RECENT DEVELOPMENTS WITH MULTICUSP ION SOURCES AT GRUMMAN

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ABSTRACT

The Grumman Accelerator Technology Development program utilizes two ion source test stands as well as other accelerator facilities. One test stand is for pulsed operation up to 1% duty cycle, and the other is for continuous duty (CW). Recently our key focus has been on improving the RF driven multicusp source configuration developed by LBL. For pulsed applications we have fully automated start up and operation, including control of the RF amplifier. The control system is PC-based and uses wave form signatures as well as direct analog /digital feedback. For high brightness negative ion beams using cesium for enhanced output, we have demonstrated extended operation with good reproducibility. This was achieved by introducing a maximum of 16 mg of cesium and by control of the temperature of the collar around the aperture. For high current (100's of mA) proton CW applications such as ATW, we have initiated a test program for improvement of the long term power handling capability of the internal antenna. This includes the use of advanced dielectric coatings applied by a chemical vapor deposition process. This paper describes our results and methodology in these areas.

INTRODUCTION

The use of an RF driven ion source for H^- and H^+ production has been previously demonstrated [1,2]. Typically the sources were operated at low duty factors, or at low power/long pulse conditions.

In our research program we have focused on developing reliable high current, high brightness pulsed H^- operation, and on high current CW operation with high proton fractions. In this paper we present results relevant to automation of the RF driven source, long term high current pulsed H^- operation with cesium, and CW source operation with positive ions.

EXPERIMENTAL DETAILS

A. Ion source control and automation

The Grumman ion source (see Fig. 1) consists of a 10 cm LBL multicusp source driven by a 2.5 turn dielectric coated RF antenna operated at 2 MHz.

A single control system is used for operation of the pulsed test stand and the 1.013 MeV pulsed beamline. The system architecture is based on a network of locally rack mounted PC's controlled by a master processor which accepts input from an operator or executes various automatic control loops. The motivation for development of this system was to eliminate all slow fiber optic links which were found to be subject to drifts and were not robust enough to withstand high voltage breakdowns.

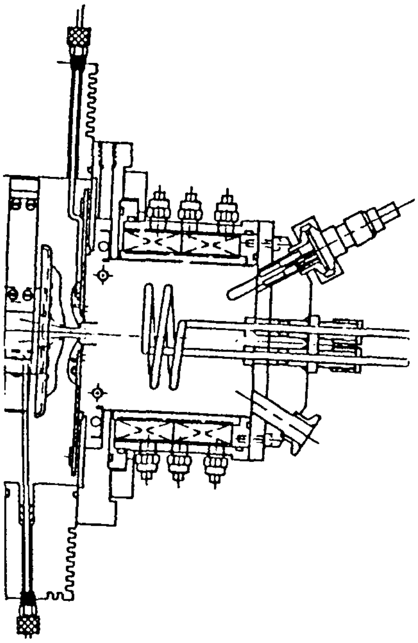

Figure 1. RF driven ion source.

Presently the network is composed of six computers: the ion source computer used for local control and monitoring of all power supplies and signals at high voltage; the LEBT computer controls and monitors the focusing and steering magnets, and monitors data collected by a pin probe diagnostic at the RFQ inlet; two RF computers which control the ion source RF power supply, and the RFQ, IMS, and DTL power supplies; a data acquisition computer used for display of digitized wave form data, and for archiving snapshots of all system parameters and monitored signals; and the master control computer.

The ion source and beamline are controlled by a series of algorithms: Auto_Start, Auto_Gas, Auto_RFQ, Auto_Current, and Auto_Steer. We have demonstrated complete automatic start up of the pulsed RF driven ion source, automatic beam current control in the LEBT, and automatic optimization of the RFQ output current.

The system is initially started by setting system parameters to values obtained from a lookup table. Typically the source is operated at a fixed frequency. The output of the ion source RF amplifier and the beam output current are controlled by gating a variable amplitude sine wave to the preamplifier stage of the high power amplifier. The Auto_Current algorithm is designed maintain a requested source output current using the average value of the current during a pulse as a feedback signal for controlling the RF drive amplitude. An initial drive amplitude (A) is set for a requested beam current (I) assuming a linear relation of the form $A = m * I + a$, where the parameters m, and a are experimentally determined. The drive amplitude is then adjusted in small steps to obtain the requested output current.

The Auto_Current algorithm operation with positive ions is illustrated in Fig. 2 where the total beam current, the RFQ input and output currents, and the ion source amplifier drive amplitude are shown in strip chart format. At the point marked (1) the drive amplitude is set to the value read from the set up table. The source output current slowly increases as the amplifier and source warm up. At the points marked (2 - 5) beam current values of 65 mA, 55 mA, 75 mA, and 30 mA are requested and the drive amplitude is automatically adjusted to the necessary values. At point (6) we see the system recovering from an intentional perturbation caused by setting a higher drive amplitude but not changing the requested beam current.

