BEAM MEASUREMENTS WITH THE NEW RFQ BEAM MATCHING SECTION 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. A new beam transport system between RFQ accelerator and deflector has been constructed and mounted. With these extended RFQ-electrodes the drift between the Two-Beam-RFQ and the rf-deflector will be minimized and therefore unwanted emittance growth reduced. After first rf measurements current work are beam tests with the improved Two-Beam-RFQ. First results 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 uses the shift to higher current limits with 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 f_0 as shown in Figure 1. Ideally the beam emittance could remain 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.

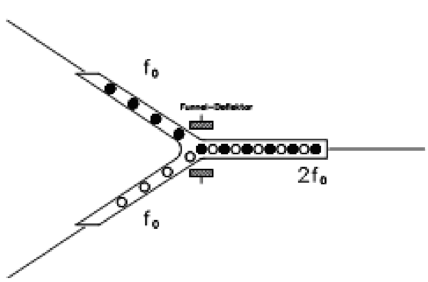

Figure 1: Bunch trace through the funneling deflector in top view.

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EXPERIMENTAL SETUP

The setup of the Frankfurt Funneling Experiment consists of two identical multicusp ion sources, a two channel RFQ accelerator, a funneling deflector and a beam diagnostic device (Fig. 2). 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: Picture of the experimental setup.

The Two-Beam RFQ accelerator consists of two sets of quadrupole electrodes arranged with an angle of 76 mrad in one common resonant structure [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]. At the beam crossing point the deflector merges the two beams to the common axis.

RFQ COMMISSIONING

In the new set-up the beam matching to the deflector was improved by a new electrode section design and a shorter drift to the deflector [3]. The installing of the novel matching section is implemented in a complex adjustment procedure of the entire electrode system.

The entire beam line, which implements ion sources, RFQ, diagnostic and vacuum system was not used for a longer period and had to be restarted.

The high power shunt impedance and the inter vane voltage in dependence of RF power verification using x-ray end point measurements was planned using an AMPTEK X-123 CdTe x-ray detector. Because of the low electrode voltage of 10 kV the x-rays could not be detected, not even through a glass or PVC window.

The flatness was readjusted to better than 12% (Fig. 3) using tuning angles as additional capacity (Fig. 4). This achieved a better flatness, but the resonance frequency was out of the optimum tuning range of the amplifier and additional tuners were used. An upgrade to better coupling tuners is in progress.

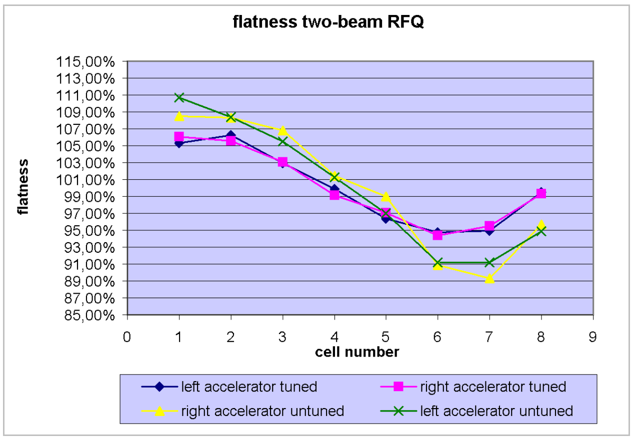

Figure 3: Longitudinal voltage distribution in the RFQ.

