FUNNELING WITH THE TWO-BEAM RFQ*

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Abstract

New high current accelerator facilities like proposed for ESS requires a beam with a very high brilliance. These beams can not be produced by a single ion-source. The increase in brightness in the driver linac is done by several funneling stages at low energies, in which two identically bunched ion beams are combined into a single beam with twice the frequency, current and brightness.

Our Two-Beam-RFQ funneling experiment is a set-up of two ion sources, a Two-Beam-RFQ, two different funnel deflectors and beam diagnostic equipment to demonstrate funneling of ion beams as a model for the funneling stage for the ESS driver. The progress of the funneling experiment and results of simulations will be presented.

1 INTRODUCTION

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

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.

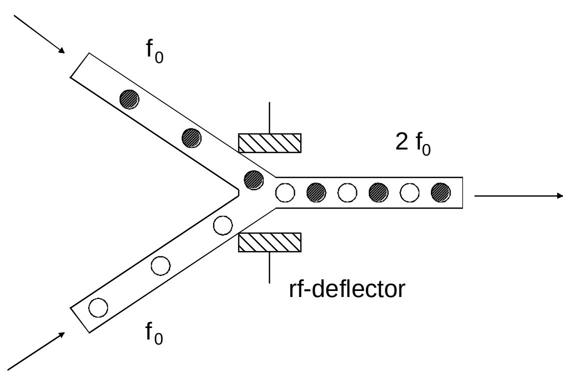

Fig. 1: Principle of funneling.

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. The HIDIF linac starts with 16 times 3 ion sources for three different ion species to allow so-called „telescoping“ at the final focus [4]. With four funneling stages the frequency has been increased from 12.5 MHz to 200 MHz and the beam current from 35 mA to 400 mA accordingly [5].

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. Two small multicusp ion sources and electrostatic lenses, built by LBNL [6,7], are used. The ion sources and injection systems 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. Figure 2 shows a scheme of the experimental set-up of the two-beam funneling experiment.

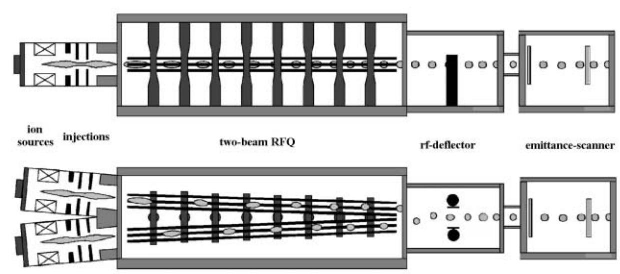

Fig. 2: Experimental set-up of the two-beam funneling experiment.

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 reduce the beam radius and phase width. At present this section consists of unmodulated electrodes for first beam tests. Figure 3 shows the Parmteq simulations for the actual electrodes. The calculations of the new electrode design has been finished. The production will be starting soon. The new electrode design gives approximately half the beam radius and phase spread at the funneling deflector. This will allow us to improve the total beam. At the present the beam radius is too big for our emittance measurement device [8].

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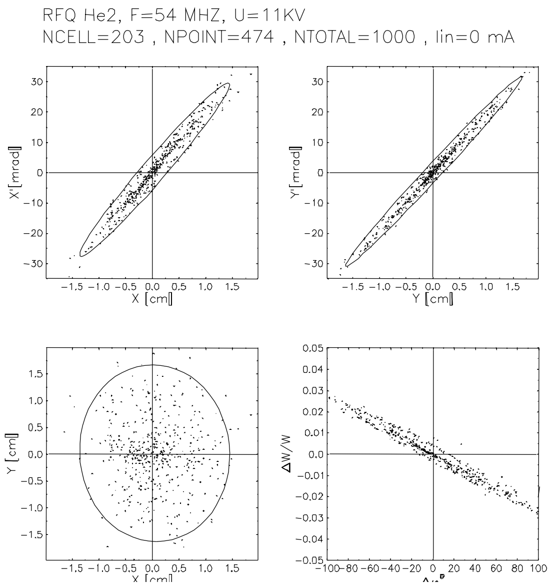

Fig. 3: Beam data of the funneling deflector with actual RFQ.

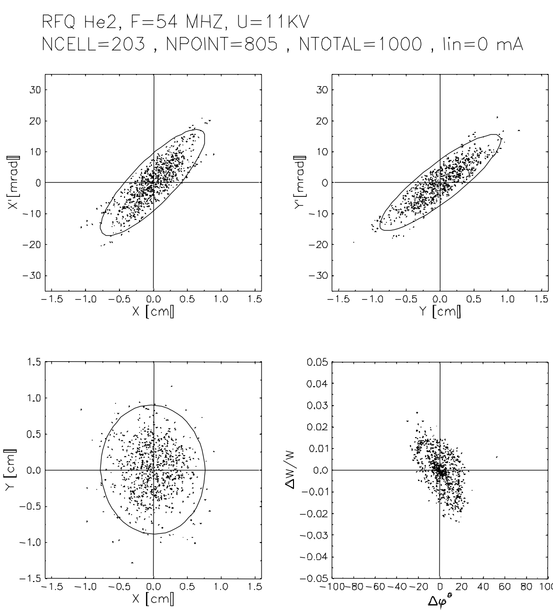

Fig. 4: Beam data with the new design of the RFQ electrodes.

