A LOW BETA RF LINAC-STRUCTURE OF THE IH-TYPE WITH IMPROVED RADIAL ACCEPTANCE

U. Ratzinger

GSI, Gesellschaft für Schwerionenforschung mbH
Postfach 11 05 52, D-6100 Darmstadt
Federal Republic of Germany

Summary

Recent injector plans at GSI asked for an RF structure to continue the acceleration behind an ECR-RFQ-combination up to W_f = 1,4 MeV/u which is the injection energy of the Alvarez section of Unilac.

The interdigital H-type structure is very well suited to provide an efficient acceleration at that energy range. The beam dynamics and construction of an IH-type cavity for the energy range from W_i = 0,3 MeV/u to W_f = 1,4 MeV/u is described. The duty factor can be adjusted up to 60 %. A calculation is presented which demonstrates that by this kind of beam dynamics also heavy ion beams with substantial space charge forces can be handled.

Introduction

The multi-gap cavity of the Munich SchweIN-type,[1,2,3] is used in several Tandem laboratories to postaccelerate heavy ion beams with injection energies above 2 MeV/u. This structure is characterized by its simple construction and its very high shuntimpedance. Our goal is to keep these advantages but to enlarge the radial acceptance by one order of magnitude as well as to increase the effective average voltage gain along the tank up to 3 MV/m and to lower the injection energy down to W_i = 0,3 MeV/u.

We decided to do the acceleration from 0,3 MeV/u to 1,4 MeV/u with one cavity as the needs for RF equipment are minimized and the operating becomes more easy. One RF amplifier of the type which usually drives a GSI single-gap resonator cavity is sufficient to drive the IH-structure at a duty factor up to 0,6. In the following the combination of accelerating and rebunching sections - consisting of slim drifttubes - together with magnetic quadrupole tripletts is described. Experimental results from the investigations at our 1:2,5-scaled RF model are shown.

Finally, beam dynamics calculations with LORASR demonstrate the capability of that kind of structure to transport high beam intensities at W_i ~ 0,6 MeV/u.

The IH-cavity for the new 1,4 MeV/u-injector at GSI

Beam Dynamics

The new injector,[4] consisting of an ECR-source with W_1 = 2,5 keV/u, an RFQ with W_2 = 300 keV/u and an IH-cavity will be operated at the Alvarez RF frequency of 108 MHz. The design particle for the cavities is $^{238}U^{25+}$. The design acceptances of the IH-structure are α_{norm} = 1,5 π mm mrad, α_{long} = 150 π keV/u deg. These numbers are bigger than the expected emittances out of the RFQ by a factor 2-6. The transformation of the phase space ellipses between RFQ and IH will be done by quadrupole lenses and a quarterwave coaxial resonator with 4 gaps.

A sketch of the drifttube structure of the cavity is shown in fig. 1a. Behind each quadrupole housing follows a three gap section with negative synchronous phase ϕ_s = - 30° to rebunch the particles. The beam dynamics principle along the ϕ_s = 0° sections follows the scheme described in ref. 3.

The figs. 1 bcde show results of the program LORAS in x/z-, y/z-, ΔE/E-, and Δϕ/z-planes using the raytracing method. The injected ellipse areas are $\varepsilon_{ntr.}$ = 0,8 π mm mrad, ε_{long} = 54 π keV/u deg.

The synchronous phase along the last 6 gaps is shifted in five degree steps from ϕ_s = -15° to ϕ_s = - 40° in order to rotate the phase ellipse in the longitudinal phase space. By that the debunching at a position about 4 m behind the IH cavity is more efficient.

RF-model measurements

The IH-structure uses the TE 111 mode. The distribution of the capacity along the tank must be tuned accurately to get a flat accelerating electric field distribution. The question is how to install big quadrupole lenses inside the cavity at positions shown in fig. 1a without disturbing the TE111 mode.

By keeping the lense housing at zero RF potential as shown in fig. 2b, the TE111 mode is transmitted in that region. The resonance frequency can be adjusted to the resonance frequency of the neighbouring drifttube sections by changing the distance between quadrupole housing and tank, which defines the effective capacity.

