RF-TUNING OF THE ISIS-RFQ [1]

H. Vormann, A. Schempp, E. Winschuh, H. Liebermann,
Johann Wolfgang Goethe-Universitaet, Frankfurt, Germany,
D. Findlay, J. Hirst, A. Letchford, G. Murdoch,
Rutherford Appleton Laboratory, Great Britain

Abstract

The ISIS-RFQ is a 202.5 MHz 4-Rod-RFQ which is designed to replace the present Cockroft-Walton Pre-Injector. It will accelerate a beam current up to 50 mA at 2,5 % d.c. from 35 keV input energy to 665 keV output energy.

The RFQ injector has been completed and aligned at IAP Frankfurt. After low level measurements it is now installed in the beamline at Rutherford Appleton Laboratory.

1 INTRODUCTION

The ISIS neutron source at the Rutherford Appleton Laboratory presently consists of a H$^-$-Penning source (extraction voltage 35 kV), a Cockroft-Walton injector (output energy 665 keV), an Alvarez Drift Tube Linac (output energy 70 MeV), the ISIS synchrotron (final energy 800 MeV) and a heavy metal target (average beam current 0.2 mA, average beam power 160 kW) [1].

The Cockroft-Walton is now going to be replaced by a new RFQ accelerator [2, 3] with the same figures of energy. The resonance frequency of the RFQ is the same as the one of the Alvarez linac, 202.5 MHz. The beam current is 50 mA with high transmission, allowing a later upgrade to 100 mA with 85 % transmission.

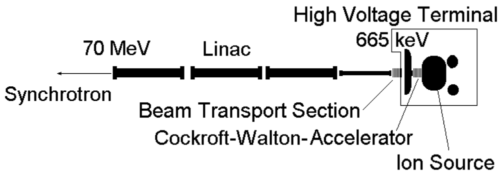

Figure 1: The ISIS injector section.

ISIS has reached a maximum beam current of more than 55 mA with a stable operation at 2.5 % duty cycle in early 1997. The new RFQ is planned for 10 % duty cycle. These values are not far away from the proposed values for the next generation of neutron source, the European Spallation Source ESS, where 6.5 % and 5 MW beam power (1.34 GeV) are planned. So the ISIS upgrade is a test bench for the future ESS injector. The present plans for the ESS project provide 107 mA, achieved with two RFQs (54 mA each) at 280 MHz.

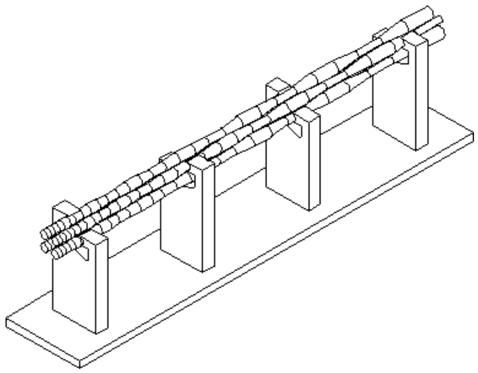

Figure 2: Principle of the 4-Rod-RFQ-Structure.

2 HIGH DUTY CYCLE RFQ

The HLI-RFQ at GSI Darmstadt is an operating RFQ with high duty cycle: It operates at 15 kW/m average power (duty cycle 25 %). Its resonance frequency is 108.5 MHz, lower than the frequency of the RAL RFQ (202.5 MHz). Lower frequencies go along with larger resonator structures and a distribution of the power to a larger surface. Such a higher thermal stress has been applied to a short test model (202.56 MHz) with 20 kW/0.3 m in c.w. operation. This model worked well and showed that an RFQ resonator with completely cooled electrodes works well even at 60 kW/m [4].

3 RF CALCULATIONS

MAFIA calculations and experiments have been made to investigate resonator properties and field distribution. They have shown that thicker stems at the RFQ insert’s ends and directly cooled electrodes (with cooling pipes) have a negligeable influence on resonator properties and field distribution.

4 PARTICLE DYNAMICS

For the particle dynamics design, the methods for compact RFQs are used [5]. With adiabatic variation of parameters and 90 kV electrode voltage a high acceptance at large aperture is reached. The beam dynamics parameters are shown in table 1.

