

Progress at the RAL Front End Test Stand

J J Back^b, G Bellodi^a, M A Clarke-Gayther^a, D C Faircloth^a, F Gerigk^a, S Jolly^c, A Kurup^c,
A P Letchford^a, J Pozimski^{a+c}, P. J. Savage^c

^aISIS Accelerator Division, Rutherford Appleton Laboratory, Oxon. OX11 0QX, UK

^bDepartment of Physics, University of Warwick, Coventry CV4 7AL, UK

^cDepartment of Physics, Imperial College, London SW7 2BW, UKS

The progress in the design of a proton driver front end test stand at the Rutherford Appleton Laboratory (RAL) in the UK is presented. The aim of the test stand is to demonstrate the availability of well chopped H⁺ beams suitable for future high power proton accelerators.

1. Introduction

High power (MW range) proton accelerators, have many applications, including drivers for spallation neutron sources, neutrino factories, transmuters (for transmuting long-lived nuclear waste products), energy amplifiers and tritium production facilities. For the short pulse operation necessary for neutron spallation sources and neutrino factory drivers, only much lower beam powers have been used so far (0.08MW for PSR and 0.16MW for ISIS) [1]. Both machines use H⁺ injection to accumulate intense short bunches and need an increase of at least a factor of 30 to reach the goal of 5MW for future high power proton accelerators (HPPAs). In order to contribute to the development of HPPAs, to prepare the way for ISIS upgrades and to contribute to the UK design effort on neutrino factories [2], a front end test stand covering a variety of beam current and pulsed distribution regimes is being constructed at the Rutherford Appleton Laboratory (RAL) in the UK.

2. Front End Test Stand

The aim of the RAL front end test stand is to demonstrate the production of a 60 mA, 2 ms, 50 pps chopped beam. The test stand is made up of several main elements: A 60mA H⁺ ion source, a low energy beam transport (LEBT) to match the beam from the ion source into the RFQ, a RFQ for bunching the beam and accelerating it to 3 MeV, a beam chopper and a medium energy beam transport (MEBT) section and a set of beam diagnostics. The RFQ requires 1-2 MW of RF power. The resonant frequency of the RFQ was chosen to be 324 MHz because of the availability of a klystron from Toshiba at this frequency. The schematic set up of the test stand is shown in figure 1. Each of the main elements as envisaged at present will now be described briefly.

2.1. H⁺ ion source

The ion source development program, based on the highly successful ISIS H⁺ ion source at RAL [3], has already showed encouraging results.

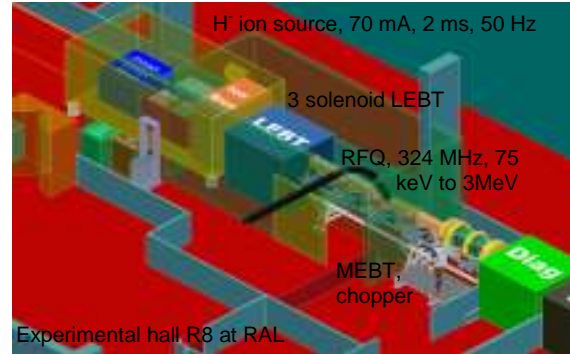


Fig. 1: Schematic drawing of the layout of the RAL front end test stand in R8 at RAL.

The intention is to increase the extracted H⁺ ion current from 35mA to 70mA and to increase the pulse length from 250 μ s to 2 ms. After re-engineering the source on the basis of results from detailed electromagnetic [4] and thermal [5] modelling and upgrading the discharge power supply, the required ion current has already been extracted from the source (as shown in figure 2). The pulse length of the discharge has been increased by a factor of 4. Further improvements including an upgrade of the extraction voltage and improvement of the beam extraction will follow. The work is part funded by the European Union [6].

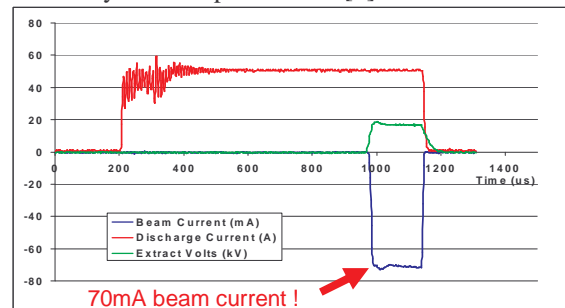


Fig. 2: Arc and extracted beam current as a function of time, measured at the ISIS ion source development rig.

