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Workshop on Performance Variations in H^- Ion Sources 2012: PV H^-12[*]

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Abstract. This paper briefly summarizes a workshop held in Jyvaskyla the day after NIBS'12. The half-day workshop aimed at globally capturing the issue of performance variations in H^- sources. There was a focus on production facilities and facilities that work under production-like conditions, because there are often high expectations to be met.

Keywords: Cesium, H^- ions, ion source
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INTRODUCTION

The production and extraction of large ion currents from plasma is not an exact science. Periodic maintenance is normally required to remove residues, recondition worn parts, or replace torn parts. When the source is restarted, resetting all operational values rarely brings the same beam current. Slightly reoptimizing the operational values will normally enhance the beam current. Often the current grows over the first time period, although sometimes it decays. Such variations seem to be especially severe in negative ion sources, especially in H^- sources.

There are many ways one can define and quantify performance variations. For a production environment it is most fitting to define the "single source" performance variation as the output of transportable ion current, measured with a standard beam current monitor, normalized to the plasma power, after a fixed number of hours or

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days, often linked to the start of the production. Adjusting the plasma power often allows for compensating the performance variation, except when operating near an upper limit, which is not uncommon in high performance applications. Variations of ±5 to 10% appear to be typical, however more rigorous data are desirable, especially for optimizing the performance of different source geometries.

In addition there are "source to source" performance variations in sources that were built from the same construction drawings, identical for all practical purposes, except for a few minute differences that do not significantly affect the performance. SNS data suggest these variations to exceed ±10% [1].

High performance ion sources are prototypes, and therefore are likely to fail or underperform from time to time for reasons that become obvious after the fact. Statistics on performance variations should only include normal operations, where there is no obvious reason for the variations.

To capture the width and depth of those issues, participants were asked to give a short presentation describing their experiences.

SHORT LAB REPORTS

CERN

CERN's H^- ion source program includes investigation of volume, cesiated surface and magnetron discharge ion sources [2]. An operations database is essential to quantitatively assess the stability of the future linac4 ion source and to understand reliability issues. The database will consist of time-stamped traces of all pulsed variables, and slowly varying variables stored at 1-hour intervals (i.e. temperatures and controls parameters). Furthermore, parameters will be derived from the pulsed traces and this reduced data stored for each pulse or at 1-min intervals. Certain parameters, which can only be obtained from dedicated off-line calibration experiments, such as the pressure in the plasma chamber, will be recorded at regular intervals. Parameter drifts from their nominal values will trigger warnings to the operator's control panel. A post mortem analysis implies an automatic storage of the last moments before beam loss, this however requires LHC-like monitoring standards that are not (yet) foreseen for the Linac4 ion source. Eventually the content of the database will be analyzed at regular intervals and will provide feedback to the ion source design and to the operation teams together with reliability and stability figures of merit.

ISIS, Rutherford Appelton Laboratory

ISIS operates at 50 Hz with constant charge per pulse achieved by modulating the pulse length to compensate for beam current variations. The source normally runs with pulse lengths of about 220 to 240 μs and currents between 48 and 55 mA. The source runs with about a 13 mA/kW efficiency and a 1 A/cm2 current density at extraction.

Source lifetime varies between 5 and 40 days, with scheduled changes often taking place at 14 days. There are ten nominally identical sources used on ISIS. The main factor limiting source lifetime is electrode sputtering. Sputtered molybdenum deposited on the inside of the plasma (aperture) electrode has a tendency to flake off, creating debris that bounces around inside the discharge volume. If the flakes are not destroyed in the plasma they can cause a partial blockage of the outlet aperture or electrical shorting of the anode to the cathode.

The co-extracted electron current increases as the source ages with the fastest increase occurring in the first 5 days of operation. The e/H^- ratio can increase from about 1 to 10, however the source is often removed before a ratio of 10 occurs because the pulsed extraction voltage power supply reaches the limit of its current output capability. The source is tuned throughout its lifetime by very slowly adjusting the cesium oven temperature, hydrogen flow rates and cooling.

Temperatures, currents, voltages, flow rates and machine parameters are sampled every 2 seconds and archived. A comprehensive Quality Assurance procedure collects information about the refurbishment of each source and a thorough autopsy report is generated when each source is removed. Over the last 6 years the source has delivered 99.0% availability to ISIS.

LANSCE, Los Alamos National Laboratory

The LANSCE filament source [3] was reported to yield a stable predictable beam of 16 ± 1 mA after starting up the source over a 2-4 day period. However, the filament lifetime has significant scatter between 28 and 36 days. The scatter can be mitigated by careful on-line monitoring of the filament resistance and active balancing of the output of the two filaments. Other (occasional) causes for performance variations include irregularities of the cesiation procedure, e.g. bursts of elemental Cs from the resistively heated oven, and variations of the ambient temperature, e.g. seasonal drifts.

Max-Planck-Institut fuer Plasmaphysik,

The RF driven ion sources at IPP, developed for the neutral beam injection systems of fusion plasmas, have to operate reliably in hydrogen and in deuterium at low pressure (0.3 Pa) in the cw-mode. Due to the usage of cesium, source conditioning is required and performance variations are observed in short pulse (5s) and long pulse (1 hour) operation. Concerning the source conditioning time, typically 200s plasma-on-time is needed, for which a low leak rate and low background pressure is beneficial. Impurities have to be avoided. Temperature-controlled surfaces (grid at 150°-200° C; chamber at 40° C) are mandatory although inside the source passivated cesium is still to be found after a campaign. Long term degradation of the extracted currents attributed to the cesium degradation is observed. The ion currents are much more stable than the electron currents. At high performance the ion efficiency (negative ion current density/RF power) is 0.3 mA/cm^2kW. In general, the source performance is limited by the co-extracted electrons, which is more pronounced in deuterium than in hydrogen. Since cesium seems to be the crucial factor, focus will be laid on understanding the cesium dynamics.

SNIPPETS FROM THE OTHER LAB REPORTS

NIFS reported that the injected power varies from shot to shot.

JAEA reported that a 1 hour Ar discharge leads to stable operation.

Culham reported on earlier experiments with a filament source, which exhibited significant variations and degradation.

FNAL reported ±8% variations in the beam current, and a few % from pulse to pulse.

SNS reported ±5% performance variations for a specific source but more than ±10% for different sources of identical design [1]. The growing current of co-extracted electrons is currently limiting the life of the sources.

CONCLUSIONS AND OUTLOOK

The short reports and the snippets are inadequate to describe the full width and complexity of problems the H^- community is facing to improve performance and reduce variations of their sources. However, they give a flavor of how difficult it is to standardize critical measurements and reporting formats, one of the original goals of the workshop.

The discussion gravitated towards cesium, which plays a critical role for high current sources. The H^--producing cesium is imbedded in an extremely complex environment, being adsorbed on a metallic substrate while being bombarded by plasma ions and being flashed by thermal and hyper-thermal hydrogen atoms and molecules. Neither surface chemistry nor surface physics have explored such complex systems, with the degree of complexity being enhanced by imperfect technical surfaces and the presences of impurities.

Considering the uncertainties, it was not surprising that the majority of participants believed that the Cs could dominate the observed performance variations. This led to a proposal to organize a workshop on such Cs issues in Japan, following the next ICIS, which will be held in Chiba, September 9-13, 2013.

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