PROGRESS ON THE FACILITY UPGRADE FOR ACCELERATED RADIOACTIVE BEAMS AT TEXAS A&M *

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Abstract

The Cyclotron Institute at Texas A&M University is involved in a project to provide radioactive ion beams accelerated to intermediate energies by the K500 cyclotron. To obtain these ions the K150 cyclotron (the 88") is being re-commissioned to be used as a driver. At first light, ions from the K150 will be used to create radioactive ions that will be stopped in and extracted from a helium-filled cell. Singly charged ions from this cell will be transported to an ECR ion source for charge-boosting to the proper charge-state and subsequently injected into the K500. Eventually, a heavy-ion guide will be added for the creation of more exotic radioactive species. Progress on the K150, the associated ECRIS and injection line, the light-ion guide and the charge-boosting ECRIS is presented.

INTRODUCTION

Since 1989 the Cyclotron Institute of Texas A&M has been operating a K500 superconducting cyclotron injected with ions supplied by ECR1, an electron-cyclotron-resonance ion source (ECRIS). From 1967 to 1986 the Institute had operated a K150 conventional cyclotron, the Texas A&M 88", but had decommissioned it in preparation for the final construction of the K500. In response to a desire to upgrade the facility in order to take advantage of the growing interest in experiments using beams of short-lived radioactive ions, a plan was finalized. The U.S. Department of Energy, Texas A&M University and the Robert A. Welch Foundation funded this project in 2005 with a projected completion date of 2011. Partial funding will also come from sale of beam time mainly for electronic component testing.

The plan for the upgrade is to re-commission the K150 cyclotron to use as a driver for the production of radioactive ions. The primary method is to first stop radioactive products from beam-target collisions in a helium-filled cell and then to transport them as low-charge-state ions. For products resulting from K150 heavy-ion beams, a heavy-ion guide (HIG) based on development at Argonne National Laboratory [1] will eventually be installed. For products resulting from K150 light-ion beams, Texas A&M is developing a suitable light-ion guide (LIG). These low-charge-state ions will be injected into an ECR ion source (CB-ECRIS) for charge-breeding to higher charge states. A beam of one selected charge-state will then be transported to the injection line of the K500 and finally accelerated by the K500. Figure 1 illustrates this scheme with the light-ion-guide.

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K150 CYCLOTRON

The decommissioning of the K150 cyclotron extended to disposal of all the major power supplies and of the vacuum diffusion pumps, to removal of the axial injection line, and even to the removal of the high-current buss bar for reuse with the K500. To prepare the laboratory for the operation of two cyclotrons, three ion sources and beam lines, electrical power capacity and a new water-cooling loop were added. All new coil power supplies were procured and installed, new buss bar was installed and the power supplies were tested with all the coils.

Vacuum System

A new vacuum system was designed. A new 35" diffusion pump with baffle was purchased, installed on the resonator tank and tested. This was a copy of the old system, but where there had been smaller diffusion pumps on the periphery of the dee tank, these were replaced by modern cryopumps. At a later date cryopanels will be installed inside the dee tank. After repairing numerous vacuum leaks and with only the 35" pump operating, a vacuum of $2X10^{-6}$ torr was measured at the extraction region.

Deflector, Inflector and RF System

The deflector assembly was withdrawn from the machine, cleaned and reinstalled. The deflector positioning mechanism was also repaired and tested. Also, the mirror inflector was refurbished and installed in the center of the machine. A new driven rf system was designed, built and installed. The dee was cleaned examined, partially repaired and then reinstalled. After leaks were repaired in the large resonator panels and associated components, the rf system was tested with power to the dee. With no main field a measured dee voltage of 70 kV was achieved.

ECRIS AND INJECTION LINE

The ECRIS that will be used for injection into the K150 cyclotron, ECR2, was initially developed for K500 injection [2]. ECR2 uses a primary microwave power transmitter at 14.5 GHz. ECR2 was chosen for its ability to deliver higher beam intensities than the 6.4 GHz ECR1.

ECRIS Development

Recently, a new aluminum plasma chamber was installed in ECR2. This replacement plasma chamber is cooled by water flowing through an array of small-

