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ARC AND CONVERTOR TRANSIENT STUDIES FOR MULTI-CUSP CESIATED SURFACE-CONVERSION H⁻ SOURCE AT LANSCE

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Abstract

The Multi-cusp Cesiated Surface-Conversion H^- Ion Source at the Los Alamos Neutron Science Centre (LANSCE) has provided beam at ~14 mA, 120 Hz, and 10% D.F. for many years of neutron science research. Recently, random high current transients were discovered in the Arc current used to ionize hydrogen in the LANSCE H^- ion source, and in the Convertor current used to convert protons to H^- ions. Most have no effect, but more severe transients can cripple beam output. Hypothesized causes are related to cesiation effects, plasma potential changes, tungsten filament evaporation/sputtering, or from the pulsed power system. A dedicated study was recently done on the LANSCE H^- ion source test stand to determine the cause of these transients. Current understanding indicates that the more severe transients come from a combination of cesiation effects and plasma potential changes. The status of these current transient studies on the LANSCE H^- ion source will be discussed.

INTRODUCTION

The Los Alamos Neutron Science Centre (LANSCE) H^- ion beam injector has reliably produced 14 mA of H^- ions at 120 Hz, 10% Duty Factor (D.F), for over 30 years, supporting LANSCE scientific goals [1, 2]. The focus of this presentation is on the initial H^- ion beam injection, which consists of a Multicusp Cesiated Surface-Conversion H^- ion source, and an 80 kV extraction column.

Even with several years of reliable operations for LANSCE scientific needs, only recently has more attention been given to understanding transient currents in the H^- ion source, which were first discovered when monitoring the Arc ionization current. While most of these transients have no direct effect on the stability of beam output for LANSCE, the more severe transients manifest themselves in an arc down of the 80 kV extraction column, which inhibits reliable beam output for LANSCE operations.

Basic Ion Source Operation

In order to understand the origin of transients, the basic ion source operation in absent of such phenomena is explained. Figure 1 shows the basic operation of the H^- ion source:

- **Tungsten Cathode Filaments.** A 120 Hz, 10% D.F. (833 µs) Arc pulse is sent on top of 10 V, 100 Amp DC to ionize H_2 that is in the source, which creates a plasma sustained by a Multicusp magnetic field.
- **Surface-Conversion.** The Convertor is set to a negative potential. H^+ ions in the plasma are attracted to Convertor, which is covered in low work function cesium, which surrenders electrons to make H^- ions.
- **H^- Beam.** H^- ions leaving negatively biased Convertor are focused to the beam exit. There the Repeller rejects most excess electrons. H^- beam and remaining excess electrons are then extracted by the 80 kV extraction column (not shown).
- **Cesium transfer.** Transfer tube continuously supplies cesium from a heated reservoir to replace cesium on Convertor head that is sputtered by cations from the plasma.

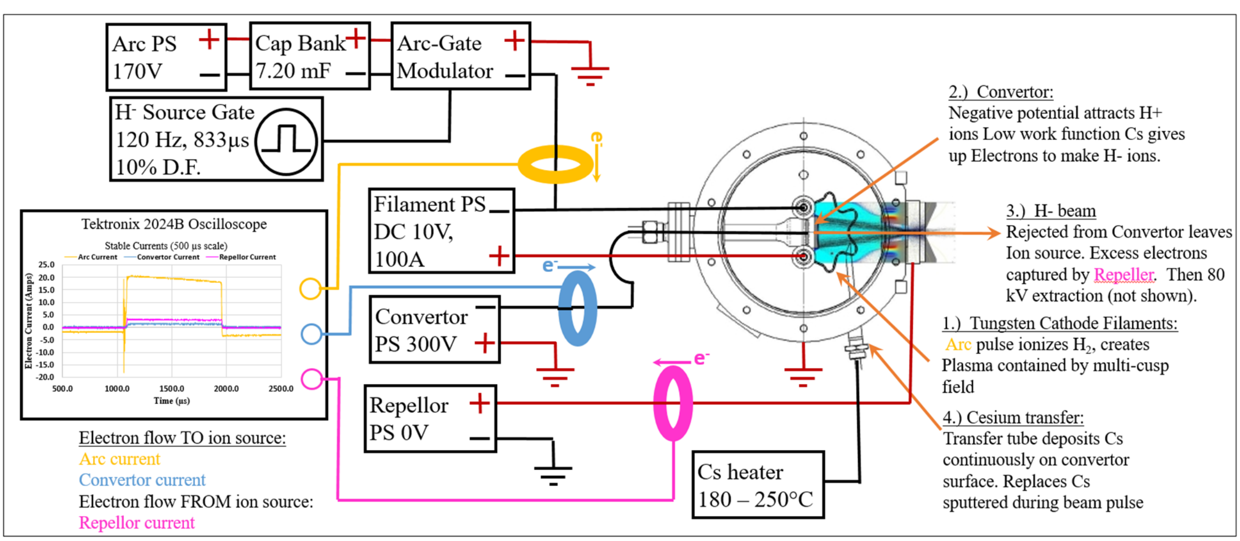

Figure 1: Diagram of H- ion source ideal operation.

