PRELIMINARY RESULTS OF SPATIALLY RESOLVED ECR ION BEAM PROFILE INVESTIGATIONS*

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Abstract

The profile of an ion beam produced in an Electron Cyclotron Resonance Ion Source (ECRIS) can vary greatly depending on the source settings and the ion-optical tuning. Strongly focussed ion beams form circular structures (hollow beams) as predicted by simulations [1] and observed in experiments [2] and [3]. Each of the rings is predicted to be dominated by ions with same or at least similar m/q-ratios due to ion-optical effects. To check this we performed a series of preliminary investigations to test the reqiured tuning capabilities of our ion source. This includes beam focussing (A) and beam steering (B) using a 3D-movable extraction. Having tuned the source to deliver a beam of strongly focussed ions of different ion species and having steered this beam to match the transmittance area of the sector magnet we also recorded the ion charge state distribution of the strongly focussed beam profile at different, spatially limited positions (C). The preliminary results will be introduced within this paper.

EXPERIMENTAL SETUP

Within this section a short overview of the ECR ion source including the beam line and the profile measuring device, the Faraday Cup Array (FCA), will be given.

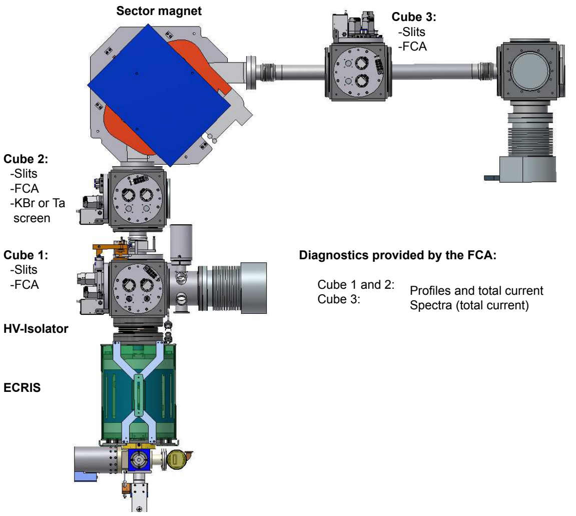

Figure 1: overview of the setup

ECRIS and beam line

The ion source we use to generate the ion beam is an all-permanent magnet ECR ion source. One special feature of this source is the extraction electrode that is movable in three dimensions, along the beam axis and perpendicular to it. After the extraction the ions pass two cubes providing access to the beam (see figure 1). The cubes are equipped with `slits` to limit the beam and with a `profile`-measuring device described in the following subsection. A 90° sector magnet is used to separate the ions according to their m/q-ratio. Sweeping the magnetic field we are able to record m/q-spectra using the detector placed in the third cube along beam line.

The tuning of the source was similar during all tests. At a comparatively high pressure in the vacuum chamber of 10^{-5} mbar we axially guide microwaves at a power of 50 W into the plasma.

Faraday Cup Array (FCA)

In order to monitor the ion beam from the source to the experimental chamber we have developed a new kind of beam profile monitor. Its working principle is based on the well-proven Faraday cup (FC). Having arranged a total number of 44 tiny (Ø = 0.3 mm) FCs to an array and driving this arrangement through the beam we record the position and the current for each tiny cup in a repetitive measurement. This allows the reconstruction of the beam profile. We have combined this detector with a standard FC to be able to also determine the total beam current. This detector is characterized by its sensitivity in combination with high durability. The spatial arrangement of the tiny cups allows the detection of profile-structures on mm-scale in a large range of current densities. More detailled information can be found in [4]. A CAD-view of the detector is presented in figure 2.

