Status of the 2Q-LEBT Facility at ANL*

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Abstract The concept for a 2 charge state injector for a "RIA type" accelerator has been presented. Progress toward an operational prototype 2Q-LEBT system at Argonne National Laboratory (ANL) is under way. The existing BIE 100 all permanent magnet ECR has been placed on a high voltage platform capable of a combined >100kV with q/m separation at ground level. Remote control of the devices on the platform has been implemented. Other components of the facility are currently being tested. The components of an achromatic bending system are currently being procured. This paper will present recent work at the facility as well as preliminary development of solid materials using the BIE 100.

Key words ECR ion source, multi charge LEBT

1 Introduction

In the past years it has been recognized that a heavy ion driver linac capable of producing 400kW uranium beams at 400MeV/u is required for the proposed Rare Isotope Accelerator (RIA)[1]. Envisioned at Argonne National Laboratory (ANL) is an accelerator that is upgradeable to RIA called AEBL (Advanced Exotic Beam Laboratory). AEBL would possibly have a driver linac that could produce a 400kW uranium beam at 200MeV/u. This goal can be achieved utilizing expected performance of the VENUS ion source[2] and RF linac[3] technologies when combined with the concept of simultaneous acceleration of several charge states.

Work is in progress to build an operational two-charge-estate Low Energy Beam Transport (2Q-LEBT) system at ANL. This would be a prototype injector for a RIA or AEBL-type linac. The facility at ANL has previously been described[4]. The LEBT begins with the BIE 100[5] all permanent magnet Electron Cyclotron Resonance Ion Source (ECRIS) mounted on a high voltage (HV) platform producing high charge state ions. Q/m separation will occur at ground level in an achromatic bend with the use of two 60 degree dipole magnets. After the second magnet two charge states of the beam are recombined, then bunched and accelerated. This paper will describe the current experimental setup, the planned layout of the 2Q-LEBT facility and some metal beam production techniques utilized in the BIE 100.

2 Current layout

Presently the 2Q-LEBT Facility is located in the Dynamitron high bay area of the Physics Division at Argonne National Laboratory. The Dynamitron is located approximately 20m from the Argonne Tandem

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Linear Accelerator System (ATLAS) experimental areas.

Since the last report[6], the BIE 100 permanent magnet ECRIS has been installed on a HV platform. The ECRIS is isolated from the platform and biased at up to 30kV and the HV platform is biased from ground at up to 75kV for a combined possible >100kV operation. The HV installation includes a Faraday cage and a 300kV, 100kW isolation transformer. A fence was erected around the perimeter of the ion source, isolation transformer and exit beamline for personnel safety. The fence has a gate with capture key system that does not allow HV operation when the gate is open. Water cooling is provided from the ground through a de-ionized system. A long path length for water transport was used to insure HV isolation.

LabVIEW control programs are used to control the source parameters and measuring devices. All equipment on the HV platform is controlled using a personal computer. This PC is connected by a fiber optic link to a second PC at ground level. The PC at ground level controls all the system devices including beam diagnostic devices on the ground and all hardware on the deck via a remote desktop connection.

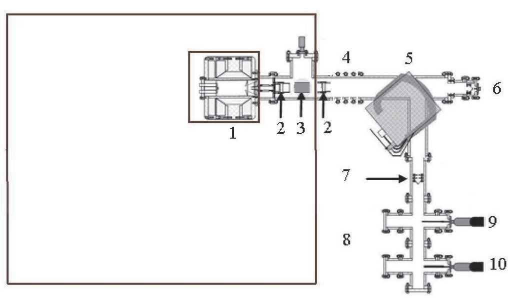

Fig. 1. Current diagnostic station layout. BIE 100 on stand (1), Einzel lenses (2) and y-axis electrostatic steering (3). Off of the platform are the accelerator tube (4), 90° magnet (5), faraday cups (6,7) and emittance measurement station (8) with actuators (9, 10).

