CURRENT STATUS OF THE RAL FRONT END TEST STAND (FETS) PROJECT

A. Letchford, M. Clarke-Gayther, D. Faircloth, S. Lawrie, STFC/ISIS, Rutherford Appleton Laboratory, Harwell, UK

S. Alsari, M. Aslaninejad, A. Kurup, J. Pozimski, P. Savage, Imperial College of Science and Technology, London, UK

C. Gabor, C. Plostinar, STFC/ASTeC, Rutherford Appleton Laboratory, Harwell, UK

G. Boorman, A. Bosco, Royal Holloway University of London, London, UK

S. Jolly, University College London, London, UK

J. Back, University of Warwick, Coventry, UK

A. Garbayo, AVS, Eibar, Gipuzkoa, Spain

Abstract

The UK proton accelerator strategy aims to develop a viable high power proton driver with applications including spallation neutrons, the neutrino factory and ADSR. An essential first ingredient, identified as one of the main UK R&D accelerator projects, is the Front End Test Stand (FETS) at the Rutherford Appleton Laboratory (RAL), aimed at producing a high quality, high current, cleanly chopped H^- beam. Through its component parts, FETS has triggered development of a high brightness, 60 mA H^- ion source, a three-solenoid Low Energy Beam Transport line (LEBT), a 3 MeV four-vane Radio-Frequency Quadrupole (RFQ) and a Medium Energy Beam Transport line (MEBT) with a high speed chopper. The project is well advanced and when operational should be sufficiently versatile to explore a range of operating conditions. In this paper we present the current status of the construction, and plans for operation, experiments and future development.

THE FRONT END TEST STAND

The Front End Test Stand was first proposed nearly a decade ago [1], as a demonstrator for fast, high quality beam chopping. Since then, FETS has become the main proton R&D project in the UK, being a collaborative effort between Rutherford Appleton Laboratory where it is being built, and several universities as well as international partners [2]. FETS is of high relevance for the next generation of high power proton accelerators that are aiming to deliver beam powers in the megawatt range, in particular, the ISIS upgrade plans [3] and the UK neutrino factory design efforts [4].

A schematic FETS layout can be seen in Figure 1. It consists of five main components: an H^- ion source, a LEBT based on three solenoids, a 3 MeV RFQ, a MEBT with a fast chopping system and a wide-ranging set of diagnostics. When completed it will deliver a 60 mA, 2 ms, 50 Hz chopped beam at 3 MeV [5]. With the commissioning efforts in full swing, in this paper we will briefly present the current status of each section, highlighting recent progress as well as future plans.

ION SOURCE

A Penning surface plasma H^- ion source is used in FETS. The source is a modified version of the existing ISIS ion source that has successfully been used in routine operation for nearly 30 years. To meet the FETS requirements, a systematic development programme was started several years ago. This has led to a number of modifications including: geometry changes, transport optimisations, cooling improvements, power supply upgrades and operating parameter investigations.

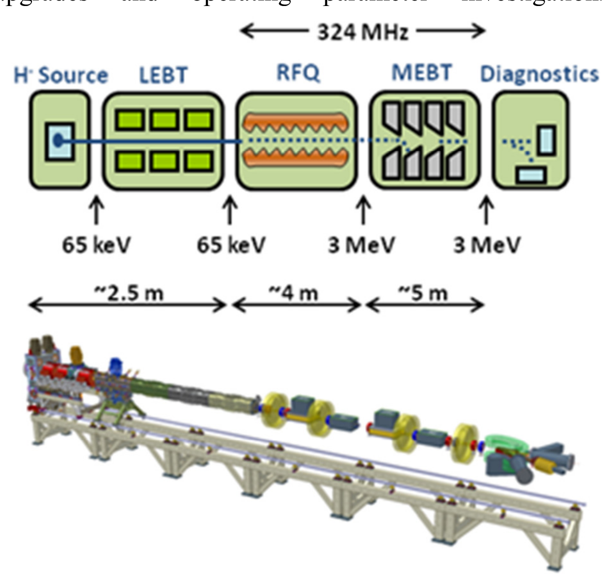

Figure 1: Schematic FETS layout.

