DESIGN OF A HIGH CURRENT RFQ INJECTOR WITH HIGH DUTY FACTOR *

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Abstract

An RFQ injector with a duty factor up to 10 % is planned for the spallation source ISIS at Rutherford Appleton Laboratory (RAL). The accelerator will be a Four-Rod RFQ with directly cooled electrodes, operating at 202 MHz.

The RFQ will provide a H^--beam current up to 50 mA with an output energy of 665 keV (input energy 50 keV). The beam dynamics, rf and mechanical designs are presented.

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 will be the same as the one of the Alvarez linac, 202.56 MHz. The beam current will be 50 mA with high transmission, allowing a later upgrade to 100 mA with 85 % transmission.

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 175 MHz.

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 %) [4]. Its resonance frequency is 108.5 MHz, lower than the frequency of the RAL RFQ (202.56 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 [5].

3 RF CALCULATIONS

MAFIA Calculations and experiments have been made to investigate the magnetic field distribution around the stems and for optimizing the input coupling loop. The magnetic field in a groove, milled into the surface of the copper stem, is very weak, compared to the field strength around the stem (<1%).

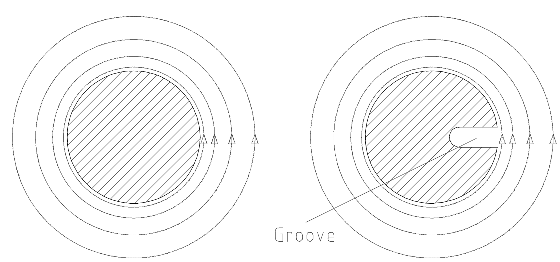

Figure 1: Magnetic field around stems.

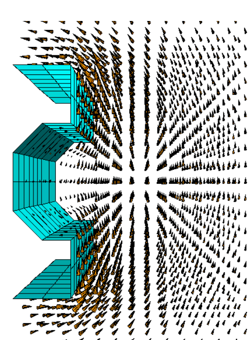

Figure 2: Magnetic field (arrows) on a grooved stem's surface.

To decrease the sensitivity of the loop, caused by the inhomogeneous magnetic field, the effect of a groove, milled into the stem has been tested. With this groove the loop can "dive" into the stem, thus giving a stronger coupling, as shown in figurs 1 and 2.

Another subject within the RF calculations was the influence of the electrode cooling pipes on the field distribution and the resonator properties.

It has been shown that multipole components of the electrodes with cooling pipes differ less than 0.1 % from the values of regular rods (circle shaped), and remain in the same range of difference from the hyperbolical (ideal) quadrupole geometrie, as shown in figure 3. The flatness (percentage rate of the intervane voltage) is shown in figure 4.

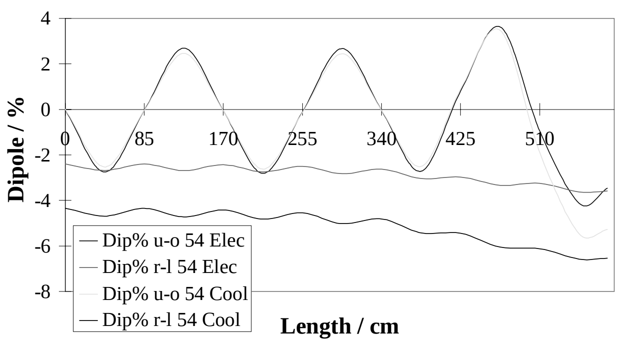

Figure 3: Influence of the cooling pipes on the field components.

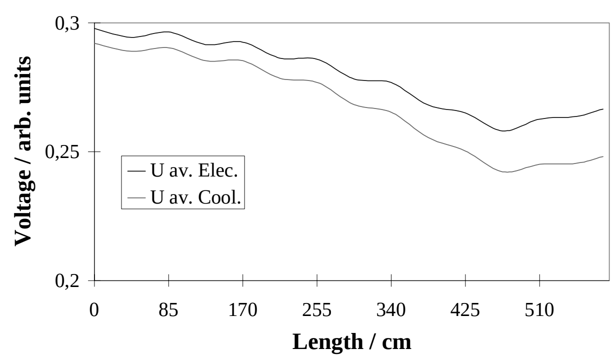

Figure 4: Influence of the cooling pipes on the field distribution along the beam axis.

The calculated values of Q-value and shunt-impedance differ less than 1 %, what is a negligible variation of change.

