FUNNELING WITH THE TWO-BEAM RFQ*

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Abstract

By ion beam funneling the beam current can be multiplied without changing the emittance, which is proposed for new high current accelerator facilities like HIDIF or ESS. There the required beam current can not be produced by a single pass rf-linac. The increase in brightness in such a 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 funneling experiment is a setup of two ion sources, a two beam RFQ, a funnel deflector and beam diagnostic equipment to demonstrate funneling of ion beams as a model for the first funneling stage of a HIIF 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.

Funneling is doubling the beam current by the 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.

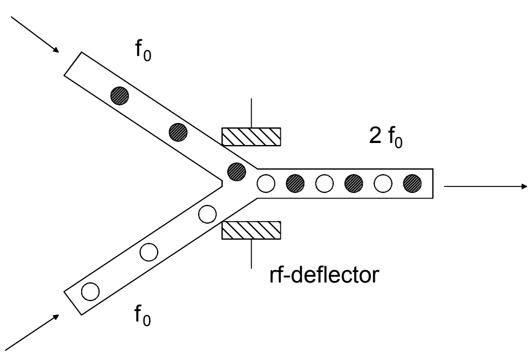

Fig. 1: Principle of funneling.

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, are not 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 [5]. With four funneling stages the frequency has been increased from 12.5 MHz to 200 MHz accordingly [6].

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 [7,8], are used. The ion sources and injection systems are attached directly on the front of the RFQ with an angle of 76 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.

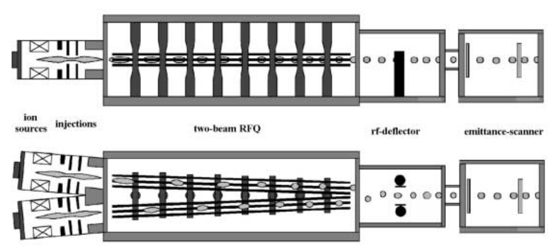

Fig. 2: Experimental set-up of the two-beam funneling experiment.

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 improve the matching of the beam to the funnel deflector to reduce the beam radius and phase width. This section consists of unmodulated electrodes for beam tests. Figure 3 shows the Parmteq simulations of these electrodes.

The new electrode design gives approximately half the beam radius and the phase spread at the funneling deflector. This will allow us to determine the emittance growing during funneling. At the present the beam radius is too big for our emittace measurement device.

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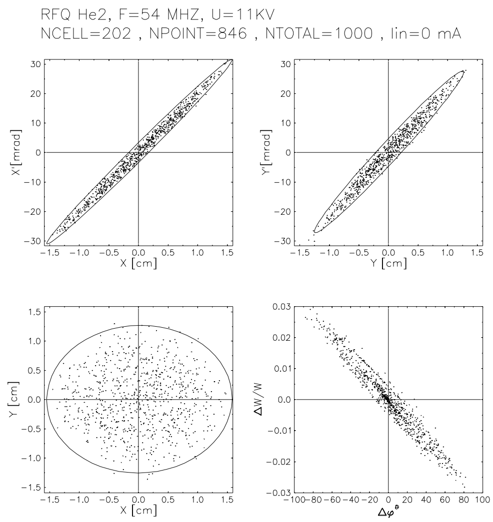

Fig. 3: Beam data of the funneling deflector with actual RFQ.

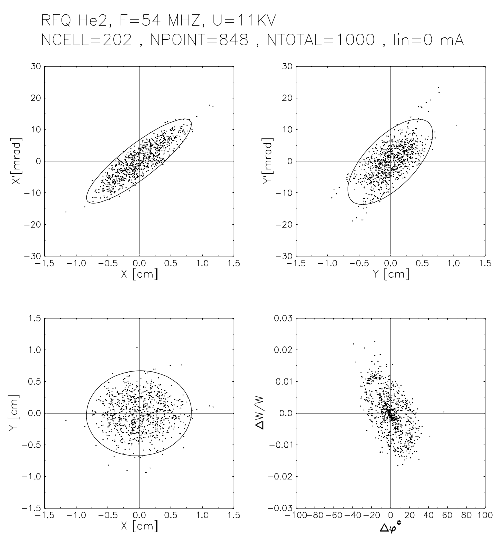

Fig. 4: Beam data with the new design of the RFQ electrodes.