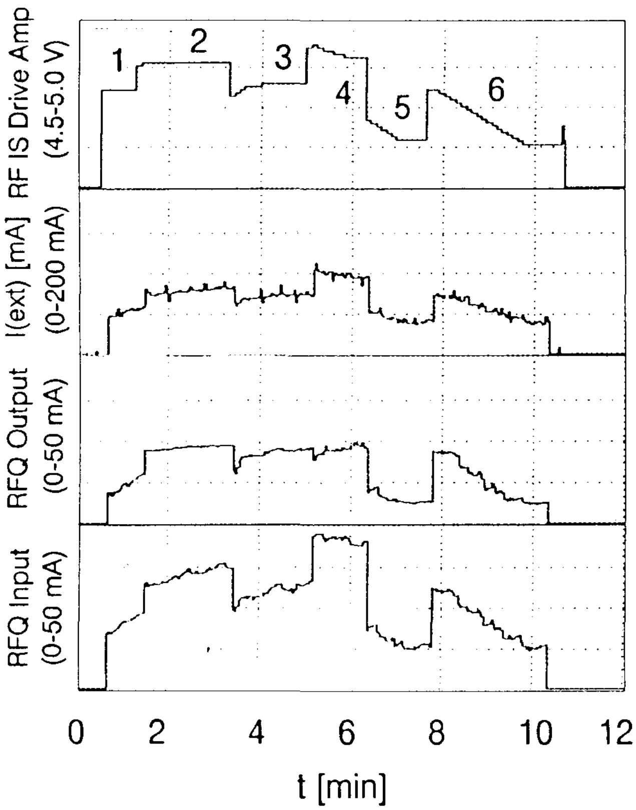

Figure 2. Beam current vs. RF ion source drive amplitude set by the Auto_Current algorithm.

B. H- Operation with Cesium

Two types of dispensers were used for introducing Cs into the pulsed RF source. The first was developed by Culham Laboratory for NPBSE applications. With this dispenser liquid Cs was transported via a capillary tube through the back flange where it was vaporized and injected into the source volume [3]. Approximately 150 mg of cesium were injected in a single shot, and the entire chamber walls were cesiated. The cesiation procedure was repeated until 250 mg of Cs was injected in the source at which point an optimum H$^-$ output was achieved.

The second dispenser injected 16 mg of Cs in the immediate vicinity of the plasma aperture with four SAES strip dispensers mounted in a special collar around the plasma aperture [4]. In this configuration the collar wall temperature could be crudely controlled by adjusting the current passing through the dispenser strips, and the wall temperature could be monitored with a thermocouple spot welded to the collar wall.

With both dispensers the H$^-$ ion current was measured as a function of the RF power with an 8.0 mm diameter plasma aperture (See Fig. 3). At 15 kW of RF power the H$^-$ current was approximately 40% greater with the Culham dispenser compared with the collar dispenser; however, long term operation could not be evaluated due to clogging of the capillary tube that was caused by the reaction of Cs with an Al gasket in a cutoff valve in the dispenser.

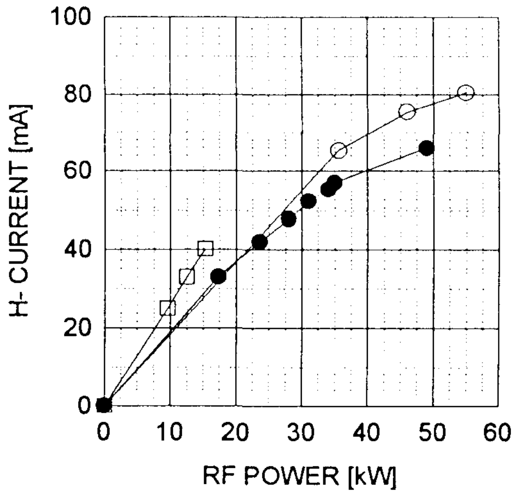

Figure 3. H$^-$ current vs. RF power. ☐ Liquid Cs dispenser (300 μs pulse), ○ SAES dispenser (300 μs pulse),● SAES dispenser (600 μs pulse).

The procedure for cesiating the source using the SAES dispensers consisted of passing 7.5 A - 9.0 A of current through the strips for approximately 90 sec per shot, followed by lowering the heating current to approximately 4 A/strip for steady state operation. At this current the steady state collar wall temperature was approximately 170 C. At the optimum collar temperature a steady state H$^-$ current of 80 mA was reproducibly achieved with 300 micro-sec pulses at 55 kW of RF power. The H- ion current and the electron to ion ratio were strongly dependent on the collar wall temperature (See Fig. 4). At the optimum collar temperature the H$^-$ output was stable and no significant degradation of the H- current was observed during daily operation. The high output currents shown in Fig. 3 were reproducible on a daily basis for 40 days, after which time the experiment was terminated.

