STATUS OF THE RAL FRONT END TEST STAND

A. Letchford, M. Clarke-Gayther, D. Faircloth, S. Lawrie, ISIS STFC RAL, Didcot, UK
C. Gabor, C. Plostinar, ASTeC STFC RAL, Didcot, UK
A. Garbayo, AVS, Eibar, Gipuzkoa, Spain
S.Alsari, M. Aslaninejad, A. Kurup, P. Savage, Imperial College of Science and Technology, London, UK
J. Pozimski, STFC RAL, Didcot, UK & Imperial College of Science and Technology, London, UK
G. Boorman, A. Bosco, Royal Holloway University of London, Surrey, UK
S. Jolly, University College London, London, UK
J. Back, University of Warwick, Coventry, UK

Abstract

The Front End Test Stand (FETS) under construction at RAL is a demonstrator for front end systems of a future high power proton linac. Possible applications include a linac upgrade for the ISIS spallation neutron source, new future neutron sources, accelerator driven sub-critical systems, a neutrino factory etc. Designed to deliver a 60mA H-minus beam at 3MeV with a 10% duty factor, FETS consists of a high brightness ion source, magnetic low energy beam transport (LEBT), 4-vane 324MHz radio frequency quadrupole, medium energy beam transport (MEBT) containing a high speed beam chopper plus comprehensive diagnostics. This paper describes the current status of the project and future plans.

FRONT END TEST STAND

Originally conceived simply as a chopper beam test, FETS has since expanded its objectives to become a generic test stand for technologies related to the front end of several proposed projects which require a high power proton driver. These projects include but are not limited to ISIS upgrades, future Spallation Neutron Sources, a Neutrino Factory, Muon Collider, Accelerator Driven Sub-critical Systems and Waste Transmuters.

FETS has been extensively described elsewhere [1][2]. It consists of an H^- ion source, magnetic low energy beam transport (LEBT), 324 MHz Radio Frequency Quadrupole accelerator (RFQ), medium energy beam transport and chopper line (MEBT) and comprehensive diagnostics. The rest of this paper describes the status and future plans for each component of the test stand.

FETS STATUS

Ion Source

FETS uses a Penning Surface Plasma H^- Ion Source [3]. A programme of continuous development over many years has resulted in source performance which is very close to the demanding FETS specification [4][5][6][7].

Parametric studies of the source indicate that the current configuration is already delivering close to its maximum performance [8]. Increases in the extraction voltage are limited by saturation in the sector magnet and power supply limitations. The discharge current can be increased up to 100A but does not lead to a commensurate increase in beam current. Figure 1 shows the variation in beam current with discharge current.

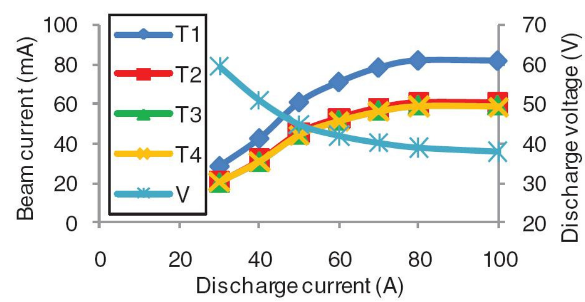

Figure 1: Ion source beam currents and discharge voltage vs discharge current.

Although 80 mA is routinely achievable at the source output a combination of beam stripping and collimation in the pumping vessel means that only 60 mA can be successfully delivered into the LEBT. Pulse lengths of up to 2 ms at 60 mA have been achieved with some droop seen in the current, possibly due to depletion of surface Caesium during the long pulse.

Spectroscopic studies of the light from the source discharge are leading to a better understanding of the processes involved in ion formation and destruction [9]. Stripping of negative ions by hot electrons limits the output current for dense discharges. A scaled source with larger discharge volume will be constructed to help mitigate these effects.

LEBT

FETS employs a three solenoid magnetic LEBT to transport and match the beam from the ion source into the RFQ [10][11]. Figure 2 shows the layout of the LEBT.

An extensive study of the effects of ion source, post-acceleration and solenoid parameters on the beam current and emittance has been undertaken [12]. This investigation has shown that a 60 mA beam with the correct phase space orientation to be matched into the RFQ can be successfully transported through the LEBT [13]. The emittance still exceeds the FETS requirement however a strategy to reduce it further is under development.

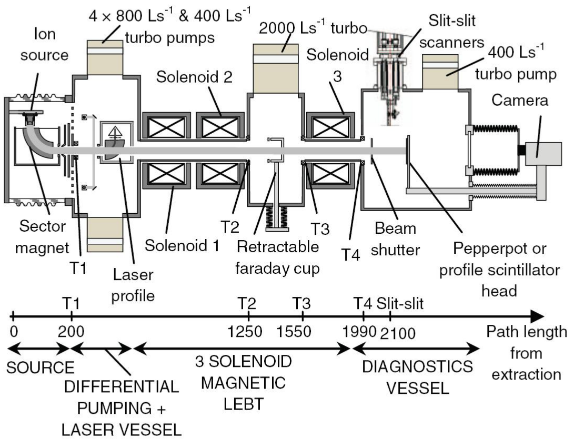

Figure 2: A schematic of the FETS LEBT beam line.

An electrostatic residual gas ion spectrometer has been commissioned in the LEBT to investigate the space charge compensation process [14]. A new finite element code to simulate the beam-gas interactions is under development.

Radio Frequency Quadrupole

The FETS RFQ is a 324 MHz, 4-vane with a final energy of 3 MeV and a total length of ~4.0m.

