INITIAL RESULTS FROM THE FRONT END TEST STAND HIGH PERFORMANCE H⁻ ION SOURCE AT RAL

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Abstract

The RAL Front End Test Stand (FETS) [1] is being constructed to demonstrate a chopped H^- beam of up to 60 mA at 3 MeV with 50 pps and sufficiently high beam quality for future high-power proton accelerators (HPPA).

High power proton accelerators with beam powers in the several megawatt range have many applications including drivers for spallation neutron sources, neutrino factories, waste transmuters and tritium production facilities.

The aim of the FETS project is to demonstrate that chopped low energy beams of high quality can be produced and is intended to allow generic experiments exploring a variety of operational conditions.

This paper details the first results from the initial operation of the ion source.

INTRODUCTION

High power proton particle accelerators in the MW range have many applications including drivers for spallation neutron sources, neutrino factories, transmuters (for transmuting long-lived nuclear waste products) and energy amplifiers. In order to contribute to the development of HPPAs, to prepare the way for an ISIS upgrade and to contribute to the UK design effort on neutrino factories, a Front End Test Stand (FETS) is being constructed at the Rutherford Appleton Laboratory (RAL) in the UK. The aim of the FETS is to demonstrate the production of a 60 mA, 2 ms, 50 pps chopped H^- beam at 3 MeV with sufficient beam quality.

FETS consists of a high power ion source, a 3 solenoid magnetic LEBT, a 324 MHz, 3 MeV, 4-vane RFQ, a fast electrostatic chopper and a comprehensive suite of diagnostics.

The RF system for the RFQ has reciently been comssioned to 1 MW.

ION SOURCE OVERVIEW

The basic design of the ISIS H^- source has previously been described in detail [2]. The source is of the Penning type [3], comprising a molybdenum anode and cathode between which a 55 A low pressure hydrogen discharge is produced. A transverse magnetic Penning field is applied across the discharge. Hydrogen and caesium vapour are fed asymmetrically into the discharge via holes in the anode. The anode and cathode are housed in a stainless steel source body.

The beam is extracted through an aperture plate (plasma electrode) using an extraction electrode. On the ISIS operational source the aperture is a 0.6 mm by 10 mm slit and the extraction electrode is of an open ended jaw design, with a jaw spacing of 2.1 mm and a separation from the aperture plate of 2.3 mm. A +17 kV extraction voltage is used operationally. For the FETS high performance source a +25 kV extraction voltage is used, the aperture widened and the extract electrode terminated.

The source is pulsed at 50 Hz, the operational source runs with a 250 µs pulse length. The FETS source is modified to run with a 1.8 ms pulse length by improving the cooling system [4].

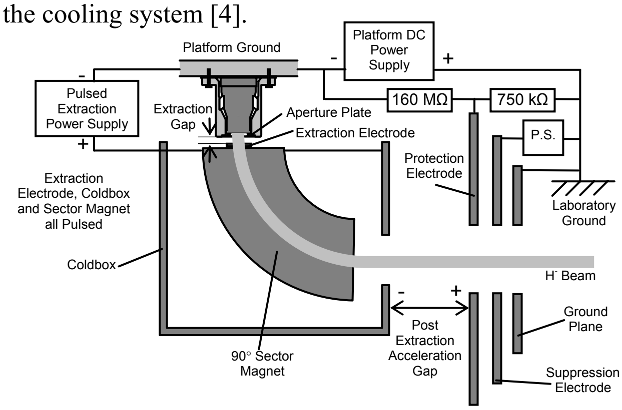

Figure 1: Schematic of the FETS ion source extraction and post acceleration system.

After extraction the beam is bent through a 90° sector magnet mounted in a refrigerated coldbox (Figure 1). The sector magnet has two main purposes; to analyze out the electrons extracted with the H^- ions, and to allow the coldbox to trap caesium vapour escaping from the source.

The H^- beam emerges through a hole in the coldbox and is further accelerated by a post extraction acceleration gap. On the ISIS operational source this is an 18 kV post acceleration voltage giving a total beam energy of 35 keV. For FETS this is a 40 kV voltage giving a total beam energy of 65 keV.

INSTALLATION

Figure 2 shows the installed source, it is mounted on a high voltage insulator, which in turn is mounted on the source and laser diagnostics vessel (figure 7).

The ancillary equipment required to operate the source is installed on a high voltage platform shown in figure 3.

The high voltage platform is enclosed in an interlocked high voltage cage with the platform bias power supply outside the cage shown in figure 4. The platform voltage is monitored using a voltage divider and the platform is automatically earthed with a pneumatically driven earthing arm as shown in figure 5.