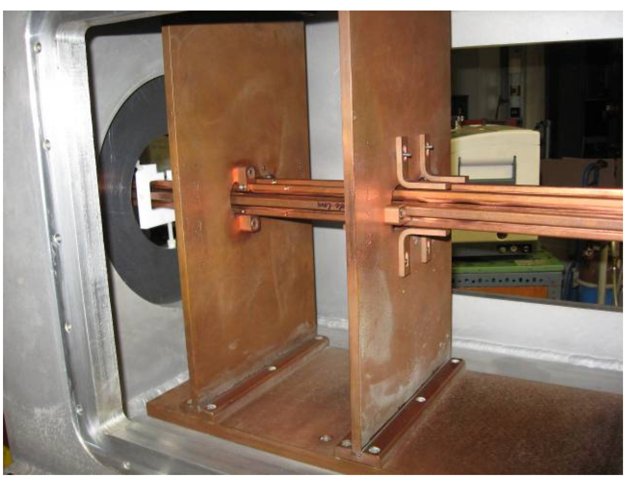

Figure 4: Small tuning angles as additional capacity for a better voltage symmetry.

The resonator structure has a Q value of 2900, a resonance frequency ω_0=54.5 MHz and a R_P=35.5 kΩ. At a power of around 3 kW the resonator starts to accelerate the bunches. The galvanic main coupler has S_{11} -28 dB. The pickups S_{12} are -37.4 dB and -43.2 dB.

The regulation for the plunger piston was tested and works to specifications. The maximum shift is up to 200 kHz.

During the tests the RFQ was conditioned in pulsed mode to 4 kW. The RFQ was able to reach the reliably electrode voltage after a few hours at low duty cycle.

FIRST BEAM TESTS

The He^+ ion beams, delivered from two identical filament driven multicusp ion sources, have an emittance of 0,026 mm mrad rms normalized 90% at a beam current of 0.8 mA [2]. The two Low Energy Beam Transport (LEBT) systems are running very stable, after a broken cable was fixed, which lead to an unstable beam current after one accelerator.

For a first beam diagnostic of the accelerated beams a fast Faraday cup was used at the beam crossing point (Fig. 5).

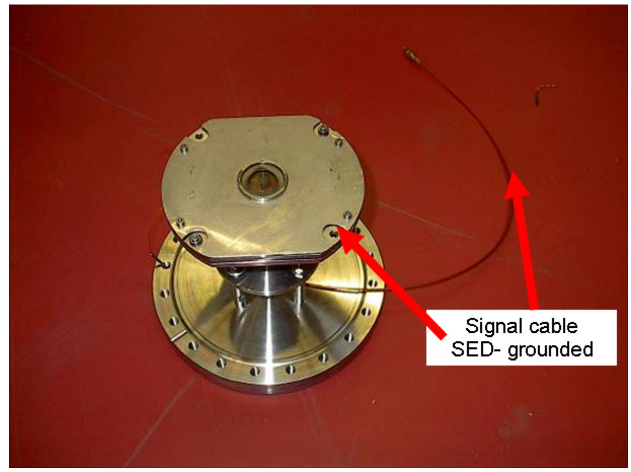

Figure 5: Picture of the fast Faraday cup used.

A beam current for one accelerator at the point of beam crossing of about 0.2 to 0.3 mA was measured. This matches to expected RFQ-transmission of 60%, but further investigations have to be done.

An FWHM pulse lengths of 2.7 ns was measured (Fig. 6), which fits to the PARMTEQ simulated value of 45° (Fig. 7).

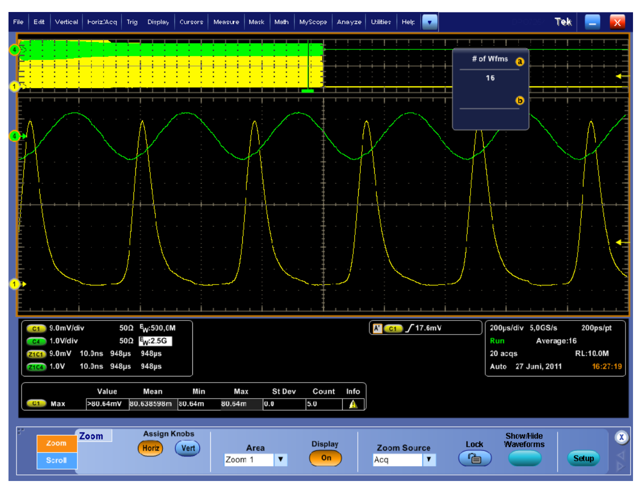

Figure 6: Pulse structure of one accelerator.