2.2. LEBT

The LEBT will be based on the three-solenoid design of the test stand previously built and operated

at RAL to test the RFQ3. The solenoids will incorporate built-in Lambertson dipoles for beam steering. The LEBT will be designed to produce a good vacuum which is essential to minimise stripping losses of the H⁻ beam. The particle dynamic design of the LEBT using the measured ion source output emittance as the initial particle distribution is nearly finished and experiments to measure the degree of space charge compensation as a function of time are in preparation.

2.3. RFQ

The input and output energies of the RFQ are 75 keV and 3MeV respectively, and the frequency is 324MHz. The modelling of the focussing, bunching and acceleration of the beam through the RFQ is under way as well as the modelling of the electromagnetic properties of a 4-vane and a 4-rod structure. The construction of two cold models is in preparation as well as investigations on the manufacturing process. Measurements of the RF properties of the cold models will start in the beginning of 2006.

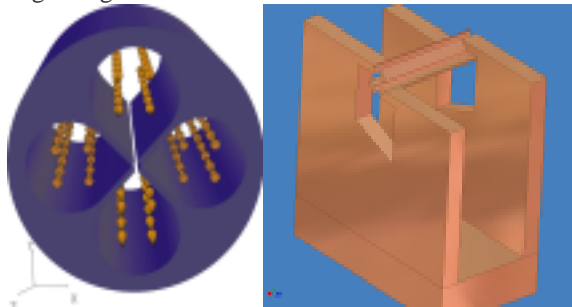


Fig. 3: Models of a 4-vane (left) and 4-rod (right) RFQ. Numerical calculations of the electromagnetic properties of these structures using Mafia, MWS and Superfish have already started.

2.4. Beam Chopper

The bunched beam from the RFQ will be matched into a 3MeV MEFT line consisting of a series of quadrupoles, RF cavities, and a fast beam chopper (see figure 4). The optical design of the MEFT will ensure that emittance growth is minimized. In the presented layout, the efficiency of the beam chopper is enhanced by a defocusing quadrupole in the deflecting plane between the chopper and beam dump.

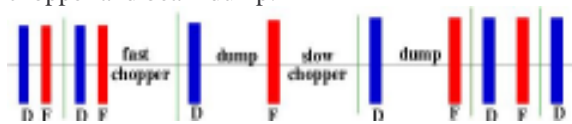


Fig. 4: Schematic layout of the MEFT line with beam chopper.

The chopper design, based on a proposal [7] for the ESS, addresses the challenging requirement for a fast (~2 ns) field transition time, combined with a long (~0.1 ms) chopped beam duration. The chopper will consist of two consecutive chopping mechanisms. The first has a fast transition time (~2 ns) but short duration (~12 ns), with a distributed element (transmission line) electrode. This is followed a lumped element electrode chopper that has a slower transition time (~12 ns) but long duration (~0.1 ms). The fast structure will pre-chop just three bunches at the beginning and end of each chopped beam interval, and will ensure that no partially chopped bunches result from the slower transition time of the slow structure. A prototype of the fast pulse generator has recently been demonstrated [8, 9] and the results are shown in figure 5.

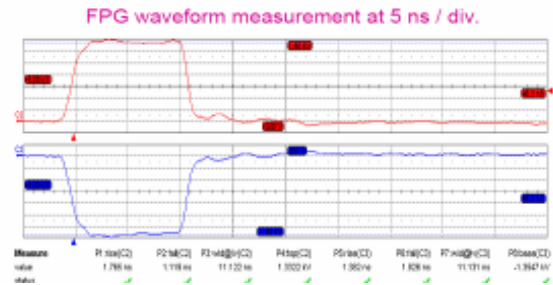


Fig. 5: Measured output voltage of the fast pulse generator as a function of time.

3. Summary

The progress on the front end test stand work at RAL to contribute to the development of high power proton accelerators has been described. Design and development work is well under way, with first beam through the LEBT planned for 2007.

References

- [1.] Neutron News, vol. 15 (2004), ISSN 1044-8632. See also <http://www.isis.rl.ac.uk/>.
- [2.] T R Edgecock, 6th Int. Workshop NeutrinoFactories & Superbeams (NuFact04), July/August 2004, Osaka
- [3.] J W G Thomason and R Sidlow, EPAC 2000, p. 1625.
- [4.] D C Faircloth, J W G Thomason and M O Whitehead, Rev. Sci. Instrum. 75 (2004)1735.
- [5.] D C Faircloth, JWG Thomason, W Lau, and S Yang, Rev. Sci. Instrum. 75 (2004) 1738.
- [6.] EU network HPRI-CT-2001-50021.
- [7.] M A Clarke-Gayther, EPAC'02, p. 2136.
- [8.] M A Clarke-Gayther, EPAC'04, p. 1449.
- [9.] HIPPI/CARE/ESGARD programme, part funded by the EU under FP6.