ISBN: 978-3-95450-223-3 ISSN: 2673-7000 doi:10.18429/JACoW-NAPAC2019-MOPLH08

TESTS OF Cs-FREE OPERATION OF THE SNS RF H⁻ ION SOURCES*

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Abstract

Tests were performed at SNS in collaboration with visiting colleagues from ISIS, UK to evaluate the uncesiated beam performance of the SNS RF H^- ion sources. Two spare experimental sources, one with internal antenna and one with external antenna were used for the tests. The beam currents achieved with Cs-free operations accounted for about 1/3 to 1/2 of the beam currents produced with cesiated operations. ~17 mA uncesiated H^- current was demonstrated within the tested RF power range up to 65 kW with the internal antenna source and ~15 mA with up to 40 kW RF with the external antenna source. In Cs-free operations, the power supply for the electron dumping electrode was loaded down below its set voltage but was not too drastic to tamper the operation.

INTRODUCTION

The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) employs an RF-driven, multicusp H^- ion source. This type of source was conceptualized and developed at Lawrence Berkeley National Laboratory (LBNL) initially for the Superconducting Super Collider project and then for the Spallation Neutron Source project in 1990s to early 2000s. There were reports of ~30 mA H^- current when operated as a volume source without Cs in the early years. However, to produce higher beam current, Cs was introduced to enhance the H^- production through surface mechanism [1-3]. Since the source was delivered to ORNL in 2002, it has been operated and further developed to highly reliable, long lifetime (several months), persistent high current (>50 mA) H^- source operating at 6% duty-factor (1 ms, 60 Hz) [4, 5]. Figure 1(a) shows a cut view of the SNS H^- ion source in its present form. A porcelain coated copper tube antenna placed inside the stainless-steel source chamber drives the plasma. A SNS inhouse developmental source with AlN ceramic chamber and an external RF antenna is shown in Figure 1(b) [6]. Both sources operate in the same way in terms of Cs system, beam extraction and suppression of co-extracted electrons. A solid reaction Cs dispenser system, the Cs collar in the figures, with cartridges containing a mixture of Cs chromate (Cs_2CrO_4) and getter materials (Zr, Al) is used to release elemental Cs for ion source cesiation by heating it up to ~550 °C. Since the mission of the ion source efforts at SNS is to produce high current H^- beam for the operation and future upgrade of the SNS facility, the focus has always been with Cs enhanced operation of the ion sources. However, the ISIS Facility in the UK expressed interest in testing the performance of the SNS H^- ion sources in Cs-free operation to aid their efforts in developing a moderate current (~35 mA) RF-driven H^- ion source preferably without using Cs [7]. This work presents the tests performed at SNS for this purpose in collaboration with ion source colleagues from ISIS.

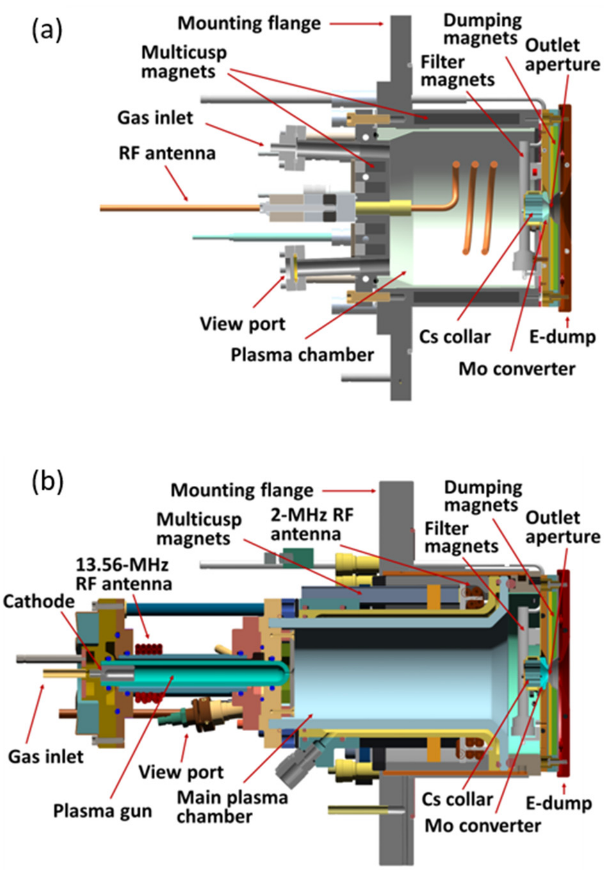

Figure 1: SNS RF-driven H^- ion sources, (a) with internal antenna and (b) with external antenna.