The geometry of the electrodes with the cooling pipes has an influence on the electric field distribution and the resonator properties. MAFIA calculations and measurements have been made to investigate that effect, particularly the ratio of aperture to rod radius is important for the capacitance of the electrodes, what has a big influence on the resonance frequency and the flatness and field distribution along the beam axis.

4 PARTICLE DYNAMICS

For the particle dynamics design, the methods for compact RFQs are used [6]. With adiabatic variation of parameters and 80 kV electrode voltage a high acceptance at large aperture is reached. The beam dynamics parameters are shown in table 1. Figure 5 shows results for simulations using the ideal two term potential.

Letchford [7] has developed a code which solves the field equations with respect to higher multipole components. The result was, that the design chosen for ideal shaped electrodes must be only slightly modified when it is used with rod electrodes, to match the properties of a hyperbolical shaped quadrupole.

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 [8].

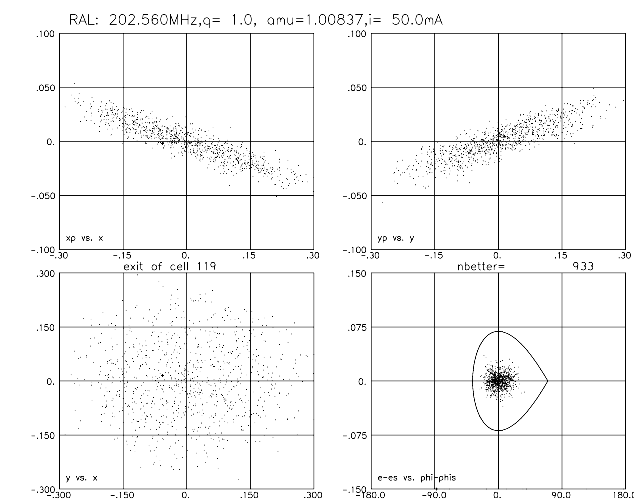

Figure 5: Particle Output Distribution.

5 MECHANICAL DESIGN

Results of MAFIA calculations have shown that 34 % of the power is lost on the electrodes, 44 % on the stems and 22 % on the ground plate. To get the temperature distribution on a stem, ANSYS calculations have been made. These calculations showed that a cooling of the end cells with only one coaxial cooling channel or with water flow split into two channels (figure 6) is not sufficient: So a "one way cooling channel" has been chosen, as shown in figure 7. The channel is milled into the stem and covered by a brazed plate, avoiding any direct water-to-vacuum seals [9, 10].

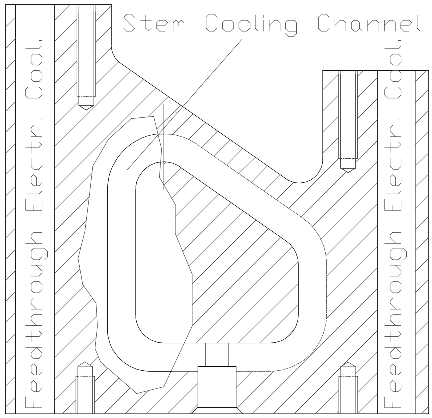

Figure 6: Cooling of the endstem with split water flow.

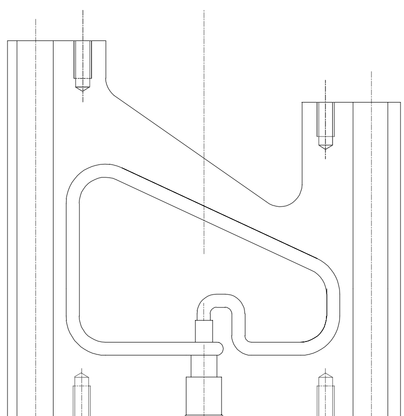

Figure 7: One way cooling channel of the endstems.

At present the tank is ready for copper plating. The parts of the RFQ insert should be ready in September, so that electrode alignment and cavity tuning can be done in Fall 1998.

ACKNOWLEDGEMENTS

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

Total Length	1190 mm
Diameter	250 mm
Frequency	202.56 MHz
Q-Value	3000
Shunt Impedance	65 kΩ
E in	35 keV
E out	665 keV
ε^{in}_{norm}	1.00 π mm mrad
ε^{out}_{norm} (50 mA)	1.05 π mm mrad
ε^{out}_{norm} (100 mA)	1.15 π mm mrad
ε_{rms}	0.07 °MeV

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