STATUS OF THE RAL FRONT END TEST STAND

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Abstract

High power proton accelerators (HPPAs) with beam powers in the several megawatt range have many applications including drivers for spallation neutron sources, neutrino factories, waste transmuters and tritium production facilities. The UK's commitment to the development of the next generation of HPPAs is demonstrated by a test stand being constructed in collaboration between RAL, Imperial College London, the University of Warwick and the Universidad del Pais Vasco, Bilbao. The aim of the RAL Front End Test Stand is to demonstrate that chopped low energy beams of high quality can be produced and is intended to allow generic experiments exploring a variety of operational conditions. This paper describes the current status of the RAL Front End Test Stand.

BACKGROUND

Beam chopping will be an important feature of the next generation of HPPAs. The requirement to minimise the need for remote handling of accelerator components dictate that beam loss in future machines must be kept to levels comparable to those of current facilities in order to avoid activation. With beam powers an order of magnitude or more greater than those currently achieved, fractional beam loss must necessarily be reduced by a similar factor.

Beam Chopping

In circular machines a significant source of beam loss occurs when the continuous linac beam is trapped and bunched in the ring RF bucket. Trapping efficiency can be improved with higher harmonic RF systems but to achieve the improvements necessary for MW scale beams, the linac beam must be chopped at the ring revolution frequency. This chopped beam allows for the ring RF bucket to be precisely filled with little trapping loss. The low levels of beam between bunches also reduces loss at extraction.

The linac beam has RF structure everywhere downstream of the RFQ, this structure typically being at some 100s of MHz. If the chopping is not precisely synchronised with the linac beam RF bunch structure, partially chopped bunches in the linac can result. With less charge than normal and possibly off axis or off momentum, these partially chopped bunches may lead to beam loss in the linac. The ideal is perfect chopping where the chopper switches on and off in the time between two successive linac beam bunches, typically a few ns. This very fast switching requirement coupled with the increasing stiffness and power of the beam at higher energies dictates that chopping is carried out at the front of the linac, downstream of the RFQ at around 2.5 – 3 MeV.

Front End Test Stand

The RAL Front End Test Stand (FETS) project [1][2][3][4] aims to achieve several goals. The primary goal is to demonstrate a high quality, high current, chopped H^- beam. This objective does not have a single future application in mind but tries to be as generic as possible. FETS is funded by the Science and Technology Facilities Council (STFC) as part of their HPPA and Megawatt Spallation Source programme [5] and as a generic work package of the UK Neutrino Factory (UKNF) project [6].

The secondary goal of FETS is to help promote proton accelerator technology within UK universities and foster international collaborations on HPPA research. High energy and particle physics has been well served by UK universities who are enthusiastic users of accelerator facilities and contributors to detector and physics projects. Accelerator technology has traditionally been less well served however. It is hoped that the FETS collaboration will help to spread STFC's accelerator expertise to UK universities.

TEST STAND COMPONENTS

The front end test stand consists of an H^- ion source, magnetic low energy beam transport (LEBT), 324 MHz RFQ, medium energy beam transport (MEBT) chopper line and comprehensive diagnostics.

Ion Source

FETS will use an ion source based on the well-proven and highly successful Penning type H^- surface plasma source (SPS) [7] which is in routine operation on ISIS producing currents in excess of 50 mA at a duty factor of ~1%. Its use with an RFQ pre-injector has been previously demonstrated [8].

Following previous work which concentrated on increasing the current and duty factor of the source [9][10][11], recent work has focussed on understanding the beam transport and optics with a view to decreasing the emittance to the FETS specification. Considerable experimental and computational effort, using CST EM & Particle Studies [12] plus General Particle Tracer (GPT) [13], is leading to a much better understanding of the beam behaviour [14][15][16]. Figure 1 shows the highly detailed EM model of the source that has been developed.

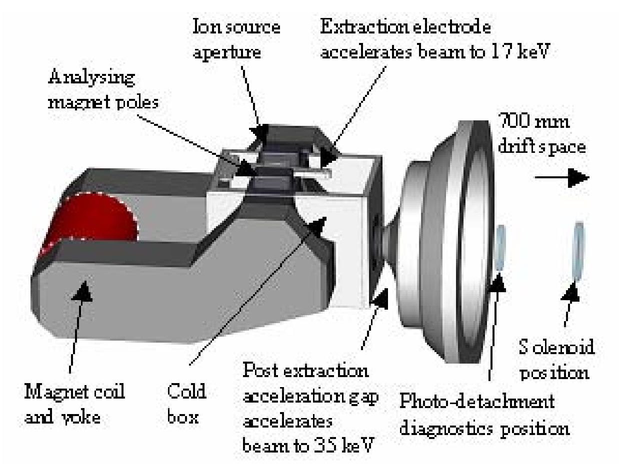

Figure 1: CST Studio Suite 2008 model of the ion source.