The extraction region remains the same as the original BIE 100 design[5] with electrostatic vertical steering added after the first Einzel lens. A second Einzel lens is in place after the steering plates which are followed by a 75kV NEC[7] general purpose accelerating tube. After acceleration, mass and charge are selected by the 90 degree dipole magnet that came with the BIE 100. At full acceleration voltage, $q/m > 1/16$ can be analyzed. The faraday cup and emittance measuring system are located after the dipole in their original configuration. Following the dipole at zero degrees are a rotating wire beam profile monitor and a large aperture fixed position faraday cup (as shown in Fig. 1).

3 Final facility requirements

Previous simulations have shown the ability of an achromatic bend to separate and then recombine 2 charge states of beam delivered by an ECRIS[4, 6, 8]. Analysis of the measured data was performed to verify that the ECR source forms a beam with similar phase space distributions of the neighboring charge states[9], which is essential in the concept of simultaneous acceleration of two charge states developed for the AEBL. We found that the Twiss parameters of different charge states generated by BIE-100 are very close to each other. One goal of the 2Q-LEBT Facility is to perform a proof of principle demonstration of extraction, combining and acceleration of two-charge-state ion beams.

The layout of the facility when complete is as follows (see Fig. 2.). The HV platform will remain in its current location with the ECRIS being moved vertically to match the new beam-line height and axially for optics matching. Two 60° bending magnets form the achromatic bend with charge selection slits and electrostatic steering and focusing elements placed in between. The 60° magnets are currently being fabricated and the design of the beamline is almost complete. After the 120° bend is a straight section with transverse focusing and steering elements leading to a Multi Harmonic Buncher (MHB) for longitudinal focusing. Beam then will be injected into a one segment Radio Frequency Quadrupole (RFQ) prototype for acceleration.

Upgrade of the controls should be straightforward. The existing LabVIEW code can be easily adapted to more devices and the existing hardware has extra channels.

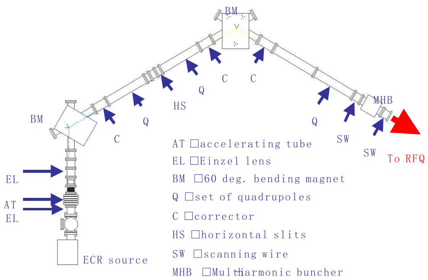

Fig. 2. Layout of the 2q-LEBT.

4 Beam production

The BIE 100 ECRIS[5] is used for ion production at the facility. It is an all permanent magnet source designed for main plasma heating at 14.5GHz but also operable down to 12.75GHz or lower. The radial field provided by a sextupole magnet is 11kG ($B_{\mathrm{wall}}/B_{\mathrm{ecr}} = 2.1$). The maximum fields on axis are 14.3kG at the bias disc and 7.0kG at the extractor. A 2kW, 14.5GHz klystron amplifier and a 700W, 12.75 — 14.5GHz traveling wave tube amplifier are in service.

For the 2q-LEBT facility to demonstrate the design goal, high mass and medium - high charge states must be produced out of the ion source. A good example would be lead or bismuth at 25+. These beams would replicate a uranium beam without the radioactive material contamination. In the BIE 100 ECRIS several metal production methods have been attempted.

4.1 Sputtering

Sputtering[10] was attempted in May 2005 before the ECRIS was installed on the HV platform. Natural lead material was introduced into the source axially (no radial ports, Fig. 3). The distance between the sputter sample and the plasma chamber wall is ~7.7mm. The sample is not cooled.

Best performance achieved was Pb^{23+} 13μA with 13.8GHz @500W and 12.5GHz @100W (one of the CSD spectra given in Fig. 4). The sample was biased at −2kV. When the total RF power surpassed 650W the sputter sample melted off of the probe assembly. As proof of sputtering occurring beam current responded to voltage applied and diminished to background levels with voltage removed.

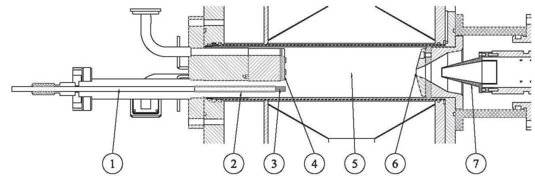

Fig. 3. BIE 100 Sputter probe (1) with alumina insulator (2) and Sputter sample (3). Bias Disc (4), Plasma Chamber (5), Extractor (6) and Puller Electrode (7) are shown.