EXPERIMENTAL SETUP

The production tier ion sources for the SNS accelerator operation (internal antenna sources Int#2, 3, 4, 6) and the external antenna sources used on the SNS 2.5 MeV Beam Test Facility (Ext#3, 4) were not available for testing. An experimental ion source (Int#5) from the internal antenna

* This work was performed at Oak Ridge National Laboratory, which is managed by UT-Battelle, LLC, under contract number DE-AC05-00OR22725 for the United States Department of Energy.
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source pool and an external antenna ion source (Ext#2) that was recently rebuilt using spare parts were available and tested on the ion source test stand to evaluate their uncesiated beam performances. The temperature of the Cs collar, as shown in Figure 2, is determined by the plasma heating and the air flow cooling. To prevent accidental/uncontrolled release of Cs when tested for Cs-free operations, these two sources were started up with empty collar without loading the Cs cartridges. For each ion source, after the Cs-free test was completed, it was removed from the test stand, opened, loaded with Cs cartridges, remounted back on the test stand, restarted, conditioned, cesiated, and beam measurement was repeated for comparison.

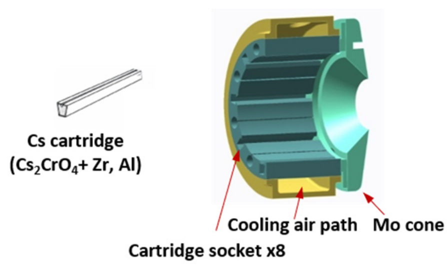

Figure 2: Cs dispenser system of the SNS H^- ion sources.

The H^- beam current was measured with a transformer type beam current monitor (BCM) and a faraday cup (FC) at the exit of a 2-lens electrostatic beam transport system as illustrated in Figure 3. The BCM over reported beam current by a nonconstant value of several mA due to a baseline calibration issue during our tests. Here we only report numbers measured in the faraday cup. In Figure 3, deflection of the co-extracted electrons is also shown schematically. The ion source and e-dump electrode together can be tilted and offset to compensate the effect of the electron dumping field (it is generated with permanent magnets embedded in the outlet electrode) on the H^- beam trajectory.

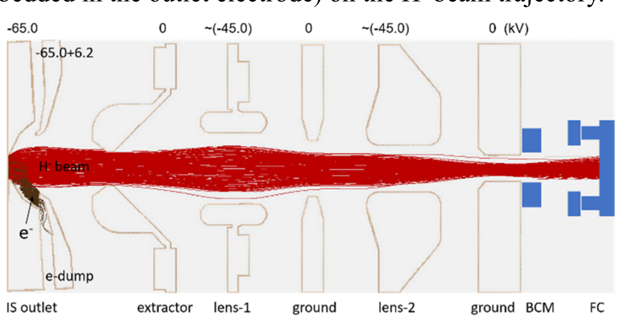

Figure 3: Schematic illustration of beam transport and measurements on the SNS ion source test stand.

TESTS RESULTS

Internal Antenna Source

The Int#5 source without Cs cartridges was conditioned with plasma per our standard protocol for outgassing and sputter cleaning the source chamber and its internal components. After the source was fully conditioned, the ion source and the beam transport system were tuned for beam current. The optimal H_2 flow rate was found to be near ~35 sccm. The measured H^- current vs. the RF power in the range of 20-65 kW is shown in Figure 4. ~17 mA H^- current was produced with 65 kW RF. The waveforms of the H^- current measured in the FC and the e-dump electrode current measured with a current transformer after a spike suppressing RC filter, are shown in Figures 5 and 6, respectively for the 65 kW RF power case. About 170 mA of e-dump peak current was detected, which loaded the e-dump power supply down to ~6.1 kV from its set value of 6.2 kV.