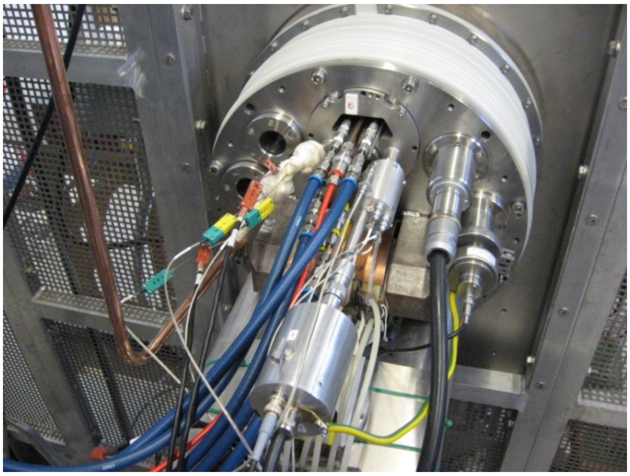

Figure 2: The installed FETS ion source.

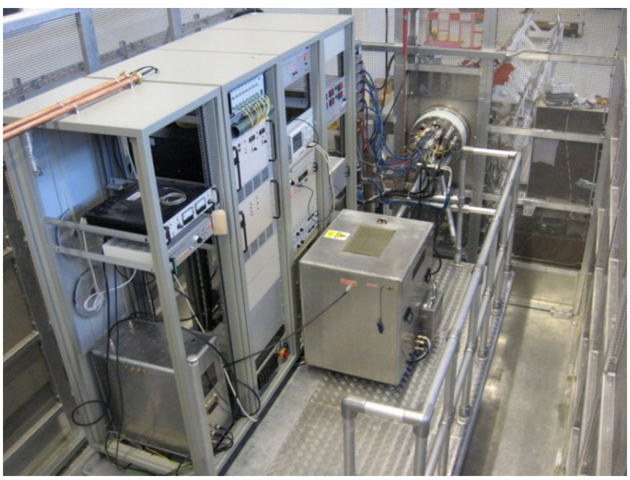

Figure 3: The high voltage platform.

Figure 4: The platform bias DC power supply and the high voltage cage.

Figure 5: The automatic earthing arm and voltage divider under the high voltage platform.

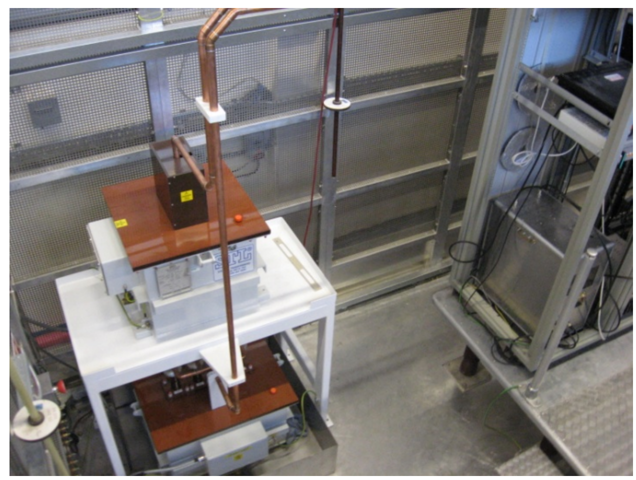

Figure 6: The single and three phase isolation transformers.

Power is provided to the ancillary equipment on the high voltage platform using separate single phase and three phase isolating transformers shown in figure 6.

DIAGNOSTICS

A laser profile measurement system [5] is installed in the ion source vessel (figure 7). A beam current toroid is also installed in this vessel and a Faraday cup can be seen mounted on the back of the vessel in figure 7. A 500 V suppression electrode is included in the Faraday cup assembly to suppress secondary electrons.