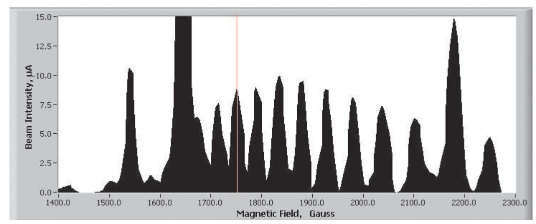

Fig. 4. Lead beam current spectrum using the BIE 100 with sputter probe. Source not installed on HV platform. Line indicates Pb^{23+}. Masses 206, 207, 208 are not resolved.

4.2 Low temperature oven

Since temperature requirements are fairly low, attempts are being made to use a low cost ($50 USD) easily replaceable commercial heating element. The device is a Chromalox CIR 1014 cartridge heater purchased from Omega Engineering[11]. This heater has been successfully used for calcium metal production from metal at the ATLAS ECR 1 ion source and is capable of temperatures of slightly above 800℃. Off-line measurements have shown 450℃ on the heater wall at 40% rated voltage. This oven should be sufficient for bismuth with an operating temperature near 550℃. Previous installations allowed for the heater to remain outside the vacuum to avoid out-gassing. Most recent construction keeps the heater in the vacuum and uses ceramic insulation on the leads instead of the standard fiberglass.

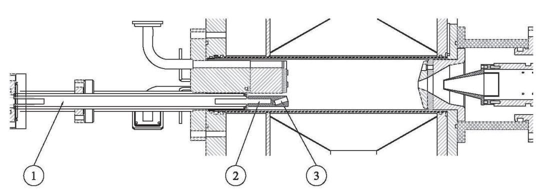

Fig. 5. BIE 100 with (1) oven support assembly, (2) cartridge heater insertion point and (3) sample material.

The low temperature oven was recently out-gassed in the ECRIS to 20% rated voltage. Bismuth was seen in the beam spectrum at the <500nA level at 500W RF power. The experimental setup is given in Fig. 5.

5 Conclusion

In the coming year work will continue toward a fully operable facility. The final design of the 60 degree dipole magnets has been approved and fabrication started. The grid-less MHB is being designed. Beam transport system is in final design. Near completion of the magnet construction, the existing ground level beam transport will be dismantled and preparations for installation will begin.

The oven will be tested at higher temperatures, then with high RF power and full acceleration. The sputter sample failure occurred because of high heat. It is believed other materials like nickel or zirconium would perform better on the present sputter assembly. Since lead or bismuth are required for our tests, a water cooled sputter probe assembly will be developed.

References

1 Ostroumov P N et al. Proc. of the XX Linac Conf., Monterey, CA，Aug. 21-25, 2000. 202
2 Leitner D et al. Rev. Sci. Inst., 2006, **77**: 03A302
3 Nolen J A. Nuclear Physics, 2004, **A734**: 661
4 Ostroumov P N. Proc. of the PAC-2003, Portland, Oregon. 400
5 XIE D Z. Rev. Sci. Inst., 2002, **73**(2): 531
6 Vinogradov N E et al. Proc. of the 16th International Workshop on ECR Ion Sources, ECRIS04, Berkeley, CA, Sep. 26-30, 2004. 215
7 National Electrostatics Corp. www.pelletron.com
8 Kolomiets A A et al. Proc. of the PAC-2003, Portland, Oregon. 2875
9 Vinogradov N E et al. Two-Charge-State Injector for a High Power Heavy-Ion Linac. Paper Submitted to LINAC-2006, Knoxville TN, August 2006
10 Power Heavy-Ion Linac. Paper Submitted to LINAC-2006, Knoxville TN, August 2006
11 Harkewicz R, Pardo R C et al. Rev. Sci. Inst., 1995, **66**: 2883
12 Omega Engineering, Inc., www.omega.com