For cesiated operation, the optimal H_2 flow rate was found to be near 30 sccm. The H^- current dependence on the RF power in the tested range of 50-65 kW is overlaid on Figure 4, and the waveforms of the H^- beam and e-dump currents for 65 kW RF power are added on Figures 5 and 6, respectively. The beam currents were more than doubled in cesiated operation as compared to the Cs-free operation for the same levels of RF power. Dependence of the H^- current on the power level is also stronger in cesiated operation. At 65 kW RF, the beam current with Cs was 2.7 times of the beam current without Cs. The e-dump current was drastically lower in cesiated operation and the e-dump power supply held steady at its set value of 6.2 kV.

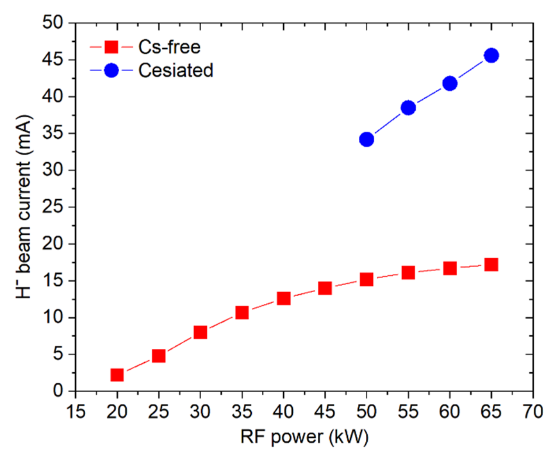

Figure 4: Int#5 source beam current vs. RF power in the operations with and without Cs.

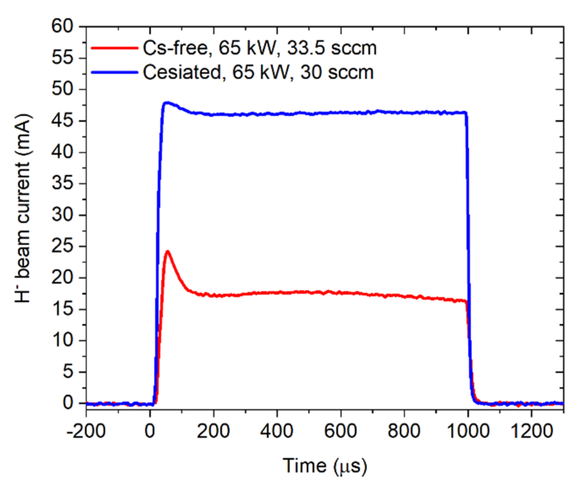

Figure 5: Int#5 source beam pulses @65 kW RF in the operations with and without Cs.

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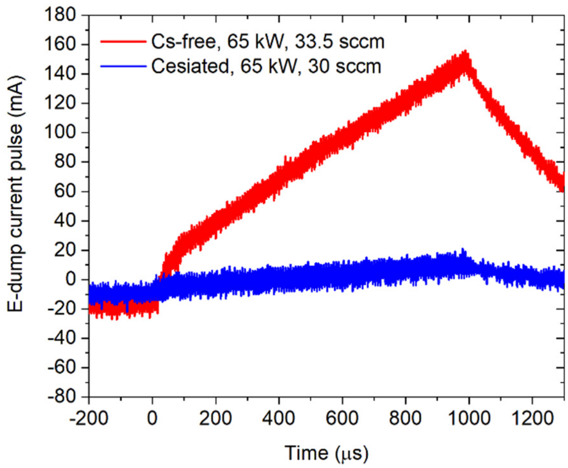

Figure 6: Int#5 source e-dump current pulses @65 kW RF in the operations with and without Cs.

External Antenna Source

Tests with the Ext#2 source were conducted in a similar way as to those with the Int#5. However, due to instabilities experienced with the plasma gun (a critical component used to inject initial electrons into the main plasma chamber to support ignition of the high power pulsed plasma), the source had to be operated with high H_2 flow during the tests, and we could not fully explore the parametric optimization of the beam current. The H^- beam current vs. RF power was measured with the source running at 47 sccm of H_2 flow for the Cs-free operation. The power was varied in the range of 20-45 kW. For the cesiated operation, we sampled the beam once with 30 kW RF at 40 sccm H_2 flow, and one other time with 40 kW RF at 35 sccm. The beam current vs. RF power data are plotted in Figure 7. Like in the internal antenna source case, Cs boosted the beam current roughly by a factor of 2 or more for the same levels of RF power.

