Paper presented to the Joint Meeting of the Eighth International Symposium on the Production of Neutralization of Negative Ions and Beams and Seventh European Workshop on the Production and Application of Light Negative Ions

September 15-19, 1997

SEPARATION OF BEAM AND ELECTRONS IN THE SPALLATION NEUTRON SOURCE H+ ION SOURCE

J. H. Whealton and R. J. Raridon
Oak Ridge National Laboratory

K. N. Leung
Lawrence Berkeley National Laboratory

Prepared by the
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-8088
Managed by
Lockheed Martin Energy Research Corporation
for the
U. S. Department of Energy
under contract DE-AC05-96OR22464

Research sponsored by the LDRD Program of Oak Ridge National Laboratory managed by Lockheed Martin Energy Research Corp. for the U. S. Department of Energy under Contract No. DE-AC05-96OR22464.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
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, make 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.
DISCLAIMER

 Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
Abstract: The Spallation Neutron Source (SNS) requires an ion source producing an H beam with a peak current of 35mA at a 6.2 percent duty factor. For the design of this ion source, extracted electrons must be transported and dumped without adversely affecting the H beam optics. Two issues are considered: (1) electron containment transport and controlled removal; and (2) first-order H beam steering. For electron containment, various magnetic, geometric and electrode biasing configurations are analyzed. A kinetic description for the negative ions and electrons is employed with self-consistent fields obtained from a steady-state solution to Poisson's equation. Guiding center electron trajectories are used when the gyroradius is sufficiently small. The magnetic fields used to control the transport of the electrons and the asymmetric sheath produced by the gyrating electrons steer the ion beam. Scenarios for correcting this steering by split acceleration and focusing electrodes will be considered in some detail.

1. INTRODUCTION

Extraction of negative ions from volume sources is usually attended by a large unwanted flux of extracted electrons, which cause heat loading and sometimes affect the beam directly or indirectly. Direct effects on the beam include enhanced space charge. But most deleterious effects of these electrons on the ions include concomitant effects of the necessary magnetic field normally present in the extraction region. The ambient magnetic fields cause a drift motion of the electrons across the extraction aperture leading to an accumulation of electrons on one side of the aperture, which in turn could cause a steering of the negative ion beam (opposite to the steering of the beam due to the magnetic field itself) and perhaps an azimuthal density asymmetry in the extracted negative ion beam.

Research sponsored by the LDRD Program of Oak Ridge National Laboratory, managed by Lockheed Martin Energy Research Corp. for the U. S. Department of Energy under contract number DE-AC05-96OR22464.
Two facets of the electron issue will be addressed in this paper. The correction to steering of the ion beam by imposing a dipole field is done in a 3-D geometry having some similarity to accelerator designs being considered for the SNS. The second consideration will be a plasma electrode trapping of these electrons before they get to high energy.

2. EMITTANCE REDUCING RESTEERING OF ION BEAM

To offset beam steering due to the magnetic field, we will consider a split accelerator (second) electrode such as to provide an average electric field restoring the beam. The object of this preliminary study is to see if the RMS emittance of the beam can be brought back to its symmetric value (without magnetic field). The conventional model of negative ion extraction is used [1] where the positive ions are represented by an equilibrium Boltzmann distribution and the negative charges are represented by a kinetic description (collisionless Boltzmann equation) with the charge balance in the presheath assumed to be symmetric with the case of positive ion extraction.

To make this comparison, we examine Fig. 1, which is the baseline symmetric case. Figure 1a shows the conventional view of a slice through the accelerator in a plane perpendicular to the applied magnetic field (although in this case the magnetic field is zero. The electrodes including a LEBT are shown with the entrance to the RFQ appearing at the right-hand side. An end view is shown in Fig. 1b, which shows a more or less axially symmetric beam. An emittance, or phase space occupation, distribution is shown in Fig. 1c in that transverse plane corresponding to Fig. 1a. This emittance diagram is approximately symmetric about the origin as expected.

