FIRST RESULTS OF THE TWO–BEAM FUNNELING EXPERIMENT*

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Abstract

High intensity accelerator concepts for **H**eavy **I**on **I**nertial **F**usion (HIIF) injectors require small emittance, high current and high energy beams. The improvement of 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. For the **H**eavy–**I**on **D**riven **I**gnition **F**acility (HIDIF) we have proposed the use of a two–beam accelerator structure which provides two beams within one cavity, and a single r.f. deflector structure which bends the two beams to one common axis. The progress of the experiment and first beam–test results will be presented.

1 INTRODUCTION

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 [1, 2, 3], are not necessary. A short r.f. funneling deflector will be placed around the beam crossing position behind the RFQ. The layout of the proposed HIDIF–injector with two–beam RFQs in front of the first and second funneling sections is shown in Figure 1. 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 accordingly.

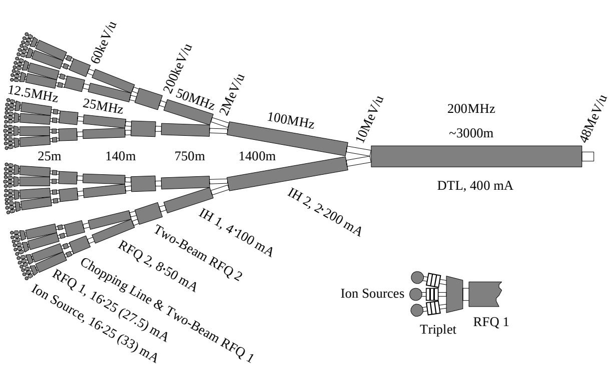

Figure 1: Layout of the 12.5...200 MHz HIDIF linac system for 400 mA of Bi^+.

For studies of the new two–beam RFQ structure and the r.f. deflector, the first two–beam funneling experiments will be carried out 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 (Lawrence Berkeley National Laboratory) [5, 6], 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 axes of the two–beam RFQ. Figure 2 shows the experimental set–up of the two–beam funneling experiment. In Table 1 the main parameters of the experiment with He^+ and the design parameters of a first HIDIF funneling stage for Bi^+ are shown.

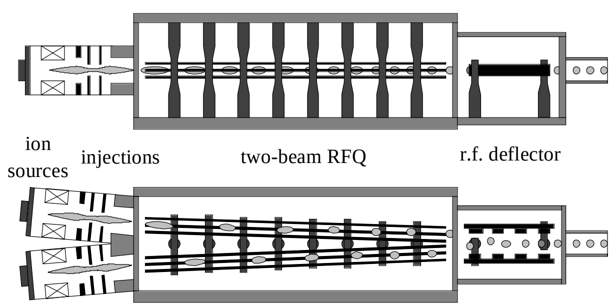

Figure 2: Experimental set–up of the two–beam funneling experiment.

Table 1: Main parameters of the experiment with He^+ and the design parameters of a first HIDIF funneling stage for Bi^+.

Two–beam RFQ	He^+	Bi^+
f_0 (MHz)	54.5	12.5
Voltage (kV)	10.5	180
R_p value (kΩ m)	80	250
Q_0 value	1800	5000
T_{in} (keV)	4	209
T_{out} (MeV)	0.16	12.54
Angle between beam axes (mrad)	76	76
Beam separation at output (mm)	40	40
Multigap funneling deflector		
f_0 (MHz)	54.5	12.5
Voltage (kV)	6	450
Length ($\frac{\beta\lambda}{2}$)	9	2