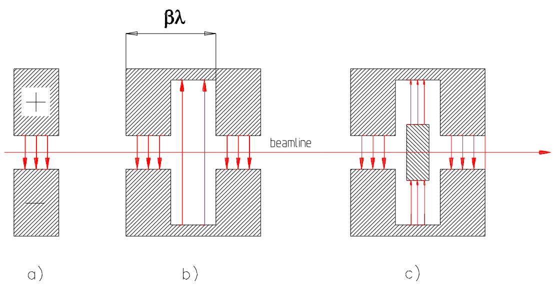

Fig. 5: Schemes of funnel deflectors. The arrows show the electric field during one period. a) a one cell one gap deflector , b) a three cell multigap deflector, c) multigap deflector with one central drift tube.

3 FUNNELING DEFLECTOR

For beam bending to a common axis we use two types of deflectors, the one gap and the multigap funnel deflector, as shown schematically in figure 5. The crossing point of the two beams is right in the middle of the deflector, which is 52 cm behind the RFQ. This deflector is like a plate capacitor, oscillating with the same resonant frequency as the RFQ. A photograph of the twin line resonator with the one gap deflector is shown in Figure 6.

Fig. 6: Picture of the one gap funnel deflector . The deflector discs are mounted at water-cooled stems. The height is about 2 m.

The angle between the two beam axes is 76 mrad. The one gap 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 gap funnel deflector. The deflector bends the beam from an average angle of 38 mrad down to zero.

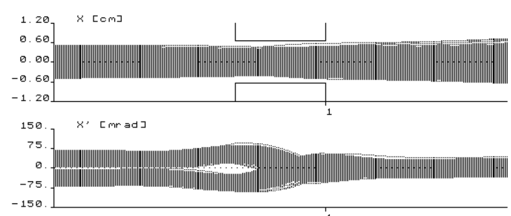

Fig. 7: Simulation of the beam bending in the one gap funnel deflector . The rectangles are the deflector plates (top picture), the lower picture shows the beam bending from 38 mrad down to zero.

Figures 8 and 9 show two emittance measurements. If the funnel deflector is switched off, the beam drifts through the deflector and we measure the beam-angle of 76 mrad. Figure 9 shows an emittance measurement with the one gap funnel deflector switched on. The two beams are merged into a common beam.

Figure 10 shows a funneling simulation of two beams. The angle between the two beams is reduced from 76 mrad down to zero. The “banana form” of the emittances is caused by inhomogeneous electric fields.

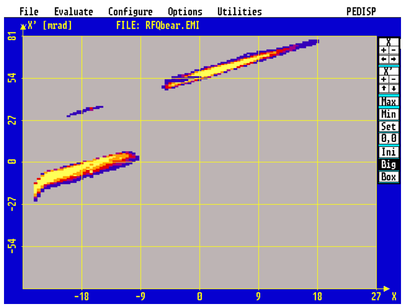

Fig. 8: Emittance measurement with the deflector switched off.

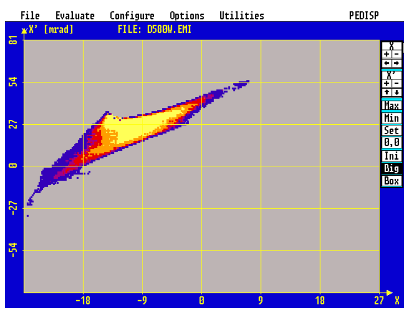

Fig. 9: Emittance measurement with the one gap deflector switched on. The two emittances are merged into a common beam.

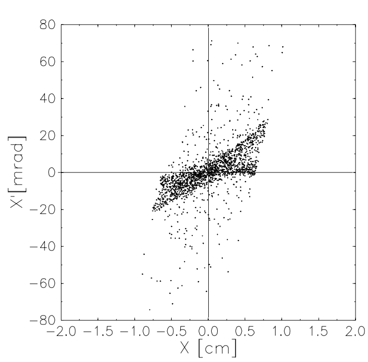

Fig. 10: Simulation of funneling with two beams with the present beam

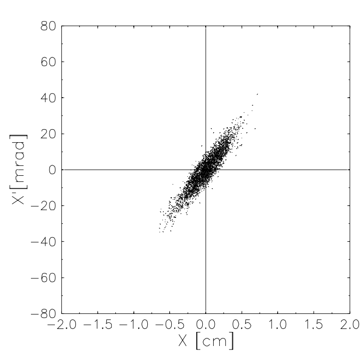

Fig. 11: Simulated funneling with ideal beam data

Figure 11 shows a simulation of funneling with an “ideal” beam. The beam radius at the deflector is 0.25 cm, the phase shift $\Delta\varphi \approx \pm 25°$ and the energy spread ±1.5%.

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. We will change RFQ electrodes to achieve a smaller diameter and phase width of the beam to reduce the “banana form” of the funneled beam.

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.

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