THE RUTHERFORD RFQ TEST STAND

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Abstract

A facility has been built at the Rutherford Laboratory, Oxfordshire, England, for characterising and testing RFQs. The facility is being used at present for making measurements on an RFQ which has been built as a Frankfurt University / Rutherford Laboratory collaboration and which is intended as a replacement for the existing Cockcroft-Walton preinjector for the ISIS spallation neutron source at the Rutherford Laboratory. Thereafter the facility will be used for making measurements on an ESS RFQ. The design principles, construction details and operational features of the facility are described.

1 CONTEXT

The Rutherford Appleton Laboratory (RAL) is home to the world's leading spallation neutron source ISIS [1]. The ISIS neutron-producing target is driven by an 800 MeV 200 µA proton beam from a rapid cycling synchrotron, which is fed by a 70 MeV H^- linac which in turn accepts beam from an H^- 665 keV Cockcroft-Walton preinjector. It is planned to replace the ageing Cockcroft-Walton preinjector accelerator with a radio frequency quadrupole (RFQ) preinjector accelerator in the expectation that benefits accrued will include significantly improved transmission of beam between the ion source and the linac. However, in the interest of maintaining the excellent operational reliability prevailing at ISIS at present, it is necessary to fully test the RFQ before it can be installed on ISIS. Therefore an RFQ test stand has been built at RAL, and it is described in this paper. The function of the test stand is to provide a radiation-shielded environment in which all the services necessary to run and characterise RFQ accelerators are provided.

The test stand is being used first for the RFQ intended as the replacement preinjector for ISIS. This 4-rod 202.5 MHz RFQ [2,3] has been built by the Institut für Angewandte Physik at the Johann Wolfgang Goethe - Universität in Frankfurt as part of a collaboration between the university and RAL, and preliminary results from this RFQ are being presented elsewhere at this conference [4]. The test stand will then be used for characterising a 2.5 MeV 4-rod 280 MHz RFQ for the front end of the European Spallation Source.

2 DESCRIPTION

A diagram of the test stand is shown in Fig. 1. Apparatus is enclosed within a radiation-shielded room with dimensions ~3 × 3 × 7 metres. The walls and roof of the room incorporate lead sheet to attenuate the X-rays from the RFQ. The roof is removable to facilitate installation and removal of apparatus using a crane. High voltage platforms both inside and outside the room accommodate the requirements of the caesiated H^- ion source. Two demineralised water circuits are provided, one supplying water for the RFQ at a constant temperature from a dedicated refrigerator unit outside the room, and another for general cooling purposes. Comprehensive water flow monitoring arrangements are incorporated. The Frankfurt-RAL RFQ is cooled internally by twenty-four separate water circuits each of which includes a turbine flow meter in its return line. Compressed air is also supplied, with a local reservoir to provide air for a short time in the event of a failure at the distant compressor(s).

X-rays are produced by an RFQ when electrons are accelerated between rods and then are stopped in rod material. On the bases of radiation measurements taken at RFQs elsewhere and the peak rod-to-rod voltage of 90 kV, a thickness of 5 mm was chosen for the lead sheet incorporated in the walls and roof of the room enclosing the RFQ. The mass attenuation coefficient for lead is at least 1.6 cm^2/g for photon energies up to 160 keV, and so attenuation factors of at least 10^4 are obtained. In practice, X-ray dose rates are attenuated by much more than this, because the shape of the X-ray spectrum is strongly skewed towards lower photon energies where the attenuation coefficients are larger. Typical radiation dose rates inside the shielded room within ~1 m of the RFQ vessel are of the order of magnitude of 1 mSv/hour, but outside the dose rate is not measurable on the lowest range (0–10 µSv/hour) of an Eberline RO-10 health physics ion chamber dose rate meter.

On the HV platform inside the shielded room are mounted a refrigerator for cooling the cold box incorporated in the H^- ion source assembly to condense caesium vapour, and a cooler for water circulating through the windings of the 90° analysing magnet which is also part of the overall ion source assembly and which separates H^- ions from electrons (further details of the ion source are given in [5]). Apparatus mounted on the HV platforms outside the shielded room includes the ~50 A pulsed power supply to drive the ion source arc, the ~17 kV pulsed power supply for the ion source extraction electrode, and an optical fibre link system for transmitting signals between ground and the HV platforms. For the Frankfurt-RAL RFQ the HV platforms are run at a voltage of –35 kV, and a 4 μF capacitance is connected between the HV platforms and ground to maintain the energy of the beam entering the RFQ during the beam pulse.

