

LOW POWER MEASUREMENTS ON A FINGER DRIFT TUBE LINAC*

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Abstract

The efficiency of RFQs decreases at particle energies higher than a few MeV/u and thus typically DTL structures are used in this energy region. However, the rf field in the gap always has a defocusing influence on the beam. In order to compensate this effect, fingers with quadrupole symmetry were added to the drift tubes. Driven by the same power supply as the spiral drift tubes, the focusing fingers do not need an additional power source or feedthrough.

Beam dynamics have been studied with the code RFQSIM. Detailed analysis of the field distribution was done and the geometry of the finger array has been optimized with respect to beam dynamics. A prototype cavity with finger drift tubes was built, and low power measurements were done. In this contribution, the results of the rf simulation with Microwave Studio are compared to bead perturbation measurements and the focusing effect on the beam is discussed.

INTRODUCTION

At low energies, RFQs are widely used to accelerate ions up to energies of a few MeV/u. Since they can capture relatively high current dc beams and convert them with a high efficiency into a bunched beam, they have found numerous applications [1-3]. However, at velocities above 0.1c, the efficiency of RFQ accelerators decreases.

Spiral loaded cavities have been developed over many years at IAP and are the ideal tool to further accelerate and bunch the beam [4, 5]. Their characteristic parameters can be calculated with high precision, and their compact design and large energy acceptance allows a usage in most beam lines.

A 4-gap spiral loaded cavity was planned as a booster after the 4 m RFQ of the COSY SCL upgrade, which consists of a room temperature RFQ with a booster cavity to inject into a superconducting linac [6]. In order to accelerate deuterons from 2 MeV/u to 2.5 MeV/u an overall voltage of 1 MV is needed in the booster. A four gap structure was chosen in order to keep the required peak voltages in each section low. Table 1 gives an overview of the design parameters.

Table 1: Parameters of the booster cavity

Input Energy	2 MeV/u
Length	300 mm
Diameter	280 mm
Beam aperture radius	10 mm
Gap / total voltage	250 kV / 1 MV
Power consumption	150 KW
$\beta\lambda/2$	62 mm

While the desired energy gain can be realized with this structure, the rf-defocusing from the fields in the acceleration gaps would lead to a growth of the transverse dimensions of the beam. Therefore, fingers in quadrupole symmetry were added to the drift tubes in order to focus the ions. A prototype cavity, designed and built at IAP, is shown in fig. 1.



Figure 1: View of the spiral loaded cavity with finger drift tubes.

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BEAM DYNAMICS

A detailed analysis of the particle motion was done with the code RFQSIM [7], developed at IAP. For that purpose, the original design of the COSY SCL Injector linac was chosen, which consists of a 4 m RFQ and a small booster cavity of only 0.3 m length.

The RFQ accelerates protons and deuterons to a final energy of 2 MeV/u where the booster takes over and increases the energy to 2.5 MeV/u.

The field distribution was calculated with an excel macro using the successive over-relaxation method. It allows the input of arbitrary geometrical structures and calculates a static 3D voltage distribution that can be imported into RFQSIM. The components of the electric field at the position of the particle are then calculated automatically. The simulation results for a beam passing through one cell of such a combined accelerating / focusing structure are shown in fig. 2. The beam is focused in the x-x' plane, while it is defocused in the y-y' plane. Modifications of the geometrical layout of the fingers and changes in the distances between the gaps can be combined to reach a compensation of the rf-defocusing and a match to the following accelerator stage.

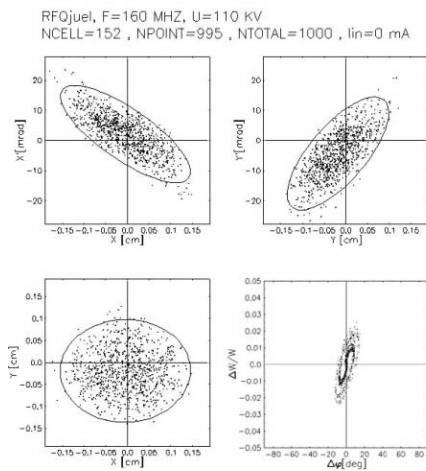


Figure 2: RFQSIM results with finger drift tubes.

SIMION SIMULATIONS

The simulations with RFQSIM were done with limited geometrical resolution and the assumption of an rf field based on a static potential distribution.

Therefore, the geometry was put into the program SimIon [8] and the effects on singly charged ions were analyzed. As a first test, the z-component of the electric field as shown in fig. 3 was calculated. It matches with earlier measurements [5]. In standard mode, SimIon is used for the analysis of static problems.. Thus a user program was written to fast adjust the voltage on the electrodes depending on the individual ion positions. This allows simulating the real field behaviour with high accuracy.

The resolution in the model was 1mm, the ion parameters were chosen as given in table. 1. The geometrical parameters of the finger drift tubes as calculated are shown in table 2.

