H^- ION SOURCE DEVELOPMENT FOR THE NATIONAL SPALLATION NEUTRON SOURCE[*]

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Abstract

The ion source for the 1 MW National Spallation Neutron Source (NSNS) is required to provide 35 mA of H^- beam current (1 ms pulses at 60 Hz) at 65 keV with a normalized rms emittance of less than 0.2 pi mm mrad. The same ion source should be able to produce 70 mA of H^- at 6% duty factor when the NSNS is upgraded to 2 MW of power. For this application, a radio-frequency driven, magnetically filtered multicusp source is now being developed at LBNL. In preliminary experiments with an existing ion source developed for the Superconducting Super Collider, 15 mA of H^- ions were extracted at an accelerated voltage of 10 kV and an RF output power of 20 kW without cesium. The design of a new source equipped with a cesium dispenser collar, a fast ion beam pre-chopper (rise times < 100 ns) and a strong permanent-magnet insert for electron deflection will be presented.

1 INTRODUCTION

Volume produced, low temperature (< 2 eV) H^- ions can be directly extracted from a multicusp, rf-driven, plasma source to form a high-brightness beam as required for the National Spallation Neutron Source (NSNS). To verify that the performance objectives of the ion source, as mentioned in the abstract, can be achieved at the relatively high duty factor of 6%, we performed some initial experiments with an existing source, which was originally developed at LBNL for the SSC [1]. A schematic of such a multicusp, rf-driven (1.8 MHz), H^- ion source is shown in Fig. 1. A detailed design of this source has already been described elsewhere [2,4].

2 EXPERIMENTS

2.1. Total Current

All of our experiments were limited to an rf input power of 23 kW and an extraction voltage of 5 kV. The extraction hole was 6 mm diam., and there was no cesium added to the ion source. Fig. 2 shows, that under these conditions we could extract up to 15 mA of H^-. The H^- current increases linearly with rf power, as seen in previous experiments [3]. This shows that an ion source operated for NSNS needs at least 50 kW of rf input-power without cesium added.

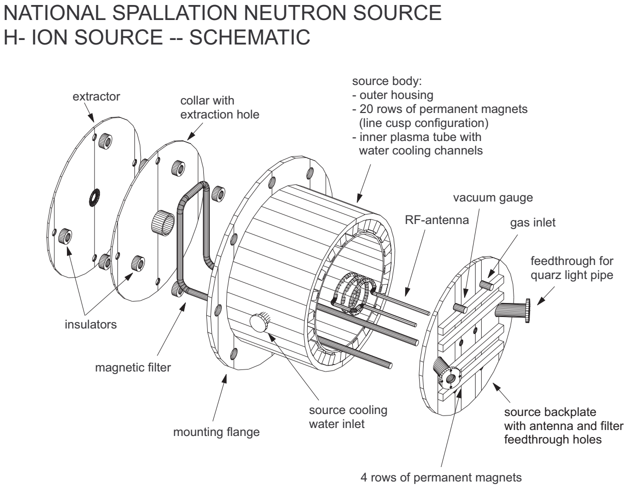

Figure: 1 Rf-driven, multicusp volume H^- ion source.

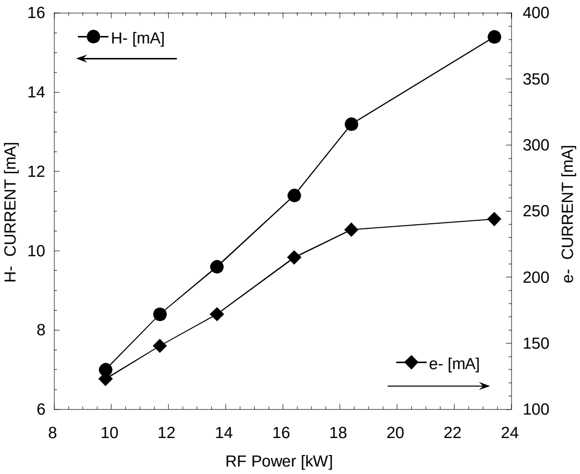

Figure: 2 Extracted H^- current vs. rf power at 6% duty factor.

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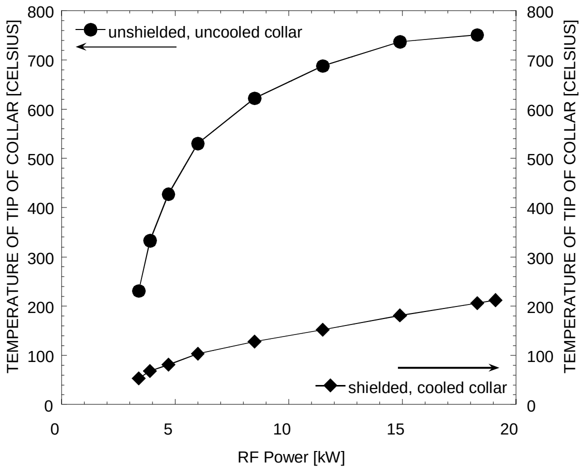

Figure: 3 Collar temperature vs. rf power for different collar geometries as explained in the text.