* Work supported by the BMBF

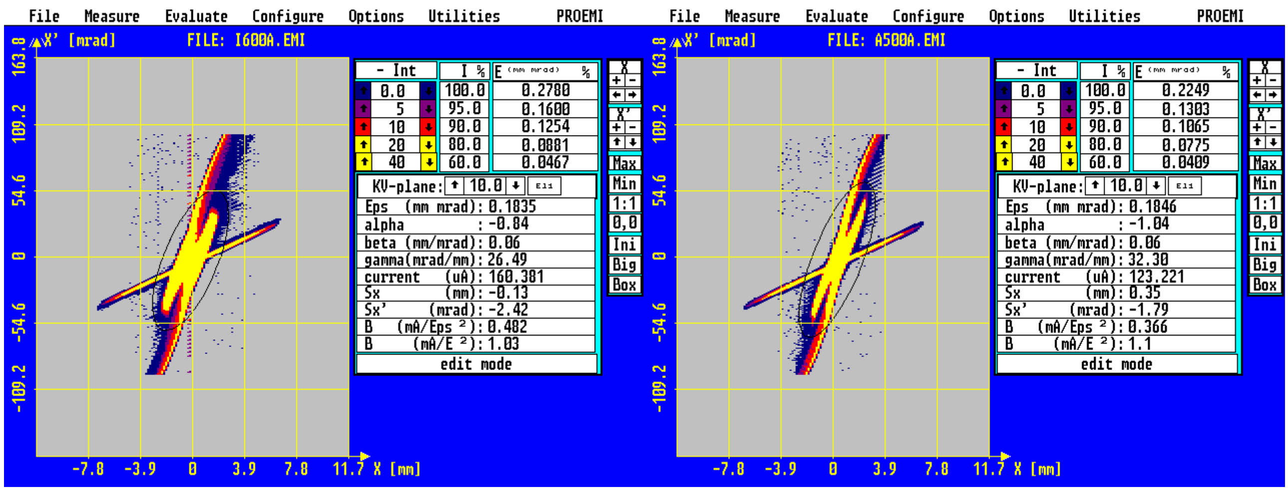

Figure 3: Comparison between the emittances of the extracted beams of the two ion sources at 0.8 mA. The ellipses correspond to the 90% normalized KV–emittances which are ϵ_{KV} =0.1835 π mm mrad for the first source and ϵ_{KV} =0.1846 π mm mrad for the second source.

2 ION SOURCES AND INJECTION SYSTEMS

To optimize the synchronous operation, both ion sources and injection systems have been tested on an emittance measurement device. Figure 3 shows the measured emittances of the extracted ion beams of the two ion sources at 0.8 mA, which scales to a beam current of 40 mA of Bi^{+}. The minimum difference of the two normalized 90% KV–emittances was 0.5%. The values are dependent on the included divergent neutral beam.

3 THE TWO–BEAM RFQ

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. With the use of identical RFQ electrode designs for both beam lines, the electrodes of one beam line are installed with a longitudinal shift of 2.55 cm (i.e. $\frac{\beta\lambda}{2}$) to achieve the 180° phase shift between the beam bunches of each beam line. In Figure 4 a photograph of the two–beam RFQ, with the first section of the electrodes mounted, is shown.

The RFQ electrodes are divided into two sections with different functions. While the first section, 140 cm long, bunches and accelerates the ions to the final energy of 160 keV, the second 60 cm long section consists of a drift and a matching section. So an x, y focus is at the funneling deflector position, while the axial focus will be behind the deflector for a matching into the next accelerator stage [7].

In Figure 5 the measured energy spectra behind the RFQ are shown. The final beam–energy of 166 keV is reached at an electrode voltage of 10 kV. Up to 4 kV electrode voltage the He^{+} beam is only transported.

At the beam crossing position behind the two–beam RFQ emittance measurements have been done. In Figure 6 the 2D– and 3D–view of the two emittances at an electrode voltage of 11.5 kV is shown. The difference between the two emittances is mainly dependent on the parameters of the injection systems.

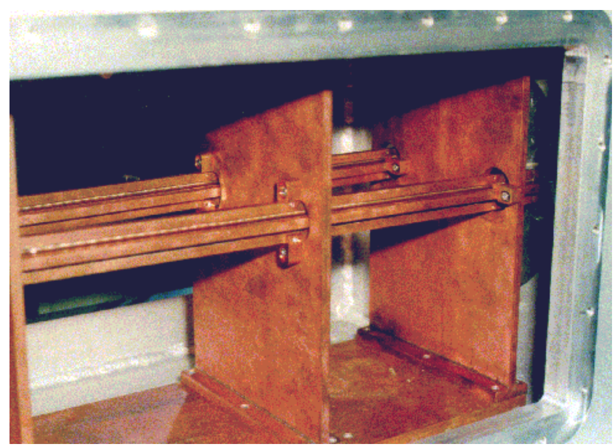

Figure 4: Photograph of the two–beam RFQ with the first section of the electrodes mounted.

4 THE FUNNELING DEFLECTOR STRUCTURE

The electrode geometry of the multigap deflector consists of several deflector plates divided by sections with larger aperture with equal length. In this geometry, the particles will see the deflecting field in one direction several times but the deflection in the opposite direction is always less. The length of the sections have to be proportional to the particle velocity and to the inverse frequency of the deflector system. For beam funneling, the frequency of the deflector has to be the same as the accelerator frequency, so that the bunches from different beam axes will see opposite

