DEVELOPMENT OF NEW ION SOURCES FOR THE FRANKFURT FUNNELING EXPERIMENT*

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Abstract

Funneling is a method to increase beam currents in several stages. The Frankfurt Funneling Experiment is a prototype of such a stage. The experimental setup consists 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 and the last parts of the RFQ electrodes achieve a 3d focus at the crossing point of the two beam axis. A funneling deflector combines the bunches to a common beam axis. The newly optimized ion sources are adapted to the front end bunching section. First results and measurements will be presented.

INDRODUCTION

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.

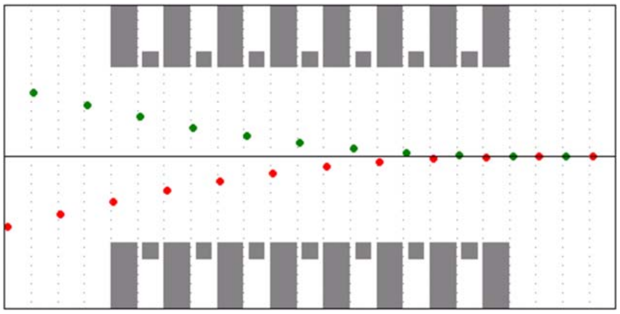

Figure 1: Bunch trace through the funneling deflector in top view.

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.

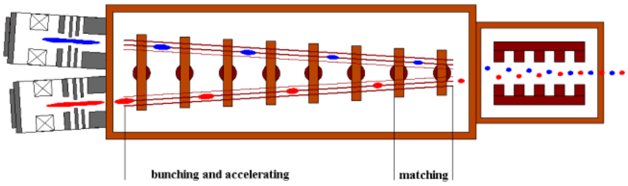

Figure 2: Scheme of the experimental setup.

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 center of the deflector with low acceleration to 179keV. The matching section reduces the beam size to about 60% [3].

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

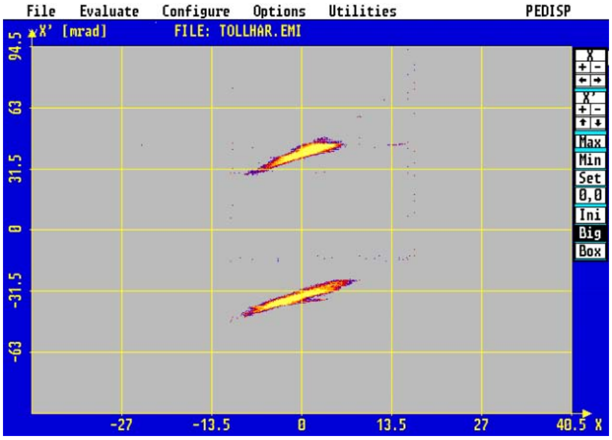

Figure 3: Upgrade of both beam lines.

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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.

DEFLECTOR

Because of the electrode design of the last RFQ section the final energy rises from 160 keV to 179 keV. Therefore the electrode length of the old 17 cell funneling deflector has been adjusted and the number of cells have been reduced from 17 to 15. The drift tubes are now mounted on two grounded stems. The separation of mode 1 and mode 2 is now 10 MHz instead of only 400 kHz. The deflector is more mechanically stable now [5].

The flatness curve of the bead-perturbation measurement delivers a R_p-value of 420 kΩ. The duty factor determined with the 3dB method is Q = 2260. With the help of the mounted and moveable coils the frequency tuning is now very easy (fig. 4).

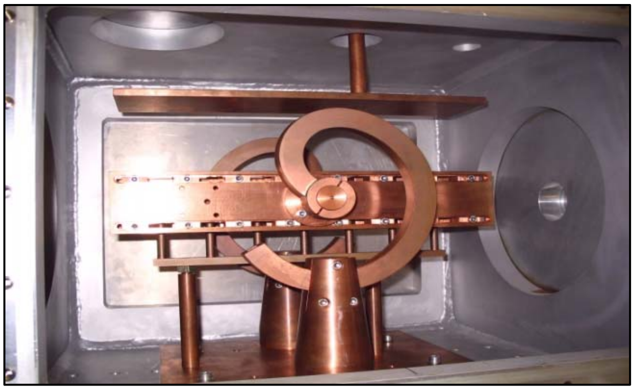


Figure 4: Photo of the new 15 cell funneling deflector.