2.2 Collar Geometry

By installing a collar electrode around the extraction aperture, the extracted electron current can be reduced by a factor of two without significant change in the H$^-$ output current [3]. In such an arrangement a small cylinder (~1 cm diam., 9 mm long) is mounted on the plasma electrode, facing the plasma side. A basic collar configuration is shown in Fig. 1.

It has been demonstrated that the H$^-$ output current can be enhanced by introducing only a trace amount of cesium into the collar region [4]. This can be achieved by placing tiny cesium getter wires in vertical cuts around the collar. It has been shown, that cesiation of the collar region is critical to temperature [5], with an optimum at ~200°C. Therefore we investigated the variation of the collar temperature at various conditions (Fig. 3). At 6% duty factor and 20 kW pulsed rf-power an uncooled and unshielded collar reaches temperatures above 700°C. A slightly modified, better-cooled collar stayed at considerably lower temperatures.

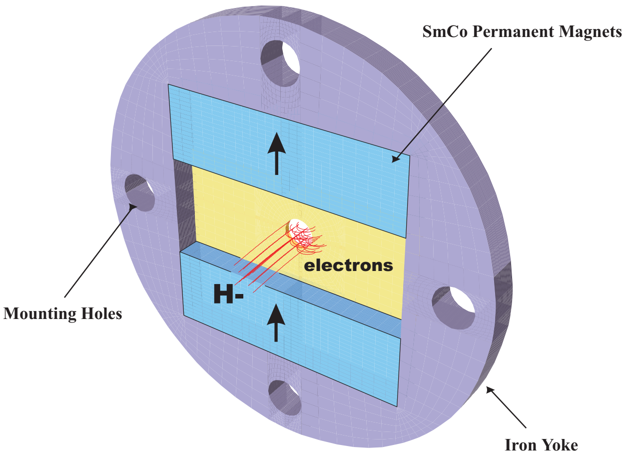

Figure: 5 The new electron deflection scheme at the first electrode (TOSCA 3D simulation).

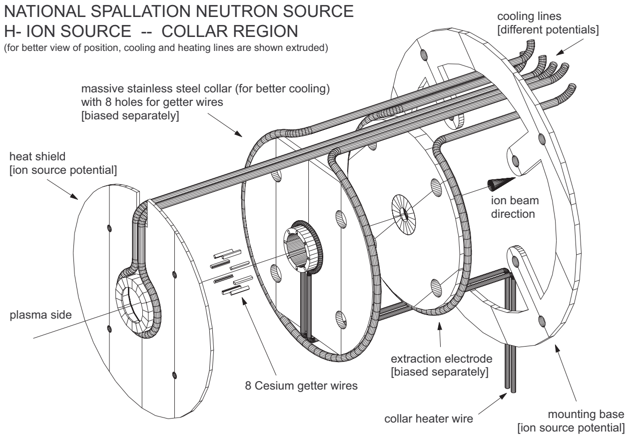

Figure: 4 Expanded view of the new collar design for the NSNS R&D ion source.

In order to meet the NSNS ion source requirements of 50 kW pulsed rf-power, an enhanced collar design was necessary to control the collar temperature. Fig. 4 shows the new collar region design: Eight cesium getter wires slide into the massive stainless steel collar, which is directly water-cooled by a tube, mounted on the outer perimeter of the collar aperture. For further temperature control a heater wire is attached to the collar. A heat shield was placed in front of the collar. The collar was isolated from the extraction electrode, to allow independent biasing of both electrodes in respect to the ion source potential. This feature is necessary for fast ion beam chopping.

