STATUS OF THE RAL FRONT END TEST STAND

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Abstract

The Front End Test Stand (FETS) under construction at RAL is a demonstrator for the 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 and non-destructive photo-detachment diagnostics. This paper describes the current status of the project and future plans.

FETS

Although FETS was originally conceived as a chopper beam test, and this continues to be the primary objective, the project 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, a Muon Collider and Accelerator Driven Systems.

FETS has been described in detail in various publications eg [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 line (MEBT), high speed beam chopper 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].

The ion source is routinely and reliably operated for LEBT studies and delivers 60 mA at 50 Hz to the RFQ injection point with an emittance close to the specification. Recent developments as part of a PhD study have indicated how up to 100 mA can be extracted from the source in the absence of the 90° sector magnet. Figure 1 shows extracted beam current under different operating conditions for the development source.

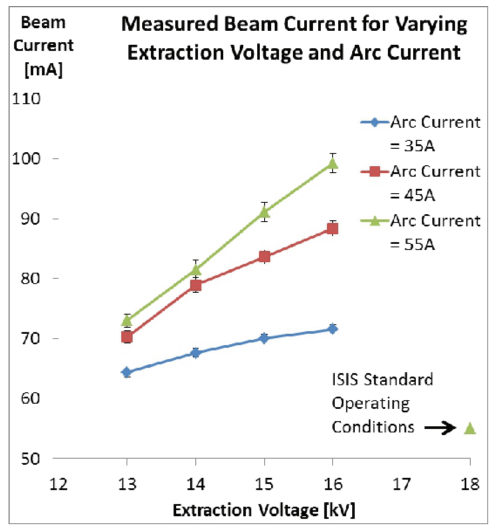

Figure 1: Development ion source beam current.

Although it's too early to know if all of the 100 mA could sensibly be transported through a LEBT these results offer encouragement that the FETS requirement of 60 mA might be produced with a lower discharge current thereby increasing the source lifetime.

A new 25 kV pulsed extraction power supply, capable of operating at the full FETS duty cycle of 10% at 50 Hz, has recently been commissioned [8]. This development should also increase extracted beam current for a given discharge current.

LEBT

FETS employs a three solenoid magnetic LEBT to transport and match the beam from the ion source into the RFQ [9]. Using the suite of installed diagnostics available until the RFQ is installed, the LEBT performance has been comprehensively characterised [10].

An issue that has proved difficult to remedy is a significant offset of the beam, at times >10 mm, at the end of the LEBT. Following a complete re-survey of the LEBT and extensive measurements the misalignment has been traced to unrepeatability of the ion source flange mounting. An engineering solution will be implemented in the near future. However, despite tracing the source of the mis-steer, attempts to model the LEBT have

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consistently led to significant discrepancies with measurement. Figure 2 shows the differences in the beam centre behaviour between measurement and simulation.

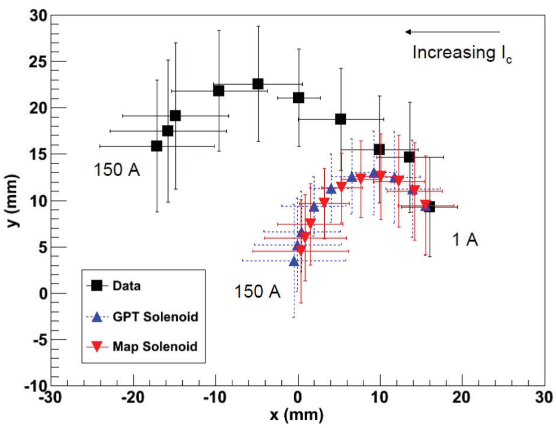

Figure 2: LEBT beam centre behaviour in simulation and measurement.

Further investigations are required to understand these differences.

Configurable clearing electrodes and a residual gas ion spectrometer have been installed in the LEBT to allow investigation of the dynamics of the space charge compensation process. The latest results of this ongoing study are presented in [11].

RFQ

The FETS 324 MHz four vane RFQ has an ambitious bolted construction negating the necessity for large scale vacuum brazing [12]. The structure is built from four ~1m long sections, each section made from two 'major' and two 'minor' vane segments joined together with a 3D viton o-ring for the vacuum seal.

Production of the RFQ is well advanced [13]. Machining of the first section is complete and all external features have been machined on the remaining sections. The internal features on the remaining three sections are just awaiting their final cut. Figure 3 shows a test assembly of section 1 in the machine shop. A clean tent has been erected at RAL for assembly and alignment procedures in anticipation of delivery of the first parts.

