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ION SOURCE AND INJECTOR IMPROVEMENTS AT THE SUPERHILAC*

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Abstract

Major improvements have been made on the Adam injector at the SuperHILAC heavy ion accelerator. Adam is a pressurized Cockcroft-Walton injector, typically run at voltages in excess of 2 MeV. The PIG ion source was redesigned to increase the length of the discharge column and the extraction slit, while remaining within the magnet poles of the source magnet. To maintain cooling, part of the thinner soft-iron end cap was replaced with a copper section, modifying the magnetic circuit. These modifications resulted in more than doubling the ion beam intensity. A large liquid nitrogen cryotrap within the pressure vessel was replaced by an RF shielded, commercial cryopump head with a custom pumping array. This reduced the pressure at the ground end of the injector by an order of magnitude and reduced that at the source by a factor of two, even with the additional gas load due to the longer slit. The pressure reduction was essential to minimize charge exchange loss of the highly charged ions, such as Fe^{4+}. Plans are underway to replace a 3 watt cryopump in the terminal end with a 10 watt pump which is expected to result in a 50% faster cooldown time, and greater than a 50% increase in running time before regeneration of the cryopump is necessary.

Introduction

The SuperHILAC is used primarily as the injector for relativistic heavy ion experiments at the Bevalac. The middle range of masses is provided by the Adam injector,[1] a pressurized Cockcroft-Walton injector run at voltages in the range of 2 MeV, shown in Fig. 1. Experiments at the Bevalac using secondary beams (radioactive beams produced by fragmentation of the primary beam in a thick target) often use ions from Adam for the primary beam. Since the secondary beam intensity is reduced by orders of magnitude compared to that of the primary beams, intensity improvements in the Adam injector are crucial to the experiments. In this paper we describe several recent improvements to the Adam injector which more than double the injected beam into the Bevalac, enhancing secondary beam production.

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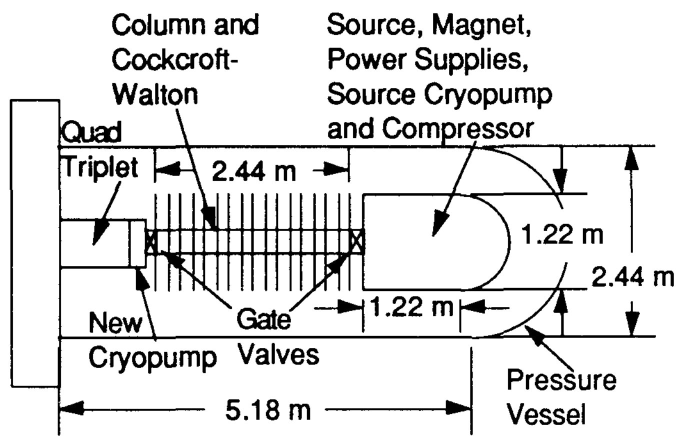

Fig. 1. Sketch of the Adam injector, showing the limited space available.

Ion Source Improvements

As can be seen in Fig. 1, space in the Adam injector pressure vessel (165 psi nitrogen) is at a premium. All components, including the source magnet, the source itself, and the power supplies are optimized to fit in the smallest possible volume. The PIG ion source[2] was redesigned to accomplish several objectives without enlarging the overall size of the source. A schematic of the ion source is shown in Fig. 2. Not shown in the diagram is the sputter electrode (which provides the beam for solid elements), located opposite the slit.

The principle objective was to lengthen the ion source active region, providing a longer ionization region and extraction slit. It was hoped that this would increase the beam intensity while keeping the emittance within the acceptance of the accelerator. A second objective was to improve the mounting of the vanadium cathode, allowing it to be pressed into the holder.

To make these changes while remaining within the poles of the magnet, the soft-iron caps on the source needed to be made thinner, which presented two problems. First, making the iron thinner would reduce the heat transfer from the cathodes to the cooling channels. Since the source works best at close to the maximum power, reducing the power-handling ability was not desired. Secondly, any change in the magnetic circuit which results in a non-uniform field in the active region of the source would likely degrade performance. As can be seen in Fig. 2, the changes increased the non-uniformity of the end caps in the vicinity of the active region of the source.