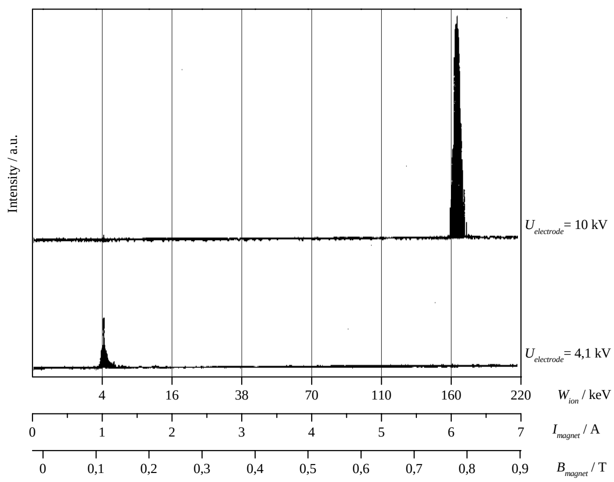

Figure 5: Energy spectra behind the RFQ. With the design voltage of 10 kV the final beam–energy of 166 keV is reached.

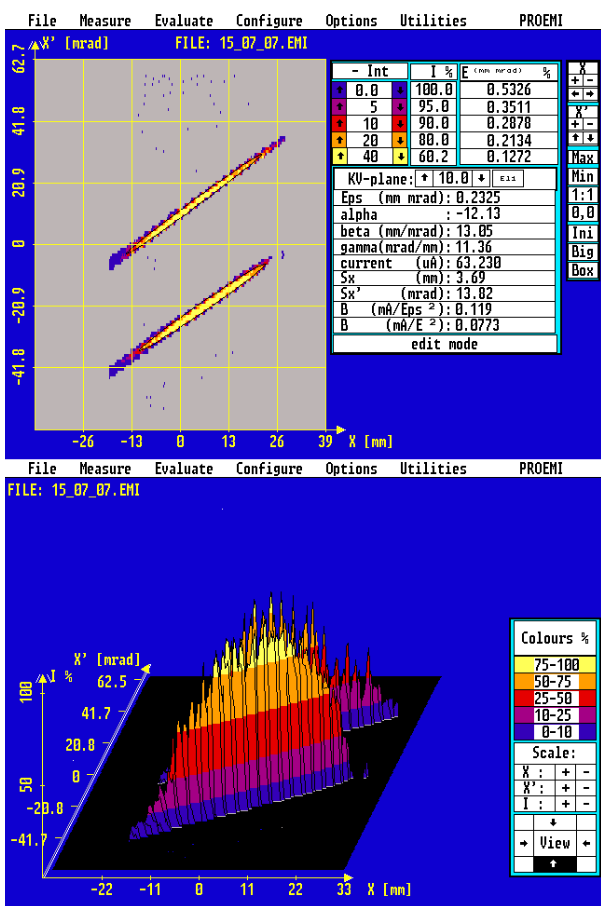

Figure 6: 2D– and 3D–view of the measured emittances behind the RFQ at the place of beam crossing. The ellipses correspond to the 90% normalized KV–emittances which is about ϵ_{KV} =0.25 π mm mrad for each beam.

field directions because of the phase shift of 180° between each bunch. Figure 7 shows a schematic drawing of the 9–gap funneling deflector which will be used.

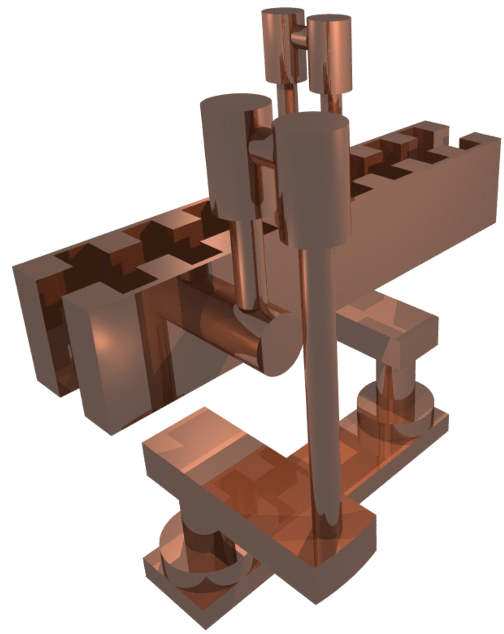

Figure 7: View of the multi–gap funneling deflector.

5 CONCLUSION

The beam tests results of the injection systems and the two–beam RFQ have shown that the chosen set–up can deliver two nearly identical ion beams for the planned funneling experiment. Next step will be the installation of the r.f. funneling deflector behind the two–beam RFQ.

The experiment with He^+ is a scaled version for funneling of Bi^+ at 60 $\frac{keV}{u}$ as it is required in the first funneling section of HIDIF, but can also be scaled to higher energies for e.g. the second section at 200 $\frac{keV}{u}$ or other funneling applications like spallation source.

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