In addition to these scientific endeavours, installation of the ion source infrastructure in the FETS building at RAL is nearing completion [17]. Figure 2 shows part of the installation. First beam is anticipated in summer 2008.

Figure 2: The high voltage cage and 65 kV high voltage platform.

Magnetic LEBT

A 3 solenoid magnetic LEBT has been chosen for FETS [18][19]. In part this decision was informed by the successful combination of such a LEBT with the Penning ion source in the ISIS RFQ pre-injector upgrade [8]. An electrostatic Einzel lens LEBT, although offering some advantages, was rejected for this application due to fears about operating such a LEBT in close proximity to the highly caesiated ion source.

Figure 3 shows the simulated beam envelopes in the LEBT, calculated with GPT and based on the latest ion source measurements. Calculations suggest that from 0 – 100% space charge neutralisation can be accommodated by varying the solenoid fields.

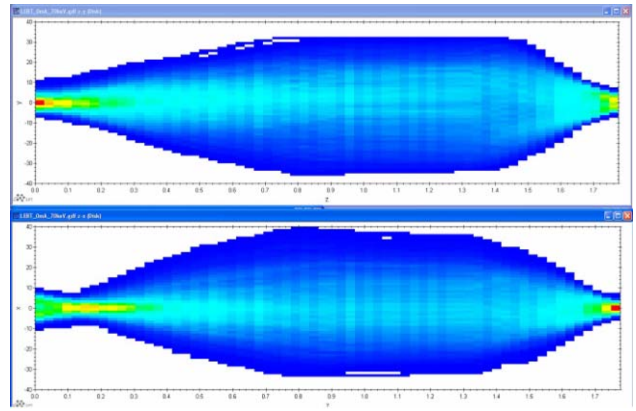

Figure 3: LEBT beam envelopes calculated with GPT.

Manufacture of the solenoids has been completed by Elytt in Spain. Design of the LEBT support structures is complete with installation due by late summer 2008. Figure 4 shows the full LEBT design and one of the completed solenoids.

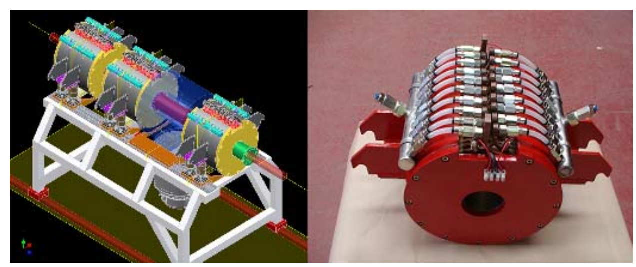

Figure 4: Layout of the FETS LEBT and one of the completed solenoids from Elytt.

RFQ

A frequency of 324 MHz has been chosen for the FETS RFQ, determined by the ready availability of the Toshiba E3740A klystron developed for the JPARC linac [20]. One of these klystrons has been purchased and is at RAL. A contract has been signed for a HV power supply and solid-state modulator from Diversified Technologies, Inc [21] for delivery late in 2008.

A design for a 4-vane RFQ is well advanced with a cold model completed and extensively measured and compared to simulations [22][23][24]. Figure 5 shows the cold model during tests at Imperial College.

MEBT and Chopper

FETS will use the novel fast-slow chopper scheme developed at RAL [25][26]. Having previously demonstrated operation of the ‘fast’ high voltage pulsers, attention has now focussed on the ‘slow’ pulsers [27] and prototyping the slow wave deflector structures [28].

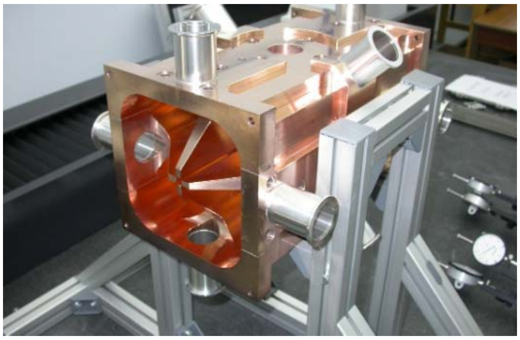

Figure 5: The RFQ cold model under test at Imperial College.

An optical design has been chosen as the FETS baseline for the MEBT. Compact PMQ/EMQ magnets are under investigation [29]. It is hoped to develop cavity cold models soon.

Diagnostics

High quality diagnostics are essential to fully exploit the test stand. In addition to a suite of traditional diagnostics devices, non-destructive laser stripping techniques will also be employed. Non-destructive techniques are attractive due to the high beam power. A laser stripping transverse emittance measurement system is under investigation [30] as is a laser wire beam tomography system for determining beam density profiles [31]. The laser diagnostic vessel is manufactured and ready for installation.

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