THE RFQ TEST STAND ION SOURCE AT RAL

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Abstract

The RFQ test stand at Rutherford Appleton Laboratory (RAL) is now being operated with an ion source identical to that used on ISIS. This is a surface plasma ion source of the Penning type, and on ISIS routinely produces 35 mA of H^- ions during a 200 μs pulse at 50 Hz for uninterrupted periods of up to 50 days. A new ion source vacuum chamber which is compatible with the low energy beam transport system for the RFQ has been constructed, and the layout of power supplies and other essential services have been reconfigured in order to ensure that the RFQ will fit the space available when it is eventually installed on ISIS. An extensive redesign of many power supplies, where exact duplication of the ISIS equipment has proved impossible because of component obsolescence, has been necessary. In addition a new timing system and control systems using fibre optic ethernet have been developed specifically for this application.

1 INTRODUCTION

The design and operation of the H^- ion source for the ISIS spallation neutron source at RAL have previously been described in detail[1, 2].This source has proved to be extremely successful and will continue to be used on ISIS when the ageing Cockroft-Walton preinjector accelerator is replaced with an RFQ. An RFQ test stand has been built at RAL to provide a radiation-shielded environment in which all the services necessary to run and characterise RFQ accelerators, including an ion source identical to that used on ISIS, are available[3].

2 THE RFQ ION SOURCE LAYOUT

Figure 1 shows the ion source, power supplies and other essential services on the RFQ test stand. The configuration of all the components mounted on the magnet flange is identical to that on ISIS. The magnet flange is attached to the ion source vacuum chamber using an insulator, fabricated from PEEK (polyethylethylketone), which stands off the acceleration potential of –35 kV at which the ion source and all of its associated apparatus must be run (all equipment at –35 kV is shaded orange in figure 1). The ion source vacuum chamber is a new design, which is compatible with the low energy beam transport (LEBT) system of the RFQ. It accommodates the ion source and two $1000\ \mathrm{ls}^{-1}$ turbomolecular drag pumps. These pumps are used in preference to normal turbomolecular pumps as they provide higher pumping speeds for hydrogen in the pressure range ($5–9\times10^{-5}$ mbar) encountered when maintaining an adequate flow of hydrogen for ion source operation.

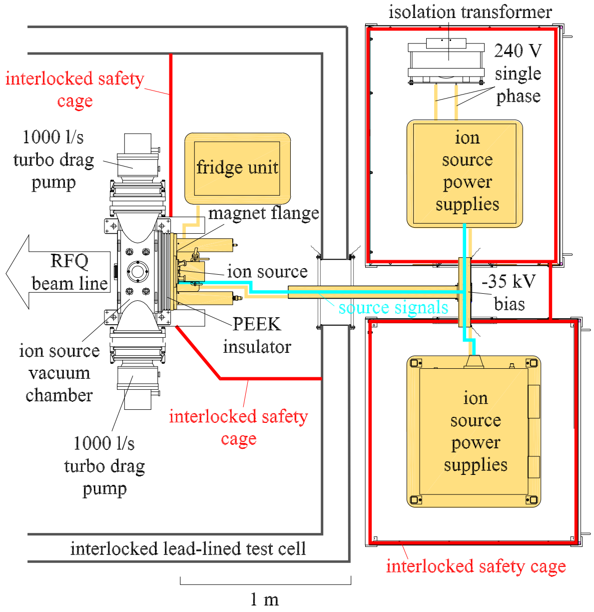


Figure 1. Schematic of the RFQ ion source layout.

