BEAM MEASUREMENTS AT THE FRANKFURT FUNNELING EXPERIMENT*

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Abstract

Funneling is a method to increase low energy beam currents in multiple stages. The Frankfurt Funneling Experiment is a model of such a stage. The experiment is built up of two ion sources with electrostatic lens systems, a Two-Beam-RFQ accelerator, a funneling deflector and a beam diagnostic system. The two beams are bunched and accelerated in a Two-Beam RFQ. A funneling deflector combines the bunches to a common beam axis. Current works are beam tests with the new beam matching section. First funnelling beam and energy measurements with the improved Two-Beam-RFQ will be presented.

INTRODUCTION

The maximum beam current of a linac is limited by the beam transport capability at the low energy end of the linac: For a given ion source current and emittance the linac current limit is proportional to $\beta = v/c$ for electric and to β^3 for magnetic focusing channels and ideal emittance conservation. The funneling scheme is making use of the higher current limits at higher beam energies by doubling the beam current combining two bunched beams preaccelerated at a frequency f_0 with an rf-deflector to a common axis and injecting into another rf-accelerator at frequency $2 \cdot f_0$ as shown in figure 1. Ideally the beam emittance could be staying as low as for one single beam. Extracting twice the beam from a single ion source would result in at least twice the emittance for the following accelerators.

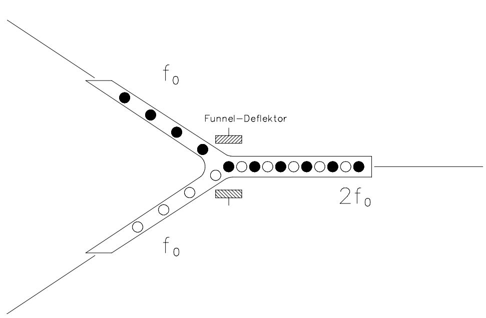

Figure 1: Bunch trace through the funneling deflector in top view.

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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. Both ion sources with an electrostatic LEBT are directly mounted at the front of the RFQ resonator and deliver a He^+ beam at energy of 4 keV.

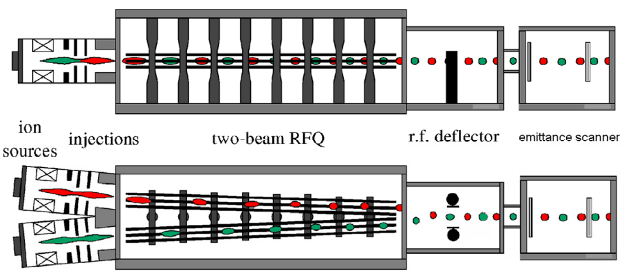

Figure 2: Scheme of the experimental setup.

The two-beam RFQ accelerator consists of two sets of quadrupole electrodes arranged with an angle of 75 mrad in one common resonant structure (fig. 2)[1]. The beams are bunched and accelerated with a phase shift of 180°. The quadrupole sets with a total length of approx. 2 meter are divided into two sections: The first section bunches and accelerates the beam to a final energy of 160 keV. The new matching section focuses the beam longitudinally and radially to the beam crossing point at the centre of the deflector with low acceleration to 180 keV. The matching section reduces the beam size to about 60% of the old value [2].

Figure 3 shows the measured emittance with the upgrade of both RFQ channels. The emittances are nearly equal.

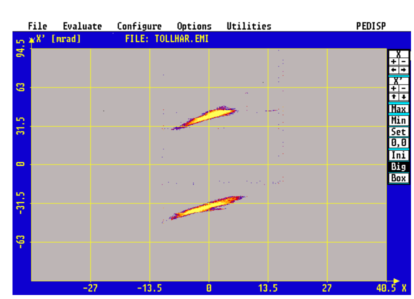

Figure 3: Emittance measurement of both beam lines with the matching electrodes.

At the beam crossing point the deflector reduces the angle of the transversal coordinate from x'=37.5 mrad to x'=0 mrad in one, with the single cell deflector, or in several steps, with the 15 cell deflector [3].