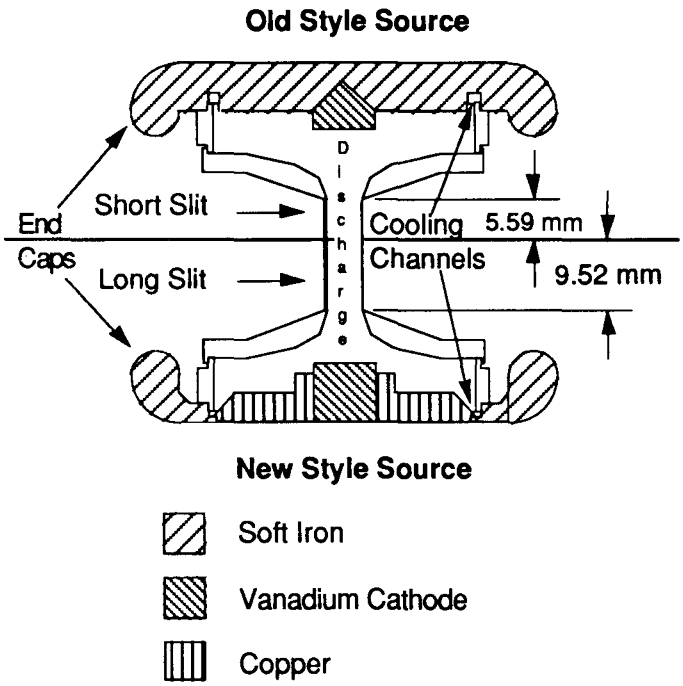

Fig. 2. Schematic of the Adam ion source. The top part of the schematic shows the previous version of the source, while the lower part of the diagram shows the new version of the source.

These problems were both solved by replacing the central section of the iron caps with copper. The copper conducts heat much more efficiently than the iron, allowing a much thinner section of copper to conduct the same heat flux as the thicker iron. In addition, the copper is not a high permeability section of the magnetic circuit, so any non-uniformities in its thickness do not result in a non-uniform field. The field is, of course, slightly reduced by removing the iron from above and below the active region, but it remains uniform.

A number of sources were built to test these hypotheses. Fig. 3 shows the performance of several sources. The sources were run at a number repetition rates to represent the various operating conditions.

The graph clearly shows that the new source, with the extended slit and the copper end cap, performs best at all repetition rates. These intensity increases were also verified at the exit of the linac, where the intensity increased by a factor of two for low pulse rate operation.

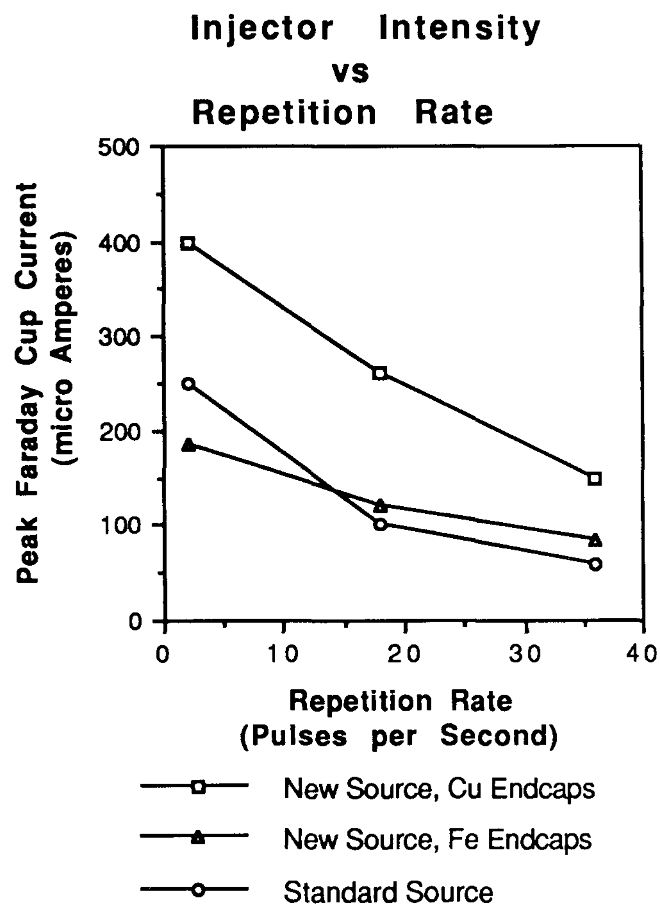

Fig. 3. Performance of various source models versus repetition rate. Intensity is measured at the entrance to the SuperHILAC Alvarez linac. The three curves represent two new versions, one with copper endcaps and the other with iron endcaps, both with a 19 mm long slit, and one older version with an 11 mm long slit.