The RFQ vane modulation design has been completed using the integrated design method described in [15]. Beam dynamics simulations in GPT have shown excellent agreement between those using the approximated field maps from the RFQSIM modulation parameter generation and more sophisticated electrostatic field maps produced with Comsol. These Comsol field mapping simulations, based upon the CAD model of the real RFQ, have also allowed the machining and alignment tolerances to be estimated with the tightest tolerances - in the region of 20 microns - reserved for the machining of the vane tip modulations. Extensive simulations have been carried out with mis-alignmeed CAD models to provide guidance on the final RFQ assembly alignment tolerances, both vane-to-vane and section-to-section.

It has been decided to manufacture the RFQ as a bolted, braze-free structure employing a 3D o-ring for the vacuum seal [16]. The 4m long cavity consists of 4 sections made up of 2 major and 2 minor vane segments. Machining of the copper is currently underway with rough machining of all sections complete and the final surface cut on the first section just commencing having completed tool wear tests [17]. Figure 3 shows the RFQ during manufacture.

MEBT

The beam chopper and associated beam dumps are located in the MEBT. Achieving low emittance growth under the influence of strong, non-linear space charge in a lattice which has to accommodate the long chopping elements – which inherently break the periodicity of the

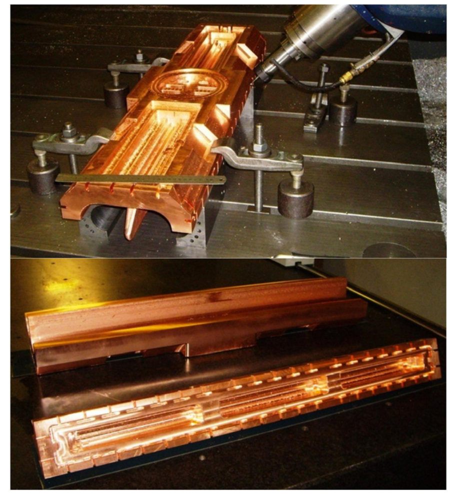

Figure 3: Parts of the FETS RFQ during machining.

lattice – is challenging. The baseline FETS MEBT design [18] is 4.5m long and contains 11 quadrupoles, 4 rebunching cavities, a fast and slow chopper deflector and two beam dumps. Initial particle dynamics simulations using a distribution from an RFQ simulation as input indicated that the emittance growth is no more than 5% in the transverse plane. Beam loss for the un-chopped beam is ~1.5% while the chopping efficiency is ~99%. More detailed simulations using field maps for the MEBT components are currently underway. Figure 4 shows an engineering layout of the MEBT.

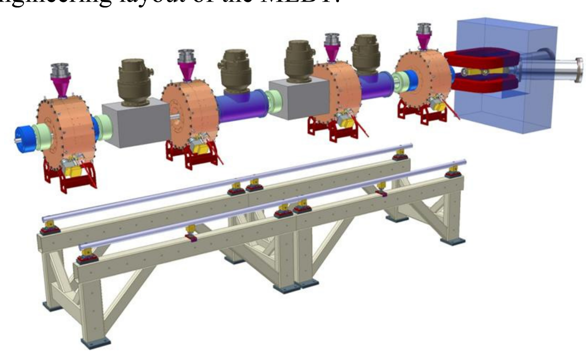

Figure 4: Engineering layout of the FETS MEBT.

Chopper

The FETS fast-slow beam chopper has been described in detail in [19]. This novel combination of two distinct chopper types, working in tandem, allows both very fast rise time and long flat-top pulses to be generated without losing the fidelity of the sharp pulse edges as the wave propagates through the deflector.

New 3D models of the helical and planar 'short length' prototypes are being developed in the CST Microwave Studio Code, following the results of a study on the dimensional optimisation of the strip - line structures [20].

A scheme to address the non–adjustable nature of the planar electrode delay has been identified. The delay of the structure can be adjusted by configuring the strip-line in four discrete 'blocks' coupled by three coaxial links. Varying the length of these links will enable the total

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delay to be adjusted. A 3D layout has been designed and drafted. An alternative micro-strip on ceramic structure, that may prove to be a more cost effective design, is also being developed.

Progress has been made with the design and testing of a master timing system that will be phase locked to the FETS 324 MHz RF reference source. Figure 5 shows a schematic of the chopping system layout and timing.

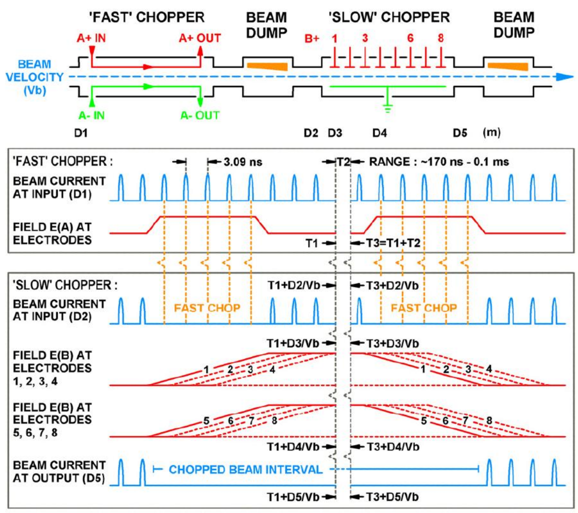

Figure 5: FETS chopper timing schematic.

Diagnostics

Due to the relatively high beam power at FETS, non destructive diagnostic methods are under investigation. In particular laser photo-detachment methods are being pursued as they are well suited to H^- beams [21]. Maximum entropy is a promising method for tomographic reconstruction from measured profiles and is being jointly investigated by PSI and FETS [22].

In addition a new, compact wire scanner capable of resolving 2D profiles in x-y space is under investigation [23]. Tests of this device in the LEBT are currently underway.

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