A NEW 14 GHZ ELECTRON-CYCLOTRON-RESONANCE ION SOURCE (ECRIS) FOR THE HEAVY ION ACCELERATOR FACILITY ATLAS

M. Schlapp[1], R.C. Vondrasek[1], J. Szczech[1], P.J. Billquist[1], Z.Q. Xie[2], R. Harkewicz[3] and R.C. Pardo[1]

[1] Argonne National Laboratory, Argonne, IL 60439

[2] Lawrence Berkeley National Laboratory, Berkeley, CA 94720

[3] National Superconducting Cyclotron Laboratory, East Lansing, MI 48824

Abstract

A new 14 GHz ECRIS has been designed and built over the last two years. The source design incorporates the latest results from ECR developments to produce intense beams of highly charged ions. An improved magnetic electron confinement is achieved from a large mirror ratio and strong hexapole field. The aluminum plasma chamber and extraction electrode as well as a biased disk on axis at the microwave injection side donate additional electrons to the plasma, making use of the large secondary electron yield from aluminum oxide. The source will be capable of ECR plasma heating using two different frequencies simultaneously to increase the electron energy gain. To be able to deliver usable intensities of the heaviest ion beams the design will also allow axial access for metal evaporation ovens and solid material. The main design goal is to produce several eμA of at least $^{238}U^{34+}$ in order to accelerate the beam to coulomb-barrier energies without further stripping. First charge state distributions for ^{16}O and ^{40}Ar have been measured.

1 INTRODUCTION

This new ECR ion source has been constructed as part of an improved high-charge state injector for the heavy ion accelerator facility ATLAS, providing the Positive Ion Injector (PII) section with a second, independent ECRIS. A layout of the ion source, beam line and associated components mounted on a high voltage platform, designed for 275 kV operation is given elsewhere [1]. The design goal of producing usable beam intensities of heavy elements such as uranium, lead or gold in charge states sufficiently high so that acceleration to the coulomb barrier is possible without foil stripping will increase the beam intensity available for experiments by at least an order of magnitude. In addition to that the beam quality should be significantly improved over beams requiring stripping for acceleration.

2 SOURCE DESIGN

1.1 Mechanical Design

The mechanical design of this single stage ECRIS is shown in Fig. 1. It shows the complete ion source assembly including solenoid coils and iron yoke together with a cross sectional view of the microwave injection tank with microwave inputs for two frequencies and a detail of the extraction system assembly. For the production of metallic ions the source allows the installation of high temperature ovens and sample insertion for sputtering. A Glazer lens is used as a beam focusing element between the ECRIS and a 90° double focusing analyzing magnet. All intensities are measured in a Faraday cup directly behind a set of 2-jaw slits at the exit focal point of the dipole magnet.

1.2. Magnetic System

The magnetic system for confining the hot plasma electrons takes into account the latest understanding that a high axial mirror ratio as well as a strong radial field inside the plasma chamber are extremely important parameters for improving the performance of high charge state ECRIS. The axial magnetic field is produced by two solenoids each consisting of 9 double layer pancake coils with 16 turns per layer and a surrounding iron yoke and plugs. The power supplies are capable of providing up to 750 A to each pancake. Fig. 2 shows the calculated (POISSON-code [2]) axial magnetic field distribution on axis for different iron yoke configurations. For the dashed line an additional iron plug between injection tank and plasma chamber and an extraction electrode partly made out of iron has been added. The iron plugs allow a very similar axial field distribution at 78% of the power level required without the plugs. This power saving is important on a high voltage platform when the available power is limited. In addition part of the iron between the coils has been removed. The hexapole magnet mounted into the aluminum plasma chamber consists of 6 double trapezoidal NdFeB magnets and produces a maximum radial field of 1.0 T inside the plasma chamber. This open permanent magnet structure also allows for radial pumping.