In figs. 3 abc the connection between the electric gap field distribution along the tank and the capacitive coupling of the lense housings is demonstrated. When the bars with quadratic cross section in fig. 2b were dismantled we got the field distribution shown in fig. 3a; only the drifttube section between the lense housings is excited. Fig. 3b shows the distribution with the bars mounted. A further increase of capacitive coupling at the HE lense housing and a change in gap numbers per section resulted in fig. 3c. These measurements demonstrate that a combination of drifttube sections and big lenses inside one IH-type cavity is possible. For the array of fig. 3b with f_r = 284 MHz we measured a Q-value of 10000 and a shuntimpedance Z_0 ≅ 450 MΩ/m. All parts of the model are electrolytically copper plated.

Table 1: Characteristic parameters of the IH-tank

Design ion	$^{238}U^{25+}$
Frequency	108,48 MHz
Input energy	0,3 MeV/u
Output energy	1,4 MeV/u
Radial acceptance	60 π mm mrad
Normalized acceptance	1,5 π mm mrad
Longitudinal acceptance	150 π keV/u deg.
Tank length	3,55 m
Tank diameter	68 cm
Pulse frequency	100 Hz
Duty cycle	50 %
Eff. voltage	10,4 MV
Peak RF power	100 kW
Eff. shunt impedance	310 MΩ/m
Max. electric field	150 kV/cm

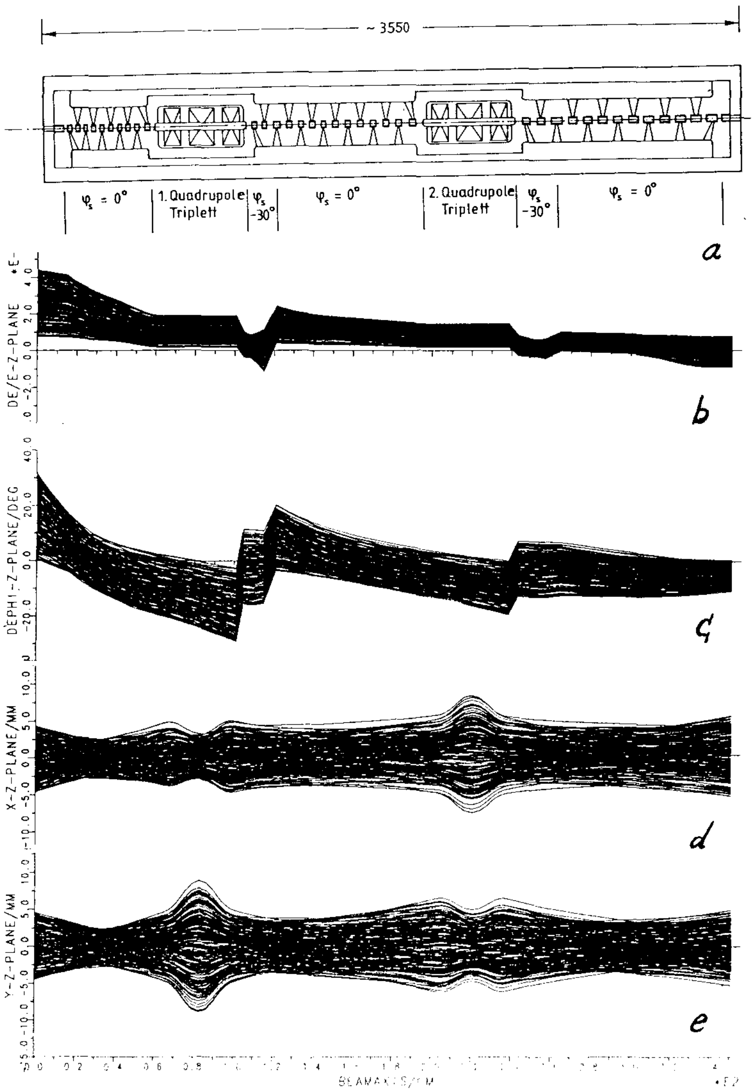

Fig. 1: Geometry of the accelerator structure and raytracing plots. Fig. 1 ab show the particles position in relation to the synchronous particle which is redefined at the points of non continuity. The structure is a combination of accelerating-, rebunching-, and transversal focussing sections.