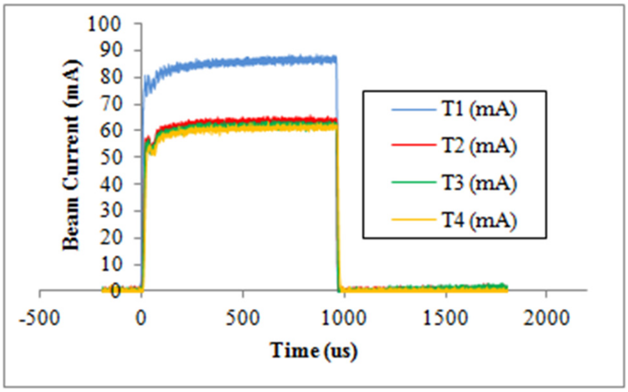

Figure 2: 1 ms beam current profiles at 50 Hz, at different positions: ion source (T1), inside the LEBT (T2, T3) and LEBT output (T4).

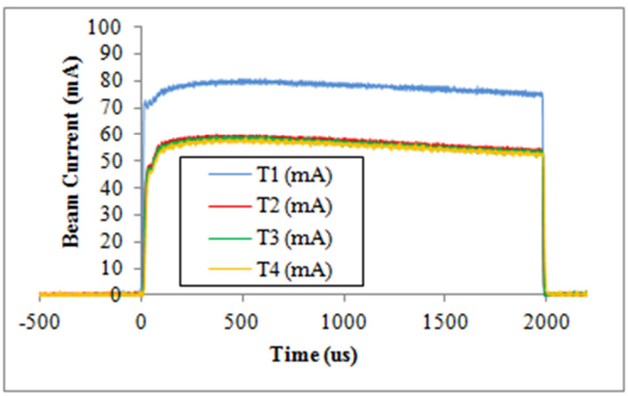

Figure 3: 2 ms beam current profiles at 25 Hz.

As a result, the ion source is now very close to delivering the FETS specifications [6].

However, not all the operating parameters have been met simultaneously. While the source can routinely produce 80 mA beams (see Figure 2), a significant droop in the H^- beam current can be seen for pulse lengths above 1 ms, at 50 Hz. By retuning the ion source and reducing the repetition rate to 25 Hz, 2 ms pulse lengths have been achieved (see Figure 3) [7].

To overcome this limitation, a new set of developments is under way, aimed at gaining a deeper understanding of the processes involved in the plasma formation. These include optical spectroscopy studies [8], plasma modelling simulations as well as geometry modifications with the intention of having a larger discharge volume by scaling the source [9].

LEBT

The LEBT design is based on the existing ISIS LEBT. It consists of three solenoids separated by drift sections of various lengths as it can be seen in Figure 4 [10]. Detailed and extensive parametric studies have been performed in order to understand the optimal operating parameters and the effects of the ion source. At present, a beam loss of ~20% is observed between the ion source and the first pumping vessel. However, the LEBT is capable of

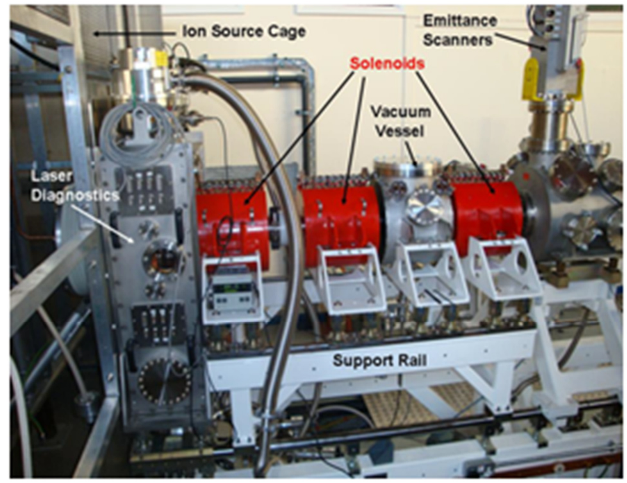

Figure 4: LEBT setup overview.