PARTICLE DYNAMIC SIMULATION SOFTWARE

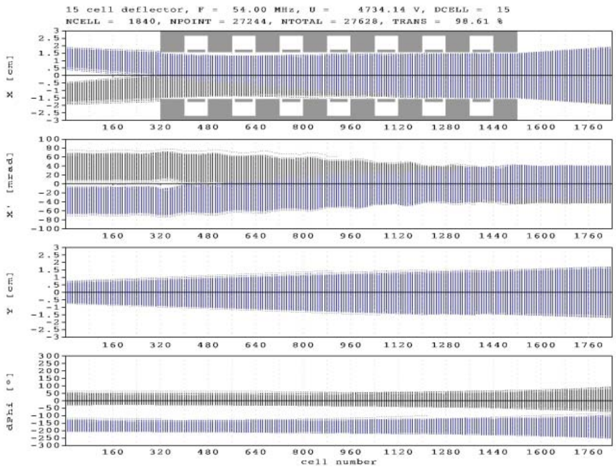


Figure 5: Beam trace through the 15 cell deflector.

RFQSim is a macro particle dynamic program to calculate ion beams in an RFQ accelerator.

The beam through the funneling deflector is simulated with *FUSIONS* (**Fu**nneling **S**imulation for **Ion** Beam**s**). It is a newly developed particle dynamic simulation software for funneling deflectors [2, 6]. The 6-dimensional particle distribution from *RFQSim* is transported segmentally through the deflector. Both space charge routines, a particle-particle and a PIC (particle in cell) routine, are now integrated.

NEW ION SOURCES

The new ion sources are developed for a better matching to the accelerator. Above all a longer life span from the filaments was the centre of attention during the new development. The result of this development is that the sources can be operated with the same beam current and a lower filament current into the new plasma chamber. Fig. 6 shows one of the newly Multicusp ion sources with an electrostatic lens system mounted at an emittance scanner. Coated neodym magnets (300 mT) are inserted Since the magnets are water cooled it is nessasary that they are coated, otherwise they would be destroyed within a short time by corrosion.

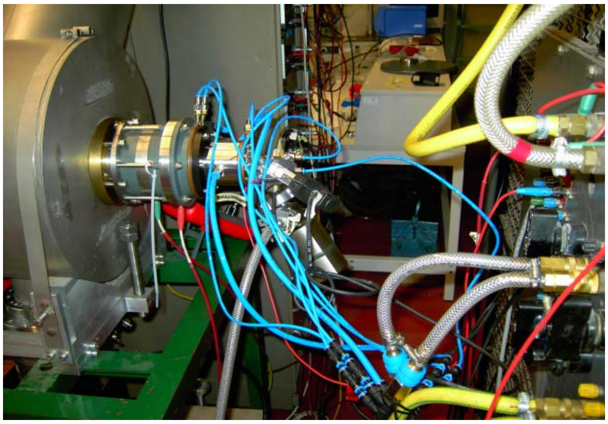


Figure 6: New multicusp ion source.

