A Status Report of the KVI-AECR*

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Abstract. In this paper the first results of the new ECR source at the KVI are presented. The source has been built following the design of Jyväskylä University, which is based on the AECR-U of LBNL. As the commissioning is going on, it seems that the extraction and analysing systems inherited from the old source are the limiting factors for the performance of the new source. Beam currents achieved with the source are at the moment a factor of 3 lower than the AECR source used at the Jyväskylä University. Further modifications to improve the source performance will be discussed.

1 Introduction

In order to meet the requirements for radioactive beam experiments at the KVI, the existing CAPRICE type ECR source was converted into an LBNL-AECR-U type source [1], following the design used at Jyväskylä University. Design and calculations as well as tests of various subsystems, have been described earlier [23]. In October 2005 the first beams were extracted from the new KVI-AECR and injected into the AGOR cyclotron at KVI. Before presenting the experimental results achieved with the reconstructed source, we will briefly describe the extraction and analysing systems, which have turned out to be the elements limiting further increases in beam intensity.

2 Beam extraction and analysis

The KVI-AECR inherited from the old CAPRICE type ECR source: a puller system, the analysing system and the aperture ladder in the image plane of the analysing system. These systems were not modified during the reconstruction. The analysing system consists of a dipole magnet that is capable of selecting particles with a magnetic rigidity up to 0.154 Tm, which is more than the 0.07 Tm needed for injection into the AGOR accelerator.

2.1 Extraction systems.

The beam is extracted by a single puller system with an entrance aperture of 16 mm diameter and a length of 85 mm. The puller can be moved over 20 mm longitudinally. A ground electrode is located behind the puller with an inner diameter of 29 mm and a length of 190 mm. A top view of the extraction system is shown in Fig. 1. This ground electrode minimizes the acceptance of the analysing systems to 200 π mm mrad, which is still larger than of 140 π mm mrad, which is used as the design specification of the acceptance of the AGOR injection systems. Horizontally a beam with a width of 120 mm could be accepted at the entrance of the magnet. In the vertical plane a beam can be accepted with a width of 60 mm at the entrance, limited by the gap of the analysing magnet and the inside dimensions of the vacuum chamber.

Fig. 1. Top view of the extraction systems of the KVI-AECR

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2.2 The analysing system.

The analysing magnet is an unclamped double focusing magnet with straight, 37° tilted edges, for the vertical focusing. The pole gap is 67 mm. The effective pole width is 120 mm. The dipole bends the beam over 110 degrees with a bending radius of 400 mm. The distance from the extraction aperture to the effective field boundary (EFB) is 682 mm and the distance between the image and the FFB is 374 mm resulting in a first order magnification of 0.6. The extraction aperture at the exit of the plasma chamber is 10 mm in diameter and is imaged to the analysing plane were a Faraday cup with an entrance diameter of 10 mm is located. The magnet itself in combination with the extraction aperture does have a horizontal acceptance of 440 π mm mrad and vertically of 244 π mm mrad.

![Fig. 2. The M110 analysing magnet.](image)

2.3 Measuring beam intensity.

In the image plane an aperture ladder is placed containing a) a Faraday cup with a 10 mm aperture, b) a Faraday cup with a 20 mm aperture, c) a diaphragm of 2 mm diameter and d) a diaphragm of 10 mm diameter. The Faraday cups do not have an electron suppression ring. The cups are connected to ground with a resistor of 0.5 MΩ. The voltages measured on the Faraday cup are mostly above 20 Volts and due to this, most secondary electrons will not escape from the cup. The Faraday cup with an entrance aperture of 20 mm was installed to be able to compare the performance of the KVI-AECR with earlier publications [4]. (see Table 2).

3 Experimental results.

Since October 2005 beams were developed with the KVI-AECR (see Table 1). Every time a new beam was developed for the AGOR cyclotron the maximum beam current of the specific charge state and the charge state distribution were measured at an extraction voltage of 12 kV. Furthermore the beam intensity of the optimised charge state was measured as function of the extraction voltage. From these data we could determine, a) the performance of the source by the maximum intensity, b) how this maximum relates to the whole charge state distribution, c) the intensity as a function of the extraction voltage so as to be able to determine the beam current in relation to the perveance.

3.1 Extracted beams

Since October 2005 only medium charge state beams have been requested for experiments (e.g. 20Ne7+, 19F6+, 12C6+, 11B7+, 4He2+, 16O6+, 40Ar8+). The 11B7+ beam was made with a BF3 gas, which is a highly reactive gas. The gas system needed for this was flushed with an inert gas to get rid of all the oxygen. At first Ar was used, but this was not a good choice because the production of Ar-ions reduced that of B-ions. Using He to flush the gas system solved this problem. Beams were extracted up to an extraction voltage of 35 kV.

3.2 Beam perveance

In Fig. 3, the extracted current of a 19F6+ beam is plotted as a function of the extracted voltage. For extraction voltage below 15 kV the current-voltage dependence nicely follows the Child-Langmuir law [5] indicating that in this range the beam current is space charge limited. The beam current levels off at extraction voltage higher than 15 kV, i.e. in this range the beam is emission limited. By increasing the injected RF power the saturation effect is pushed towards higher extraction voltages, which indicates that the maximum beam intensity is determined by the available ionisation rate. It seems that the plasma cannot produce the high charged ions at the rate needed to maintain a space-charge dominated regime.

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3.3 Maximum intensities

The maximum intensities were measured at an extraction voltage of 12 kV (see Table 1) with a 10 mm aperture before the Faraday cup in the image plane of the analysing magnet. Measurements were accepted if the ripple was less than 10% and the intensity stable for over half hour. No mixing gas was added to the plasma and the bias disk was in operation. The new beams were optimised for one specific charge state, which is marked in bold in the table.

In order to compare the performance of our source with the performance of the Jyväskylä group a Faraday cup aperture of 20 mm was installed (see Table 2). The values of Jyväskylä were scaled from 10 kV to 12 kV.

![Graph](image)

Fig. 3. Measured beam current of a $^{19}$F$^5$ beam as function of the extraction voltage with a Faraday of 10 mm entrance diameter.

Table 1. Beam currents in $\mu$A produced at an extraction voltage of 12 kV, with a Faraday cup with 10 mm diameter aperture.

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Table 2. Beam currents in $\mu$A produced at 12 kV extraction voltage, with a Faraday cup with 20 mm aperture.

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On the Faraday cup with the 20 mm aperture we measure 170 $\mu$A of O$^{6+}$, while with the 10 mm Faraday cup we find 112 $\mu$A, which is a 35% difference. Taking in consideration that the size of the image in the analysing plane should be in first order of 6 mm and 35% of the beam is measured in between a diameter of 10 mm and 20 mm than we can conclude that the image is seriously distorted. During the commissioning period no attention has been paid to the position of the extraction aperture with respect to the maximum magnetic field on extraction side. This could be the reason that the emittance of the extracted beam is large and affected by the aberrations of the magnet.

4 Conclusion

At this stage of commissioning of the source we are satisfied with the extra beam current as well as the long-term stable operation of the source during experiments. However, we did not yet reach the beam currents obtained by the Berkeley and Jyväskylä group with this type of ECR source. Table 2. shows that we are still a factor of 3 below their intensities. In the near future we will start measurements of the 4D-emittance using an emittance meter currently under construction in the framework of the ISIBHI-project. From these measurements and simulations we expect to learn the origin of the current limitations and how to improve the extraction and analysing system.

5 Acknowledgments

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REFERENCES