STATUS OF THE FETS PROJECT

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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, high energy physics proton drivers 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 laser diagnostics. This paper describes the current status of the project and future plans.

FRONT END TEST STAND

FETS was originally conceived as a chopper beam test facility but has since expanded its objectives to become a generic test stand for high power proton accelerator front end technologies. Applications 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 4-vane 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.

ION SOURCE

FETS uses a Penning Surface Plasma Source (SPS) [3]. A programme of continuous development over many years has resulted in source performance which is very close to the demanding FETS specification [4].

Recent developments include new sector magnet poles design to allow higher fields with less aberration [5], a new high voltage extraction power supply capable of 25 kV at the full 10% duty factor [6] and a redesigned downstream post-acceleration system which results in a considerably less divergent beam entering the LEBT. The beam emittance is now ~0.35 π mm mrad, still higher than the ideal value but much reduced over earlier values.

LEBT

The FETS LEBT consists of three identical magnetic solenoids with maximum on axis field of 0.4 T. Previous studies had shown high beam currents of up to 60 mA at the end of the LEBT with a reasonably small rms-emittance. However, large offsets of ~10mm in position and ~10 mrad in angle were observed in both transverse planes. These were traced to a lack of repeatability in mounting the ion source assembly following source changes or maintenance. An improved datum and alignment system has largely corrected this and although a perfect alignment cannot be achieved due to the length of ~2 m, minor offsets can be corrected with the dipole steerers integrated into the solenoids.

An extensive parametric evaluation of the LEBT has shown that a well aligned, well matched beam can be delivered to the RFQ injection point [7][8].

RFQ

The FETS RFQ is a 324 MHz, 4-vane type with a final energy of 3 MeV and a total length of ~4.0m. It employs a bolted, braze-free construction with a 3D O-ring for the vacuum seal and RF finger contacts [9]. The 4m long cavity consists of 4 sections each made up of 2 major and 2 minor vane segments.

Manufacturing of the RFQ is well advanced [10]. Following delivery of the first section to RAL, inspection showed a manufacturing error resulting in a transverse and longitudinal shift of the vane modulations. This error was traced to a changed datum setting in the 5-axis CNC machine. Although simulations showed that the effect on the beam dynamics would have been acceptable the resulting resonant frequency shift cannot be compensated for. Fortunately the internal surfaces can be re-machined and both major and minor vane segments recovered. Machining of sections 2, 3 & 4 is almost completed.

Resonant frequency measurements of section 1, including the error, showed good agreement with modelling confirming the inspection results. The first bead pull measurements on section 1 with tuneable end flanges have started.

MEBT

The beam optics design of the Medium Energy Beam Transport has been fixed for some time [11]. The first part

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of the MEBT consists of 7 small bore quadrupole magnets and 3 re-bunching cavities. The re-bunching cavities have an elliptical as opposed to circular beam aperture in the accelerating gap region to better match the beam shape and improve transmission. Beam dynamics simulations show transmission >99% using a realistic distribution obtained from RFQ modelling and field maps for the MEBT components [12]. The second part of the MEBT which accommodates the laser diagnostic consists of 6 large bore quadrupoles, the diagnostic dipole magnet and laser interaction vessel. The MEBT also houses the fast and slow choppers with their respective beam dumps.

The small bore quadrupoles are in manufacture. The cavity design is complete with manufacturing about to commence. The large bore quadrupoles are designed and costed with the order to be placed in the next FY. The engineering design for the first part of the MEBT is essentially complete with many parts either purchased or in manufacture.

BEAM CHOPPER

The FETS fast-slow beam chopping concept has been extensive described elsewhere [13]. Comprehensive modelling and proto-typing has demonstrated that both the planar and helical fast chopper structures can meet the challenging specification. A decision on which method to implement will be made in the near future following an assessment of the manufacturing processes and costs. All parts for the fast and slow high voltage electronic switches have been procured as have the major components of the timing system.

Thermal analysis of the chopper beam dumps has demonstrated the feasibility of the simple inclined plate design [14]. An analysis of the shock effects resulting from the micro-bunch structure is underway.

DIAGNOSTICS

Diagnostics in the MEBT will consist of beam current transformers, beam position monitors (BPMs) and a laser photo-detachment emittance measurement system.

The toroidal current transformers have been manufactured and tested. Two types of BPM are under consideration: the CERN Linac4 shorted stripline design and a FETS designed compact button type [15]. The button BPM has been prototyped and six production models manufactured. Both BPM types share common analogue front end electronics and FPGA IQ sampling. The first front-end electronics and digital processing module has been constructed and fully evaluated. A wire test rig has been constructed and the prototype button BPM measured, indicating that it can achieve the desired 100 µm resolution [16].

Beam emittance in the MEBT will be measured using a photo-detachment laserwire system [17]. Simulations have shown the feasibility of such a system [18] and a proof-of-principle experiment has been carried out in collaboration with CERN on the 3 MeV Linac4 test stand [19] which showed excellent agreement with traditional methods. This experiment is to be repeated at 12 MeV following installation of the first DTL tank.