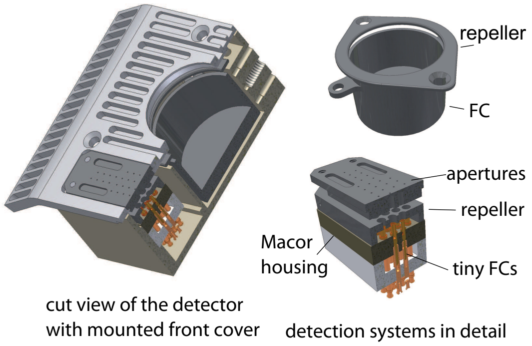

Figure 2: different CAD-views of the FCA

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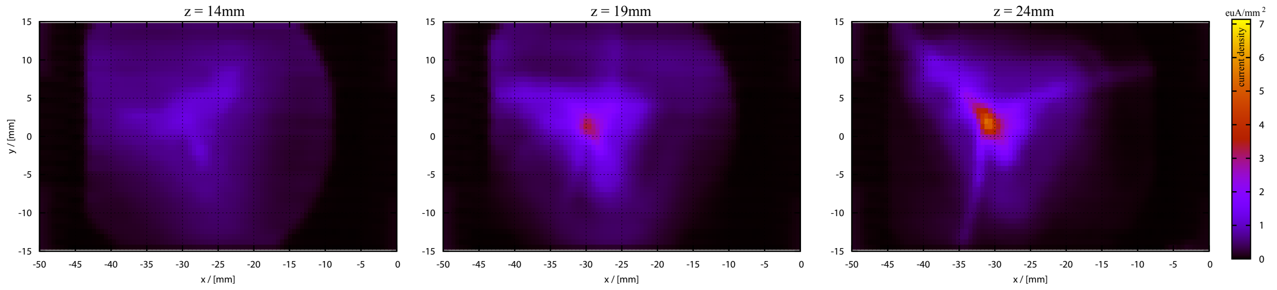

Figure 3: beam profiles recorded at different positions of the extraction electrode along the beam axis show different focussing properties

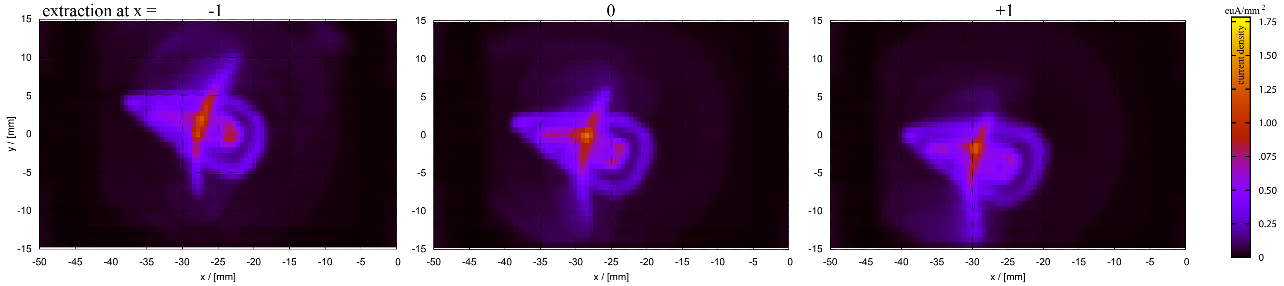

Figure 4: beam profiles for different positions of the extraction in the horizontal direction perpendicular to the beam axis; the stronger focussing in comparison to figure 3 is achieved by additionally lowering the extraction voltage

PROCEDURES AND RESULTS

A *Beam focussing*

For the beam-focussing investigations we move the extraction electrode along the beam line at a constant acceleration voltage and record beam profiles for different distances. A selection of the recorded profiles is shown in figure 3 in the same current density scale. As visibe, the beam is being focussed with increasing distance between the plasma electrode and the extraction electrode. As a result for our beam-focussing investigations we can state that we can focus the beam at a constant acceleration voltage by moving the extraction along beam line. To even increase the focussing effect we additionally can lower the extraction voltage. The higher focussing results in beam profiles similar to those shown in figure 4. We see that the triangular structure changes its shape and more hollow rings appear.

B *Beam steering*

In order to investigate the beam steering capabilities of our source we tuned the source to deliver a strongly focussed beam. Moving the extraction in the plane perpendicular to the beam axis we recorded the movement of the beam in both cubes, again using our profile monitoring device, the FCA. The resulting profiles shown in figure 4 are recorded in cube 1. As we can see the beam moves roughly downwards when the extraction is moved horizontally from left to right. This corresponds a rotation of roughly 90° in the clockwise direction. We can observe the same effect (a rotation of roughly 90° clockwise) when moving the extraction vertically in the same plane. In conclusion we can state that we can effectively steer the beam by changing the position of the extraction in the plane perpendicular to the beam axis. This technique can be used to match a certain, non-central region of the beam into the transmittance area of the sector magnet, i.e. for subsequent m/q-recordings.

