Tests of Cs-free Operation of the SNS RF H⁻ Ion Sources*

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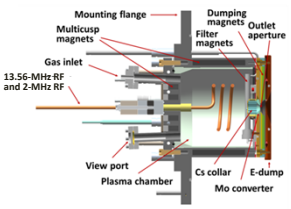
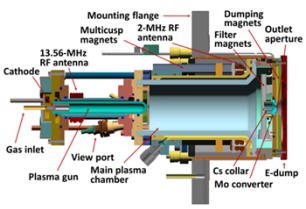
BACKGROUND AND MOTIVATION

- The SNS RF-driven, multi-cusp H⁻ ion sources are capable of delivering high beam current (>50 mA) with high reliability for long life-time (several months) operating at 60 Hz with 1 ms pulse.
- Cs enhancement is necessary to achieve the high beam current required for SNS. The focus of the ion source efforts at SNS has always been with Cs enhanced operation of the ion source.
- The ISIS Facility in the UK expressed interest in testing the performance of the SNS H⁻ ion sources in Cs-free operation to support their efforts in developing a moderate current (~35 mA) RF-driven H⁻ ion source preferably without using Cs.
- Tests were performed at SNS in collaboration with visiting colleagues from ISIS, UK to evaluate the Cs-free beam performance of the SNS RF-driven H⁻ ion sources.

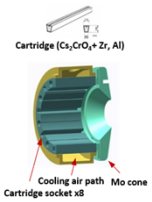
EXPERIMENTAL SETUP



Internal antenna source



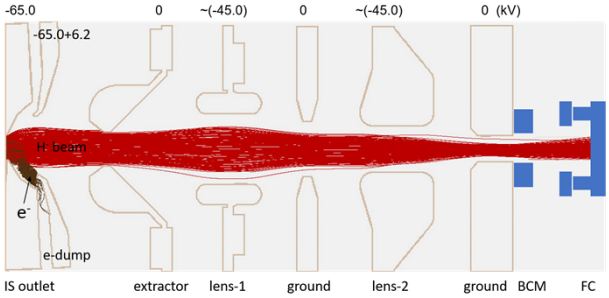
External antenna source



Cesium collar

- Multi-cusp, RF-driven, H⁻ ion sources are used at SNS as RFQ injector, Cs enhancement is needed for high beam current
- RF antenna is placed inside (internal) the stainless-steel chamber or outside (external) the aluminum nitride chamber
- High power 2-MHz RF operates at 60 Hz with 1-ms pulse length, CW 13.56-MHz RF (~300 W) supports ignition of the high power pulsed plasma either by applying on the same antenna or on a separate chamber
- A solid reaction Cs dispenser system is used for ion source cesiation

$$4\,Cs_2CrO_4 + 5\,Zr \rightarrow 8\,Cs + 5\,ZrO_2 + 2\,Cr_2O_3$$
$$6\,Cs_2CrO_4 + 10\,Al \rightarrow 12\,Cs + 5\,Al_2O_3 + 3\,Cr_2O_3 \quad @\sim 550\ ^\circ C$$

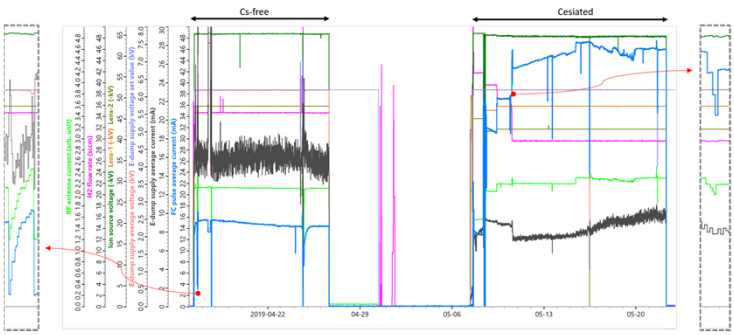


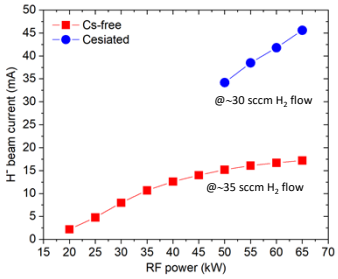
- The ion source test stand is equipped with a 2-lens electrostatic beam transport system and a transformer type beam current monitor (BCM) and a faraday cup (FC)
- Co-extracted electrons are deflected toward the e-dump electrode by a transverse B field.