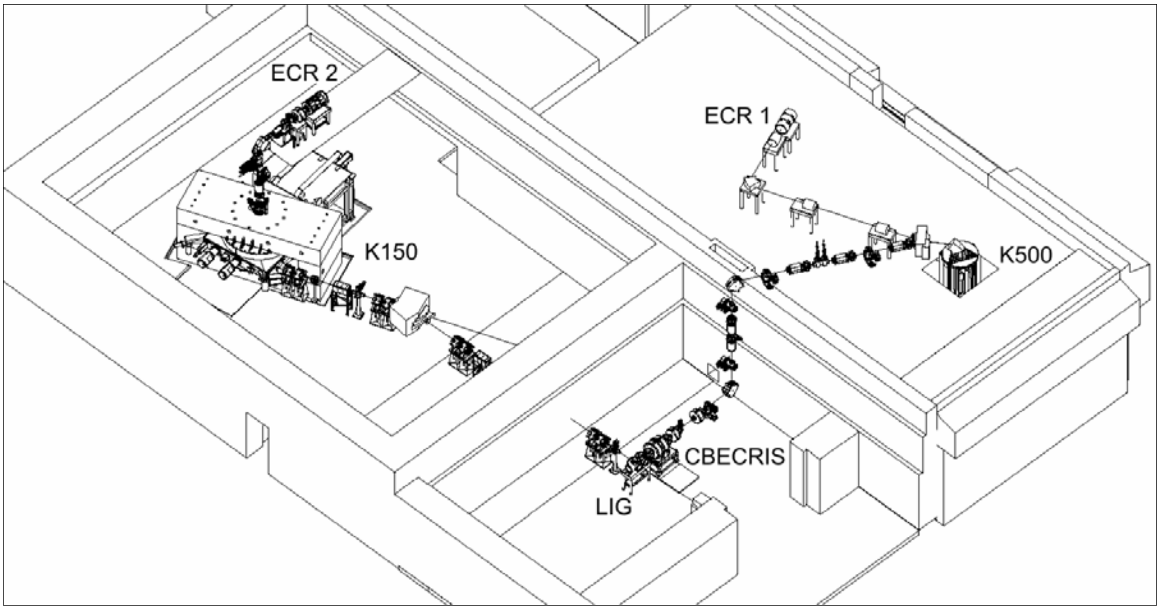

Figure 1: Layout of the scheme to accelerate radioactive beams

diameter copper tubes interposed between the aluminum of the plasma chamber wall and the six magnet bars. This cooling scheme allows the water flow to be tripled from the previous scheme of a thin, pressure-limited, water-cooled liner.

At an extraction voltage of 10 kV, ECR2 has produced 258 eμA of $^{16}O^{6+}$, 168 eμA of $^{16}O^{7+}$, 69 eμA of $^{40}Ar^{12+}$, 48 eμA of $^{40}Ar^{13+}$ and 27 eμA of $^{40}Ar^{14+}$.

Injection Line

In the spring of 2007 ECR2 was moved to its new position above the K150 cyclotron. Components of the ECR2 injection line were also removed to be incorporated into the new K150 injection line.

A compact injection line connecting ECR2 with the K150 cyclotron was designed and installed (Fig. 2). The line incorporates a double focusing 90º magnet, four solenoidal magnet lenses, x-y steering magnets and beam buncher. The line has been installed except for the second Glaser on the horizontal part of the line and the solenoidal coil in the center plug. This Glaser has not yet been designed but will be needed for injection of high intensity beams. The center plug coil has been built and will soon be installed. Recently, a low intensity oxygen beam was transported to the inflector with 50% efficiency.

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LIGHT-ION GUIDE

Based on extensive Ion Guide Isotope Separator On-Line (IGISOL) studies at the Jyväskylä Cyclotron Laboratory (JYFL) [3], an ion guide with an rf-only hexapole has been designed and constructed at Texas A&M. In this technique a light ion beam (*p*, *d*, *α* or ^{3}He) impinges on a production target that also serves as a separator foil for a helium gas cell. The recoil ions are

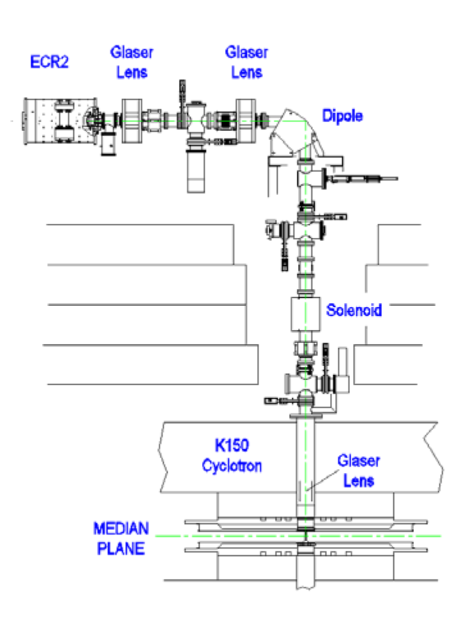

Figure 2: K150 injection line.

thermalized in the high-pressure helium and are ejected with the gas flow at 90º to the beam axis through a small aperture. Since the first ionization energy of helium is much larger than that of higher Z species, the recoils tend to be left in the 1+ charge state.

In pumping tests two oil-free roots blower pumps maintain a pressure of 0.9 mbar outside the 2 mm diameter aperture of the gas cell with an inner pressure of 500 mbar. In testing this system for ion transport, a pair of spark-discharge electrodes was installed inside the cell. Ions from the discharge are carried by the flow of helium out through the aperture. The aperture is followed at a distance of 3 mm by an rf-only open hexapole with an inner diameter of 4 mm in order to transport the ions to an area of better vacuum. Initial results with a 30 cm long hexapole demonstrated almost 100% transmission from the gas cell to a faraday cup at the end of the hexapole. A one meter long hexapole was constructed and demonstrated 30% transmission. However, this hexapole could be seen to sag along its length. More support will be added to the hexapole for further trials.

