BEAM TEST STAND OF THE RFQ-DRIFTTUBE-COMBINATION FOR THE THERAPY CENTER IN HEIDELBERG*

A. Bechtold**, M. Otto, U. Ratzinger, A. Schempp, B. Schlitt**, E. Vassilakis,
IAP, J. W. Goethe-Universitaet, Frankfurt, Germany.

Abstract

A beam test stand for the Heidelberg medicine RFQ [1] has been installed at the IAP in Frankfurt. The installation consists of a 8 keV/u H^+ duoplasmatron ion source, the 400 keV/u RFQ itself and several diagnostic elements comprising a slit-grid emittance measurement system for scanning the transverse beam profile and a bending magnet for measuring the longitudinal beam properties. The test installation will be described in detail, first measurements will be presented and compared to corresponding beam dynamic simulations.

INTRODUCTION

Before its final installation at the Heidelberg tumor facility the RFQ-drifttube-combination (fig. 1) will be tested with protons. Basic beam parameters like output energy and emittance shall be examined in detail. The structure was originally designed for a charge to mass ratio of $q/m = 1/3$ with an electrode voltage of 70 kV. In the case of protons where $q/m = 1$ it is only a third of that and we do not have to care much about shielding during experimentation.

The rf-power consumption of the RFQ will be in the range of 20 kW (pulsed) on the basis of the results of low power measurements presented at [2]. The duoplasmatron ion source with its electrostatic lens system is mounted directly to the end flange at the entrance of the RFQ tank. It is not planned to use any additional matching section in order to keep the set up as compact as possible.

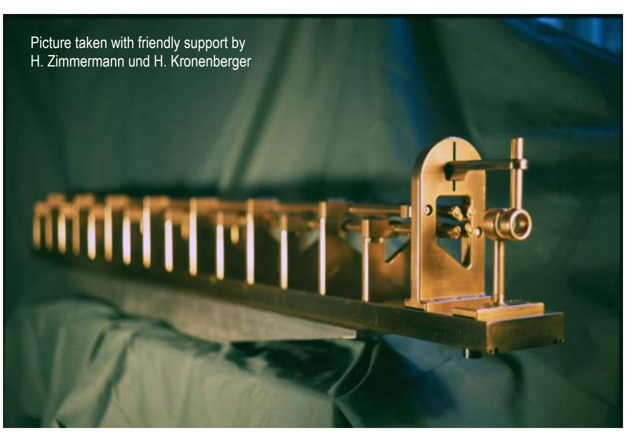

Figure 1: The RFQ-Drifttube-Combination right before its installation into the tank.

Ion species	$^{12}C^{4+}$, protons
Length of the electrodes	1,28 m
Length of tank	1,40 m
Tank diameter	250 mm
Min. aperture	2.63 mm
Max. modulation	1.867
Max. focusing strength *B*	4.84
Input energy	8 keV/u
Input emittance	$\varepsilon_{x,y}$=150 π mm mrad
Electrode voltage	70 kV
Exp. Power consumption	165 kW
Current	max. 2 mA H^+
Output energy	400 keV/u
max. beam angle at the exit	±20 mrad (in both planes)
Phase width at IH entrance	$\Delta\varphi \le \pm 15°$

Table 1: Main RFQ parameters [3].

A test stand has been set up to measure beam properties at different positions (ion-source, RFQ). For measuring the transversal beam properties a two dimensional slit-grid emittance measuring system is used. The height of the slit is 0.1 mm, the diameter of the 60 grid wires is also 0.1 mm with a distance of 1 mm. The distance between slit and grid differs in both planes: 262 mm in x- and 310 mm in the y-plane. For a first measurment of the output energy of the RFQ we will use a 90° double focussing bending magnet with a bending radius of 150 mm. For more precise investigations it is planned to do an additional time of flight measurement.

One of the main aspects of the RFQ-Drifttube-Combination is the variation of the bunching voltage by adjusting the height in which the second drifttube is connected to the last RFQ-stem, as one can see in fig. 1. This height can still be adjusted to vary the beam properties durig the experiments to fulfill the disired values of the linac section of the Heidlberg therapy center [4, 5].