Letchford [6] has developed a code which solves the field equations with respect to higher multipole components. The result was, that the design chosen for

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[1] work supported by the BMBF

ideal shaped electrodes must be only slightly modified when it is used with rod electrodes, to match the properties of a hyperbolical shaped quadrupole. Figure 3 shows results for simulations using the higher order potential terms.

Another special feature is used for this RFQ: The last cell consists of half an RFQ-cell and half a cell with a symmetrical output matcher to achieve a good output emittance matching [7].

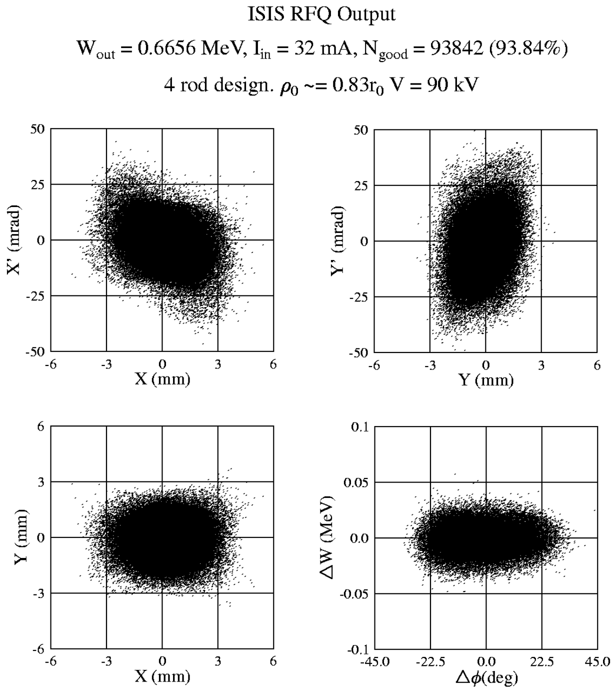

Figure 3: Particle Output Distribution [6].

5 COMMISSIONING OF THE RFQ

MAFIA and ANSYS calculations have been made to investigate the temperature distribution on the stems and to develop a cooling channel arrangement [8, 9].

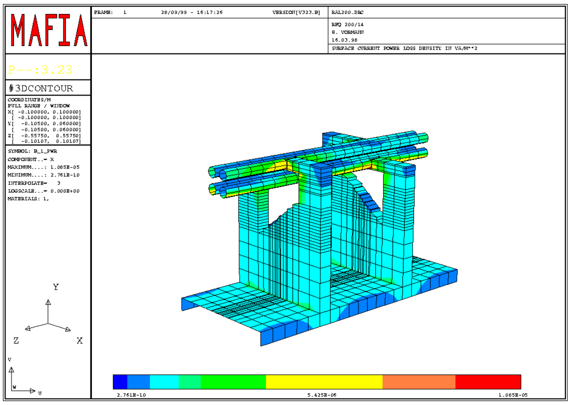

Figure 4: Power loss distribution calculated by MAFIA.

In addition to this, a concept without rubber sealings between water and vacuum has been made: all connections, e.g. electrodes to stem tips, stem tips to cooling pipes, are brazed. Only the sealings on the bottom of the vessel, dividing atmosphere pressure from inner vessel pressure, are Viton-O-rings.

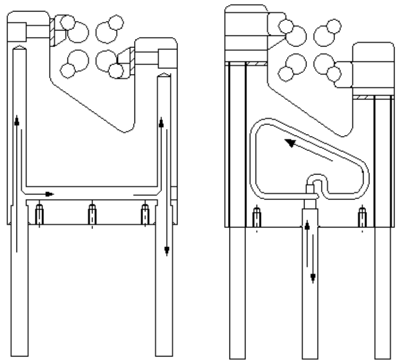

Figure 5: Cooling water flow in the stems.

The electrodes have been aligned exactly by +- 0.3 mm. After completion and cleaning of the vessel, the vacuum pressure decreased to 5 x 10^{-7} mbar, after acceptable pumping time.

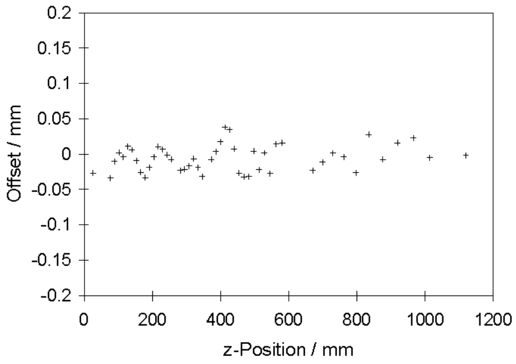

Figure 6: Position offset from the ideal value (upper X-Electrode) after alignment.