The behavior of the ions traveling through the hexapole will be studied when the hexapole is placed along the axis of the solenoidal magnetic field of a Glaser lens (Fig. 3). This lens will approximate the axial field on the injection end of the CB-ECRIS. As a last step before on-line runs, tests and development with a ^{228}Th source will be carried out as this will simulate on-line conditions more accurately than the spark discharge ionization. The ^{216}Po in the thorium decay chain decays by α emission in 145 ms and will be used as a probe to measure efficiencies of transport out of the gas cell, through the hexapole and eventually through the CB-ECRIS.

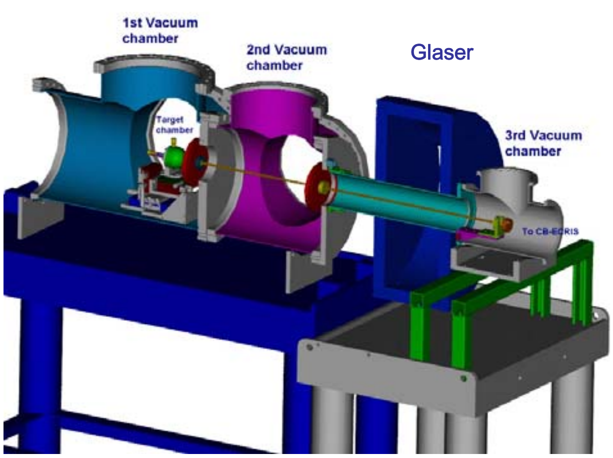

Figure 3: Light-ion guide in test set-up.

CHARGE-BREEDING ECRIS

Texas A&M has recently acquired the ECRIS (Fig. 4) that will be devoted to charge breeding the radioactive ions produced by the ion guides. It was designed and built by Scientific Solutions of San Diego, California with Small Business Innovative Research grants from the DOE. Two large coils supply the axial mirror field and a cylinder of Nd-Fe-B permanent magnets provides the hexapolar radial mirror field. The source will operate at 14.5 GHz with the possibility of adding a lower second frequency later. The source has recently been transferred to Texas A&M, where it will be finally commissioned. Texas A&M will supply the 14.5 GHz microwave transmitter, the high-current power supplies and vacuum pumps necessary for its operation.

Vacuum tests at Scientific Solutions confirmed that the plasma chamber was stable under the pressure applied for

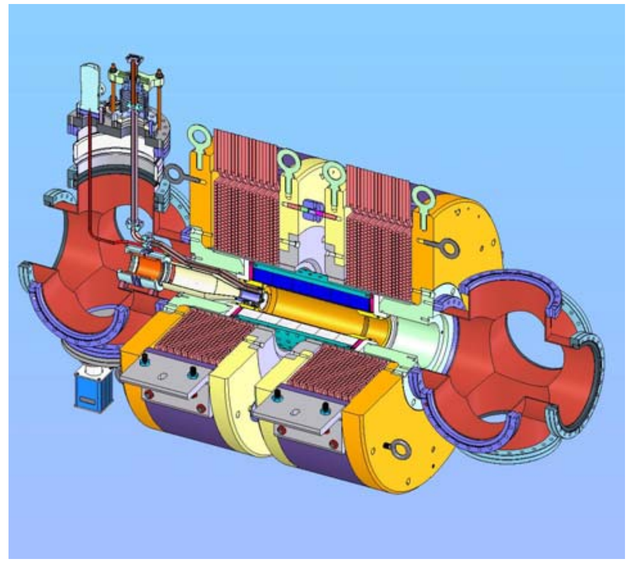

Figure 4: Charge-breeding ECR ion source

water flow to the liner added to the pressure of the outside atmosphere with the chamber under vacuum. Magnetic field measurements showed that the axial coils produced peak mirror fields of 1.6 kgauss at 65 amperes corresponding to over 1.2 Tesla at 500 amperes and that the hexapolar field exhibited uniform pole strength of 1.15 Tesla at the inner wall of the hexapole assembly.

FUTURE PROGRESS

At present, first beam tests are just beginning for the revamped K150. After successful beam extraction, the beam-line elements connecting the K150 to the LIG and to the experimental areas will be installed. Meanwhile, the CB-ECRIS will be assembled with its analysis beam-line so that ion-source tests can be performed. Injection of ions from the LIG into the CB-ECRIS will be attempted with the hexapole extending into the injection end of the CB-ECRIS. If this mode of injecting ions is not satisfactory, then the more conventional approach of acceleration of the LIG products followed by deceleration into the CB-ECRIS will be used [4].

Finally, the beam-line connecting the CB-ECRIS to the K500 injection line will be installed so that K500 acceleration of radioactive beams can be attempted by late 2009. Beams from a HIG, now in a conceptual stage, could be attempted as early as 2010-2011.

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