DEVELOPMENT OF THE ITEP 27 MHZ HEAVY ION RFQ*

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Abstract

A 27 MHz RFQ is presently under development and construction at ITEP, Moscow. It is based on a 90^{o}-apart-stem geometry ("ring-connected RFQ") and its parameters have been chosen to accelerate ions with charge to mass ratio of 1/60 to energies of 110 keV/u. It can also be considered as a prototype for a new 10 MHz RFQ, to be used as the initial part of a heavy ion accelerator for inertial fusion.

In this paper the 27 MHz RFQ status is presented and some simulations of RF efficiency and field distribution, carried out with MAFIA codes, are given for the 10 MHz resonant structure.

1 INTRODUCTION

Much work has been carried out at ITEP during several years for the development of a structure to accelerate intense heavy ion beams. Presently, RFQ structures are considered as the only choice for the initial part of high-power heavy ion accelerators. Because of the low charge to mass ratio (1/60), a low operation frequency is needed, around 10÷30 MHz.

Several different resonant structures have been proposed and investigated for this low-frequency RFQ: 4-rod, Split-ring, Split-coaxial, 4-rod Spiral, etc. However, all of them have some intrinsic drawbacks for low frequencies high duty cycle RFQs.

The 4-rod structure, used in a number of heavy ion linacs, is mechanically simple and has relative small size, but it has an intrinsic presence of dipole components in the operating field and a ripple of the inter-electrode voltage along the structure (due to an extremely high capacitance between a stem supporting a pair of electrodes and the not connected pair). The dipole component is present also in the other considered RFQs which, furthermore, have low mechanical rigidity. It can be reduced to some extent by proper choice of RFQ parameters, but a high intensity RFQ must allow to preserve the injected beam brightness, therefore the field distribution should be dipole free. Moreover, the structure must be easily tuneable, and a reliable stabilisation of the operational mode should be provided.

That is why the development of a new resonant structure for low frequencies, which has perfect quadrupolar symmetry of focusing field, uniform field distribution along axis, which is mechanically stable and suitable for high duty cycle operation, is still actual.

As result of this work, a new structure (henceforth called "ring-connected RFQ") was proposed, investigated and tested by numerical simulations and cold model measurements. It is the advanced version of the so-called "4-ladder RFQ", based on a 90^{o}-apart-stem geometry [1][2], with rings connecting the stems and rods connecting the rings. This allows to lower both the resonant frequency and the size, while achieving a sufficiently high shunt impedance and consequently RF efficiency. A combination of quadrupole and coaxial modes is excited in the structure, which provides a reliable separation between operating mode and dipole ones. Tests showed that it is the most suitable solution for the initial part of a high intensity heavy ion linac.

This 27 MHz RFQ was designed to accelerate 15 mA of U^{4+} ions from 1.5 to 110 keV/u, for upgrading the ITEP injector [3]. It will also allow to continue the research program on heavy ion beam interactions with dense plasma started at GSI-Darmstadt on the "Maxilac" accelerator, which has now been shut-down.

Moreover, it can be considered as the prototype of a 10 MHz RFQ to be used as a heavy ion driver for inertial fusion. The development of high current heavy ion linacs is required for inertial fusion installation: therefore designing and testing prototypes of accelerating structures for the low energy part of the linac are essential.

2 STATUS OF THE 27 MHZ RFQ

The construction of the new RFQ started two years ago in ITEP; for the mechanical design and manufacturing of some RFQ parts, IHEP-Protvino is involved, but it will be assembled, tuned and commissioned in ITEP, which is also in charge of the experimental study of its parameters and of beam dynamics. Numerical simulations with MAFIA codes were done in IAP-Frankfurt.

Parameters of the RFQ, resulting both from simulations and RF measurements on a scaled (1:2) cold model, were chosen to fit the existing equipment in

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ITEP, such as vacuum tank, ion source, high voltage platform and technological systems, beam outlet systems and diagnostics. They are the following:

Length of the vacuum tank	12.0 m
Inner tank diameter	1.2 m
Outer diameter of the rings	0.81 m
Aperture radius	0.64 cm
Peak E-field on the electrode surface	2.2 Kilpatric
Transmission at 15 mA	96 %
Specific shunt-impedance (R_{sh})	1.49 MΩ·m
Emittance	0.3 mm·mrad

Most parts of the RFQ structure have already been built in the IHEP workshop and delivered to ITEP: the oxygen-free-copper electrodes are ready; the inductor rings and the connecting rods, manufactured from an aluminium alloy, have been copper-plated. Other parts, as tuning elements, are near to be completed.

While the existing vacuum tank is being prepared for structure accommodation, a portion of the RFQ (see Fig. 1) has been assembled in room for testing the alignment and tuning procedures.

