SIMULATIONS ON A BEAM TRANSPORT SYSTEM FOR THE FRANKFURT FUNNELING EXPERIMENT*

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Abstract

The goal of the Frankfurt Funneling Experiment is to multiply beam currents by merging two low energy ion beams. Our setup consists of two ion sources, a two beam RFQ accelerator, a multi cell deflector and a beam diagnostics. Current work is the design of a new beam transport between RFQ accelerator and deflector and first simulations will be presented.

INTRODUCTION

Ion current in linear accerelartors are limited by what current the ion source can deliver within a given emitance. Funneling is a way to increase beam currents by using two ion sources. The capabilities for beam transportation in the low energy end of a linac is the limiting factor for the beam current of the linac. The limit is proportional to $\beta = v/c$ for electric and to β^3 for magnetic focusing and emittance conservation. Funneling uses an preaccelerated beam and therefor higher current limits because the higher β-factor. This higher limit will be used by doubling the beam current by bending two bunched beams at a frequency f_0 with a rf-deflector to a common beam axis. After this rf-deflector the beam will be injected into another rf-accelerator at frequency $2f_0$ filling all rf-buckets. In an optimal case the beam emittance stays as low as for one single beam. Extracting twice the beam current from a single ion source would result in alt least twice the emittance due to space charge effects.

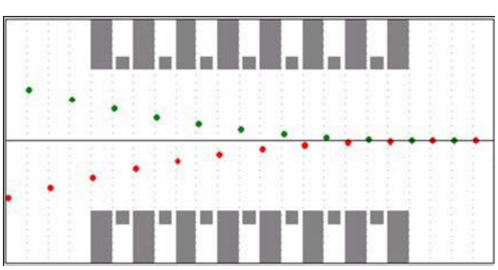

Figure 1: Scheme of funneling: two beams at f_0 are injected into the deflector and one beam at $f = 2f_0$ is extracted.

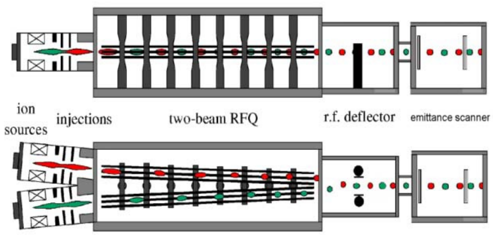

Figure 2: Top and side view of the experimental setup: the two ion sources, the two-beam radio-frequency-quadrupole,the deflector and an emitance scanner(from left to right).

EXPERIMENTAL SETUP

The setup of the Frankfurt Funneling Experiment consists of two multicusp ion sources, a two beam RFQ accelerator, two different funneling deflectors and a beam diagnostic device. The two ion sources are attached to an electrostatic LEBT and mounted to the front of the two-beam RFQ accelerator. The sources provide an He+ beam with an energy of 4 keV. The two RFQ beam lines, each with its own set of quadrupole electrodes, are arranged in one common resonant structure [1] with an angle of 75 mrad. The beams get accelerated and bunched with a phase shift of 180°. The phase shift is realised by a mechanical offset of the electrodes of $\beta\lambda/2$ witch are about 2 meters long and divided into two sections. The low energy section bunches and accelerates the beam to an energy of 160 keV. The high energy end focuses the beam longitudinally and radially to the beam crossing point at the center of the deflector. This matching section reduces the size of the beam by around 60% compared to a beamline without this focusing section (fig. 3). At the end of the two-beam RFQ the beam has an energy of 179 keV.
The deflector is located at the beam crossing point. There it reduces the transversal angle of the beams from x'= 37.5 mrad to x'=0 mrad in one, with the old single cell deflector, or in several steps with the newer multi cell deflector.