RF power for the RFQ will come from a Toshiba E3740A klystron via an AFT 3 port circulator. The majority of the RF power transmission will be by WR2300 waveguide with a transition to 6 1/8” coaxial line close to the RFQ where the power will be split to drive the two couplers. The circulator has been tested at low power and the results together with the RF system design are described in [14]. A compact 6 1/8” power coupler has been designed incorporating a Q200.5 cross-linked polystyrene vacuum window. Figure 4 shows the coupler design.

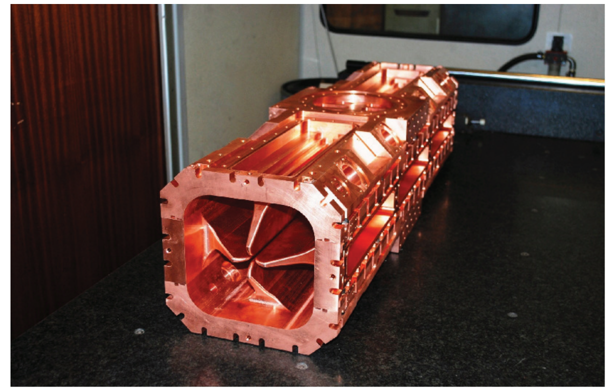

Figure 3: Test assembly of RFQ section 1.

Extensive simulations have been carried out using GPT to map the RFQ input acceptance and determine the optimum LEBT parameters [15].

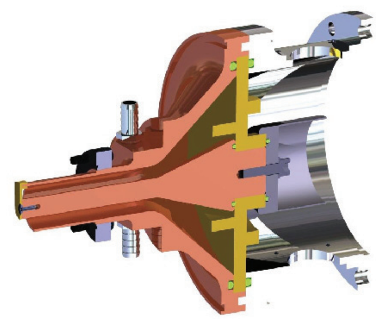

Figure 4: RF power coupler.

Chopper

The FETS fast-slow beam chopper has been described in detail in [16] & [17]. 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.

Having completed functional prototypes of both the planar and helical slow wave structures it has been decided to revisit the microstrip on ceramic option before making a decision on which structure to adopt. Although it is more difficult to maintain pulse fidelity in a microstrip and the field coverage factor is reduced compared to the planar and helical designs, the considerable reduction in complexity and cost is attractive.

MEBT

A well refined baseline design of the medium energy beam transport has been described previously [18]. In an attempt to reduce the number of beamline components and to provide more space for diagnostics, a new lattice design is being investigated [19]. Minimising emittance growth and incorporating the long drifts necessary for the chopper and dumps is challenging. The new MEBT lattice uses 8 quadrupoles and 3 re-bunching cavities operating at 5-10kW peak RF power. Figure 5 shows a beam profile in the revised lattice.

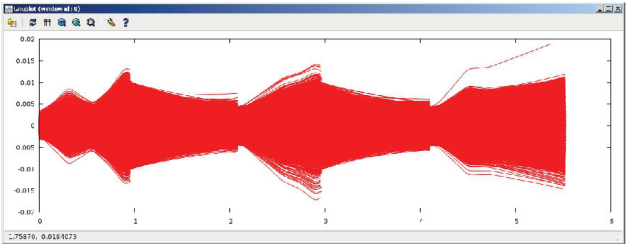

Figure 5: Vertical beam envelope in the alternative MEBT.

Diagnostics

In addition to the Faraday cup and beam current toroids already installed, beam toroids will be fitted to the entrance and exit of the RFQ and placed at strategic positions in the MEBT. The MEBT will also contain beam position monitors (BPMs) and a non-destructive laser photo-detachment emittance measurement demonstrator. With a beam power of almost 20 kW, non-destructive methods are of particular interest on FETS.

The high bandwidth performance of the BPM pickups will enable time of flight measurements in the MEBT. Several pickup designs are currently being evaluated. For the front end electronics the CERN Linac-4 IQ system will be employed [20].

The laser photo-detachment emittance system and associated tomographic reconstruction techniques have been described previously [21][22]. Progress has being made on the specification and design of the dipole magnet system and laser diagnostic vessel [23]. The laser transport system design is well advanced.

FUTURE PLANS

Although the current phase of FETS only covers generating and chopping a 3 MeV, 60 mA H^- beam consideration is being given to possible future applications or developments of the test stand. Ideas range from utilising the 3 MeV beam for technology development to boosting the energy with a CH or IH structure or even adding a high current FFAG test ring for beam dynamics studies[24].

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