The low energy beam transport (LEBT) line between the ion source and the RFQ consists of three solenoids incorporating three pairs of Lambertson-type steering magnets and a diagnostics box containing scanning emittance measuring hardware and a scintillator. Three 1000 A 15 V power supplies for the solenoids are situated outside the shielded room. The high energy beam transport (HEBT) line consists of a diagnostics box immediately following the output flange of the RFQ, a magnetic spectrometer, and a beam line designed for the measurement of beam energy by charge particle spectroscopy following attenuation of the beam by multiple scattering.

The magnetic spectrometer is designed to accommodate an energy up to 2.5 MeV, and so is suitable for both the Frankfurt-RAL RFQ and the ESS RFQ. The spectrometer magnet bends the beam through an angle of 45° with a radius of curvature of 1 m, and has a zero field index. The beam enters and leaves the magnet normally. The input and output legs are both 2.41 m, and the resolving power ($p/\Delta p$) is 2000. The spectrometer magnet will be calibrated by magnetic field mapping.

The straight-ahead line has been designed for measurement of the beam energy by charged particle spectroscopy. A series of pin-hole apertures and xenon-filled gas cells at pressures of ~0.3 mbar reduce the beam intensity by collimation and multiple scattering. Gas has been chosen as the scattering medium for ease of obtaining the very small areal densities, and xenon has been chosen to maximise the root-mean-square multiple scattering angle. The silicon detector has a typical resolution of 10–15 keV, and will be calibrated using a ^{137}Cs conversion electron source. The total areal density of the xenon gas has been chosen to limit both energy losses and energy straggling to 10 keV.

Vacuum is maintained by two 1000 litres/s turbomolecular pumps (TMPs) on the ion source vacuum box, a 200 litres/s TMP on the LEBT diagnostic box, two 1000 litres/s TMPs on the RFQ, a 200 litres/s TMP on the HEBT diagnostic box, and two 200 litres/s TMPs further downstream. A gate valve is provided in front of each TMP. A large pumping speed on the ion source vacuum box is necessary to remove the 20 ml/minute of hydrogen gas at ~0.3 bar above atmospheric pressure supplied to the ion source.

RF power for the RFQ is provided by a driver outside the shielded room. For the Frankfurt-RAL RFQ the driver is identical to the penultimate stage of the RF amplifier chains driving the ISIS linac tanks, *viz.* a Burle 4616 tetrode delivering ~200 kW of peak power. The RF is taken from the driver via a trombone phase shifter along a 3-inch HJ8-50B 50Ω coaxial line which includes a dual directional –60 dB coupler for monitoring forward and reverse RF power.

To control access to the RFQ and its associated apparatus, a personnel interlock system consisting of two main components has been installed. The first component is a mechanically interlocked key system which prevents the anode power supply to the RF driver and the high voltage bias power supply to the high voltage platforms from being energised unless the door of the shielded room is locked shut. The second system is a two - guard line system of electrical switches on doors which fulfils a similar function. Equipment interlocks are implemented through a PLC. Interlock functions include protection against cooling water flow failure, vacuum deterioration, *etc*. Active safety systems include a smoke detector and a hydrogen-in-air monitor.

3 OPERATION

So far the Rutherford RFQ Test Stand has been used to run the Frankfurt-RAL RFQ. As mentioned above, preliminary results are presented elsewhere at this conference [4]. After the RFQ has been fully characterised and soak-tested, a second similar RFQ will be tested, since a proven working spare must be available before the RFQ preinjector is substituted for the ISIS Cockcroft-Walton preinjector. Thereafter, the test stand will be used for the ESS RFQ.

REFERENCES

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[3] A P Letchford and A Schempp, "A Comparison of 4-Rod and 4-Vane RFQ Fields", EPAC 98, page 1204.

[4] A P Letchford *et al.*, "First Results from the ISIS RFQ Test Stand", paper THP4A05, EPAC 2000.

