INSTALLATION OF THE FRONT END TEST STAND HIGH PERFORMANCE H$^-$ ION SOURCE AT RAL

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Abstract

The RAL Front End Test Stand (FETS) 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). This paper details the first stage of construction- the installation 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.

ION SOURCE

Overview

The basic design of the ISIS H$^-$ source has previously been described in detail [1]. The source is of the Penning type, comprising a molybdenum anode and cathode between which a low pressure hydrogen discharge is produced. A transverse magnetic Penning field is applied across the discharge. Hydrogen and Caesium 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 length of 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 will be used and the aperture widened and the extract electrode terminated.

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.

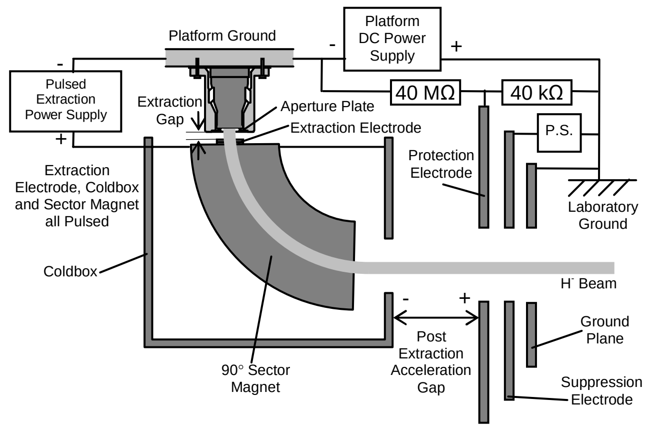

Figure 1: Schematic of the FETS ion source extraction and post acceleration system.

The H$^-$ beam emerges through a hole in the coldbox and is further accelerated by a post 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.

Figure 2: The FETS ion source.

Modified Sector Magnet

The field gradient index in the 90° sector magnet on ISIS has been found to be n =1.4 [2]. New n =1 field gradient poles have been designed also with a larger good field region to improve beam transport.

Increased Duty Cycle

ISIS operates at a 1% d.f. at 50 Hz, this will be increased to 10% d.f. at 50 Hz for FETS. To offset this extra heating, thermal insulation is reduced and cooling increased as previously demonstrated [3].

ION SOURCE 70 KV INSULATOR

The ion source is mounted on a flange which is supported by an insulator. On ISIS this insulator must hold off 35 kV. For FETS it must hold off 70 kV: to do this its length must be doubled. The insulator must support the full 150 kg load of the ion source. The insulator is manufactured out of Noryl-GFN3 (a machinable, fibre-glass reinforced plastic). This material is used because of its high strength. Unfortunately Noryl-GFN3 is only manufactured in slabs of a certain thickness and so the longer insulator is constructed from two adhered sections.

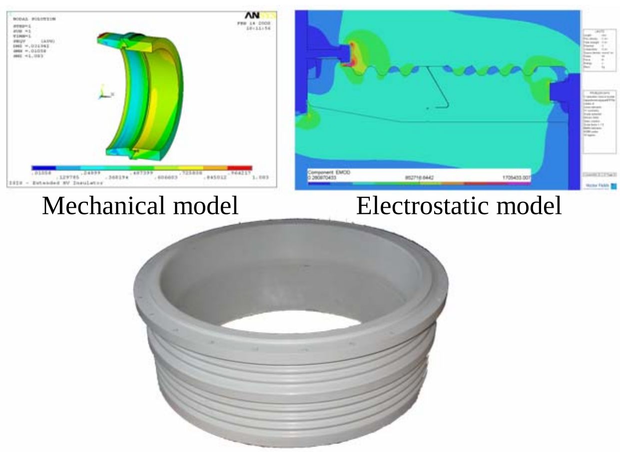

Figure 3: The 70 kV insulator.

Mechanical and electrical finite element modelling is used to confirm the design of the new 70 kV insulator.

POST ACCELERATION ELECTRODE ASSEMBLY

The 70 kV insulator is mounted on the post acceleration electrode assembly shown in Figure 4. This assembly has several purposes: It is a spacer to separate the insulator from the ion source vessel discussed in the next section. It supports the electrode to protect the extraction power supply from main platform supply (circuit is shown in Figure 1).

It supports the suppression electrode to prevent ions travelling back across the post acceleration gap. It supports the beam current toriod and ground electrode. It also employs mu-metal sheets to magnetically shield the diagnostics from the sector magnet's stray field.

The post acceleration gap is variable between 4 and 10 mm and has been previously investigated [4].