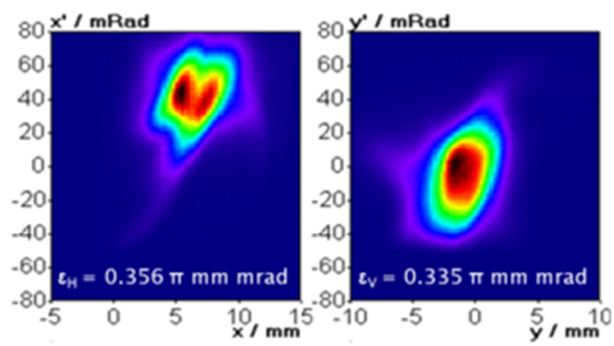

Figure 5: Measured LEBT output beam.

transporting the remaining beam with nearly 100% transmission, such that matched 60 mA beams can be effectively delivered at the input of the RFQ. Figure 5 shows the measured phase space distribution of the beam at the end of the LEBT. The normalised RMS emittance is larger than the FETS requirements and work is in progress to reduce it further [11], [12].

The LEBT is also being used for generic studies on the space charge compensation process. Preliminary results have already given an indication of the degree of variation of the Twiss parameters with time throughout the pulse, a process that can lead to beam mismatch. In addition, the recently installed residual gas ion spectrometer is expected to allow a direct measurement of the beam potential and a much more detailed analysis of the beam transport conditions [13].

RFQ

The RFQ has been designed and optimised using an innovative method which integrates the CAD design with the 3D electromagnetic modelling and the beam dynamics simulations within a single simulation framework [14]. The result is a 4 m long, 4-vane RFQ, operating at 324 MHz with a final energy of 3 MeV. Simulation efforts have concentrated on benchmarking the new method against results obtained with RFQSIM [15]: a good agreement has been observed in both transmission

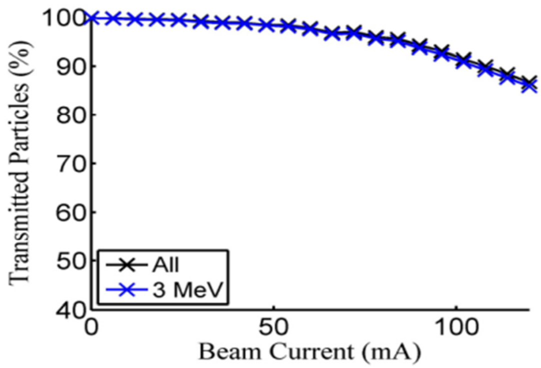

Figure 6: RFQ beam transmission.

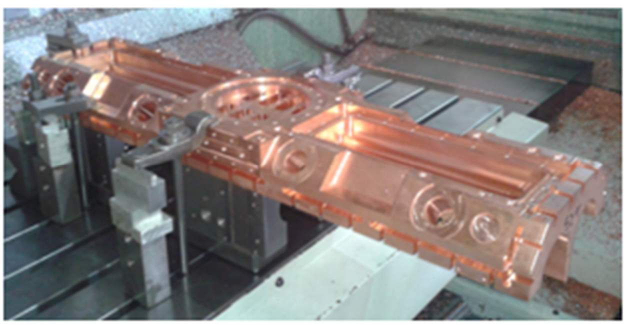

Figure 7: RFQ vane being manufactured.

and acceptance. For nominal RFQ input parameters, beam transmission is above 97% (Figure 6), while the RMS emittance growth is relatively small (< 20%) and largely independent of the beam current. In preparation for manufacturing, detailed studies have also been performed in order to estimate the machining and alignment tolerances.