Table 2: Geometrical parameters of the finger drift tubes

Gap width	30 mm
Finger length	20 mm
Aperture radius	10 mm
Finger radius	7.5 mm

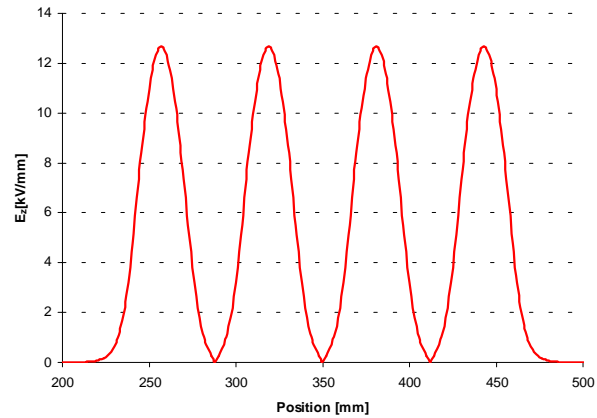


Figure 3: Z-component of the electric field as calculated with SimIon.

Individual ions were placed at radial positions from the central trajectory moving parallel to the beam axis. The strong focusing effect in one plane after passage of the whole structure is shown in fig. 4. While the ions are accelerated by the longitudinal field, a transverse focussing field component is superimposed. Like in a normal AG-beam-transport section, the beam is continuously focused and defocused.

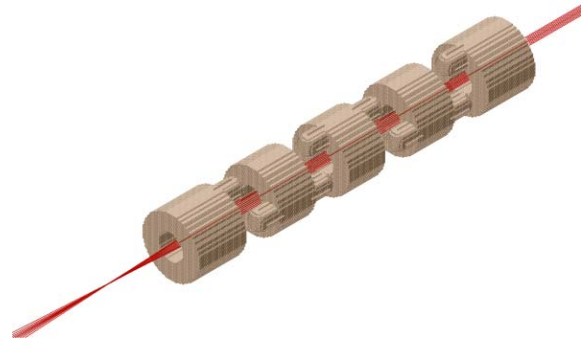


Figure 4: 3D view of the ion motion within the finger drift tube structure as calculated with SimIon.

The simulations of the particle motion show, that it is possible to optimize the design with respects to its focusing properties

BEAD PULL MEASUREMENTS

A prototype of a finger drift tube structure with the parameters given in table 1 was built up and tested at low power. These measurements show, that in the original design, the 0-mode and the π -mode are separated by a few MHz only, which would lead to unwanted effects and problems during operation.

Therefore, both spirals were first mounted in parallel orientation and in a successive step connected by a copper bridge to guarantee that they are on the same potential in 0-mode. Due to the bridge, the frequency of the π -mode was raised by about 90 MHz, which allows a very stable operation of the cavity. A comparison of the three designs is shown in table 2.

Table 2: Resonance frequency of different structures

	Original structure	parallel spirals	parallel spirals with bridge
0-mode	162.1 MHz	157.5 MHz	153.9 MHz
Q _o	1680	1980	1880
π -mode	159.3 MHz	160.8 MHz	248.3 MHz
Q _{π}	2200	1500	700

This configuration of the spirals and the short-circuit bridge between the two spirals resulted in a stronger coupling of the two spirals. Therefore the voltage on the drift tube is balanced and the operation is stable. Preliminary results of bead pull measurement on the above structure are shown in fig. 5.

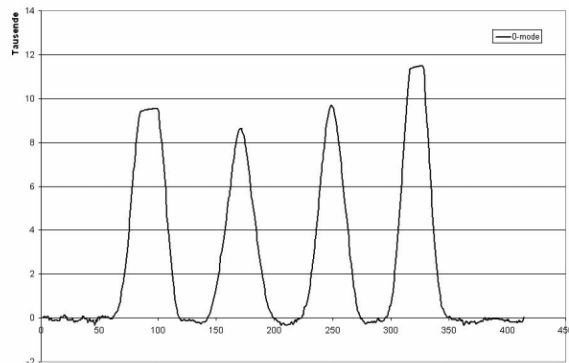


Figure 5: Measured field on the beam axis.

Besides errors due to small misalignment of the structure in the cavity, the field distribution matches nicely to the numerical simulation results obtained with Microwave Studio and SimIon.

The final layout of the inner structure with the stabilizing bridge between the spirals can be seen in Fig 6.

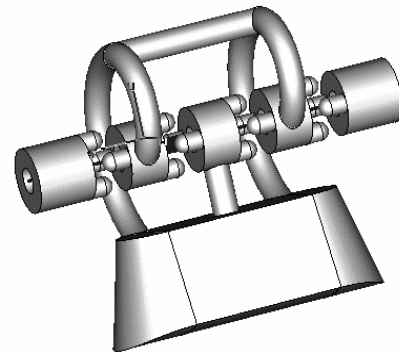


Figure 6: Spiral loaded cavity with stabilizing bridge.

CONCLUSION

The properties of this new spiral loaded cavity at higher energies were demonstrated. The field distribution measured with the bead pull method are in good agreement with the simulations. The beam dynamics calculations and the field simulations, done with RFQSIM, Microwave Studio and SimIon, allow a detailed optimization of the structure and show that such a combined focusing / accelerating structure could be used in future injectors.

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