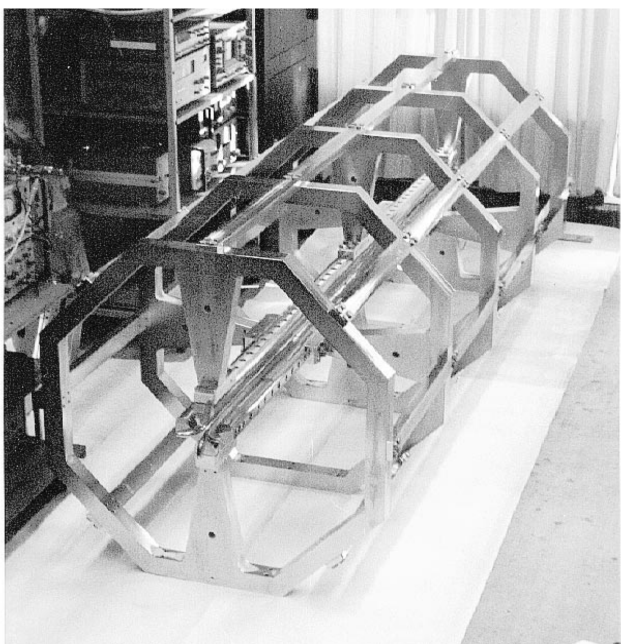

Figure 1: The 4-cell portion of RFQ assembled in ITEP.

The schedule of main expected results in 1997-98 is the following:

- alignment, tuning, measurement of field distribution of the assembled RFQ portion (under operation);
- upgrade of the RF power system and feeding elements; preparation of the U^{4+} ion source to work as pre-injector of the RFQ; development of the diagnostic equipment; manufacture of new tuning and control systems; upgrade of vacuum system; simulation of beam dynamics with parameters measured at the ion source test bench;
- commissioning and achievement of the required beam parameters;
- experiments on intense heavy ion beam dynamics, especially about processes which lead to beam emittance growth and particle losses.

3 STUDY OF THE 10 MHZ RFQ

After assembly, alignment and tuning, the 27 MHz RFQ parameters will be measured (field distribution, shunt impedance, Q-value, power dissipation, etc.). After commissioning, the intense heavy ion beam dynamics will be investigated. The obtained experimental data will be used to develop a prototype of the initial part of a high current linac driver for heavy ion inertial fusion.

The 10 MHz RFQ will have the same structure type but larger dimensions. Numerical simulations by MAFIA codes have been performed in IAP-Frankfurt to design it; the proposed geometrical dimensions are the following:

Length of a cell	1.84 m
Inner tank diameter	2.10 m
Outer diameter of the rings	1.60 m
Inner diameter of the rings	1.44 m
Width of the rings	80 mm
Ring-connecting rods cross-section	40×80 mm
Electrode supports width	80 mm
Aperture radius	12 mm
Curvature radius of electrode tips	12 mm

A drawing of a single cell of the structure is shown in Fig. 2. The resulting parameters are the following:

Resonant frequency (f_q)	10.0 MHz
Dipole frequencies (f_d)	14.5 / 15.2 MHz
Separation (f_d–f_q)	4.5 / 5.2 MHz
Q-factor	22.3×10^3
Specific shunt-impedance (R_{sh})	5.1 MΩ·m
Voltage uniformity (dV/V)	1.4 %

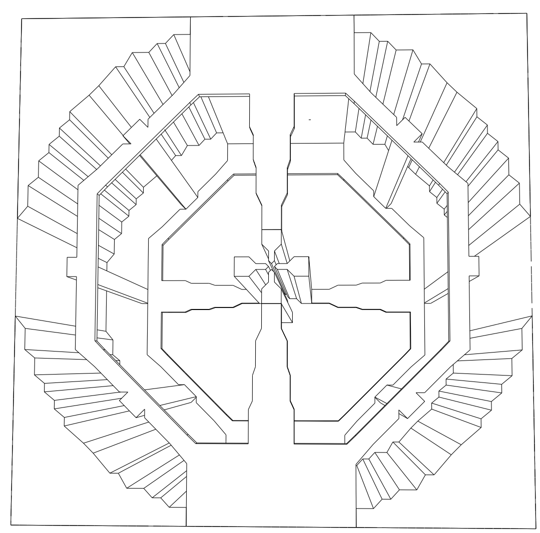

Figure 2: MAFIA plot of the 10 MHz RFQ (1 cell).

A few plots of the electric and magnetic field inside the structure are shown in Figs. 3, 4, 5, 6 and 7.

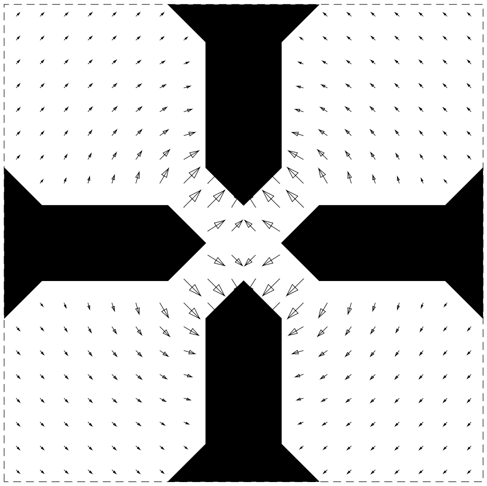

Figure 3: MAFIA plot of the electric field in a transverse section trough the electrodes (detail).

