# AN OPTIMIZED $H^-$ MAGNETRON ION SOURCE/LEBT SYSTEM*

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## Abstract

Availability and usefulness of accelerators is greatly dependent on machine efficiency. Research must focus on less expensive, more compact accelerators with brighter beams. To achieve this goal for $H^-$ ion sources, TAC has optimized the present Brookhaven AGS source[1] for use with their RFQ program. The TAC source incorporates an extraction system with a circular aperture which provides an azimuthally symmetric beam. The complete system has been simplified including removal of the gradient bending magnet found in conventional sources of this type. This source will soon be combined with an electrostatic low energy beam transport (LEBT). This will create a simpler and more compact $H^-$ ion source and beam transport system than is presently available.

## I. Introduction

The Texas Accelerator Center is close to the completion of a new surface plasma, magnetron $H^-$ ion source. This source incorporates a cesium coated cathode to enhance $H^-$ generation and should deliver very bright 100mA pulses of $H^-$ at 30 keV. The extraction for this ion source was optimized using the ion source code BEAM[2]. The $H^-$ beam will be pulsed at 15 hertz with pulse lengths from 50 - 100 $\mu s$. Following the ion source we will design a low energy beam transport(LEBT) system. Incorporation of an electrostatic transport system as opposed to a magnetic system inhibits space charge neutralization due to positively charging the background gas. This complete project of the TAC $H^-$ ion source/LEBT (THISL) should be operational by summer 1989.

## II. Ion Source Design

### A. Design parameters.

The most important parameters for extraction of the beam are shown in figure 1. Most of these parameters are either non-critical or can be optimized directly with BEAM.

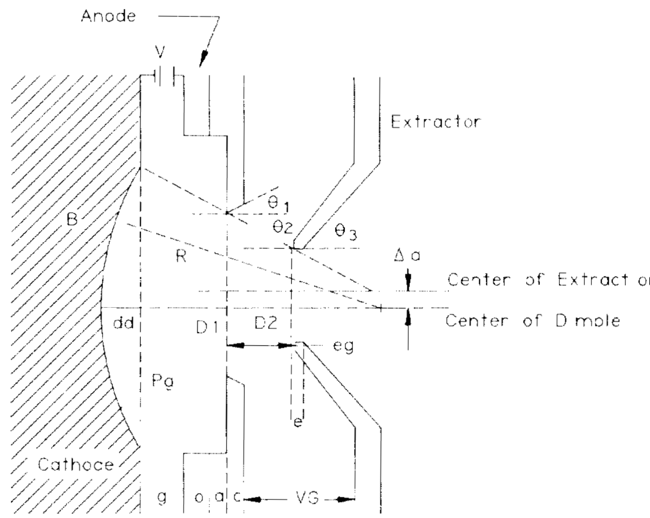


Figure 1. Ion source extraction parameters

The surface of the cathode has a spherical dimple which works like a concave mirror to focus the surface created $H^-$ ions towards the extraction aperture. The effects of the plasma filling this dimple are unknown at this point. We will be using at least two different dimple depths to study this effect. If the plasma will adequately fill into a deeper dimple, one could in principle increase the extracted beam for a given arc current.

The magnetron's magnetic field was previously created by pole tips extending out from a bending magnet. In this design the bending magnet was removed making it necessary to use permanent magnets for the magnetron field. The field from these magnets cause a slight bending of the pre-extracted beam. In order to correct for this bending, the cathode dimple is slightly offset from the extraction axis by a distance $\Delta d$. This offset is related to the average cyclotron radius of the ions and to the distance from the cathode to the extraction aperture. This bending field also helps deflect the exiting electrons from being extracted into the next stage of the system.

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Another problem to be addressed is that of extracting electrons. By increasing the anode cover offset(o+a) the extracted electron current is decreased. The extracted electrons can etch the components involved and change their dimensions. This also will decrease the ion current extracted due to destructive collisions of the ions while traversing the plasma from the cathode to the exit aperture. Keeping the desired beam current constant, we will use different arc currents to test different offsets. This increase in arc current will reduce the beam brightness, but increase the extraction dimension's lifetime.

### B. Computer simulations.

Most of the angles and distances from the anode cover to the exit of the source were optimized using BEAM. This also included the anode cover offset as discussed above. Two designs were analyzed and their parameters for 95% of the beam at 8mm from the extraction cone tip are shown in table 1. The first design was based on the beam current density that was used by Brookhaven in matching their source to BEAM simulations[3]. The second design uses a 25% increase in current density to achieve a slightly brighter beam.

**Table 1. Beam Parameters**

| Configuration | eg (mm) | D1 (mm) | D2 (mm) | I (mA) |
|---|---|---|---|---|
| 1 | 3.1 | 2.8 | 2.4 | 99.7 |
| 2 | 3.0 | 2.5 | 2.4 | 98.7 |
| Configuration | $\epsilon_n$ ($\pi$mm·mrad) | $r_{max}$ (mm) | $r'_{max}$ (mrad) | |
| 1 | 766 | 1.5 | 102 | |
| 2 | 631 | 1.6 | 122 | |

TAC plans to run tests at the higher current density by increasing the gas pressure and the arc current. Operating the source in this mode is more expensive in input power and hydrogen, but should result in a brighter beam. An example of the optimized configuration and tracking output from BEAM is shown in figure 2 for the lower current density case.