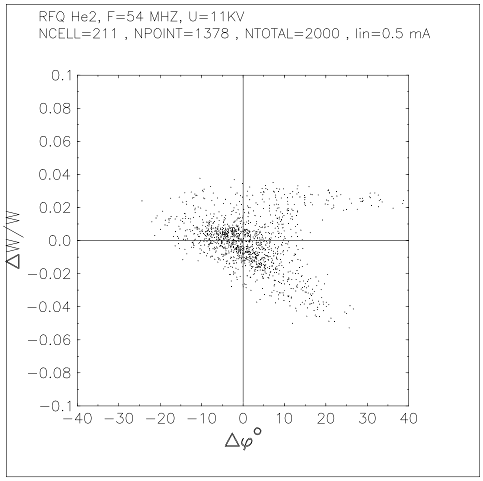

Figure 7: PARMTEQ simulation of the phase width at the beam crossing point.

In Figures 8 and 9 the pulses of both beam lines are shown. After a transient oscillation the macropulse is very stable. The micropulses show that both beams are pretty identical.

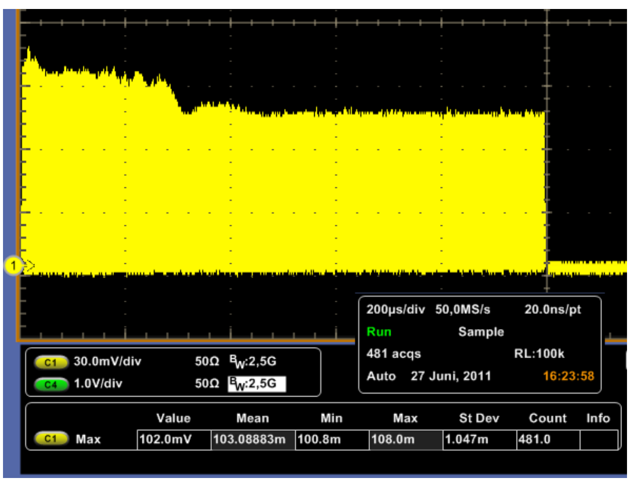

Figure 8: Macropulse of both beams. The pulses are measured behind the new matching section at the crossing point.

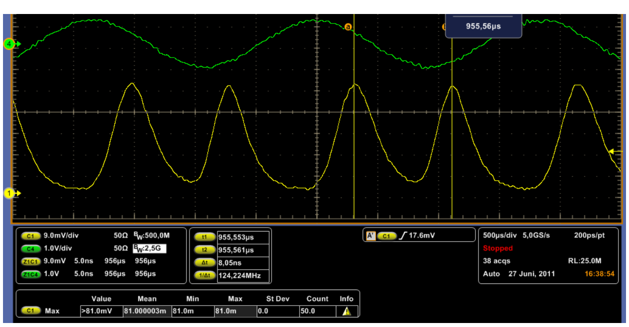

Figure 9: Micropulses of the two beams (yellow). Every second pulse belongs to one channel. The green pickup is the frequency coupled into the resonator.

CONCLUSIONS

Funneling two beams to a common beam axis could be demonstrated successful [4]. In the simulation for the extended electrodes with the beam matching system the beam radius and the phase space are reduced one more time.

Moreover, the beam loss in the matching part is minimized, so there is almost no beam loss in the range of the matching section [5]. This is achieved by the smaller field gradients through the extension of the matching section.

The extended electrodes have been mounted and adjusted. A new tuning method resulted in a considerably improved flatness. First beam measurements show that the accelerator works. The upgrade of the new electrode matching section delivers the desired phase width. Next steps will be energy estimation of both beam lines and emittance measurements with the new emittance scanner, which will be delivered soon. Then the deflector will be restarted to analyze the merged beams.

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