A Volume Ion Source with Pulsed Magnetic Field

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Abstract

The design and testing of a miniature, filamentless BNL torodial volume ion source[1] is described. The volume of the source is 2.3 cm^3. A pulsed toroidal multicusp magnetic field is created by current flowing through wires wound on the outside of the source. The magnet current was varied in the range of 100–400 A. The source plasma is created by a discharge initiated from a cold tungsten cathode. A single gap extractor was used to extract the beam from the source. We will describe the operating characteristics during the initial testing of this source.

1. INTRODUCTION

The BNL toroidal H^- ion source developed by Prelec[1] has shown that it is capable of producing intense H^- ion beams with very low electron/H^- ratios. This source has been tested using tungsten and LaB_6 cathodes. In order to avoid the operational problems associated with the short lifetimes of hot filaments, Leung[2] has developed a version of the LBL volume source which has a rf-discharge. The power levels by the LBL rf-driven volume source approached 30 kw resulting in the need for a large rf power source.

We were interested in pursuing the possibility of combining a filamentless discharge with the toroidal geometry. In the paper which follows, we present our first attempt at developing a miniature toroidal volume ion source. This source uses a pulsed electromagnet to confine the plasma, and a cold cathode discharge.

2. DESCRIPTION OF SOURCE

A small toroidal geometry ion source was constructed from aluminium and is shown in Figure 1. The plasma chamber is a cylinder having an inside diameter of 2.03 cm and .72 cm deep. An unsealed aluminum cap formed the top of the source. A 1.4 cm diameter toroidal cold-cathode was formed by warm-bending[3] 0.75 mm diameter tungsten wire about a mandrel. The tungsten cathode was then suspended on the median plane from an axial hollow tube which performed as both a power feedthrough and a gas line. The gas flowing into the source was pulsed to maintain a low chamber pressure.

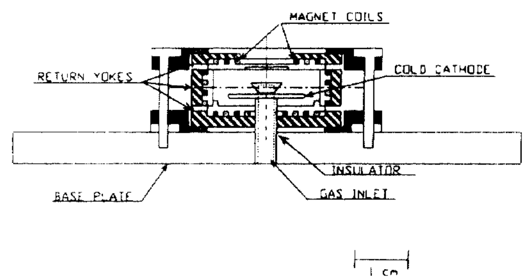

Figure 1. Drawing of the complete ion source showing the magnet coils and cold cathode.

Since the ion source was designed to be small to accomodate a cold-cathode, the design of the magnet presented several problems. The use of permanent magnets to provide the plasma confinement field in this case is impractical due to the small size of the permanent magnet rings and the brittle nature of samarium-cobalt magnets. Therefore, we decided to design a using an electromagnet.

The coil packs of this electromagnet were constructed from 0.6 mm copper magnet wire with Formvar insulation. Grooves (1 mm x1 mm) were cut on the outer surface of the source body and cover plate to provide winding bobbins for the the magnet coils. Although insulated wire was used, the tight bends needed to reverse the direction of the windings on the source body caused the formvar to crack resulting in many shorts between the wire and the aluminum source body. A coating of Konform[4] was sprayed

* This work supported by the Texas National Research Laboratory Commission under grants RGFY9203 and 92B3, and by the Houston Advanced Research Center

on the source body prior to winding the magnet coils. Each magnet coil consists of two turns of wire epoxied onto the aluminum bobbin. Our calculations indicate that we will be able to pulse up to 200 A of current through the wire for approximately 2 ms without melting the wire. The inductance of the total magnet was measured and found to be 2.53 μH and the wire resistance was 0.05 Ω in series with the 0.5 Ω output impedance of the pulser. The measured risetime of the magnet was 5 μs.

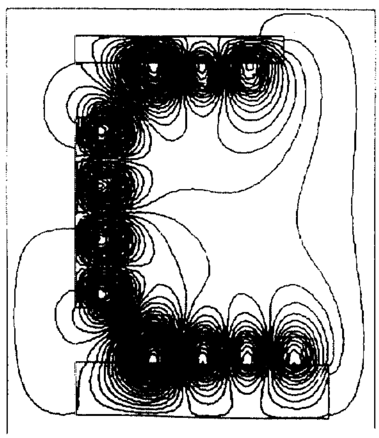

Figure 2. Results of the POISSON[5] calculation showing a toroidal multicusp field created by a pulsed electromagnet. The conical dipole filter field can be clearly seen close to the axis.

A single gap extraction system was used to extract the beam. The extraction aperture in the source was 2 mm. The gap was set to 4 mm to increase the pumping between the The extraction electrode was grounded and had a dipole filter to deflect the electrons out of the beam. The efficiency of the dipole filter to stop electrons has been measured[6] as 0.999. The current flowing onto the extraction electrode was measured by placing a Pearson Model 411 current toroid around the ground lead. The H^- current was measured using a 1 kΩ resistor between the cup and ground.

3. TEST RESULTS

The discharge started reliably at an ignition voltage of 3 kV and an estimated source pressure of 290 mTorr. After ignition, the discharge voltage dropped to 280 V and a discharge current rose to a maximum of 0.5 A. The discharge current could only be controlled through adding limiting resistors to the line between The maximum discharge current was limited by the internal impedance of the high voltage pulsing system.

The maximum achievable extraction voltage was only 500 V due to voltage breakdown through the high pressure region surrounding the extraction aperture. At this voltage, the space-charge limited H^- current is only 47 μA, while the electron current-limit is approximately 2 mA. We observed a total current on the extraction electrode of of up to 0.5 A, while seeing currents on the faraday cup which would be consistent with leakage through the dipole filter. The extraction voltage is also observed to sag during the pulse. It appears that what we are seeing is beam-induced voltage breakdown between the source and extractor caused by high pressure in the region between the source and extraction electrode.

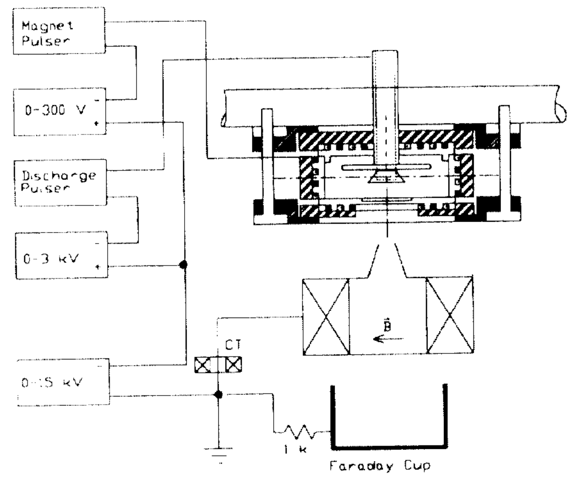

Figure 3. Block diagram of the electrical system used in this experiment.

4. SUMMARY

We have obtained a stable discharge with the pulsed magnet, gas and discharge. The pressure in the source was approximately 290 mTorr. The discharge was initiated by a 3 kV voltage pulse which rapidly decreased to 280 V when the discharge was drawing current. The extracted current was composed of 0.5 A of electrons, and the H^- current was obscured by electrons leaking through the dipole filter in the extraction electrode.

5. ACKNOWLEDGEMENT

The authors would like to thank Troy Welch for fabricating the ion source components, and to Billy Birdwell and Jim Hunter for their help with assembling the electronics for the the test stand.

6. REFERENCES

† The Texas Accelerator Center of the Houston Advanced Research Center is a research consortium composed of Texas A&M, University of Texas-Austin, University of Houston, Rice University, Sam Houston State University, the Baylor College of Medicine MR Center, and Prairie View A&M.

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