Figure 2. Example of BEAM output

## III. LEBT Design

### A. Design parameters.

An electrostatic LEBT as proposed by Raparia et al.[4] is being designed for use in the THISL project. This type of design has been chosen rather than a magnetic design[1][5] due to space charge neutralization, and overall length. The normally beneficial effect of space charge neutralization is disruptive when the rise time of the neutralization is on the order of the beam pulse length. The rise time of space charge neutralization decreases with increasing background gas pressure and is non-negligible within our operating regime. In such a situation the transport line is undergoing a continuous change in its optical properties during the full pulse length. This causes most of the beam to be mismatched into the next stage.

The electrostatic transport system is being designed to begin as close to the ion source extraction as possible. This will help to counteract the beam blow-up due to space charge. The focusing system will be as vacuum translucent as possible. The lenses, a current toroid and a set of steering coils will be immersed in a small vacuum chamber. Since the current toroid and steering coils are totally magnetic in nature they can be simply superimposed upon the totally electrostatic lenses.

### B. Computer simulations.

For the initial attempt at designing the LEBT, the computer generated beam parameters of the extracted beam were used as initial inputs into the transport part of the design code AXCEL[6]. A pair of einzel lenses were used as described by Raparia et al.[7]. The brightness of the beam was too high and we were not able to obtain focusing without first allowing the beam to diverge where the space charge forces were controllable.

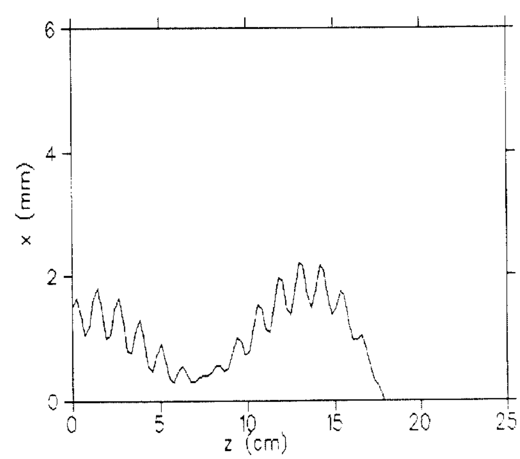


Figure 3. Beam radius in HESQ transport system.

Another alternative has been sought for our purposes. Analytical predictions of a helical electrostatic quadrupole or HESQ look extremely promising[4]. Unlike einzel lenses which have a second order focusing effect, an electrostatic quadrupole is first order. Figure 3. shows a beam entering this system and subsequently being matched to an RFQ. The input beam is comparable to our beam at a point within the extraction cone of the ion source.

## IV. System Design

### A. Ion source physical shape.

The design of the ion source portion of THISL is shown in figure 4. Initially we shall test the system by varying the two extraction configurations and two separate cathode dimple depths. The source side of the system will be connected to a 1500 l/s turbomolecular pump which should maintain $5 \times 10^{-6}$ Torr within the vacuum chamber while operating. Also connected to the source chamber is a low vacuum port, high vacuum port, a quadrupole mass spectrometer port and a leaded glass viewport.

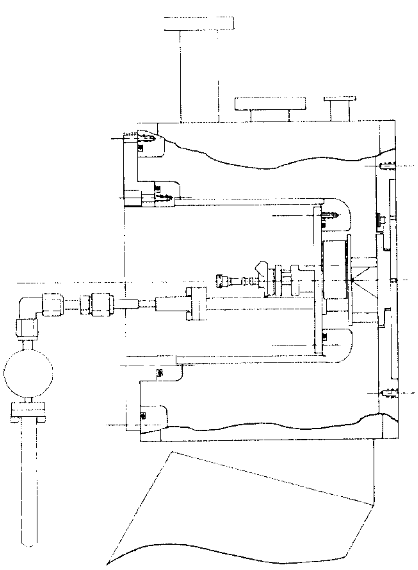

Figure 4. THISL ion source design

### B. HESQ design.

Two HESQ designs are presently being considered. The first design would be to make a series of small quads, each subsequent quad rotated by a small fixed angle from the previous one. Each individual quad would have a slightly different field gradient.

Another way to make the HESQ system is shown in figure 5. A ceramic rod could be imbedded with four wires in a helical pattern. Each alternate wire would carry the necessary voltage to form the quadrupole. For additional control of the focusing strength one could have different gradients by dividing the complete LEBT into a small number of long sections. The preliminary designs suggest that the highest voltages involved may be on the order of 8000 volts.

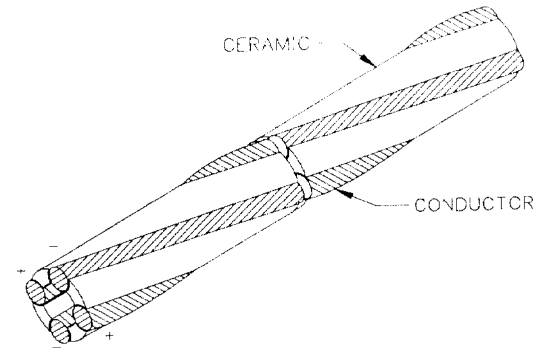


Figure 5. HESQ design.

## V. Conclusions

The THISL project should prove to be a very good ion source/LEBT. The use of a pair of einzel lenses is unsatisfactory as they obviously defeat our purpose of providing an accelerator with as bright a beam as possible with 100 mA. Conversely, the HESQ system seems to overcome these problems and may be easier to build. Also, the einzel lenses need voltages on the order of the beam energy, i.e. 30kV, while the HESQ voltages are much smaller.

The complete system, from the cesium boiler to the entrance into an RFQ should turn out to be less than 65 cm and could be easily placed onto a 30 inch stand.

## VI. References


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