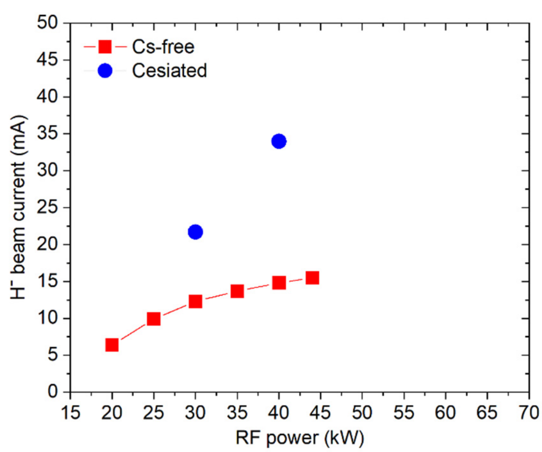

Figure 7: Ext#2 source beam current vs. RF power in the operations with and without Cs.

Figure 8 shows several waveforms of H^- beam current measured for Cs-free and cesiated operations. Cesiation increased the H^- beam current to ~2.3 times of the Cs-free current at 40 kW RF. Figure 9 shows the corresponding waveforms of the e-dump current for the conditions as in the Figure 8. The effect of cesiation on the e-dump current was not as remarkable as it was seen with the Int#5 source. The e-dump power supply was slightly loaded down to ~6.18 kV when operated with 47 sccm and was down to ~5.9 kV in trials with below 40 sccm in Cs-free operations, while it held the set value of 6.2 kV after a cesiation.

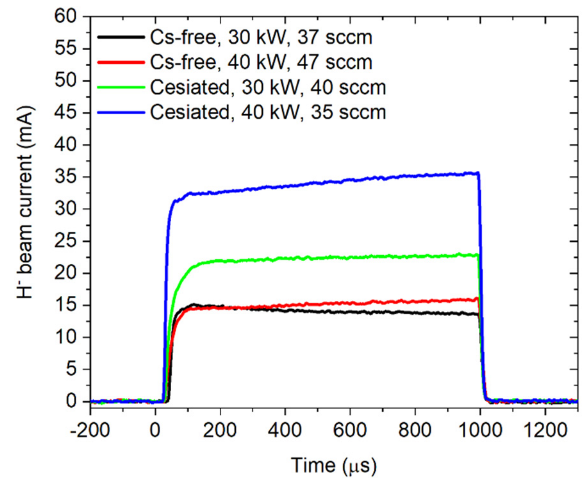

Figure 8: Ext#2 source beam pulses in the operations with and without Cs.

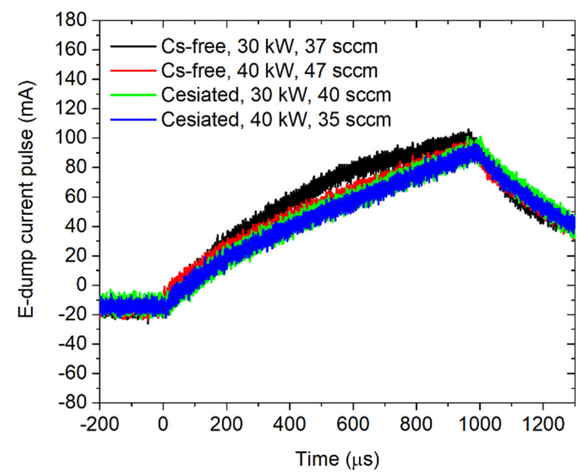

Figure 9: Ext#2 source e-dump current pulses in the operations with and without Cs.

CONCLUSION

Experimental ion sources Int#5 and Ext#2 were tested for uncesiated beam performance, and the results were compared against their cesiated performance. The beam current achieved with Cs-free operations accounted for 1/3-1/2 of the beam current produced with cesiated operations under similar conditions of RF power and H_2 flow rates. Without Cs, the Int#5 produced a maximum of ~17 mA H^- beam with ~65 kW RF and the Ext#2 produced ~15 mA with ~40 kW RF. The e-dump current was higher in Cs-free operations, especially in the case of Int#5 source at high RF power, but it was not too drastic to tamper the operation of the power supply for the e-dump. The root cause of the rather modest Cs-free performances is likely the Cs collar, which significantly reduces the plasma density [8].

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