1.2. Double frequency heating

The ion source features the possibility of heating the plasma with two different frequencies simultaneously (see cross sectional view of the injection tank in Fig. 1) to enhance the density of hot electrons in the plasma and

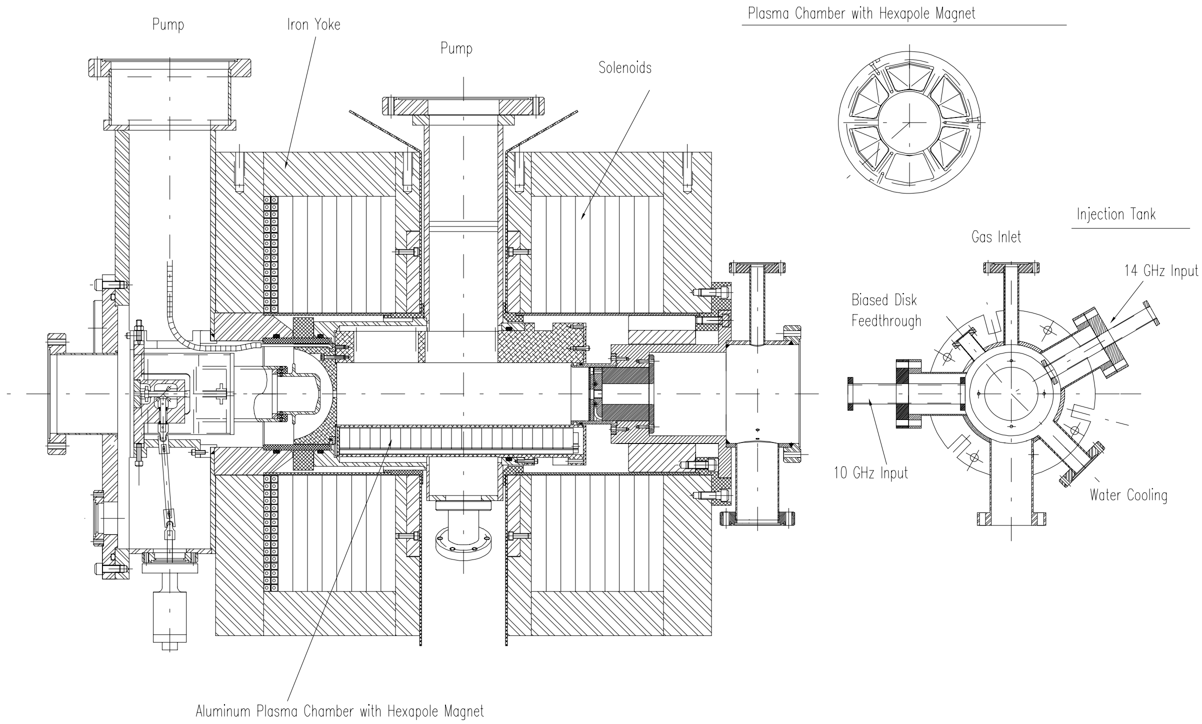

Fig. 1: Schematic overview of the mechanical set up of the 14 GHz ECR II.

improve the production of high charge states. The idea is to create two well separated ECR zones were the electrons can gain energy [3]. In addition to the confined electrons traveling between the axial magnetic mirrors and passing through the 14 GHz resonance zone, there will be electrons only heated at the 10 GHz resonance zone, located much closer to the minimum of the magnetic mirror. The electron density enhanced by this additional heating may increase the negative potential well assumed to be responsible for the confinement of the ions and therefore the production of high charge states.

Previous reports on the effect of double frequency heating by the group at LBL [3] and the Grenoble group [4] showed significantly different results. The Berkeley group used two significantly different frequencies 10.3 GHz and 14 GHz, creating well separated resonance zones. They reported a shift of the peak in the charge state distribution towards higher charge states, higher intensities for the same charge state and an increase in total RF power applied to the plasma. The French group using a fixed frequency at 10 GHz and a second frequency tunable between 9.6 GHz and 11 GHz could not find any improvement over single frequency operation.

We have obtained a transmitter which allows us to tune the second frequency over a wide range in the X-band between 8.75 GHz and 10.85 GHz using a magnetron tube. We will study the two frequency heating in order to provide some further understanding of the effect.

1.3. Extraction system

The Accel-Decel puller electrode assembly (shown in detail in Fig. 1) is movable along the beam axis allowing adjustment of the extraction system for operation with different ion species. The Accel- or screening electrode is introduced into the main extraction gap and biased to a sufficiently low potential (up to -4 kV) so as to create a negative potential well and form an electron trap to reduce the space charge influence of the ion beam [5].

