DESIGN AND CONSTRUCTION OF AN RFQ-DRIFTTUBE-COMBINATION FOR A MEDICINE SYNCHROTRON[*]

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Abstract

The GSI-design proposed for the facility for radiotherapy of cancer tumours with ions at the Radiologische Universitaetsklinik in Heidelberg has been approved by the german "Wissenschaftsrat" last year. The design and construction of the RFQ section of the LINAC system in front of the synchrotron is our contribution to this project [1]. Design studies have been done with respect to the construction and operation costs as well as to a comfortable handling of the machine [2]. Therefore the direct combination of drifttubes with the RFQ electrodes has been examined in detail by beam dynamic simulations.

1 INTRODUCTION

Because of their focussing properties RFQs are very well adapted to beam transportation and acceleration at low energies. For higher energies the accelerating efficiency decreases and drift tube structures are getting more and more relevant. Drift tubes structures are also used as rebunching units behind the RFQ to match the beam to the acceptance of a following structure longitudinally. A common solution is a separate buncher cavity in a suitable distance between the RFQ and the following DTL structure.

We have developed a new concept: A drift tube is mounted directly to the last RFQ stem at the high energy end forming a boosting or bunching unit depending on the HF-phase it is operated with [1].

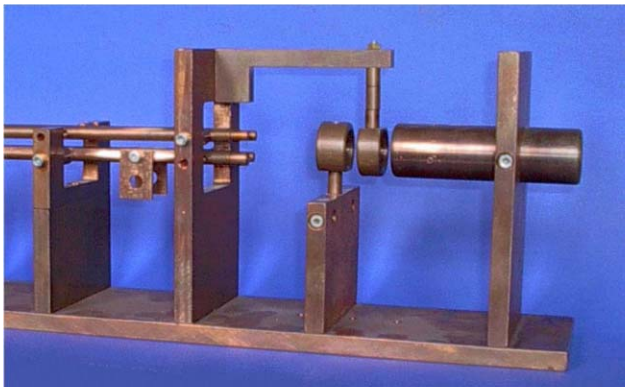

Fig. 1 Model set up of the RFQ drift tube combination.

2 RFQ DESIGN

The layout of the electrodes has been done in accordance with the following beam parameters:

Input energy	8 keV/u
Input emittance	$\varepsilon_{x,y}$=150 π mm mrad
Current	max. 2 mA H^+
Output energy	400 keV/u
max. beam angle at the exit	±20 mrad (in both planes)
Phase width at IH entrance	$\Delta\varphi \leq \pm 15°$

Table 1: RFQ beam parameters.

Particularly the small phase width of ±15° at the IH entrance puts special requirements to the particle dynamics of the RFQ. The design presented in [3] has been done, reducing the phase width to the smallest possible value by varying both, the electrode parameters of the RFQ and the gap voltages of the following drift tubes. The latest version of this design is shown in figure 2 where we have done some modifications to shorten the length of the RFQ and to improve the homogeneity of the output distribution (fig. 3).

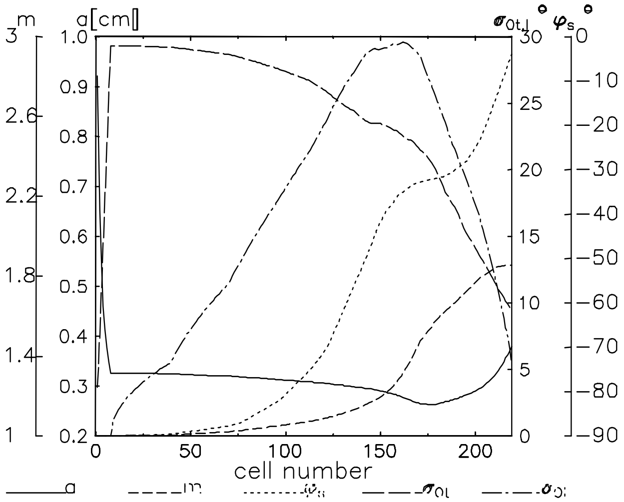

Figure 2: Design parameters of the RFQ.

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The growing aperture at the end of the electrodes leads to a decreasing focusing strength, which guarantees the maximum beam angle of 20 mrad at the exit of the RFQ. Furthermore there is an unusual increase of the ideal phase to nearly 0° corresponding to take a maximum advantage of the HF voltage, but a minimum of longitudinal focusing. This means that the beam is already drifting longitudinally within the RFQ electrodes, which allows the bunching in a distance of only 6 cm behind the last RFQ cell.