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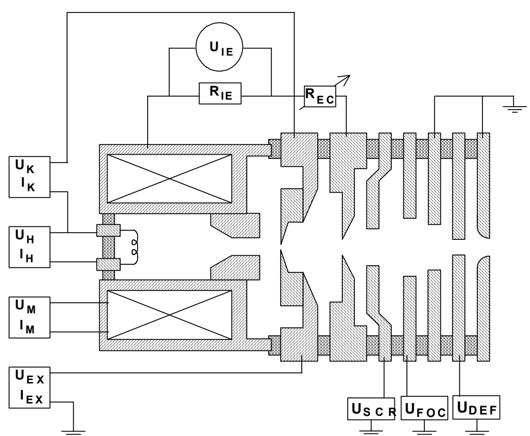
** GSI, Darmstadt, Germany.

Figure 2: The RFQ-Tank ready for vacuum.

THE DUOPLASMATRON ION SOURCE

For beam tests we intended to use an existing duoplasmatron ion source-LEBT system which was originally designed for delivering He^{2+}-Ions at an extraction voltage of U_{EX} = 4 kV.



Main parameters	
U_K/I_K	124 V / 0.64 A
U_H/I_H	6.84 V / 54.2 A
U_M/I_M	43 V / 8A
U_{FOC}	7 kV
U_{DEF}	8 kV
U_{EX}	8 kV
U_{SCR}	1.2 KV
p_{SRC}	$6*10^{-2}$ mbar

Figure 3: The modified duoplasmatron ion source and its lens system.

Since we wanted to extract protons with a higher voltage of about U_{EX} = 8 kV we had to modify the insulators shields to avoid sparking. For getting information about the RFQ´s beam-properties it is also important to know the emittance of the ion-source. Therefore it was connected to the emittance measuring system. The voltage at the focusing and defocusing lenses amounts U_{FOC} = 7 kV and U_{DEF} = 8 kV. Originally we intended to supply the defocusing lense with higher voltages which was unfortunately not possible because of sparking. However the measured emittances are ε_x = 15.43 mm mrad and ε_y = 28.53 mm mrad at a beam current of I_B = 0.1 mA, which is sufficient for RFQ experiments.

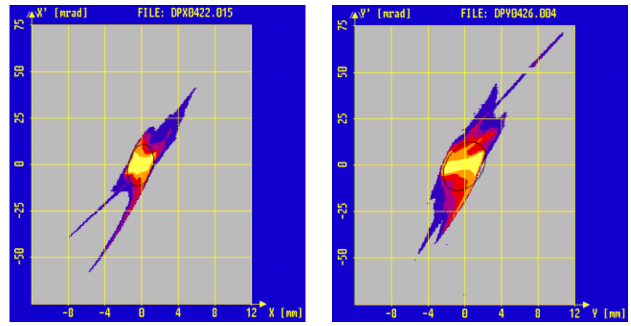


Figure 4: Measured beam-emittance in x- and y-plane.

The ion-source-LEBT will be mounted directly to the RFQ-tank for accomplishing the next tests.

BEAM DYNAMIC SIMULATION WITH MEASURED PARTICLE DISTRIBUTION

On the basis of the measured source emittance of fig. 4 beam dynamic simulations had been executed with the aim to show how the measured beam develops inside the RFQ and if it is suited to check the full range of acceleration performance. For beam dynamic simulations a new program called RFQSIM was used, which had been developed at the IAP in Frankfurt and includes new routines especially for doing calculations on such specialized problems like the attached drifttube section here. First the measured distribution had to be approximated through a program generated one (fig. 5). Generally RFQSIM is able to read extern particle distribution coordinates and transform them through a given structure, but the emittance measuring system only gives visual density distributions and the main emittance parameters like α, β, ε, but no usable data files.

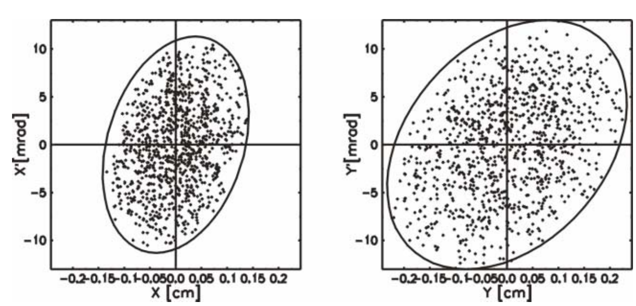


Figure 5: Particle distribution for simulations.

The two distributions of fig. 4 represent the measured ones at the position of the slit of the emittance measuring system (90 mm from the entrance in the x-plane, 65 mm in y) and had now to be transformed to the position where the beginning of the RFQ-electrodes will be: 28.3 mm behind the source (fig. 6).