The multi-gap-deflector runs at a lower bending voltage than the one-gap-deflector in case of more bending cells [4]. Though the beam diameter increases in fact of space charge effects by the longer drift through the deflector.

BEAM AND ENERGY MEASUREMENTS

After replacing the old end electrodes without modulation by matching electrodes, first beam measurements were made with a faraday cup. To compare the different deflectors, measurements with both systems were made.

At first single measurements were made of each of the beam lines. The micropulse shows a high resolution in time of each bunch, the macropulse the complete beam pulse which is proportional to the beam current. One can see that the measuring signal for both beam lines oscillates through the zero line. This is due to the stimulation of self-oscillation.

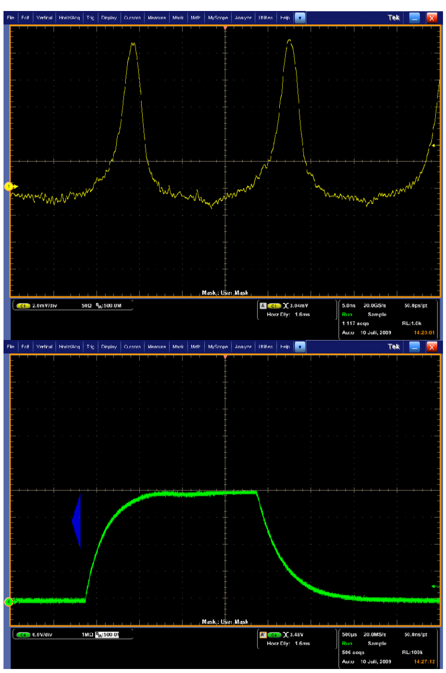

Figure 4: Micropulse (top) and macropulse (bottom) of the right beam line; similar to the left one.

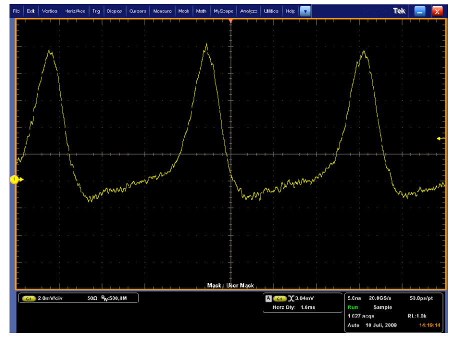

Figure 5: Micropulse of the left beam line.

In figure 5 is shown that the bunch of the left beam line (in direction of acceleration) has a larger phase width than the right one.

After turning on the one gap deflector the amplitudes of the bunches have decreased compared to the single measurements of the beam lines.

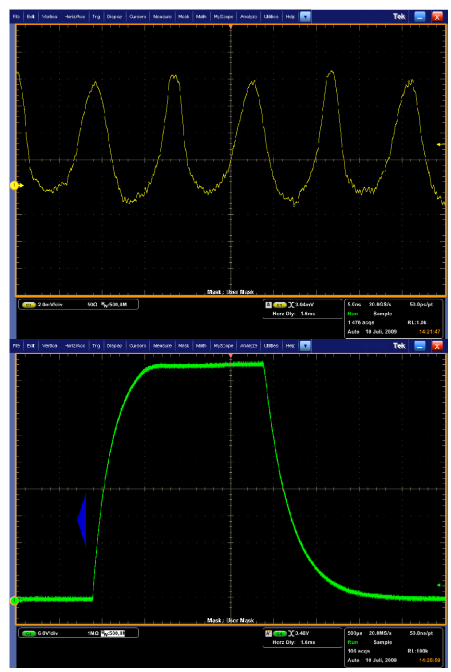

Figure 6: Pulses of the funneled beam with the one-gap-deflector.

The beam current of the right beam line is smaller although the amplitudes are nearly the same. This is a result of the larger phase width so that there are more particles in the bunch.