Inside the interlocked safety cages, located both inside and outside the interlocked lead-lined test cell, are three isolated platforms. On these are mounted all the pieces of apparatus necessary to drive the ion source. Many of these are duplicates of those on ISIS, including a ≈ 17 kV, ≈ 1 A pulsed power supply for the ion source extraction electrode, but the pulsed arc power supply is new, and will be discussed in section 3. The decision to locate the majority of the ion source equipment outside the lead-lined test cell was dictated by the space constraints which will be imposed when the RFQ is eventually installed on ISIS. Signals to the ion source are fed into the lead-lined test cell via a T-shaped ‘umbilical’ made from ϕ 80 mm copper pipe, which is insulated from the interlocked cages and test cell by nylon bushes. Mains electricity for the HV equipment is provided via a single phase 40 kV isolation transformer. Great care has been taken to ensure that earth loops are kept to a minimum, with a star point located on the ion source flange. However, this can never be entirely effective because signals are required to pass directly between some of the power supplies on the two isolated platforms outside the lead-lined test cell. Ferrite chokes have been added to most signal and power leads to suppress interference. The control and monitoring of all the HV equipment is effected via optical fibres. Analogue signals are transmitted using a PPM point2point[4] system, whereas the control and timing systems have been developed specifically for this application and will be described in section 4.

3 THE PULSED ARC POWER SUPPLY

The pulsed arc power supply used on ISIS has run very successfully for many years, but exact duplication for the RFQ test stand has proved to be impossible because of obsolescence of the power transistors which are integral to its operation. Attempts to use modern transistors of a similar specification have been ineffective, so the arc supply has been redesigned using IGBTs. A schematic circuit diagram of the new arc power supply is shown in figure 2.

In this design the IGBTs are run in the linear part of their characteristic curve, which, although contrary to the normal mode of high current switching operation associated with these devices, has proved to be reliable. The supply is capable of delivering up to 60 A during a 700 µs pulse at 50 Hz. Adequate negative biasing of the IGBTs during the periods when the arc is off is required to ensure that the devices are not triggered by spurious noise pulses. The supply has been fitted with the same control circuits as on the ISIS supply, in order to make it compatible with the existing control philosophy. Initial running on the RFQ test stand indicated that up to 80 % of the current delivered did not return to the supply via the designated lead, which resulted in sporadic damage to other equipment on the HV platforms. However, floating the entire pulsed arc power supply has reduced this effect to negligible proportions.

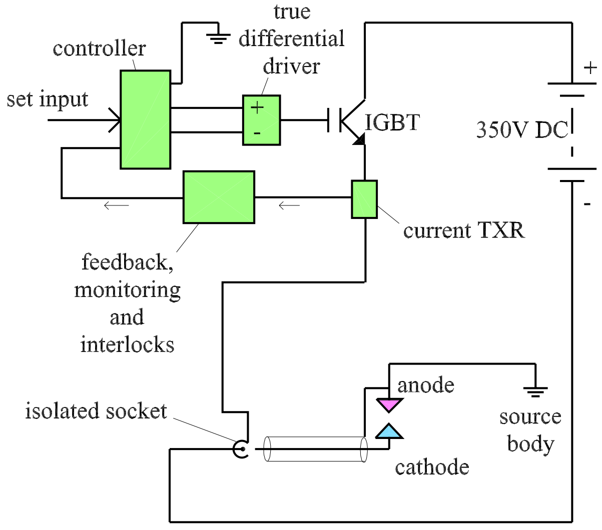


Figure 2. Schematic of the new pulsed arc power supply

4 THE CONTROL SYSTEM

A new control system has been developed for the ion source on the RFQ test stand, which replaces that used on the ISIS ion source[5] with the standard used by the ISIS controls group. CSS microprocessor systems are used for low level control of equipment. The systems consist of an ARCOM[6] SCIM88-5 optimised target processor, which has an INTEL 80C188XL-16 microprocessor interfaced to the STEbus backplane into which various I/O cards can be plugged. Communication between the ISIS control system and the CSS systems is via ethernet using an ARCOM SETHER card and ISIS controls PHIDO protocol[7].