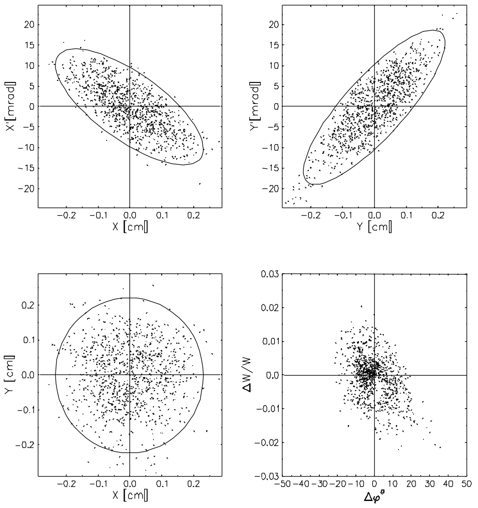

Figure 3: Particle distribution at the exit of the RFQ.

3 THE TRANSITION BETWEEN RFQ AND DRIFT TUBE

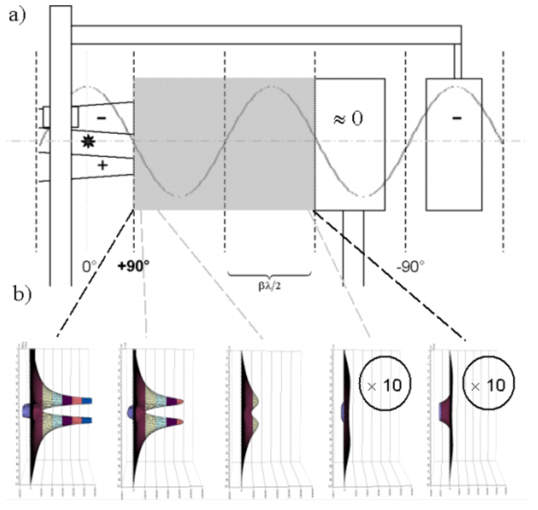

Figure 4: a) Area of interest (shaded) and its boundary conditions: -10 resp. 60 kV electrode voltage, -1,2 kV at the first drift tube (calculated by MAFIA), b) generated static potential in different planes (factorized by 10 in the last two planes).

To do detailed investigations on the dynamics in the distorted field distribution between electrodes and drift tubes, a new subroutine for the IAP version of the PARMTEQ code has been written to calculate the particle dynamics in an arbitrary potential distribution. The generation of the potential has been done externally by solving the Poisson equation with the method of successive overrelaxation. The boundary conditions and phase relations between the components are displayed in figure 4.

The beam simulations have shown very small effects in comparison to calculations, which have been done simply with a field-free drifting. Due to the rapidly decreasing field magnitude behind the electrodes the distorted field in between this gap is not critical.

4 FLATNESS

The buncher section attached at the end of the RFQ has an effect on the voltage distribution (flatness) of the electrodes. It forms a big capacity which increases the voltage at this end of the structure.

Figure 5: MAFIA plot of the RFQ structure (16 stems).

To investigate these effects in detail we have done MAFIA simulations for a 16 stem RFQ (fig. 5) structure as it is proposed for the final design. Figure 6 a) shows calculations for three different structures for upper and lower electrodes each. The first calculation has been done with equidistant stems and shows about 20% unflatness in accordance with measurements on the model set up (fig. 6 b).

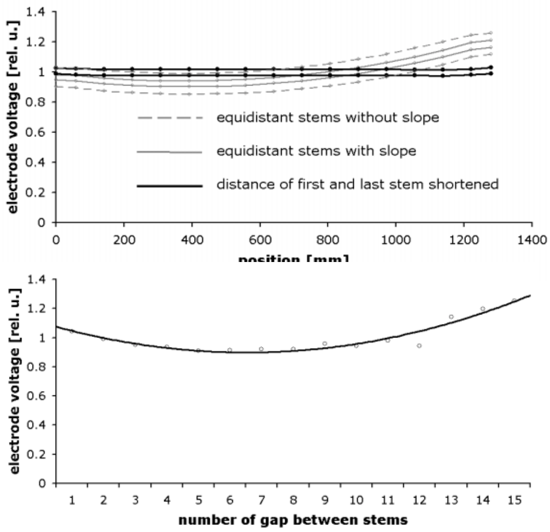

Figure 6: a) Simulations of the flatness with MAFIA. b) measured flatness on the model set up.

The second calculation has also been done with equidistant stems but with a balancing slope at each stem (fig. 7), typical for our 4-rod RFQs, to reduce the voltage difference between upper and lower electrode from 14% to less than 4%.