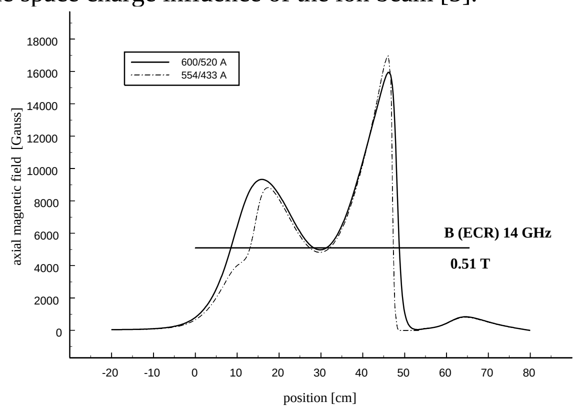

Fig. 2: Axial field distribution with different iron yoke configurations

3 FIRST RESULTS

For test runs so far we used ^{16}O and ^{40}Ar as operating gases. The ion source operated in a single frequency mode (14.25 GHz) with up to 850 watts of microwave power delivered to the plasma. In Fig. 3 and 4 spectra for ^{16}O and ^{40}Ar (at 15 kV and 12.5 kV extraction voltage, respectively) are shown. Using the magnetic field configuration show in fig. 2 as a solid line, the best observed $^{4-}Ar^{12+}$ current was 21eμA. The biased disk was optimized between -550 V and -650 V. For the O^{7+} current we obtained a enhancement of a factor of two with respect to source operation without the biased disk. One can still observe relatively large carbon peaks (32 eμA of C^{4+}), which limits the output of high charge states. Tests of the source performance for heavy elements, i.e. ^{238}U are expected in late Spring 1997 after all features of the ion source stated in the abstract have been implemented.

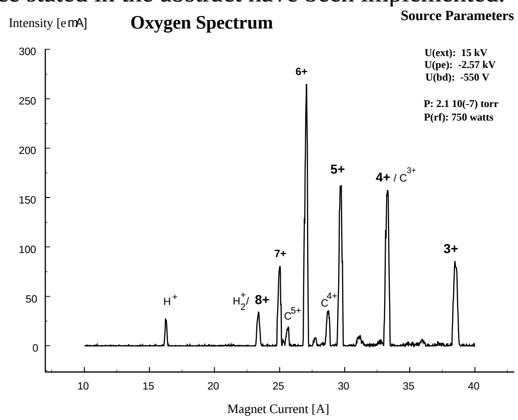

Fig. 3: ^{16}O spectrum optimized on 7+, extracted at 15 kV. Oxygen peaks are identified by their charge state only. The best observed O^{7+} current was 78 eμA.

4 ACKNOWLEDGMENTS

This work was supported by US D.O.E. Nuclear Physics Division under contract W-31-109-ENG-38.

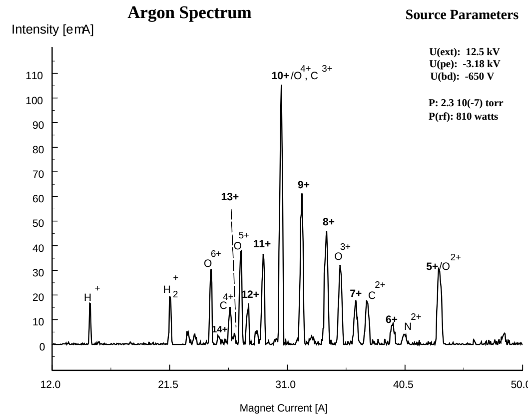

Fig. 4: ^{40}Ar spectrum optimized on charge state 12. Argon peaks are identified by charge state only.

REFERENCES

[1] M. Schlapp et al., 13th International Workshop on ECR Ion Sources, College Station/Texas (1997), in course of publication [2] A.M. Winslow, J. Comp. Phys. **2** (1957) 149

[2] Z.Q. Xie and C.M. Lyneis, 12th Intern. Workshop on ECR Ion Sources, Riken, Japan (1995) 24

[3] R. Geller et al., International Conference on ECR Ion Sources and their Applications, East Lansing, NSCL Report #MSUCP-47 (1987) 1

[4] I.G. Brown, *The Physics and Technology of Ion Sources*, Wiley, N.Y. (1989) 53