ANL/PHY/CP--87761
CONF-9509125--14

Design Parameters, Goals, and Status of the New ATLAS ECR Ion Source

R. C. Pardo, R. Harkewicz*, P. J. Billquist,
Argonne National Laboratory,
C. M. Lyneis, and Z. Q. Xie
Lawrence Berkeley National Laboratory

RECEIVED
NOV 21 1995
OSTI

Abstract

A new 14 GHz ECR ion source for the ATLAS facility is under construction. The new source is an evolution of the 14 GHz AECL Lawrence Berkeley source. The new source will feature an all aluminum hexapole main chamber and enhanced peak radial and solenoid magnetic fields compared to the existing AECL. Most of the other design features of the existing source are maintained in this design. The new source will be mounted on a new 300 kV high voltage platform in order to match the velocity requirements of the existing PII injector linac. Achieving the very precise goal of a few electrical microamps of $^{238}\text{U}^{+33}$ from this source will allow the ATLAS facility to provide coulomb-barrier energies of uranium without the use of an additional stripper foil and will significantly enhance the capabilities of ATLAS for the heaviest of beams. The project status and more details of the source system design are discussed.

*Present Address: National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, Michigan.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

The submitted manuscript has been authored by a contractor of the U. S. Government under contract No. W-31-109-ENG-38. Accordingly, the U. S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U. S. Government purposes.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Introduction

A second ECR ion source is now under construction for the ATLAS facility. The new source is a collaborative project between Argonne National Laboratory and Lawrence Berkeley Laboratory and is an evolutionary design based on the highly successful 14 GHz 'Advanced ECR' (AECE) ion source^{1,2} now in operation at the 88" Cyclotron Laboratory. Some of those improvements include enhancements in the solenoid and hexapole magnetic fields due to the recent understanding that a high mirror-ratio solenoid field design, and a strong hexapole field are extremely important parameters in the performance³ of high-charge state ECR ion sources. The new source will also possess an all-aluminum hexapole housing and other components to make use of the large secondary electron yield from aluminum oxide.

The new ATLAS ECR ion source has a design goal of delivering useable ion currents of the heaviest beams, (such as uranium, lead, gold) with charge states sufficiently high so that acceleration to the coulomb barrier by ATLAS is possible without any foil stripping. This will qualitatively change the acceleration process of these beams at ATLAS, delivering currents ten times more intense than available today and with beam quality which should be significantly improved over beams requiring stripping for acceleration. To achieve this goal requires beams with intensities between 1-10 eμA for the (at least) 33+ charge state for uranium. Such beams have already been demonstrated at the Berkeley AECE and we are confident the new source will also achieve results at least as good.

The physical source arrangement, high voltage platform and matching beamline system for the new source is shown in Figure 1 in relationship to the existing source and the Positive Ion Injector of ATLAS. The new source and all associated components will be mounted on a high voltage platform designed for 300 kV operation. The maximum voltage expected for operation is approximately 250 kV. The new platform will be similar to the high voltage system now in use at the existing ATLAS PII ECR source.

Source Design

This new ECR source is a single stage ion source. Plasma in the new source will be heated by microwaves at the single frequency of 14 GHz. Later operation at two frequencies (10 and 14 GHz) will be tried to further test the results reported on the AECE⁴. A cross-section view of the source is shown in Figure 2.

Also plotted in Figure 2 is the calculated axial field profile which will be produced by two hollow-core copper magnets and an iron yoke. Each of the magnets consists of 9 double layer pancakes with 16 turns per layer and will be powered by a separate 100 volts 750 Amp power supply. The pancakes will be wound with 8 mm square hollow core copper wire with a designed maximum current density of 950 A/cm². A 6.0 cm thick iron

return yoke and iron plugs are used to concentrate the magnetic flux inside the plasma chamber. At a total dc magnet power of 75 kW, the peak field strengths at the injection and the extraction regions will reach 1.5 and 1.1 Tesla, respectively. With the center field strength of 0.35 Tesla, the mirror ratios will be 4.2 at the injection and 3.1 at the extraction region. The higher solenoid magnetic fields and more compact design will cause the total power requirements on the new system to be approximately 30% higher than required for the existing PIIECR system.

The sextupole magnet will be constructed from strong NdFeB permanent magnets of 1.3 Tesla remanence which produces a maximum radial field strength of 1 Tesla at the chamber wall. A radial profile of the hexapole design is shown in Figure 3. Each pole is created by two magnets whose easy axis is oriented at $\pm 52^\circ$ with respect to the resulting pole axis.