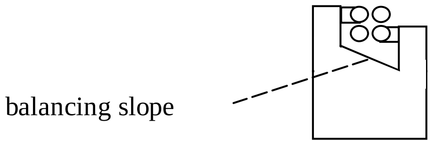

Figure 7: Scheme of a RFQ stem.

A very flat field distribution of about 1.1% unflatness can be achieved for example by a shorter first and last stem distance as it has been done in the last simulation. It is also conceivable to flatten the field by movable ground plates between the first and the last two stems used also for tuning the resonator to resonance frequency.

5 THE SHAPE OF THE ELECTRODES

Originally PARMTEQ is generating an idealised qadrupole assuming a hyperbolic shape of the electrodes (two-term potential). However in reality it is impossible to manufacture electrodes exactly like this. Therefore the manufacturing of the electrodes is always a compromise between technical practicability and theoretical design.

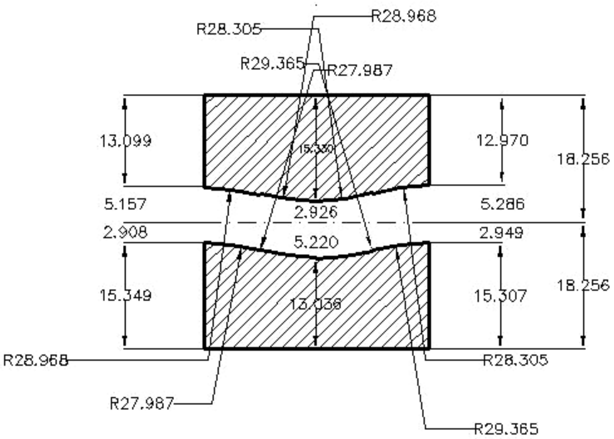

Figure 8: Cell 201 and 202.

The first step at translating the PARMTEQ output into a machine readable CNC-data file is to smoothen the transitions between the RFQ-cells: Each RFQ-cell is independently generated of the preceding cell so that there will always be a little step at each transition. For that reason PARMTEQ has now been extended with a routine that does a very little correction of aperture and modulation of each cell to avoid these steps. Like appropriate simulations have shown, these corrections have only negligible effects on the beam dynamics. The sinusoidal longitudinal modulation itself will be approximated by quarter circles, exemplary shown for cell 201 and 202 in fig. 9. Position and radius of these circles are now generated by our version of the PARMTEQ code.

A milling technique is used, which allows an individually adjusted transversal electrode radius for each cell to guarantee a constant ratio between aperture and electrode radius of a/r = 1.25 in our case.

6 CONCLUSIONS

A first application of a RFQ-Drifttube-Combination is for the medical therapy facility in Heidelberg. The final concept of two bunching gaps provides one extra stem on ground potential supporting the first drift tube between RFQ and the end flange of the tank (fig. 1). Presently most components (tank, stems and ground plate) of the RFQ have been manufactured at NTG in Gelnhausen.

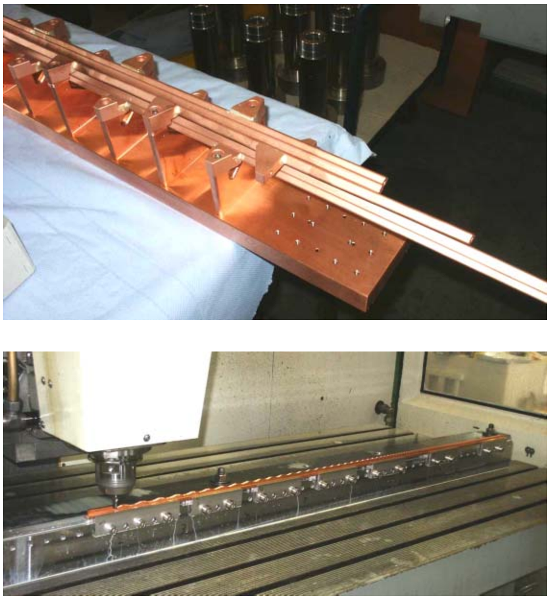

Figure 9: a) Test built up of RFQ components and b) milling of a test electrode at NTG Gelnhausen.

The manufacturing of the electrodes is still in process, the tank has been copper plated at GSI. Presently we are preparing for rf-tuning and alignment.

REFERENCES

[1] A. Bechtold, A. Schempp, U. Ratzinger, B.Schlitt, "Design Studies of an RFQ-Injector for a Medicine-Synchrotron", Proc. PAC2001, 2485.

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