THE FRANKFURT FUNNELING EXPERIMENT*

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Abstract

Funneling is a procedure to multiply beam currents at low energies which is necessary for the proposed new high current accelerator facilities like HIDIF or ESS. Funneling can be done by several stages. The beams of several LEBT's are merged in multiple stages to any kind of energy and beam current by funneling. The main goal is to keep the emittance nearly unchanged.

The Frankfurt Funneling Experiment consists of two ion sources, a Two-Beam RFQ accelerator, two different funneling deflectors and a beam diagnostic equipment system. The whole set-up is scaled in He^+ instead of Bi^+ of the first funneling stage of a HIIF driver. The progress of our experiment and the results of the simulations will be presented.

1 INTRODUCTION

At low energies the beam currents of linacs are limited by space charge effects, focusing and transport capability of the accelerator.

Funneling is doubling the beam current by combination of two bunched beams preaccelerated at a frequency f_0 with an r.f. deflector to a common axis and injecting into another r.f. accelerator at frequency $2*f_0$ as indicated in figure 1.

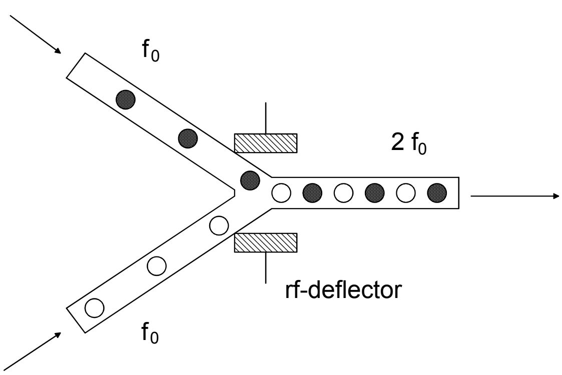

Fig. 1: Principle of funneling.

By the use of the Two-Beam RFQ the two beams are brought very close together while they are still radially and longitudinally focused. Additional discrete elements like quadrupole-doublets and -triplets, debunchers and bending magnets, as they have been proposed in first funneling studies, might not be necessary [1,2,3]. A short r.f. funneling deflector is placed at the beam crossing position behind the RFQ [4].

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2 EXPERIMENTAL SETUP

Beam experiments with our Two-Beam RFQ were done with He^+-ions at low energies to facilitate ion source operation and beam diagnostics (fig. 2). Two small multicusp ion sources and electrostatic lenses, built by LBNL [5,6], are used. The LEBT's are attached directly on the front of the RFQ with an angle of 75 mrad, the angle of the beam axis of the Two-Beam RFQ.

Fig. 2: Picture of the experimental set-up.

The Two-Beam RFQ consists of two sets of quadrupole electrodes, where the beams are bunched and accelerated with a phase shift of 180° between each bunch, driven by one resonant structure. The RFQ is divided in two sections. The first section, which is about two thirds of the total length of 2 meters, accelerates the beam to a final energy of 160 keV. The last section has to match the beam to the funnel deflector to optimize beam radius and phase width.

At present one beam axis consists of the old unmodulated electrodes whereas the other beam axis consists of the new modulated electrode endpart. This will allow to compare directly both beams. Within a short time the second beam line will be upgraded too.

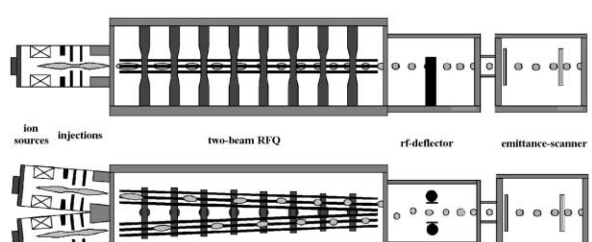

Fig. 3: Scheme of the experimental set-up.

Figure 4 shows the Parmteq simulations with the new RFQ electrode endpart. The new electrode design reduces beam radius and phase spread at the funneling deflector corresponding to the old electrode design (figure 5).

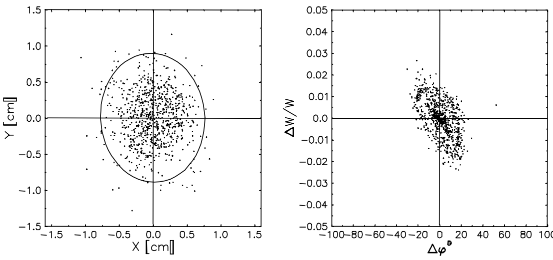

Fig. 4: Beam data with the new design of the RFQ electrode endpart.

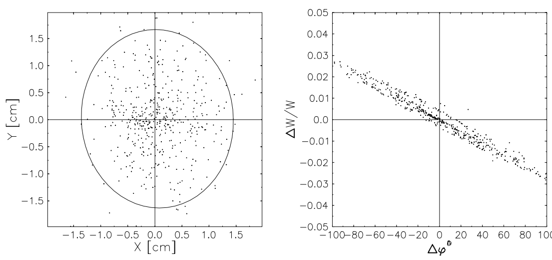

Fig. 5: Beam data with unmodulated electrode endpart.

3 FUNNELING DEFLECTOR

For beam bending to a common axis we have investigated several schemes of deflectors [7]. We have done experiments with the one cell and the multi cell deflector. The crossing point of the two beams is right in the middle of the deflector, which is 52 cm behind the RFQ.

The angle between the two beam axes is 75 mrad. The one cell funnel deflector bends this angle down to zero by an r.f. voltage of 25 kV.

Figure 6 shows a simulated beam bending with the one cell funnel deflector. The deflector bends the beam from an average angle of 37.5 mrad down to zero.