MOTIVATION

Between the two-Beam RFQ accelerator and the multi cell deflector there is a drift of the ion beams of approximately 40 cm as seen in fig. 5. At 179 keV space charge effects increase the beam diameter so that the two ion beams are to big for the acceptance of the multi cell deflector,

* Work supported by BMBF

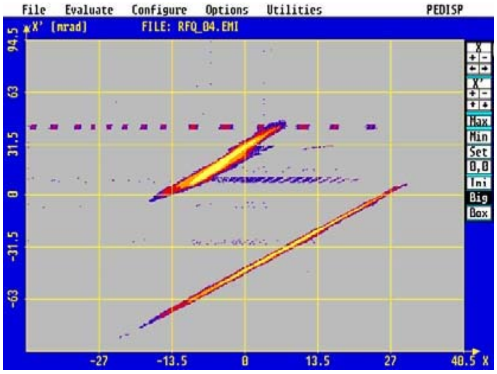

Figure 3: Emittance measurement with one beam line upgraded [2].

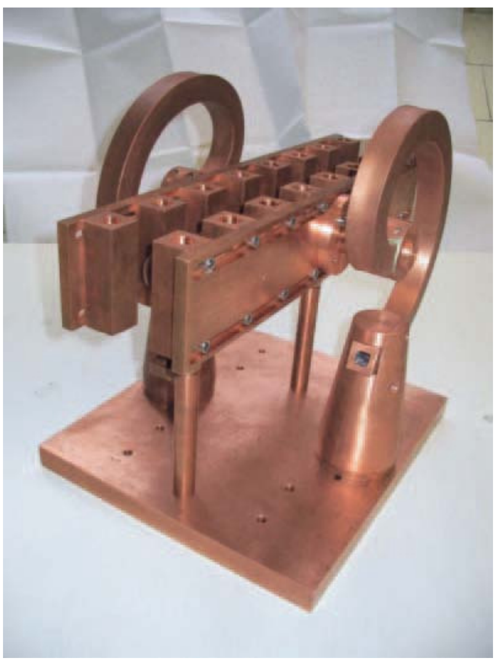

Figure 4: Photo of the multi cell deflector [3].

therefor decreasing the ion current which can be transmitted through the deflector. This is shown by simulations as seen in fig. 6.

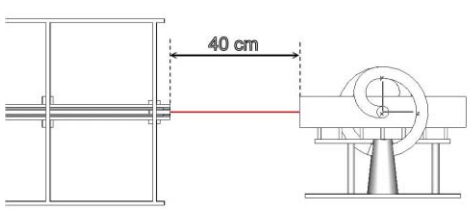

Figure 5: The drift section between the two-beam RFQ and the multi cell deflector.

First attemts to improve this section are to decrease the

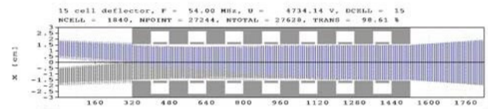

Figure 6: Drift of the ion beams against the deflector [4].

length of the drift, so that the ion bunches will be focused a longer way and space charge effects will be minimized. This could be done by extending the RFQ electrodes for both RFQ beam lines.

Because of the angle between the two beam lines of 75 mrad the two inner electrodes will start to overlap after 17 cm. The connection between those two electrodes was simulated with CST MWS (Computer Simulation Technology: Microwave Studio) to check if it is possible to realise such a system.

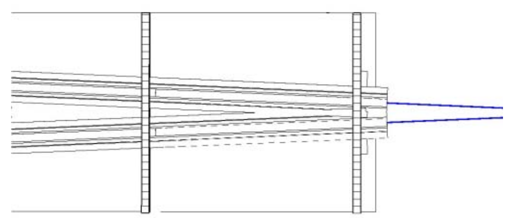

Figure 7: Detailed view on the high energy end of the electrodes with the new transport section.

SIMULATIONS

The goal of these simulations is to compare them with simulations of the existing RFQ accelerator. The resonance frequency is expected to change, but other RFQ features like focusing and bunching should not change dramatically.