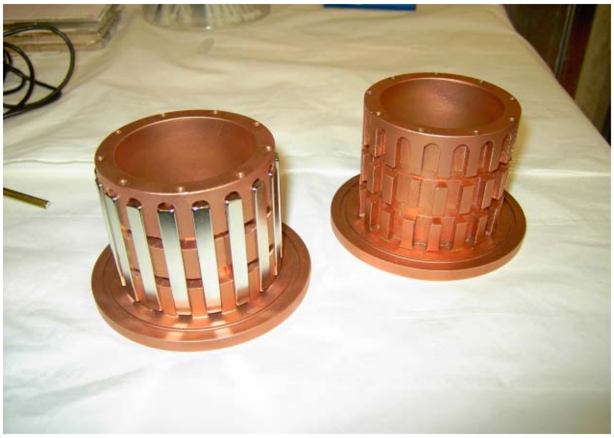
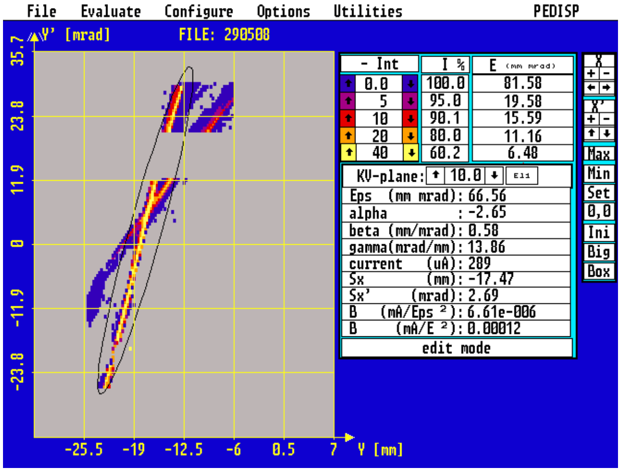


Figure 7: Plasma chamber magnets in multicusp arrangement.

Figure 8: Plasma chamber with a water cooling coating.

EMITTANCE MEASUREMENT

The gap in the emittance measurement resulted from a defect of the amplifiers of the emittance scanner. The measurement shows that the ion source has a better emittance than the old source. Thus will reduce beam losses by the injection into the RFQ.



- Int	I %	E (mm mrad)
0.0	100.0	81.58
5	95.0	19.58
10	90.1	15.59
20	80.0	11.16
40	60.2	6.48

KV-plane: 10.0 E11

Eps (mm mrad): 66.56
alpha : -2.65
beta (mm/mrad): 0.58
gamma(mrad/mm): 13.86
current (uA): 289
Sx (mm): -17.47
Sx' (mrad): 2.69
B (mA/Eps ²): 6.61e-006
B (mA/E ²): 0.00012

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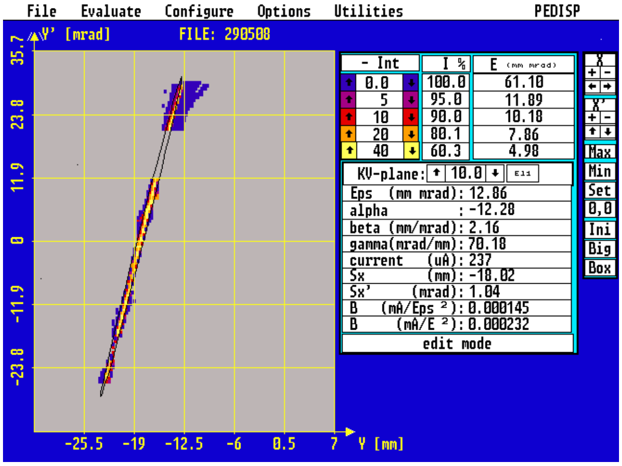
Figure 9: Emittance measurement with neutral particle beam.



- Int	I %	E (mm mrad)
0.0	100.0	61.10
5	95.0	11.89
10	90.0	10.18
20	80.1	7.86
40	60.3	4.98

KV-plane: 10.0 E11

Eps (mm mrad): 12.86
alpha : -12.28
beta (mm/mrad): 2.16
gamma(mrad/mm): 70.18
current (uA): 237
Sx (mm): -18.02
Sx' (mrad): 1.04
B (mA/Eps ²): 0.000145
B (mA/E ²): 0.000232

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Figure 10: Emittance measurement without neutral particle beam.

CONCLUSIONS

A decrease of the filament current could be achieved by the increase of the magnetic field. Thus a substantially longer live time of the filament is reached, what made longer beam time possible. With the new ion sources we became a better matching to the accelerator. Next step will be first experiments with the new setup and the verification of the matching.

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