6 EXPERIMENTAL RESULTS

First low measurements have been made at IAP Frankfurt. There, the proposed efficiency (Rp 63.7 kΩm, Q_0 3150) and good field distribution (flatness) (< 3 %) have been proved.

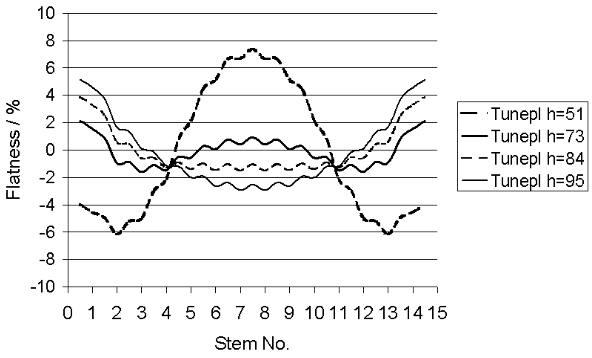

Figure 7: Calculated field distribution (MAFIA) for various heights *h* of the tuning plates.

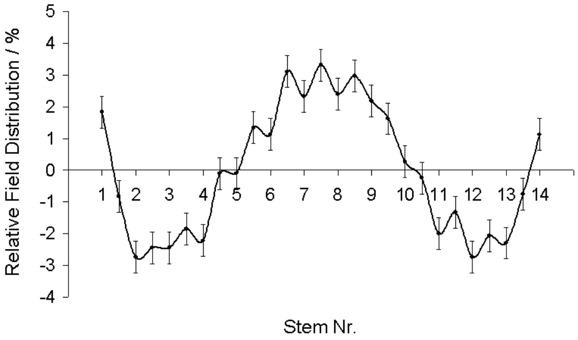

Figure 8: Field distribution along the beam axis (flatness).

After transportation to RAL, the RFQ has been mounted into the test stand. It has been operated with rf-power up to 215 kW at 2 % d.c. The design electrode voltage of 90 kV has been reached at 150 kW rf-power. The maximum X-ray level there was 1,5 mSv/h.

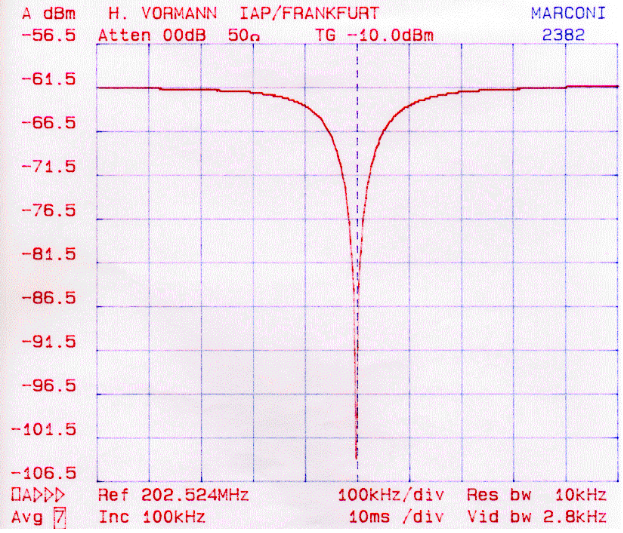

Figure 9: RF input damping of the coupling loop.

During the high power test the RFQ worked reliable. No frequency tuning by the plunger was necessary, as a result of the balanced cooling concept.

Conditioning once has been done at Rutherford Appleton Laboratory[10].

After test of long term stability in the test operation, the RFQ will be mounted in the regular ISIS beam line.

This structure is a basis for an RFQ for the future ESS injector and for future high duty factor applications.

ACKNOWLEDGEMENTS

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Table 1: RFQ specifications and beam parameters of the RFQ.

Total Length	1190 mm
Diameter	250 mm
Frequency	202.5 MHz
Q-Value	315150
Shunt Impedance	53.5 kΩ
E in	35 keV
E out	665 keV
ε^{in}_{norm}	0.40 π mm mrad
ε^{out}_{norm} (50 mA)	0.42 π mm mrad
ε^{out}_{norm} (100 mA)	0.46 π mm mrad
$\varepsilon_{, rms}$	0.096 π° mm

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