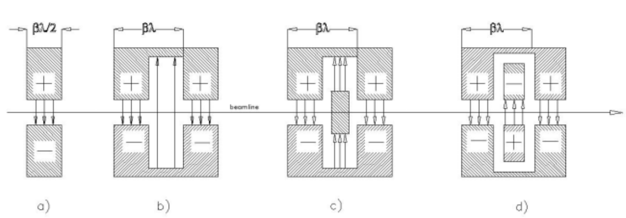

Fig. 5: Schemes of funnel deflectors. The arrows show the electric field during one period. a) a one cell deflector, b) multicell deflector, c) multicell deflector with one central drift tube, d) βλ/2-multicell deflector

3 FUNNELING DEFLECTOR

For beam bending to a common axis, we have investigated several scheme of deflectors, as shown in fig. 5. We have done experiments with the one cell and the multicell deflector. The multi cell deflector reduces the bending voltage and peak fields compared to the single cell deflector. The crossing point of the two beams is right in the middle of the deflector, which is 52 cm behind the RFQ.

A photograph of the twin line resonator with the one cell deflector of is shown in Figure 6.

Fig. 6: Picture of the one cell funnel deflector . The deflector discs are mounted at water-cooled stems. The height is about 2 m. The cell length is $\beta\lambda/2$.

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 7 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.

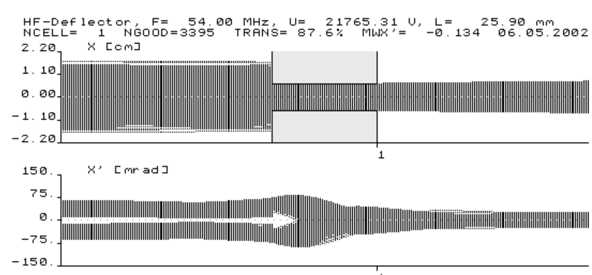

Fig. 7: Simulation of the beam bending in the one cell funnel deflector . The rectangles are the deflector plates (top picture), the lower picture shows the beam bending from 37.5 mrad down to zero.

Figures 8 and 9 show two emittance measurements, done with the one cell deflector. The one cell deflector needs a higher voltage for bending, but has less axial field. If the funnel deflector is switched off, the beam drifts through the deflector and we measure the beam-angle of 75 mrad. Figure 9 illustrates an emittance measurement with the one cell funnel deflector switched on. The two beams are merged into a common beam.

Figure 10 shows a result of a simulation for the funneling with two beams with our actual electrode design. The angle between the two beams is reduced from 75 mrad down to zero.

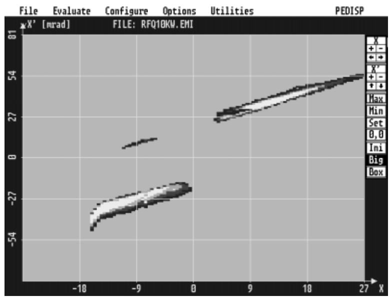

Fig. 8: Emittance measurement with the deflector switched off.

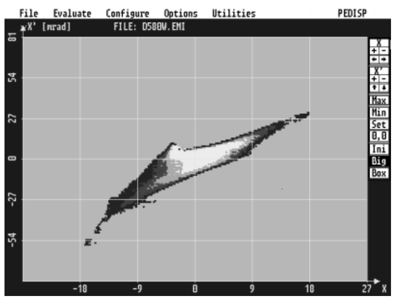

Fig. 9: Emittance measurement while the one cell deflector switched on. The two emittances are merged into a common beam.

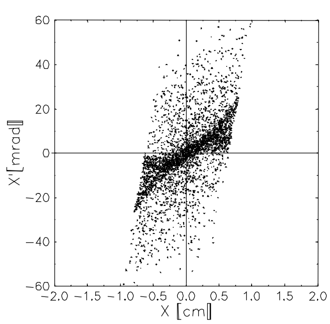

Fig. 10: Simulation of funneling with two beams with the present beam.

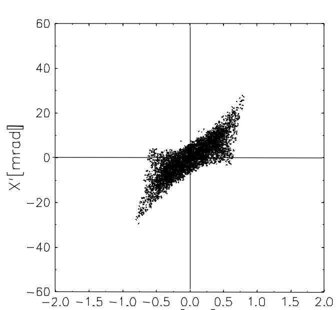

Fig. 11: Simulated funneling with new RFQ electrode design.

Figure 11 shows a simulation of funneling with the new electrode endpart.

4 CONCLUSIONS

Funneling has been demonstrated with both funnel deflectors. However, the form of the measured and simulated ellipses shows, that we have to reduce the beam radius and phase width out of the RFQ, because of the long beam drift of 50 cm to the funnel deflector and 50 cm to the emittance measurement device.

Calculations of the new electrode design show the improved matching of the beam to the funnel deflector. With the new part of the electrodes we will measure emittance growth during funneling with our beam diagnostic device.

The manufacturing of the last electrodes section is in progress. Next step will be the installation of the new electrodes and retuning of the RFQ, if the reconstruction of our laboratory can be envisaged to be completed.

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