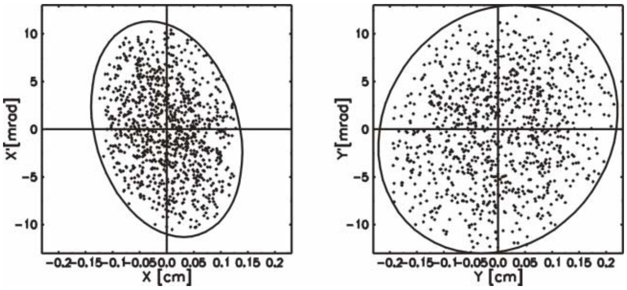


Figure 6: Distribution of fig. 5 transformed to the position of the electrodes entrance.

This distribution can now be transformed through the RFQ-electrodes:

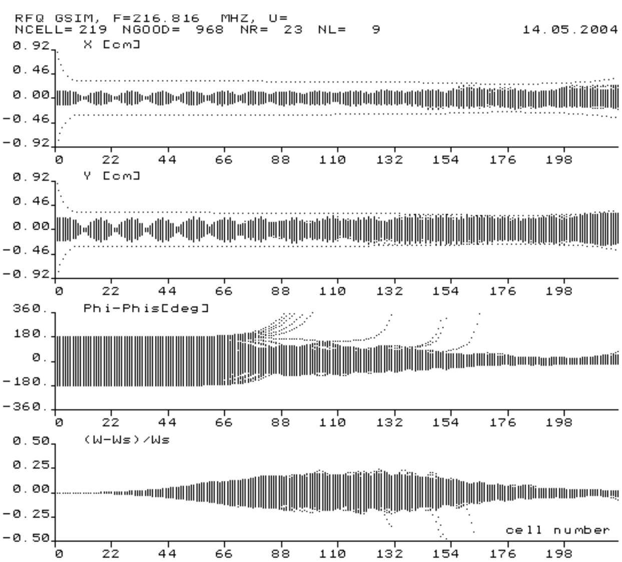


Figure 7: Dynamic simulation of the RFQ with the particle distribution of fig. 6.

Judging from the transversal oscillations of the beam shown in the two upper diagrams of fig. 7, the measured distribution is not well matched to the acceptance of the RFQ. However these oscillations do not lead to a collision of the beam with the RFQ-electrodes. Due to its very small radius the beam is transported with a transmission of nearly 97 %, which is very satisfying. The third and forth diagram are representing the longitudinal beam dynamics. The third shows the phase width, which decreases from ±180° (dc-beam) to ±20° during the bunching process and the forth diagram shows the accompanying energy spread, which increases first at low total beam energies and decreases again with higher acceleration toward the end.

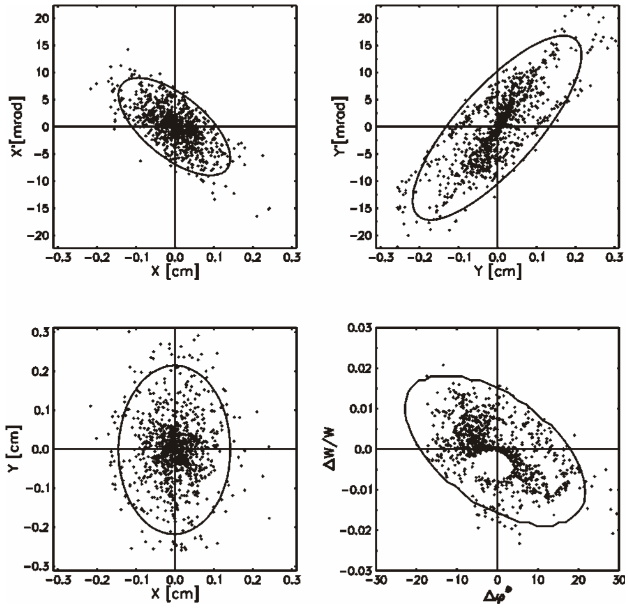


Figure 8: Particle distribution at the End of the RFQ-electrodes.

CONCLUSIONS

We have started with the built up of a beam test stand at the IAP in Frankfurt. The ion source has been installed and tuned to the desired extraction voltage, beam current and emittances are very promising. The RFQ-tank is vacuum proved and conditioned with 50 W continuously. We now have to install the rf-power system and will perform a fist RFQ test with beam in the near future.

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