Pumping Improvements

Introduction of the new source reinforced the need for improvements in the vacuum system. The longer slit allows more gas to leak out of the source, raising the background pressure. A high background pressure allows the high charge state ions (e.g. Fe^{4+}) to exchange electrons with the gas atoms, especially in the low velocity region at the upstream end of the accelerating column where the charge exchange cross section is a maximum. Charge exchange will cause the ion to be lost, reducing the intensity.

One improvement was made at the ground end of the accelerating column shown in Fig. 1. A liquid nitrogen (LN) cryotrap, operating at 77° K, acted to freeze out gases, thus reducing the background pressure. This was replaced by a commercial cryopump refrigerator (CTI 350)[3] and a custom pumping array, shown in Fig. 4. The custom array, necessitated by the available space for the pump, cools down in approximately 90 minutes. For typical operating conditions the pressure at the ground end of the column improved by an order of magnitude, and the pressure just downstream of the source, at the upstream end of the column, improved by a factor of two, even with the additional gas load due to the longer slit in the new source. Since the fraction of beam undergoing charge exchange fraction is an exponential function of pressure, the factor of two improvement is significant.

The cryogenic refrigerator required shielding to enable it to function in the field of the Cockcroft-Walton. The C-W operates at an RF frequency of 100 kHz, with the actuating coils surrounding the cryopump assembly. A copper shield was constructed to shield the moving parts of the refrigerator from the RF field, thus removing a major cause of bearing and motor driveshaft failure.

A second vacuum improvement to be installed this fall is the installation of a larger compressor for the cryopumps at the source end of the column. The increased capacity should allow most Bevalac experiments to be completed without a source change. Changing the source in the Adam injector typically requires half a shift (4 hours), due to the time needed to regenerate the cryopumps and that needed to pressurize and de-pressurize the injector tank, so reducing the frequency of source changes will be a major improvement.

Conclusion

A number of improvements to the Adam injector at the SuperHILAC have been described. These improvements have as their principle goal increasing the intensity of the beam delivered to the Bevalac, especially for secondary beam experiments which are severely intensity limited. The improvements have, so far, more than doubled the beam intensity, increased the time between source changes (with plans for further increases), and have strengthened the construction of the source, allowing for more reliable operation.

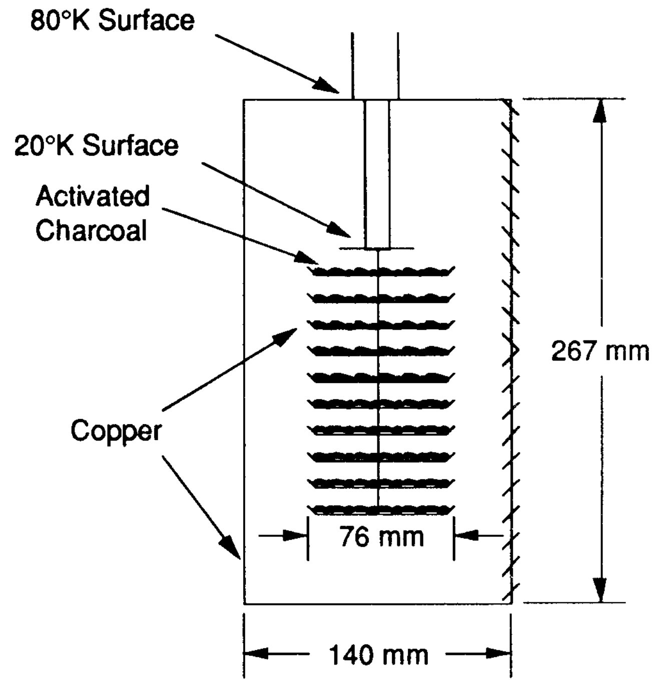

Fig. 4. Cryogenic pumping array, composed of copper with activated charcoal adsorbent.

Acknowledgements

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References

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