The measurement has shown that approximately 75% of the particles are on the new beam axis after funneling.

Now the one-gap-deflector has been replaced with the multi-gap-deflector and same measurements have been accomplished.

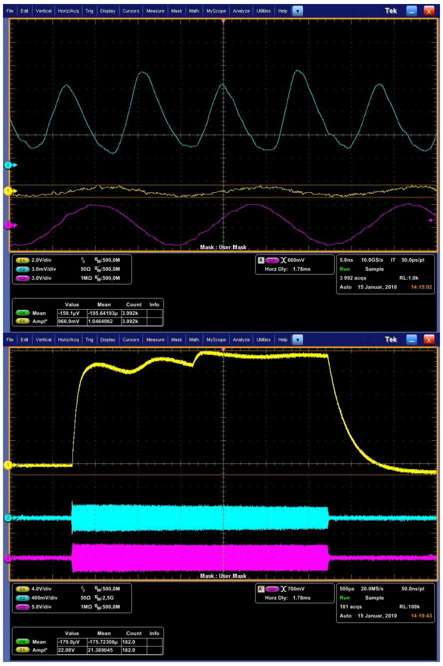

Figure 7: Beam measurement of the funneled beam with the multi-gap-deflector.

With this configuration there is a stable beam amplitude after a setting phase. For this stable part has also been measured that 75% of the particles are located on the new beam axis after funneling.

To get an impression of the beam radii and the influence of space charge on the beam a fluorescence screen measurement behind the deflector was made. This has been done with the one-gap-deflector.

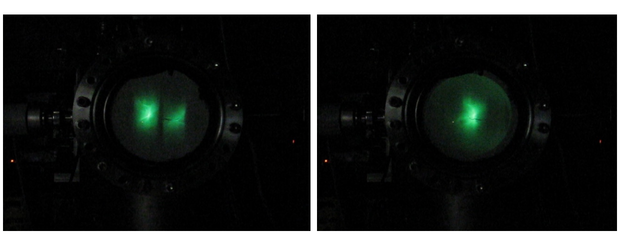

Figure 8: Fluorescence screen measurement with turned off (left) and turned on (right) deflector.

Figure 8 shows that the two beams open out radial without Hf on the deflector. The different brightness of the two beams comes from the time dependence of the bunches, so for every point in time the brightness differs.

The right picture in figure 8 demonstrates the possibility to bend two ion beams exactly on the same axis without radial offset.

With an magnetic energy spectrometer a beam energy measurement was taken. The energy peak for the transported Helium is at 4 keV and for the accelerated at 180 keV.

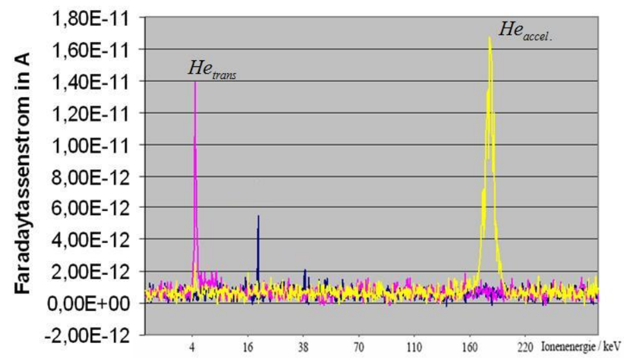

Figure 9: Energy measurement of transported Helium (pink) and accelerated Helium (yellow).

CONCLUSIONS

The frequency and energy tuning on both funneling deflectors have been done. First beam measurements have shown a good matching between the RFQ and the deflectors. Faradaycup measurements with the one-gap-deflector and the multi-gap-deflector have shown the matching end electrodes work. Measurements with an energy spectrometer have shown a small energy shift between the old and the new set-up of the electrodes. Fluorescence screen measurements demonstrate a good beam bending at the new beam axis. Next steps will be funneling experiments with an emittance scanner and a new upgrade for the matching electrodes.

REFERENCES

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