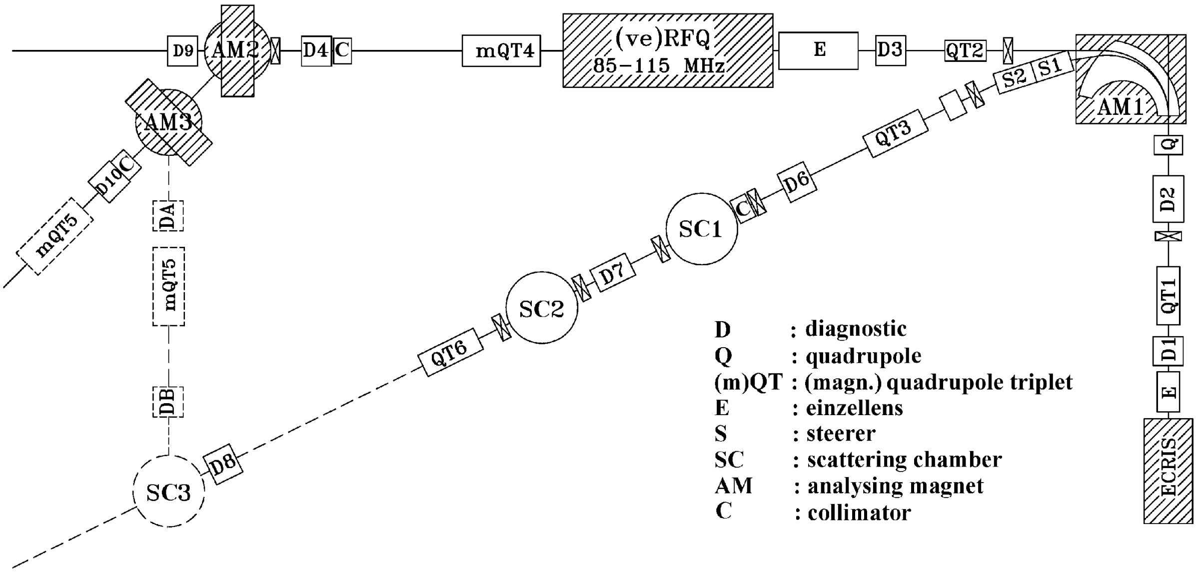

Fig. 1: Sketch of the Frankfurt 14 GHz ECRIS-(ve)RFQ facility.

First time resolved measurements of an Ar^{8+} -ion beam exposed dramatic periodic intensity fluctuations of the extracted ion currents (see dotted line in Fig.2). The reason for these fluctuations was found to originate from instabilities of the frequency and amplitude of the microwave oscillator driving the amplifier (clystron), which led to a quite analogous pattern in the forwarded power from the microwave amplifier into the source.

This problem was solved by stabilizing the oscillator frequency by means of the phase-lock-method [9] from initially (unstabilized) $1\text{x}10^{-3}$ (14.360± 0.015 GHz) to $2.7\text{x}10^{-4}$ (14.360± 0.004 GHz) in the case with stabilized frequency. For the stabilization an external reference signal is applied with a frequency of 14.346 MHz. This measure helped to abandon the variations in the forward power completely.

Measurements with and without stabilization showed that the intensity fluctuations could be reduced by this method to a level of less than 10%, being caused by the natural fluctuations of the ECR-plasma (see solid line in Fig.2). Moreover, the constant input of microwave power into the ECRIS leads to a drastically improved performance for the very high charge states. In the non stabilized mode their breeding is interrupted by the time variation of the heating power which was essentially switched off at a time scale clearly shorter than the typical times necessary to generate the highest charge states by successive ionization [2]. An increase of the yield of Ar^{16+}-ions by a factor of 45 as compared to the mode without stabilization was observed. In Fig. 3 the measured improvement factors for different charge states for a pure argon plasma are given.

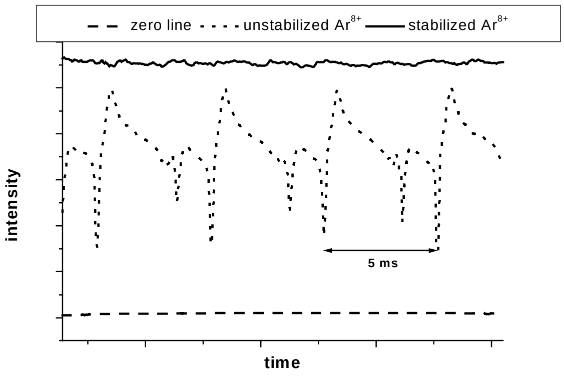

Fig. 2: Time resolved measurements for Ar^{8+} with stabilized and none stabilized oscillator frequency.