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The signals on the oscilloscope in Fig. 1 indicate that in ideal operation, the source is pulsed such that the Arc, Convertor and Repeller electron currents are 20-40 A, 1-4 A, and 1-4 A, respectively.

H^- Ion Source Transients

Two main types of transients are observed in H^- injector operations: *small and large transients*, both of which are 100 – 1000 Amps in magnitude, which is of order $10^1 – 10^3$ greater than their respective base currents. The transient types are shown in Fig. 2. Note that the actual magnitude is limited on the small transients, as bandwidth-limited fiber optic relays that read out the currents saturate at ~1000 Amps. Long term observation of these transients during the LANSCE 2017 and 2018 run cycles indicate that the smaller transients (few µs) occur at a rate of 5 – 20 per hour, whilst larger transients (hundreds of µs) occur 0.5 – 4 per hour. These transient are hypothesized to occur as a result of one or more of the following phenomena:

- **The 80 kV system.** The source, the racks containing the controls hardware and power supplies for running the H^- ion source, and the cable connecitons all floating at 80 kV, so that the beam produced can then be extracted by the 80 kV extraction column. Does this high voltage evnironment cause transients?
- **Tungsten filament evaporation/sputtering.** Do instantaneous resistivity changes in the filaments cause transients?
- **Cesiation effects.** What role does cesium play in the formation of transients?
- **Plasma Potential Changes.** Does sudden changes in the plasma short out the current sources?

CONTROLLED STUDY FOR CAUSAL IDENTIFICATION OF TRANSIENTS

In order to better understand the origin and cause of the current transient in the H^- ion source, a controlled study was done the summer of 2018 while operating the H^- ion source without 80 kV high voltage extraction. The goal of this study was to see if these transients manifested themselves absent of the high voltage system, which is the prime suspect for these transients. The H^- ion source was setup and operated as laid out in Fig. 1.

Observation of Large Transients

The first test was to run the H^- ion source with no cesium released via the transfer tube from the cesium reservoir. For three days, the source was run with no cesium, and no transients were observed.

Once cesium was transferred, large transients began appearing in the system within one hour of operation. The temperature of the cesium reservoir was then varied daily to increase the amount of cesium into the source. The strongest correlation between the number of transients was related to the cesium temperature, *i.e.* the amount of cesium introduced to the source. The transient rate ranged from

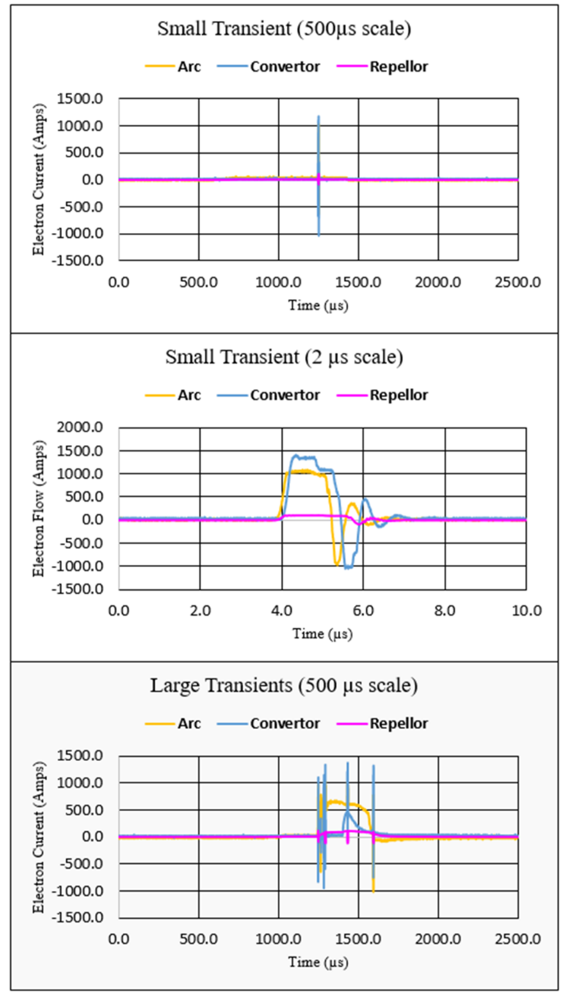

Figure 2: Observed transient in the H- injector operations at LANSCE. The top two panels show small transients (few µs) signals at different scales. The bottom panel shows a large transient (hundreds of µs).

2 – 8 per hour, with the higher rate occurring with more cesium.

Smaller transients, while observed sparingly, were not seen anywhere near the rates of 5 – 20 per hour seen in H- ion beam injector operations.