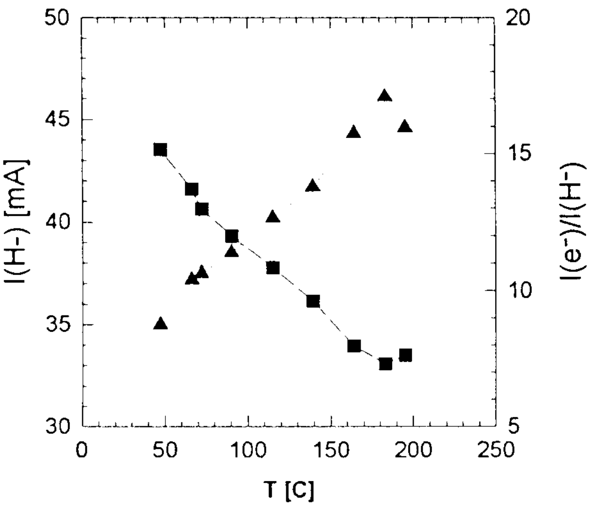

Figure 4. H$^-$ current and electron to ion ratio vs. Collar wall temperature. ▲ I(H$^-$); ■ I(e$^-$)/I(H$^-$).

C. CW OPERATION WITH POSITIVE IONS

A new class of proposed accelerators generically known as AXY machines will require CW proton currents on the order 100 mA to be supplied from the ion source. We are evaluating the feasibility of using the RF driven source to meet these requirements. Several significant issues that need to be addressed are: ion output and H$^+$ fraction vs. RF power; antenna lifetime at CW operation; and high current CW beam extraction.

We have operated at true CW conditions (100 % duty factor) at 6 kW with no beam extraction continuously for 24 hr. using an antenna with the "return leg" at the outside of the loop before the antenna failed.

Inspection of the used antenna shows that the coating on the legs of the antenna appears to be etched. Since the dielectric coating consists of a mixture of Al, Si , and Ti oxides, we believe that the primary mechanism for removal of the coating is atomic hydrogen enhanced sputtering. Presently we are investigating various antenna shielding configurations, and deposition of BN coatings by chemical vapor deposition as alternative to the porcelain.

Using an antenna with the return leg shielded with Mo foil we measured the total positive ion current extracted at 46 kV from a 6.0 mm diameter plasma aperture (See Fig. 5). At 7.5 kW of RF input power the total extracted ion current was 80 mA (283 mA/cm^2) corresponding to an H$^+$ current of 55 mA based on mass fraction measurements made during pulsed operation. The results shown in Fig. 5 suggest that an H$^+$ current of 100 mA can be obtained at 6 kW with a 10 mm diameter plasma aperture assuming a constant current density.

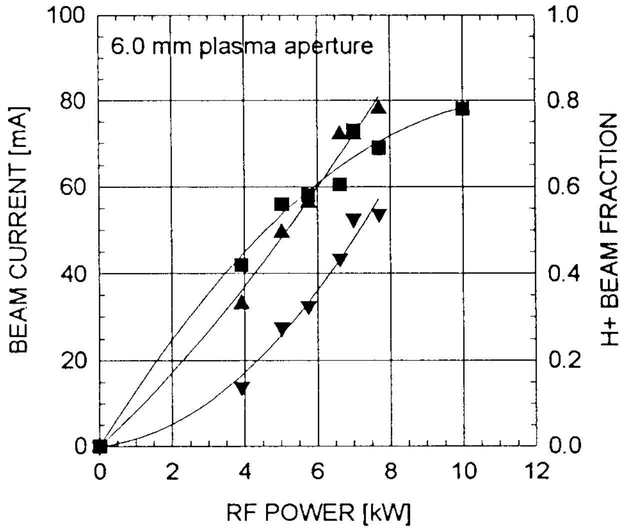

Figure 5. Beam current and H$^+$ fraction vs. RF power for CW source operation. ▲ Total positive ion current; ■ H$^+$ fraction; ▼ Calculated H$^+$ current.

Kwan et. al. have reported extending their antenna operating power to 15 kW with 1 s pulses by shielding the antenna with an additional layer of quartz sleaving. This lead to the evaporation of a thin insulating (quartz) layer on the discharge chamber walls which reduced their H$^-$ output. For H$^+$ extraction the presence of an insulating layer on the chamber walls may have the same effect as use of a quartz liner which has been shown to increase the H$^+$ output. We are currently designing a series of diagnostics for measurement of the CW beam mass fraction and emittance.

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