THE DESIGN OF LOW FREQUENCY HEAVY ION RFQ RESONATORS *

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Abstract

The development of the 4-Rod-RFQ as injector for low charged heavy ions has demonstrated that structures with spiral shaped and straight stems can be made highly efficient, very stable and compact. The design of the RFQ structures and results of impedance optimizations and the effects of monopole and dipole mode generation will be discussed.

I. INTRODUCTION

Because of improvements in ion source technology a new layout of the GSI High Current Injector can use higher charged ions: U^{4+} instead of U^{2+} , as used for the “old” High Current Injector design. The old HCI was planned as a 27 MHz-RFQ for U^{2+} as injector for the Wideroe and a stripper for producing U^{10+} with a necessary current of 25 mA. In the new concept a beam current of only 10 mA U^{4+} is required, because a stripper is not needed any more, the beam will be injected directly into a new IH-Linac.

II. RF-CALCULATIONS

The specific parameters of the rf-properties of the different RFQ resonators have been checked by model measurements and calculations with the program MAFIA. Special considerations has been given to dipole effects, distribution of losses along the structure, and the influence of electrode-capacitance on the rf-parameters.

A. Capacitance of electrodes

The capacitance of the electrodes has a strong influence on the resonance frequency of the resonator. A resonator loaded with a big capacitance usually is less efficient, the Rp-value (shuntimpedance) is smaller. Although the vane-shaped geometry has 20 % more capacitance than the circular cylindric one, the impedance is nearly equal, the greater surface produces less losses. Table 1 shows a comparison of resonators with vane- respectively rod-shaped electrodes. The numeric calculations of characteristic resonator-data was done with the programs MAFIA and OPERA. It is a question of manufacture and cooling, which shape of electrodes will be chosen. So mechanical parameters and costs may determine the choice.

	Vanes	Rods
Frequency / MHz	30.50	32.24
Quality-Factor	12700	11500
Shunt-imp./kΩm	277.3	258.5

Table 1: RF-Parameters for different electrode-shapes.

B. Dipole effects

Dipole contributions in the electrode fields correspond to differences in the potential of the electrodes, e.g. the beam axis is not on zero potential. They can be a reason for beam losses, depending on their strength and beam emittances. Dipole-components of the electrode-voltage can be reduced by shaping the stems with an angle α as shown in fig. 1, which has been used in all operating four-rod RFQs [1]. With an inclination of about 45 degrees the dipole effect can be minimized to $(U-U_{AV})/U_{AV} = 0.4\%$ (see table 2), A dipole of 2 % or less is insignificant [2], it is below the experimental tuning tolerances of RFQs.

Dipole / %	α / Degrees
1.41	0
1.17	10.2
1.04	19.9
0.89	28.5
0.76	35.9
0.60	43.9
0.45	50.3

Table 2: Dipole-effects versus shape of stems.

The dipole-effects can be reduced by longer stems too, at a lower frequency. Table 3 shows the decrease of dipoles as function of the length of the stems (rectangular cross-section).

Length of Stems / mm	Dipole / %
600	1.27
622	1.22
644	1.18
666	1.14
688	1.10
710	1.06

Table 3: Dipole-effects versus length of stems.

* supported by the BMFT

RFQ FOR U4, F=36.1MHZ, U=125KV
NCELL=356, NPOINT=1810, NTOTAL=2000, lin=15 mA

Fig. 4: RFQ output emittances, with space charge (15 mA).

Fig. 5: Beam transmission along the RFQ.

A. RF-Power Requirements

An expected R_p -value of 500 $k\Omega m$ enables the operator of an RFQ with a length of 9 meter ($= 55 k\Omega$) to reach an electrode voltage of 125 kV with an rf-power of 280 kW.

Table 4 shows a comparison of different RFQ-resonators. The stems have rectangular cross-section with different width and length, except number 5 which has stems with a circular cross-section of 120 mm, and the IH-structure with 15 mm distance of the supports of the electrodes, according to the GSI design. [4]

The low power model has a simple geometry: The stems with a cross-section of 200 mm $\times$ 10 mm have a distance of 400 mm and a height of 400 mm. The electrodes are optional cylindric with a radius of 5 mm or vane-like with a shape of 10 mm $\times$ 20 mm, each 1240 mm long, the aperture is 10 mm. The resonator was only screwed, so bad contacts reduce the shuntimpedance. Table 5 shows the comparison between calculation and measurements.

Stems	Frequency / MHz	Quality-Factor	Shunt-impedance
400 x 400	30.7	10400	770
250 x 600	36.9	13000	790
250 x 700	34.6	12900	830
250 x rad 60	33.5	11500	840
IH-Structure	37.1	8000	360

Table 4: Properties of different RFQ-resonators.

	Measurement	MAFIA
Frequency / MHz	34.3	32.2
Quality-Factor	2900	10500
Shuntimp. / $k\Omega m$	270	770

Table 5: Comparison of calculated and measured properties.

V. CONCLUSIONS

Four-rod type RFQs for low frequencies have high efficiency, good mechanical stability, good operational characteristics and suffer no dipole mode problems, which has been shown in calculations, prototypes and operating structures. Spiral shaped and straight stems supports give compact resonators. GSI will go on working with the IH-driven four-rod RFQ, for which prototyping on a number of design issues is the next stage.

VI. REFERENCES

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