[5] R Sidlow *et al.*, "Operational Experience of Penning H$^-$ Ion Sources at ISIS", paper THP084L, EPAC 96.

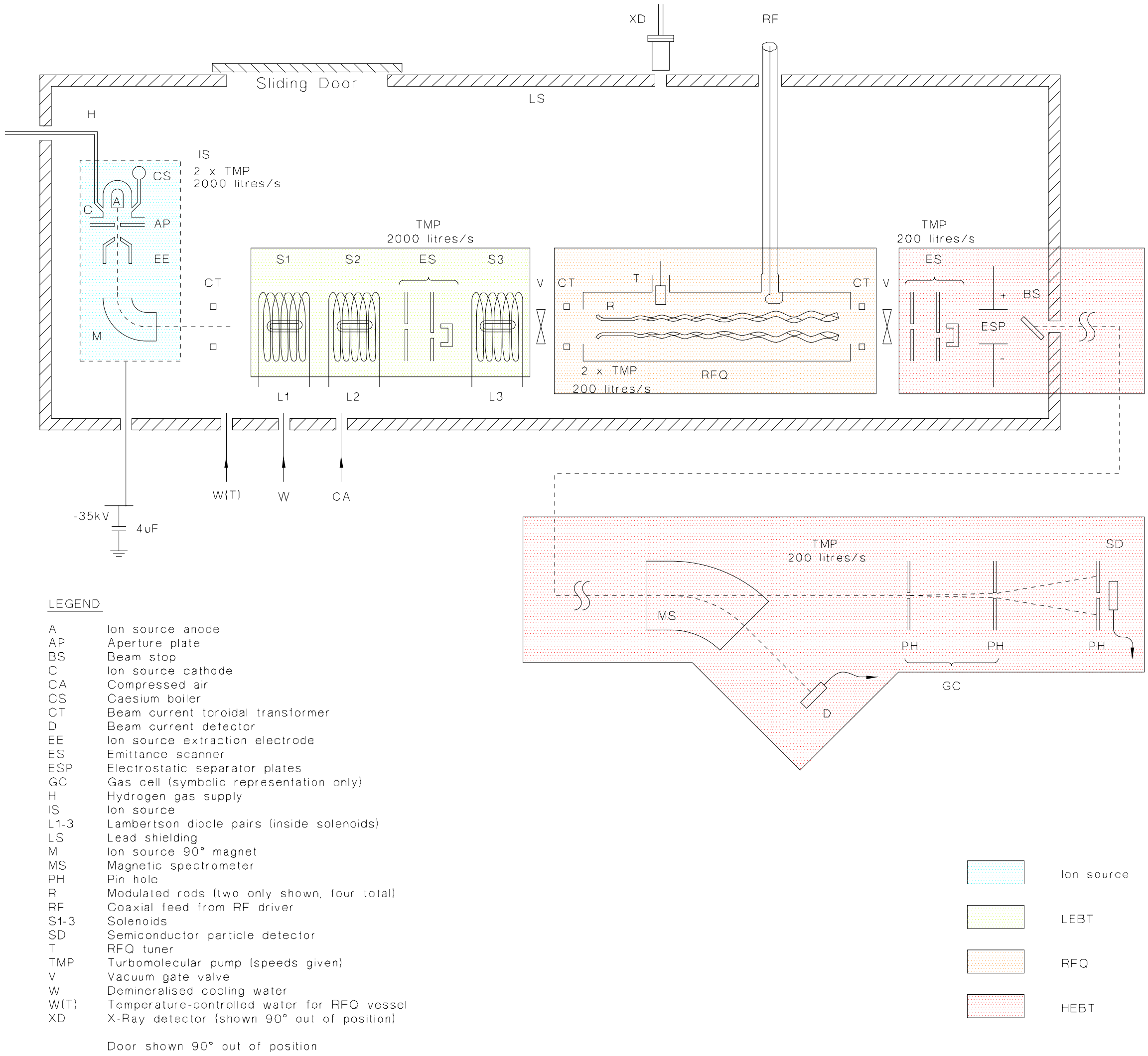

Figure 1: Functional outline drawing of the Rutherford RFQ Test Stand. The drawing is intended to show only the essential components of the RFQ Test Stand, and is not to scale.