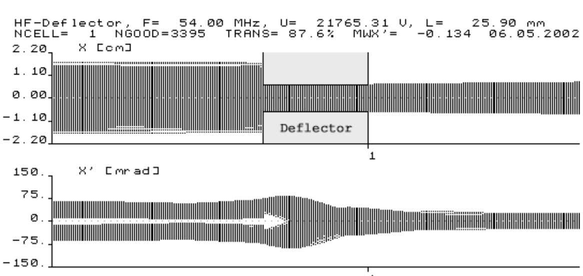

Fig. 6: Simulation of the beam bending in the one cell funnel deflector from □x’> = 37.5 mrad to <x’> = 0 mrad.

Figure 7 displays a result of a simulation for the funneling with two beams with the new electrode design.

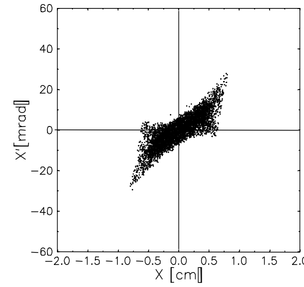

Fig. 7: Simulated funneling with new RFQ electrode design.

At the moment a new software for field calculations and particle transport (completely in 3D) for the deflector module in Parmteq is being developed. This will allow us to improve the existing deflector structures and design new structures for future funneling deflectors.

4 THE NEW RFQ ELECTRODES

The new RFQ electrode endpart has been manufactured and installed in the RFQ for first experiments.

Figure 8 shows one beam line with transfer to the new modulated electrode endpart.

Fig. 8: The mounted electrodes at the stem.

The old design uses unmodulated electrodes at constant aperture after the acceleration part until the end. In the new design the bunch drifts for 12 cells with increasing aperture. The last 8 cells have a modulation up to m = 1.4 to bunch the beam with the time focus at the funneling deflector. At the same time the focusing is made stronger to avoid a diverging beam and get more beam into the aperture of the deflector. Thus the RFQ provides a longitudinal and radial focus at the deflector.

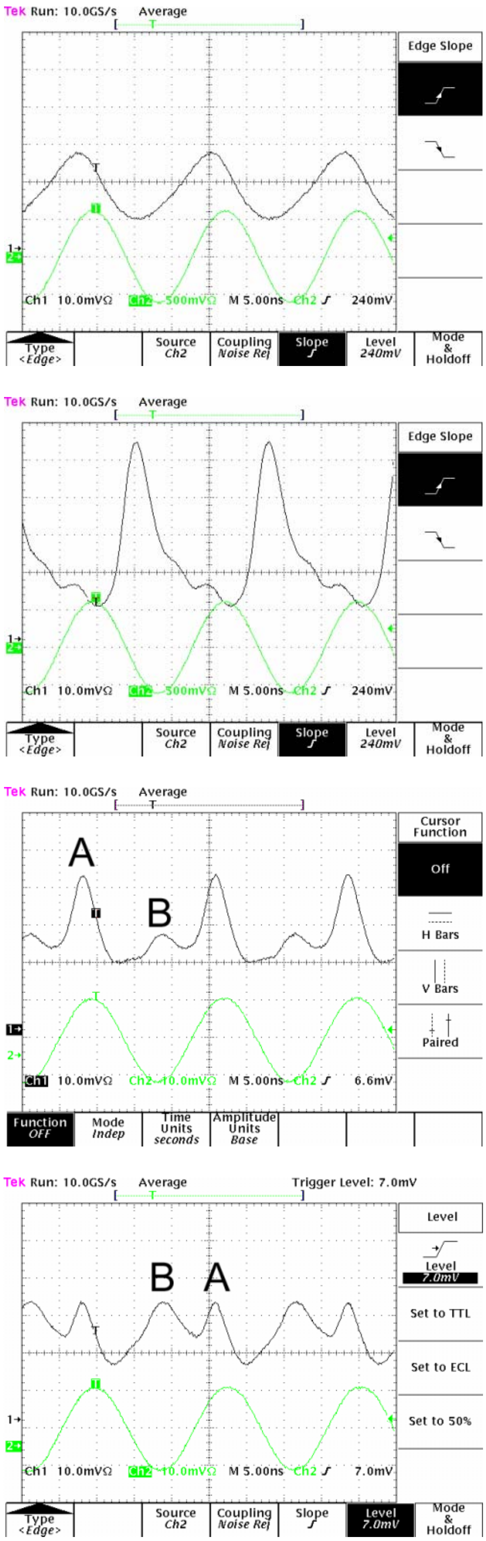

Fig. 9 a-d: Beam pulse measurements with a faraday cup.
a: Unmodulated electrode endpart
b: Modulated electrode endpart
c: Both beams
d: Same current at faraday cup

Figure 9a displays the beam pulses of the old design with unmodulated electrodes at the end. In Figure 9b shorter beam pulses with the modulated endpart is shown. Figure 9c shows the interlaced beam pulses now with $2f_0$. Both beams have the same current at the faraday cup (figure 9d).

The used faraday cup has a restricted bandwidth and cannot resolve the pulses at high resolution. But the results cleary indicates the improvements of the matching to the funnel deflector.

5 CONCLUSIONS

Funneling has been demonstrated with both kind of funnel deflectors [7]. To achieve a proper funneling the beam radius and phase width at the point of the funneling deflector has to be as small as possible.

The manufacturing of the last electrode section is done. The installation of the new electrode endpart at one beam line and the retuning of the RFQ accelerator was completed. First beam tests have been done.

Next step will be bending and diagnostics with the new beam. The installation of the new electrodes at the second beam line will follow. Then we will measure emittance growth during funneling with our beam diagnostic device.

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