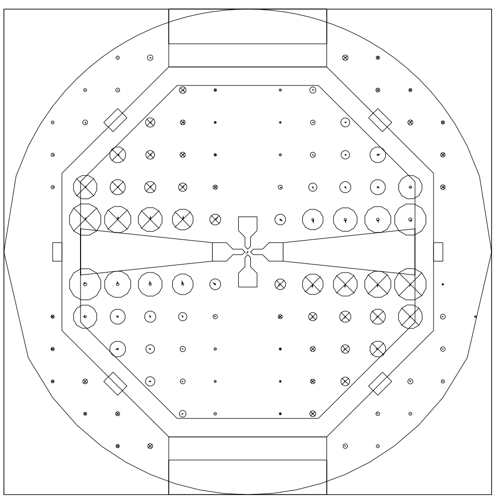

Figure 4: MAFIA plot of the magnetic field in a transverse section in the middle of a ring.

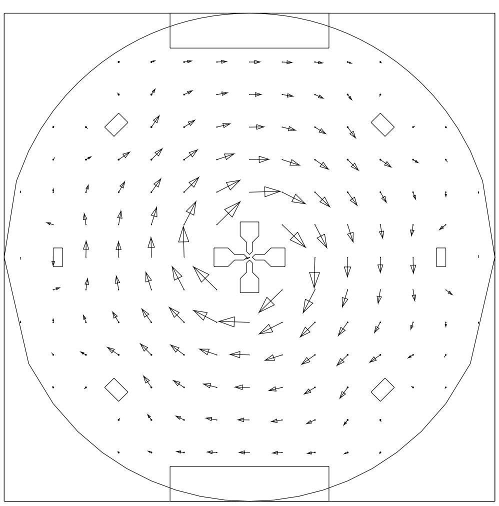

Figure 5: MAFIA plot of the magnetic field in a transverse section in the middle of the cell.

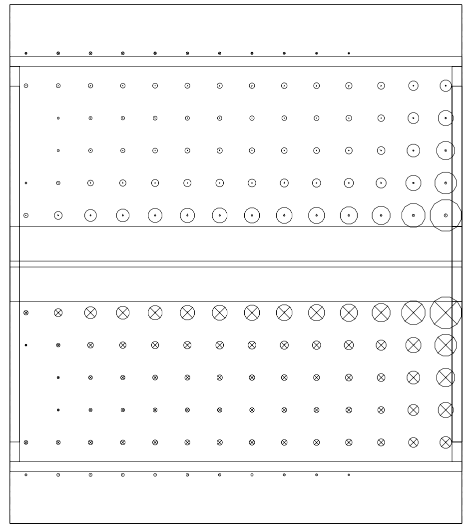

Figure 6: MAFIA plot of the magnetic field in a longitudinal section in the middle of the vertical plane.

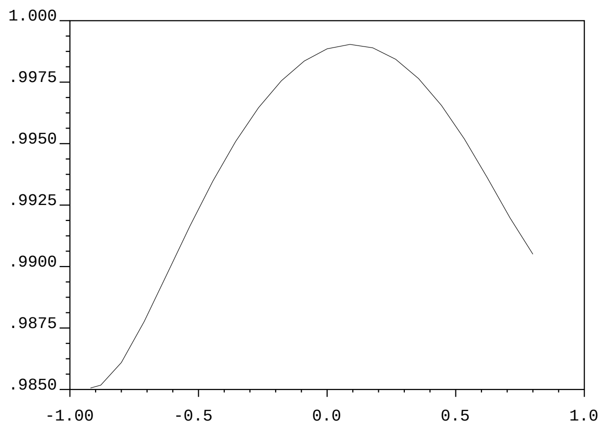

Figure 7: MAFIA plot of the normalized inter-electrode voltage.

4 CONCLUSIONS

A new RFQ structure for accelerating heavy ions was investigated, developed and tested by numerical simulations and measurements on a scaled cold model. Its manufacture is now almost completed in ITEP.

It will accelerate 15 mA of U^{4+} ions to 110 keV/u, allowing to carry out experiments on the interaction of a high intensity heavy ion beam with dense plasma.

This structure can be considered as the prototype of a 10 MHz RFQ to be used as heavy ion driver for inertial fusion. Some preliminary design is simulated by MAFIA codes, which can be base for real structure development.

5 REFERENCES

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[3] V.A. Andreev, A. Kolomiets, S. Yaramishev, J. Klabunde, “Low frequency High Duty Cycle Heavy Ion RFQ”, Proc. Linac’94, Tsukuba, Japan, August 1994.