With the design completed, the RFQ is currently being manufactured as four, 1 m long, separate sections. All the copper segments have been rough machined to +2 mm in order to discover the optimum finishing cut parameters, while the first section has already been finished to the final geometry and will be assembled, aligned and installed in the near future (Figure 7). This will allow us to gain a deeper understanding of the commissioning process before proceeding to install the remaining sections. The manufacturing of the RFQ ancillary equipment is well advanced [16], [17].

MEBT, CHOPPER AND DIAGNOSTICS

The MEBT baseline design consists of a series of quadrupoles, re-bunching cavities and the beam chopping system with its dedicated beam dumps. The lattice design is particularly challenging as it has to address two conflicting requirements: provide strong uniform focussing to maintain the beam quality under the influence of strong, non-linear space charge forces, while making available sufficiently long drifts for the chopping elements. Simulations indicate that beam loss can kept to ~1.5% with a nearly 100% chopping efficiency [18], [19].

More recently, a new lattice has been proposed that has the advantage of having fewer elements and therefore a reduced construction cost while offering more space for diagnostics (Figure 8). Optimisation work on improving the beam transmission is ongoing while efforts are being put into designing a suitable chopper beam dump.

The chopping system uses an innovative "fast-slow" deflection scheme. It is a tandem combination of fast transition time, short duration and slow transition time, long duration choppers. The "fast-chopper" removes 3 adjacent bunches at the beginning and at the end of the chopping interval, creating 2 gaps in the bunch train that will be used by the "slow-chopper" as a transition interval, thus preventing bunches being partially chopped. Work has been progressing well on electrode design, modelling and prototyping as well as on testing the master timing system [20].

On the diagnostics side, in addition to the standard MEBT diagnostics, progress has been made on designing an emittance measurement instrument to be located at the end of the MEBT. Non-destructive methods are under consideration, in particular laser photo-detachment. Tomographic reconstruction techniques from measured profiles are also being investigated [21].

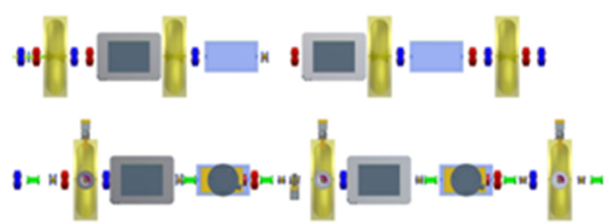

Figure 8: Schematic MEBT baseline layout (top) and a proposed alternative design (bottom).

REFERENCES

[1] D. Findlay et al., Proc. of NuFact'04, p. 323.
[2] A. Letchford et al., Proc. of IPAC'12, THPPP051.
[3] J. Thomason et al., Proc. of HB'08, WGE15.
[4] S. Choubey et al., RAL-TR-2011-018.
[5] A. Letchford et al., Proc. of IPAC'10, MOPEC075.
[6] D. Faircloth et al., Rev. Sci. Instrum. 81, 02A721.
[7] D. Faircloth et al., Rev. Sci. Instrum. 83, 02A701.
[8] S. Lawrie et al., Rev. Sci. Instrum. 83, 02A704.
[9] D. Faircloth et al., Proc. of NIBS'2012, O-3 08.
[10] J. Back et al., Proc. of IPAC'10, MOPEC078.
[11] C. Gabor et al., Rev. Sci. Instrum. 83, 02B719.
[12] C. Gabor et al., Proc. of IPAC'12, MOPPR056.
[13] J. Pozimski et al., Proc. of IPAC'12, MOPPD037.
[14] S. Jolly et al., Proc. of IPAC'10, MOPEC076.
[15] J. Maus et al., Proc. of EPAC'08, TUPP099.
[16] P. Savage et al., Proc of IPAC'10, MOPD056.
[17] P. Savage et al., Proc of IPAC'12, THPPP053.
[18] C. Plostinar, Proc. of IPAC'10, MOPD059.
[19] C. Plostinar et al., Proc of IPAC'11, WEPC039.
[20] M. Clarke-Gayther, Proc. of IPAC'10, WEPD095.
[21] C. Gabor et al., Proc. of DIPAC'09, TUPB022.