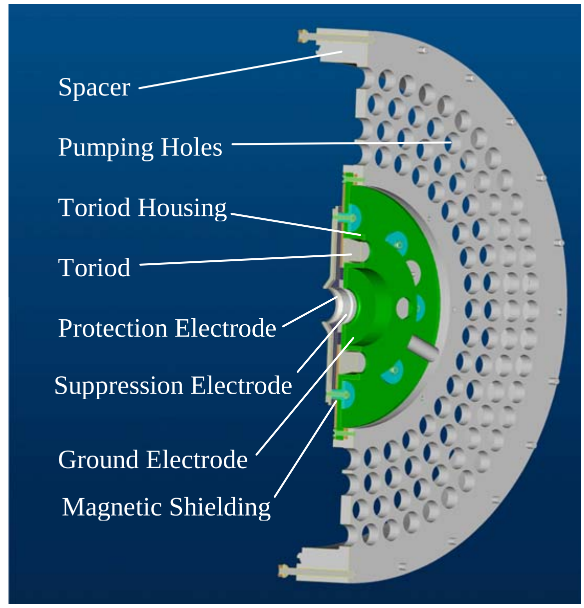

Figure 4: The post acceleration electrode assembly.

ION SOURCE VESSEL

The post acceleration electrode assembly mounts on the ion source vessel shown in Figures 5 and 6.

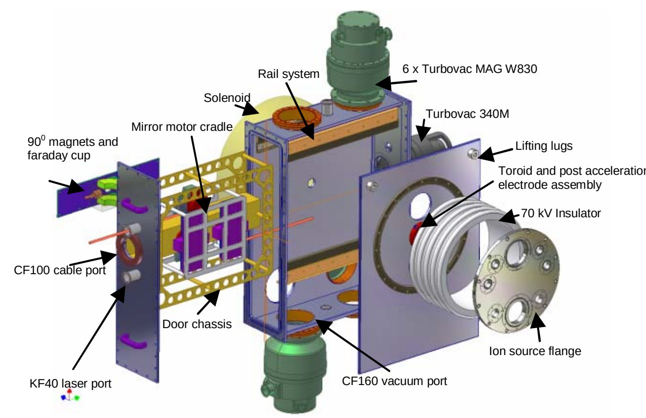

Figure 5: Exploded view of the beam profile measurement system inside the ion source vessel.

Figure 6: Ion source vessel in situ.

The ion source vessel contains a laser wire beam profile measurement system [5]. It also supports all the turbo pumps and pressure gauges. The vessel incorporates a differential pumping stage. Several ports are included for electrical feedthroughs for connection to the post acceleration electrode assembly.

HIGH VOLTAGE PLATFORM AND CAGE

A 70 kV a high voltage platform is required to support the ancillary equipment required to operate the ion source. This must be surrounded by an interlocked high voltage cage for personnel protection (Figure 7). The platform is supported using commercially available post insulators and has a handrail to allow safe working.

Figure 7: The high voltage cage and 70 kV high voltage platform.

An in-house built 70 kV DC power supply is used to energise the platform and a 1 μF capacitor is used to minimise droop during the beam pulse. Platform voltage is monitored using a voltage divider and an automatic dumping system is used to earth the platform.

Figure 8: The 70 kV platform power supply.

Two oil-filled 70 kV isolating transformers are used to provide single and three phase power to the ancillary equipment on the platform.

ANCILLARY EQUIPMENT

The ion source requires numerous ancillary equipment to operate. This is all mounted in four racks on the high voltage platform. The layout of these racks is shown in Figure 9.

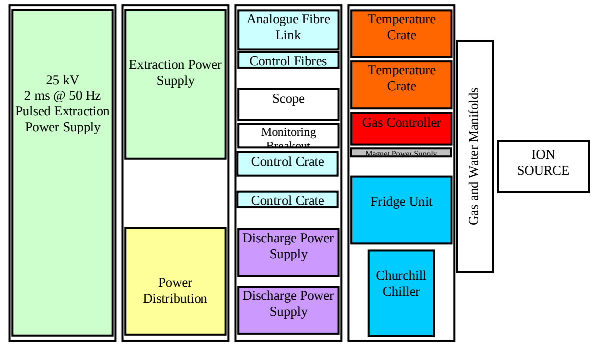

Figure 9: The layout ancillary equipment racks for FETS.

A new 25 kV (10% d.f. at 50 Hz) extraction voltage power supply has been developed, based on the standard ISIS design but using a larger TRITON 8960 tetrode tube. Danfysik DC and pulsed power supplies are used to power the source plasma discharge. New temperature controller crates have been built including extra temperature channels for additional monitoring. The rest of the equipment (H_2 controller, fridge unit, water chiller, monitoring and control) are standard ISIS items. Manifolds are used to distribute the cooling water, compressed air and hydrogen.

OUTLOOK

At the time of writing the installation is nearly complete. First beam should be produced in summer 2008. A magnetic LEBT will be installed shortly thereafter.

REFERENCES

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