The existing funneling RFQ consists of 8 stems, witch do not have the same distance between two stems. This was done to improve the field distribution [5]. The altogether 8 electrodes are 2 meters long without the new transport section and for easier simulation modeled with a flat modulation. This will result in a slightly higher frequency compared to a simulation with the accurate modulation as simulations with other RFQs showed. The simulated frequency of the first mode with this unmodulated electrodes is 3.3 MHz higher than the real frequency without the recently added capacity [6]. This added capacity further improves the field distribution to minimize beam losses in the RFQ.

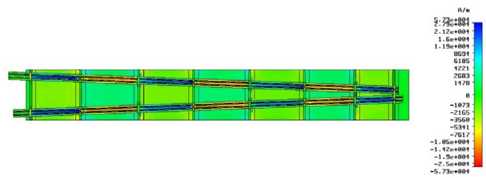

Figure 8: Current two beam RFQ with simulated surface currents in top view.

The new beam transport section will increase the length of the electrodes by 22.5 cm. A ninth stem is an option to further stabilize the properties of the resonance structure. The simulations show an increased resonance frequency by the extended electrodes: the frequency increases from 59.0 MHz to 64.4 MHz with a ninth stem 22.5 cm after the 8th stem and without to 63.8 MHz. The position of the stem influences the resonance frequency of the two-beam RFQ. The increase of the resonance frequency is dependent on the position of the added stem (see fig. 9). A greater distance between the last to stems leads to a lower frequency. This results through added capacity and inductance in the last resonances circle. The shift follows a exponential decay as a function of the distance between stems 8 and 9.

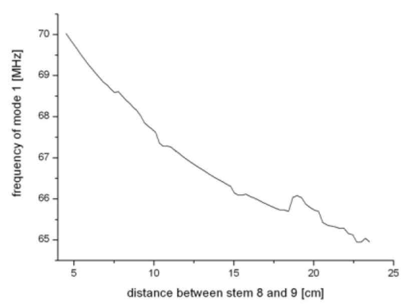

Figure 9: Shift in frequency in relation to the distance between the last two stems.

The difference between the model with and without a ninth stem are shown in figure 10 and figure 12. There seems to be a problem at the low energy end of the left beam line for both options. The surface currents are not switching directions after each stem like it is seen in a simulation of the current two beam RFQ (see fig. 8).

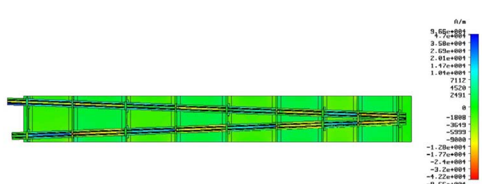

Figure 10: Top view of the surface currents on the eight stem model at a frequency of 63.8 MHz. The left beam axis shows at the low energy end an unexpected distribution.

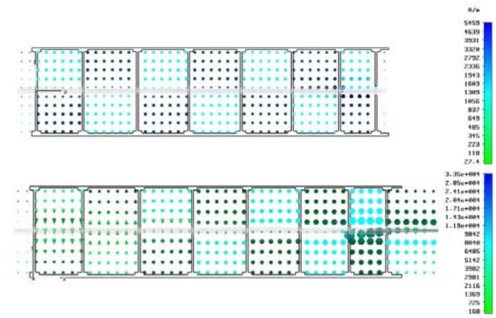

Figure 11: Magnetic field around the stems in the current Two-Beam-RFQ (top) and with extended electrodes (bottom).

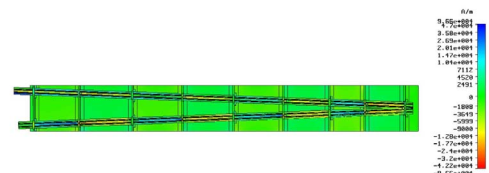

Figure 12: Top view of the surface currents on the nine stem model at a frequency of 64.4 MHz. The left beam axis shows the same behavior as with the eight stem model.

OUTLOOK

The simulations are done and the construction of the electrode extensions will be the next step. This will be done to test the simulations in a real setup and to investigate the mode and the question of the not switching surface currents. The impact of the extension to the field distrubution will also be examined.

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