2.3 Magnetic Extraction Insert

Unavoidably with volume ion sources, a high-current electron beam (hundreds of mA) is extracted together with the H$^-$ ions. It has been shown previously that a

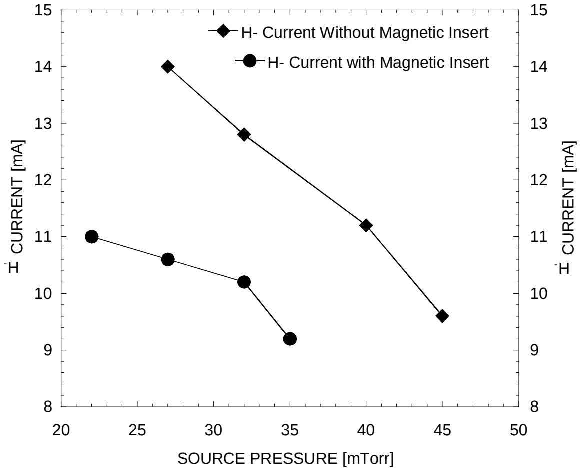

Figure: 6 H$^-$ current vs. source pressure, with and without magnetic deflection insert.

transverse magnetic field at the extraction hole can deflect nearly all the electrons out of the H^- ion beam [6]. The electrons are then dumped at the second electrode at the extraction energy. For NSNS at 6% duty factor and a proposed 85 kV potential drop at the extraction gap, this would result in a very high power loading on the second electrode. For this reason, we are developing a new scheme for electron dumping.

Computational results in Fig. 5 show the effect on the extracted electrons from a pair of permanent magnets located inside the first electrode. Due to the high magnetic field (>1000 G), the electrons gyrate back to the extraction electrode. The collection of the electrons at source potential results in no power loss due to the extracted electrons.

We could show experimentally that with the magnetic insert installed, all of the electrons could return to the source, resulting in no current lost to the second electrode. Nevertheless a strong magnetic insert results in increased H^- beam deflection. Traces at the Faraday cup showed that we were not collecting the whole H^- beam. Therefore measured H^- currents are less with the strong magnet insert installed, as shown in Fig. 6. Further computational and experimental investigation is needed to ensure that the H^- ions are focused properly for further beam transport. We have started 3 dimensional simulations with TOSCA 3D (magnet code) and ARGUS (space charge ion beams), but results are still preliminary.

2.4 Beam Chopping

The NSNS requires 300-ns gaps in the beam to eliminate activation of the extraction septum in the accumulated ring during the turn-on time of the extraction kicker. At LBNL we have tested beam chopping at the multicusp ion source by connecting a dc power supply with a fast electronic switch between the plasma electrode and the source chamber wall. If a positive voltage (~100 V) pulse is suddenly applied to the plasma electrode, the H^- current can be extinguished [7]. We developed a voltage modulator with rise/fall times of less than 100 ns. Experiments with the chopper installed at the ion source are planned. For more control over the pulse shape of the chopped ion beam, both, the collar and the extraction electrode, can be biased independently in the new ion source design

3 CONCLUSION

We have performed first experiments with an existing H^- volume ion source to define the design requirements of an R&D ion source for NSNS. This led to an enhanced ion source design with an improved collar region, a magnetic deflection scheme for complete electron removal and a fast ion beam chopper. A design drawing is shown in Fig. 7. The new source also features a longer plasma chamber, a movable antenna and a movable magnetic filter, which is inserted from the backflange - therefore eliminating the need for an additional filter flange. The purpose of this ion source is to find the optimum operational conditions for the NSNS. Construction of the ion source is already completed and first experiments will follow. Results of the new ion source testing will be reported in the near future.

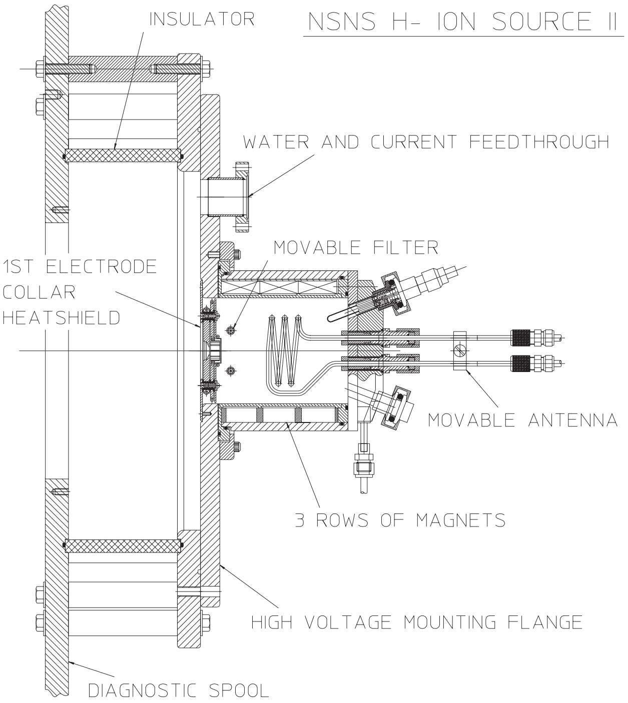

Figure: 7 The new NSNS R&D H^- ion source design. The extraction region is shown in more detail in Fig. 4.

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