The plasma chamber will be made from aluminum with 3 mm wall thickness to increase the yield of secondary electrons⁵. The chamber is water cooled to protect the permanent magnet material and chamber. The cooling channels run axially the length of the chamber. The aluminum chamber is radially slotted in three places to provide for additional pumping, access of vapors from an oven and sample insertion for sputtering or heating. In addition, the capability is provided for axial introduction of solids by ovens, direct insertion or laser evaporation.

The source will be pumped directly with one turbo-molecular pump. A second turbo pump in the extraction region will provide some additional source pumping and maintain a high vacuum in the extraction region.

Analysis Beamline

The transverse optics of the source analysis system has been studied using the beam optics programs TRACE⁶ and GIOS⁷. In these studies, the effects of space charge were included. A more complete description will be presented in a later report. The results showed that for high beam currents (> 100 eμA) significant beam loss and deterioration of the transverse emittance can occur if meaningful second order corrections are not made in the analyzing magnet. These studies showed that a 'split pole' magnet design could postpone the onset of significant space charge induced beam deterioration for currents less than 5 emA. Therefore a split-pole analyzing magnet with second order corrections from effective radii of curvature at each pole entrance and exit will be used as the first charge-state selector magnet on the high-voltage platform. This magnet is calculated to have a mass resolution of approximately 1 in 400 (FWHM). A similar magnet design⁸ used on the ATLAS tandem negative-ion source achieves a mass resolution of 1 in 450 for a slightly better beam emittance than can be expected from an ECR ion source.

The transfer beamline from the new source must match into the existing beamline as shown in Figure 1. The mass resolution of the first magnet after the high voltage platform is calculated to be approximately 1 in 660. The beamline shown has been designed as a total achromatic system to allow complete flexibility in the location of the beam buncher required for injection into the PII linac.

Studies of the longitudinal optics of the injection beamline have been done using the program TRACE3D⁹. For acceleration in a linac, the DC beam from the ECR source must be bunched into narrow bunches (<200 psec). The present system begins the bunching process on the high voltage platform and experience has shown that such a long focal length system is severely compromised by space charge effects even at beam currents of only a few μA . Our studies show that the bunching system can tolerate much higher beam currents if the first buncher is relocated to the last leg of the beamline leading to the PII linac as shown in Figure 1. This new design will be implemented as part of the new ECR source project.

Project Status

Most of the source design is complete. Construction of the components for the source is approximately 70% complete. A new building addition required to house the source system is under construction and occupancy is expected to be granted in October. At that time assembly of the high-voltage platform can begin and source assembly can proceed. First plasma is expected in the early Spring of 1996.

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

References

1. D. J. Clark, C. M. Lyneis, and Z. Q. Xie, 1991 Particle Accelerator Conference, IEEE Conf. 91CH3038-7, 2796(1991).
2. C. M. Lyneis, Zuqi Xie, D. J. Clark, R.S. Lam and S. A. Lundgren, Proceedings of the 10th International Workshop on ECR Ion Sources, Oak Ridge, ORNL CONF-9011136, 47(1990).
3. T. A. Antaya and S. Gammino, Rev. Sci. Instrum., **65**(5), 1723(1994).
4. Z. Q. Xie and C. M. Lyneis, Rev. Sci. Instrum. **66**, 4218(1995).
5. Z. Q. Xie and C. M. Lyneis, Rev. Sci. Instrum. **65**, 2947 (1994).
6. K. R. Crandall and D. P. Rusthoi, Documentation for TRACE: An Interactive Beam-Transport Code", Los Alamos National Laboratory report LA-10235-MS (1985).
7. H. Wollnik, J. Brezina and M. Berz, Nucl. Instrum. and Meth., **A258**, 408(1987).
8. E. Minehara, et al, Nucl. Instrum. and Meth. in Phys Res., **A252**, 101(1986).
9. K. R. Crandall, "Trace3-D Documentation", Los Alamos National Laboratory, LA-11054-MS, (August, 1987).

Figure Captions

Figure 1. Floor plan of the ATLAS ion source area showing the new 14 GHz ion source and its relationship to the existing facility.

Figure 2. Cross-section of the new 14 GHz ATLAS ion source and the design solenoid magnetic field profile.

Figure 3. Cross-section of the hexapole assembly. Each pole is constructed from two NdFeB permanent magnet pieces whose easy axis is oriented at 52° with respect to the pole axis. The chamber shown is of an all-aluminum construction.

NdFeB SEXTUPOLE FOR THE
ECR-II SOURCE

NOTE : Head of arrow is north pole of magnet