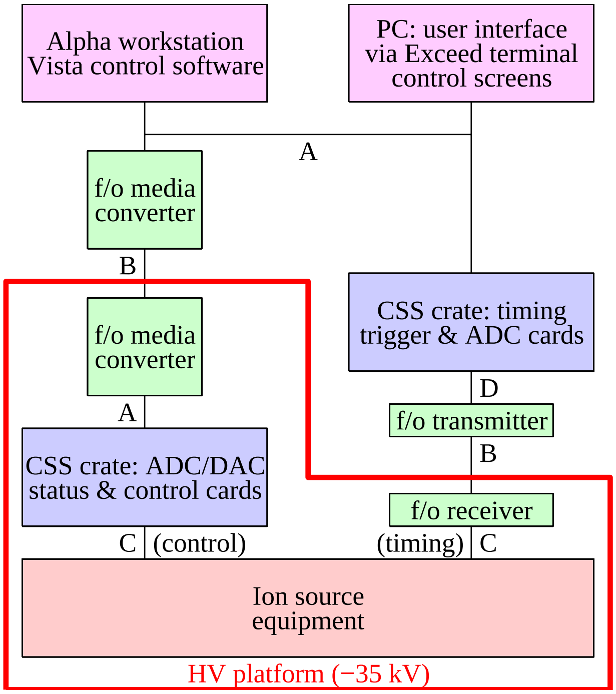


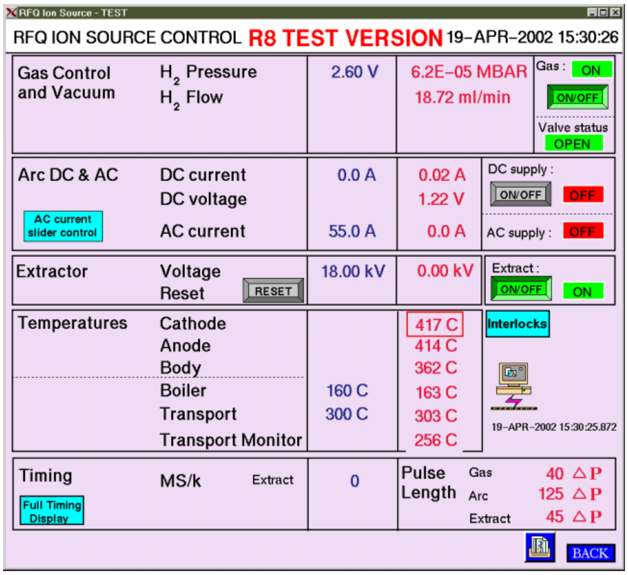
Figure 3. Ion source control system block diagram. Cable types: A = 10 base 2 ethernet, B = 10 base FL fibre link, C = coax, D = RG108 balanced twin low loss.

A block diagram of the control system is shown in figure 3. Two CSS crates are used to provide control and timing of the ion source. One of them is installed on the HV platform necessitating the use of a fibre optic duplex communication link utilising Transition Networks[8] E-CX-FRL-04 ethernet media converters. The second CSS crate primarily provides timing triggers to the ion source equipment, and is installed at ground potential. These triggers require a multi-channel fibre link to the HV platform.

The control parameters are divided into two categories, the first being control and monitoring via ADC/DAC, volt free contact output and serial communications cards, the second monitoring of equipment status via volt free contact inputs. The parameters include setting and monitoring of temperature, voltage, current and pressure and also on/off, reset and interlock control and status of all units.

All equipment on ISIS is synchronised via the ISIS timing signals which are locked to the resonant main magnet waveform. For the individual STEbus cards, every CSS crate has two primary pulse trains available for timing, a 50 pps 'MS' pulse train, and a 200 kpps 'ΔP' pulse train. Timing trigger cards are programmed to give an output trigger at a selected delay from MS. Seven triggers are provided for on and off timing of gas, extract and arc equipment and sampling of arc DC current waveform.