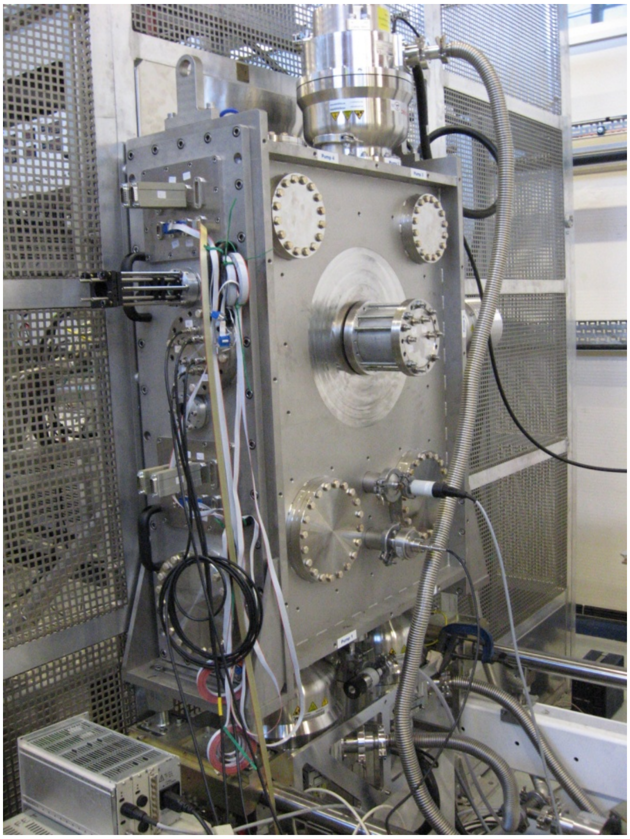

Figure 7: The ion source and laser diagnostics vessel.

EXPERIMENTAL SETUP

At the time of writing the platform bias high voltage supply is not yet fully commissioned, so to produce a beam a temporary power supply is used. The platform voltage is set to 30 kV.

The long pulse 25 kV extraction voltage power supply is also not yet complete, so a standard ISIS 17kV power supply is used.

INITIAL RESULTS

On the 30th of April 2009 FETS produced its first beam. Figure 8 shows the oscilloscope traces for the first beam. For a 50 A discharge current and a 17 kV extraction voltage, with a 13 kV post acceleration voltage, a 30 mA, 30 keV, 200 μs, 50 Hz, H^- beam was measured on the Faraday cup.

The ion source performance has not yet been optimised because the control system is not yet fully commissioned to allow remote operation. This means all the settings have to be made locally before applying the high voltage to the platform.

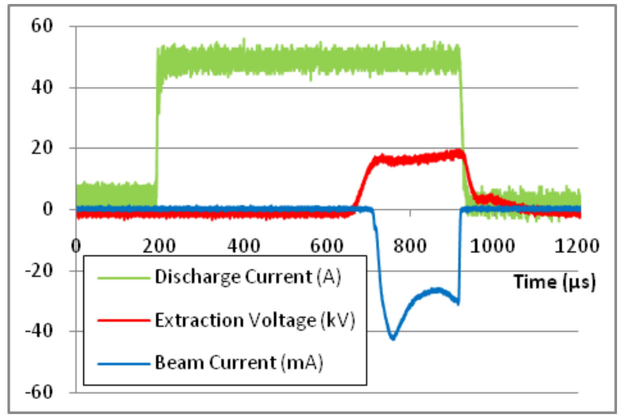

Figure 8: Oscillscope traces showing the first beam produced by the front end test stand.

The shape of the beam current oscilloscope trace indicates that the beam is mis-steered vertically. Once the control system has been commissioned, the mis-steering can be easily rectified and the source tuned for optimum performance. Previous work on the ion source development rig has demonstrated beam currents in excess of 60 mA are possible [2].

NEXT STEPS

Complete the commissioning of the platform bias high voltage supply and the control system to allow remote operation. The commissioning of the laser profile measurement system is almost complete, this will be complemented by additional diagnostics in a movable vessel containing horizontal and vertical slit-slit emittance scanners and a pepperpot emittance/profile measurement device.

The design of the new long pulse extraction supply needs to be progressed and completed, but in the short term the existing ISIS extraction supply will be modified to work at long pulse lengths but with lower repetition rates. This will allow the question of output current droop to be addressed.

REFERENCES

[1] A Letchford et al., “Status of the RAL Front End Test Stand”, THPP029, EPAC’08.

[2] D.C. Faircloth, *et al,* “Understanding Extraction and Beam Transport in the ISIS H^- Penning Surface Plasma Ion Source”, Review Of Scientific Instruments 79, 02B717 2008.

[3] V G Dudnikov, “Surface Plasma Source of Penning Geometry”, IV USSR National Conference on Particle Accelerators, 1974.

[4] D.C. Faircloth *et al*, .”Thermal Modelling of the ISIS H^- Ion Source”, Review of Scientific Instruments, Volume 75, Number 5, May 2004.

[5] D. Lee *et al.*, “A Laser-Based Beam Profile Measuring Instument for The Front End Test Stand at RAL”, ID 2681, PAC’09, Vancouver, May 2009.