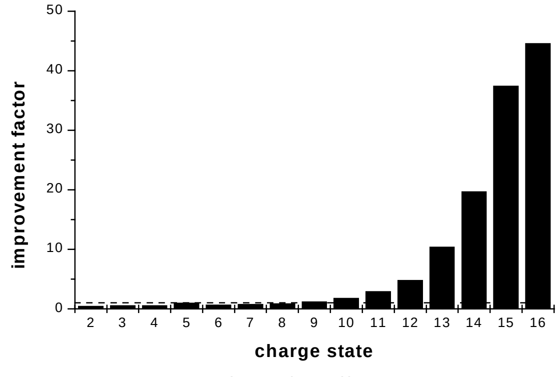

Fig. 3: Improvement factor for different Argon charge states for optimized Ar^{16+}.

Improvement of the ECRIS setup

In order to have a better access to the inner parts of the ECRIS-plasma chamber and to provide better possibilities for research combined with the basic properties of ECRIS plasmas (e.g. plasma diagnostics and manipulations), a new field shaping iron plug was constructed and installed at the injection-side of the source.

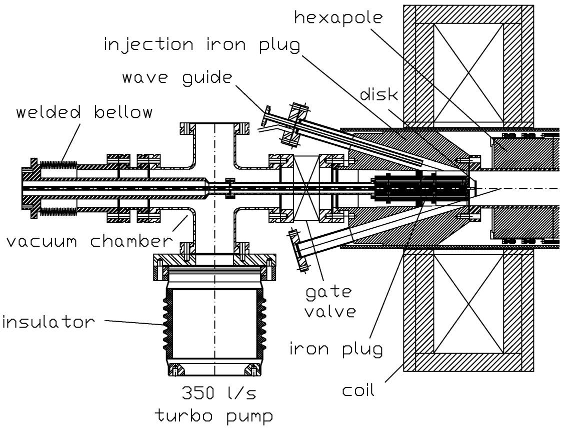

Fig. 4: **Sketch of the modified injection side of the source.**

Besides the usual entrance at 0° with respect to the source axis, which hitherto was used to mount the biased disk, to launch the microwave power and to introduce the gas inlets into the source, this module provides 6 additional vacuum ports directed to the ECRIS plasma. These ports are inclined by an angle of 17° with respect to the source axis. They allow additional direct accesses to the source plasma offering also direct viewing into the plasma volume e.g. x-ray spectroscopy or other methods of plasma diagnostics. In the new setup the microwave coupling as well as the gas inlet into the source are mounted through one of the six new ports.

By this modification the axis of the source remains completely accessible with the full diameter of the plasma chamber. This allows to easily insert devices into the plasma chamber like special cylinders to cover the plasma chamber wall with a material other than stainless steel [10]. In the new setup this rear side of the source is equipped with a manipulator unit, which is separated from the plasma chamber and the new injection iron plug by a gate valve. The manipulator unit consists of a vacuum chamber with pumping unit and two coaxially movable welded bellows with strokes of 320 and 70mm respectively. This installation serves to change and place up two different structures into the plasma chamber without breaking the main vacuum of the source. Additionally, the position of both structures inside the source can be changed independently and under vacuum. A sketch of this special section of the ECRIS is shown in Fig.4.

This new device strongly shortens the time necessary to condition the source after opening. For instance, if only the disk has been changed, the source comes back to optimal performance already half an hour after starting to pump the manipulator section down. In order to obtain the highest possible mirror ratio of the magnetic field at the injection side an iron plug is attached to the long linear motion of the manipulator (stroke 320mm). The iron plug has a diameter of 40 mm. Different disk structures can be mounted on top of the second, shorter linear motion (stroke 70 mm), which is moved together with the iron plug into ground position close to the plasma of the ECRIS. Here this shorter linear motion serves to optimize the disk's position relative to the plasma. The disk is electrically isolated. Disk voltages of up to 1000V can be applied.

The new setup is completely operational only since March of this year. Part of the results reported in the contributions to this workshop [2, 6, 10] have already been carried out with this system. Especially the measurement using the laser ablation technique [2] would not have been possible without the additional ports that provided direct access into the plasma chamber to introduce laser beam and target.

Acknowledgements

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