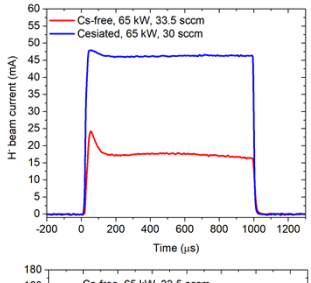
TEST PROCEDURE AND RESULTS

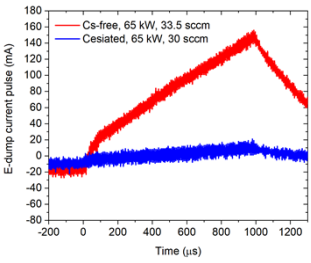
- An experimental ion source (Int#5) from the internal antenna source pool and an external antenna ion source (Ext#2) which was recently rebuilt using spare parts were available and used for the tests. (the production tier ion sources for the SNS accelerator operation (internal antenna sources Int#2, 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)
- For Cs-free operation, to prevent accidental/uncontrolled release of Cs, the sources were start-ed up and tested with empty collar without loading the Cs cartridges.
- For each ion source, after the Cs-free test was completed, the source was removed from the test stand, loaded with Cs cartridges, remounted back on the test stand, and tested for cesiated operation for comparison.
- 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 the numbers measured in the faraday cup.
- The e-dump electrode current was measured with a current transformer after a spike suppressing RC filter.

Internal antenna source Int#5



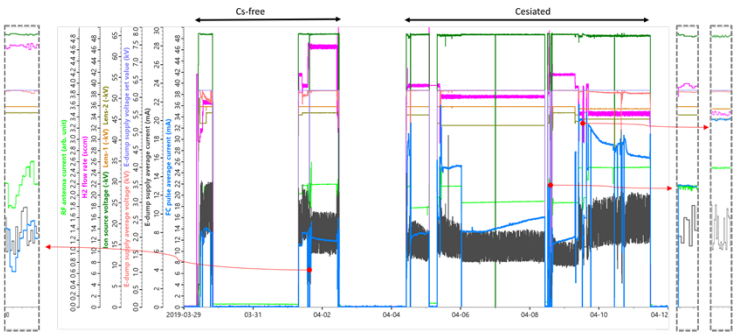


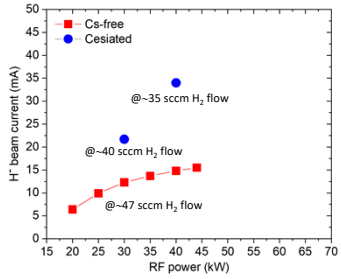


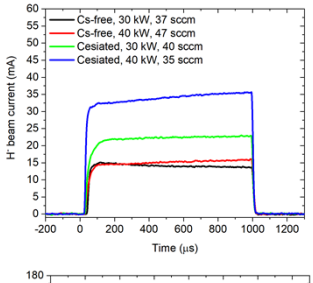


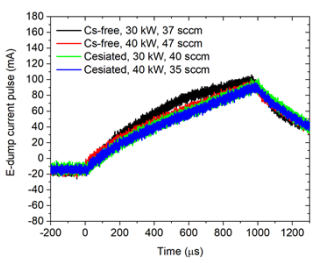
- Optimal H_2 flow rate was found to be ~35 sccm for Cs-free operation and ~30 sccm for cesiated operation
- Without Cs, a maximum of ~17 mA H⁻ current was produced with 65 kW RF whereas it was ~45 mA with Cs
- Dependence of the H⁻ current on the RF power is stronger in cesiated operation
- Overall, H⁻ current with Cs-free operation accounted for only about 1/3-1/2 of the beam current achieved with cesiated operation
- The e-dump current was significantly higher for Cs-free operation, ~170 mA was detected at 65 kW RF, and the power supply was loaded down to ~6.1 kV from its set value of 6.2 kV

External antenna source Ext#2









- Due to instabilities experienced with the plasma gun, the source had to be operated with very high H_2 flow, we could not fully explore parametric optimization for beam current.
- Without Cs, ~15 mA H⁻ current was produced with 40 kW RF as compared to ~34 mA with Cs
- Like in the internal antenna source case, H⁻ current with Cs-free operation accounted for about 1/2 or less of the beam current achieved with cesiated operation
- The effect of cesiation on the e-dump current was not as remarkable as it was seen with the Int#5 source. The loading on the e-dump power supply was mild in the tested RF power range except during the trials with lower H_2 flows

CONCLUSION

- Experimental ion sources Int#5 and Ext#2 were tested for Cs-free H⁻ 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.

* This work was performed at Oak Ridge National Laboratory, which is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.