Other tests were performed in order to attempt to force the transient rate. The Convertor voltage was adjusted from 250 – 400 V, but no noticeable change in transient rate was observed. Water cooling to the ion source body was adjusted between 18 – 30 °C in order to attempt to increase the probability of cold deposits of cesium in the ion source. There was no noticeable change in the transient rate.

It should be noted that several transients also appeared when "cold starting" a cesiated ion source, e.g., in the morning after it had been off all night. Also, it was observed occasionally that a handful transients would appear to be "bunched" together over several minutes, then return to an average hourly rate.

The majority of transient scope traces came in three flavors: Arc only transient, Convertor only transient, or combined Arc & converter transients. These are shown in

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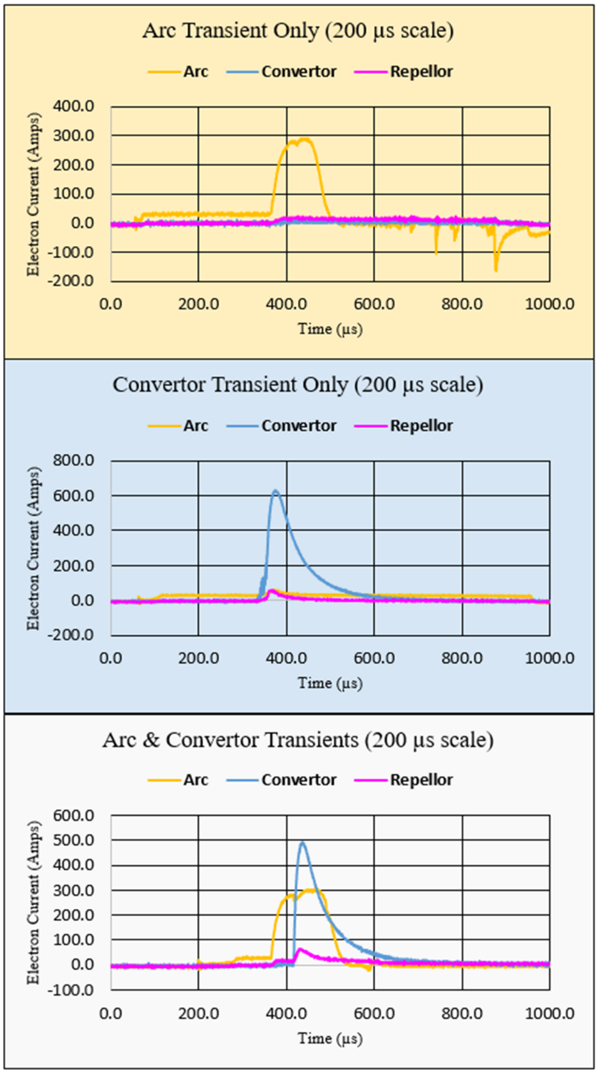

Figure 3: Large transient types observed during controlled test. The top panel shows an Arc only transient. The middle panel shows a Convertor only transient. The bottom panel shows combined Arc and Convertor transients.

Figure 3. In all cases, the Repeller shows transients in response to Arc or Convertor transients, indicating a large surge of electrons heading to the source exit. Also, no transients were observed outside of the H^- Source Gate pulse, such that a source plasma was present during the initiation of the transients. Also, note that the combined transient trace in Fig. 3 resembles the large transients observed during H^- injector operations, see Fig. 2.

Interpretation of Results

It is apparent that large transients observed during H^- ion injector operations are the direct result of cesium interplaying with the pulsed source. They are hypothetically caused by:

- **Large transients, cold cesium deposits.** Cold cesium builds up somewhere in the source body such that the Arc and/or Convertor short to the deposit. Eventually "burning" it out. This is consistent with the observed "cold start" and "bunching" effect.
- **Large transients, cesiated plasma.** Cesium cations distributed in the source plasma such that the Arc and/or Convertor short to the deposit. This is consistent with the observed overall transient rate as a function of cesium transferred to the source.

The large transient effects related to cesium could be disentangled with the use of modern Plasma diagnostic techniques [3, 4].

Small transients not observed in this study are likely related to the H- source and injector operations with 80 kV extraction. Initial observations with 80 kV on have hinted that this is the case, but more systematic studies are needed.

In order to mitigate the large transients during LANSCE operations, several quick techniques will be tested. A resister in series with the Convertor power has already shown to limit the current on large Convertor transients. Reducing the capacitor bank on the Arc current supply chain may reduce power in Arc current transients. Perhaps the best candidate for mitigation of large transients is to install a fast feed-back comparator which would turn off H^- Source Gate in the event of a sudden rise in Arc current. Finally, to mitigate thesmall transient hypothesized to be related to the 80 kV, an analysis of the current grounding scheme will be conducted.

CONCLUSION

We have successfully identified that cesiation of the LANSCE Multi-cusp Cesiated Surface-Conversion H^- Ion Source can lead to periodic large transients on the Arc and Convertor current supplies during H- ion source pulses.

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