The computer control screens are based on the commercial control system package Vsystem[9] (version 4.2) used for the main ISIS control system. This gives a fully distributed database driven system with a graphical interface available over a number of Alpha workstations currently running OPEN VMS (Version 7.2) all communicating via ethernet. PCs running Hummingbird Exceed[10] (Version 6.1) on Windows NT/ 2000 provide additional terminals and the system-wide nature of the equipment allows access from multiple locations. The ion source equipment is defined in terms of control and monitoring objects in a Vsystem database accessed via Vsystem API. The control screens are generated using the Vsystem draw package, Vdraw, linking the control and monitored objects in the database. The controls STEbus[11] equipment processor contains an identical database structure and ethernet data packets are passed to and from the control system. Vsystem provides alarm handling and logging but ISIS-specific equipment routines and applications are written 'in house'. An example of an ion source control screen is given in figure 4.



RFQ ION SOURCE CONTROL **R8 TEST VERSION** 19–APR–2002 15:30:26

Gas Control and Vacuum	H_2 Pressure	2.60 V	6.2E–05 MBAR	Gas : ON ON/OFF
	H_2 Flow		18.72 ml/min	Valve status OPEN
Arc DC & AC	DC current	0.0 A	0.02 A	DC supply : ON/OFF OFF
	DC voltage		1.22 V	
AC current slider control	AC current	55.0 A	0.0 A	AC supply : OFF
Extractor	Voltage	18.00 kV	0.00 kV	Extract : ON/OFF ON
	Reset RESET			
Temperatures	Cathode		417 C	Interlocks
	Anode		414 C	
	Body		362 C	
	Boiler	160 C	163 C	
	Transport	300 C	303 C	19–APR–2002 15:30:25.872
	Transport Monitor		256 C	
Timing Full Timing Display	MS/k Extract	0	Pulse Length	Gas 40 ΔP Arc 125 ΔP Extract 45 ΔP

Figure 4. An ion source control screen

5 OPERATION

Typical oscilloscope traces (100 µs per division) for the ion source running on the RFQ test stand are shown in figure 5. Those shown, and their steady values, are arc current (I_D, ≈ 55 A), extract voltage (V_E, ≈ 17 kV), extract current (I_E, ≈ 200 mA) and beam current (I_B, ≈ 48 mA). The ringing during the first 120 µs of the arc current pulse appears to be a characteristic of the IGBT system, but does not affect the extracted beam. The beam current is measured with a toroid immediately after the ion source, and is higher than current measurements downstream, which indicate that ≈ 36 mA of H^- ions reach the end of the LEBT in a high quality beam pulse. This is comparable with the performance of the ion source on ISIS. Furthermore the measured normalised rms emittance values of $\varepsilon_H = 0.16\ \pi$ mm mrad and $\varepsilon_V = 0.24\ \pi$ mm mrad, and excellent beam matching into the RFQ itself are very promising.

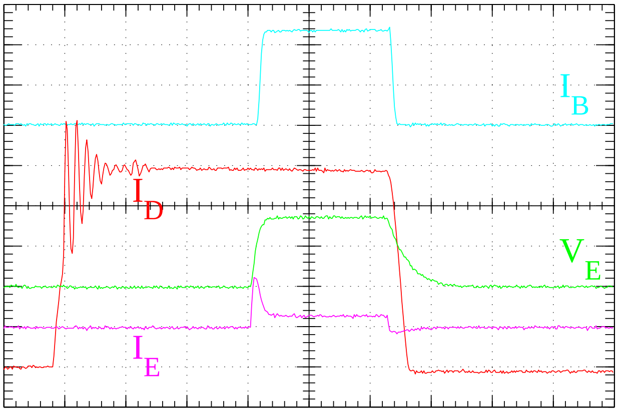


Figure 5. Typical oscilloscope traces

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[5] M. Perkins *et al.*, EPAC 96, TUP081L.

[6] ARCOM is the registered trademark of ARCOM Control Systems Ltd.

[7] D. M. Brownless and P. D. Burton, Nuclear Instruments and Methods in Physics Research A, 352.

[8] Transition Networks is the registered trademark of Transition Networks Inc.

[9] Vsystem and Vdraw are registered trademarks of Vista Controls, 128 Central Park Square, Los Alamos, NM 97544, http://www.vista-control.com

[10] Exceed is a registered trademark of Hummingbird Communications Ltd., http://www.hummingbird.com

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