Placing a magnetic field (assumed uniform for this study) of 1700 gauss over a region from the left hand side of Fig. 2a to about twice the extent of the plasma electrode thickness yields the result of Fig. 2. Here we can see that the beam is not cylindrically symmetric, almost impinging on the third electrode as Fig. 2a shows. (The aperture displacement steering method [2] exacerbates this defect.) The end view, Fig. 2b, and the emittance plot, Fig. 2c, clearly show the asymmetry and the RMS transverse emittance is about twice that of Fig. 1 without a magnetic field (as shown in Fig. 4).

Placing a gap in the acceleration electrode, indicated in Fig. 3a (the asymmetric potential can be seen in Fig. 3b), tends to resteer the beam as seen especially in the emittance plot (Fig. 3c). The RMS emittance decreases by an application of a 2-5 KV potential across this gap, as shown in Fig. 4, reducing the emittance to almost the value without the magnetic field, which proves the principle that this technique not only resteers the beam but reduced the emittance growth caused by the magnetic field. The technique of aperture displacement [2] often used in multiperture positive ion sources may be
equivalent to the split electrode technique described here with respect to steering (first order). Since the beam in the aperture displacement technique is generally closer to the second electrode than for the split electrode technique, one might expect the emittance to be higher. The split electrode technique sees a decrease in the RMS emittance from the zero resteering case since the beam is further from the second electrode than the zero displacement case.

3. ELECTRON TRAPPING

Next consider a split (longitudinally) plasma electrode to see the possible trapping effectiveness in a special case (2D slot geometry). A typical case is shown in Fig. 5 with both extracted electrons (going up) and negative ions. If we split the plasma electrode as shown in Fig. 6 and bias the split part positively with respect to the plasma side to attract electrons and assume no secondary electrons are created, we see Fig. 6b. In this case, a significant fraction of the electrons are attracted towards the split electrode, at a couple hundred volts instead of being extracted to the acceleration electrode (50 KV). The effectiveness of the bias on the split electrode in trapping electrons is shown in Fig. 7 for this geometry and conditions. We conclude from this that, if materials with very low secondary electron emissions can be found, and the primary ion optics are not adversely affected, then this technique may be useful.

4. ACKNOWLEDGEMENTS

The authors wish to thank M. A. Akerman, J. B. Green, J. M. Shover, and E. D. Stratman for their technical advice and assistance.

5 REFERENCES


6 FIGURE LEGENDS

Figure 1. The baseline symmetric case. Fig. 1c shows the conventional view of a slice through the accelerator in a plane perpendicular to the applied magnetic field (although in this case the magnetic field is zero. The electrodes including a LEBT are shown with the entrance to the RFQ appearing at the right-hand side. An end view is shown in Fig. 1b, which shows a more or less
axially symmetric beam. An emittance, or phase space occupation, distribution is shown in Fig. 1c in the transverse plane corresponding to Fig. 1a.

Figure 2. Same as Fig. 1 but including a magnetic field (assumed uniform for this study) of 1700 gauss over a region from the left-hand side of Fig. 2c to about twice the extent of the plasma electrode thickness. Here we can see that the beam is not cylindrically symmetric; almost impinging on the third electrode as Fig. 2c shows.

Figure 3. Same as Fig. 2 but including a gap in the acceleration electrode, indicated in Fig. 3a (the asymmetric potential can be seen in Fig. 3c). Tends to re-steer the beam as seen especially in the emittance plot (Fig. 3b).

Figure 4. Beam RMS emittance as a function of gap voltage also showing the emittance without a magnetic field.

Figure 5. A split (longitudinally) plasma electrode showing both extracted electrons (going up) and negative ions.

Figure 6. Electron trajectories as a function of split electrode bias.

Figure 7. Electron transmission as a function of the bias on the split electrode.
Fig. 4

$N_N (\pi \text{ mm-mr})$

$\Delta \phi (\text{kV})$

$B=0$