C *Spatially resolved charge state distribution*

To check the feasibility of determining the spatially resolved ion charge state distribution of a strongly focussed ion beam we additionally perform this third preliminary

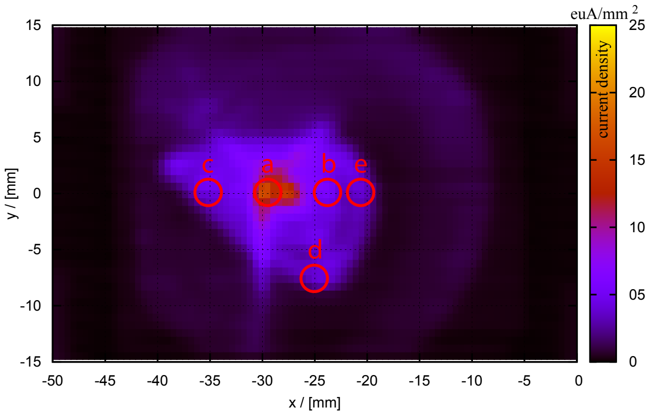

Figure 5: profile with marked positions for m/q-spectra recordings

Table 1: dominant m/q-ratios at the marked spots of figure 5

a	$O^{1+\to4+}$ $N^{1+\to4+}$
b	N^{2+} O^{2+}
c	N^{2+} O^{2+}
d	O^{2+}
e	O^{2+}

measurement. Therefore, we keep the source tuned to provide a strongly focussed beam of multiple ion species forming the characteristic ring-like structures. We use slits to limit the transmitted beam to the desired spots indicated in figure 5. Only the transmitted beam can pass the sector magnet allowing the determination of m/q spectra or charge-state distributions. For this first feasibility check we only chose a limited number of characteristic points marked ”a-e” in figure 5. To match point ”b” into the transmittable area of the sector magnet we needed to lift the beam slightly by applying our beam steering technique. The results of the different m/q-spectra are summarized in table 1.

From these preliminary results we could assume that the outer ring measured at positions d and e is (under current source settings) dominated by twice ionized oxygen atoms (O^{2+}). Since at position b the dominant ion is N^{2+} with a not negligible amount of O^{2+} one could (assuming a slight misadjustment of the slits) presume that the inner ring mainly consists of twice ionized nitrogen atoms. At position c both hollow rings seem to overlap or at least lay close to each other as visible in figure 5. This is in agreement with the results of the charge state measurement for this point since here the prominent ion species are N^{2+} and O^{2+}. At central position a the higher ionized charge states of nitrogen and oxygen are present.

From these preliminary vaild results we can state that we in principle are able to determine the spatially resolved charge state distribution of a beam profile. However, for reliable data a profile with sharper ring structures should be chosen and the charge state distribution of a higher amount of characteristic points should be determined. This technique can be used to check the theory that the hollow rings often found in strongly focussed ion beams are dominated by ions of the same or at least similar m/q-ratio.

CONCLUSIONS

In conclusion we can state that using our 3D-movable extraction we can effectively steer and focus the ion beam. In combination with our high-resolution beam-profile monitoring device we are able to focus the beam to a strongly focussed beam, steer the regions of interest of the beam into the transmittable area of the analyzing magnet and record a profile of this setting. Using the `slits` to limit the beam to small areas we are able to determine the spatially resolved ion charge state distribution of the beam profile in the plane perpendicular to the beam axis.

For the final measurements validating the theory mentioned above we tuned our source for multiple ion species whose particular m/q-depending focussing varied from strongly focussed to over-focussed. Then a series of hollow concentric rings appeared that were superimposed by a triangular structure. Using the technique described above we performed more accurate measurements in order to determine the spatially resolved ion charge state distribution of a strongly focussed beam of multiple ion species [5].

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