RF SYSTEM

RF power for the RFQ will come from a Toshiba 324 MHz klystron. The klystron, power supplies, modulator, circulator and first part of the WR2300 waveguide system have been installed. The circulator has been tested at low power. The waveguide will transition to 6" coaxial line close to the RFQ where it will split to feed two power couplers [20]. The coupler design is complete and all remaining parts of the RF distribution system have been procured.

The MEBT re-bunching cavities will each be driven by an 8kW solid-state RF amplifier. Three amplifiers have been purchased from DB Science Italy and tested to full power and duty factor [20].

INFRASTRUCTURE

Most of the electrical infrastructure is already installed in the FETS building at RAL. Two water cooling systems have been installed: a magnet and beam dump water system which is cooled by the site tower water via heat exchangers and a temperature controlled water system incorporating chillers to achieve high stability for the RFQ and re-bunching cavities.

Considerable effort has gone into reducing the possible radiological hazard from FETS. Wherever possible neutron producing materials have been excluded from beam facing components. The high beam power however means that significant fluxes of gamma rays will be present particularly from the beam dumps. To protect personnel from the radiation FETS will be enclosed in a concrete shielding bunker constructed from commercially available, interlocking concrete blocks. The shielding design is complete and has been approved. The concrete blocks have been procured and construction will start in summer 2014.

FUTURE OF FETS

The primary function of FETS is as an accelerator research and development facility. However the high power beam which will be available when FETS becomes operational is a potentially valuable resource and ways to exploit it are being actively pursued.

Interest in using the FETS beam has been shown by the fusion materials, BNCT, medical isotope and chip irradiation communities. Discussions are underway to explore funding and exploitation opportunities.

None of these opportunities should interfere with FETS continuing to be the UK's primary proton accelerator hardware R&D facility and options for future expansion are being discussed. Possibilities include the addition of one or more CH structures to increase the beam energy to 15-20 MeV which would also open up more possibilities for exploitation. A low energy proton FFAG demonstrator is also under consideration.

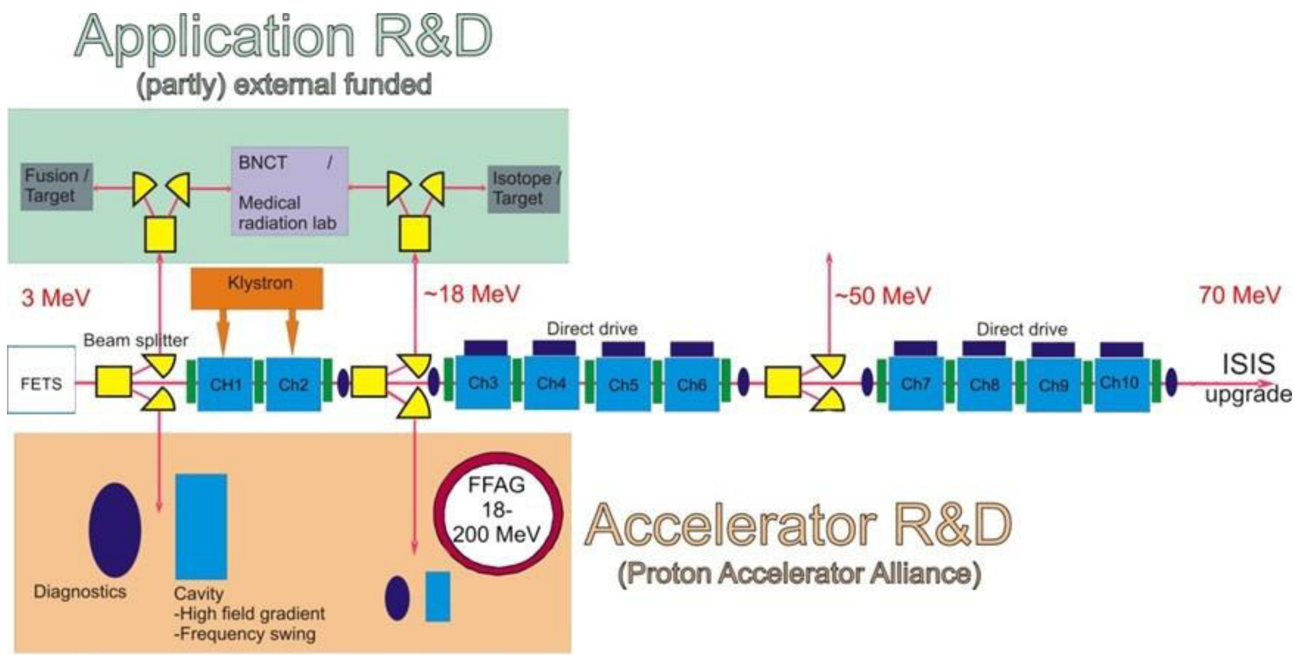

Figure 1: An idealised conceptual layout showing how FETS might be developed and exploited.

Figure 1 shows an idealised conceptual schematic of how a fully exploited FETS might develop in the future subject to funding and strategic goals. Strategy is being developed through the UK's Proton Accelerators for Science and Innovation Alliance.

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