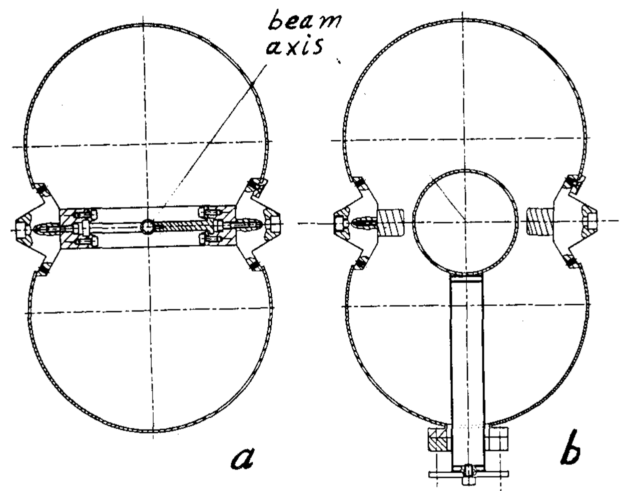

Fig. 2: Cross sectional views of the 1:2,5 scaled RF model at the drifttube structure (a) and at the quadrupole housings position (b).

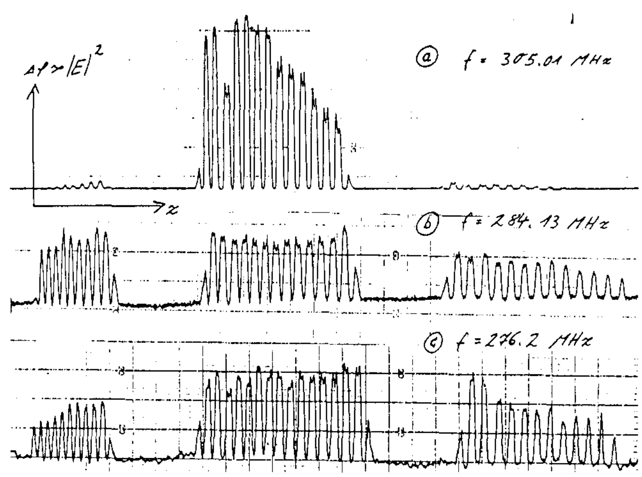

Fig. 3: Perturbation measurement of the electric field distribution along the beam axis. The capacitive coupling between cavity and lense housings is increased from (a) across (b) to (c).

Transport of high beam intensities

The generation and acceleration of high intensity heavy ion beams is still an open question. In many cases it would be attractive to have an ion source which generates short pulses with highly charged ions so that poststripping is totally avoided or at least minimized. By that way the necessary particle current out of the ion source can be reduced drastically.

The following calculations demonstrate an efficient way to accelerate heavy ion beams with $q/A \geq 0{,}084$ at an injection energy $W_i \sim 0{,}6$ MeV/u and at beam intensities up to $I_e \sim 100$ emA.

Space charge routine

The program LORAS was modified and a space charge routine was added. Particle-particle interaction is used, the number of particles being up to 500 usually. The sequence of space charge impulses on the particles can be controlled by defining the maximum allowed radial deviation caused by space charge forces between two steps for a particle on the bunch surface. To estimate roughly the space charge force at the pulse surface, a homogeneous density distribution inside the extreme values of particles positions is assumed. During acceleration sections, the maximum is one space charge impulse per $\beta\lambda/2$-cell. Mirror charges at the drift tube walls are neglected.

A structure for high beam intensities

Two tanks of the type described in the previous chapter but each coantaining only one quadrupole triplett, are combined to accelerate the design particle $^{238}U^{20+}$ from W_i = 0,6 MeV/u up to W_f = 2,4 MeV/u. The resonance frequency is f_r = 108 MHz, the total length is l = 8 m. The beam transport at zero current and at I_e = 70 emA is shown in figs. 4 a-d. If the operation parameters like RF voltage level and magnetic field gradient of the magnetic lenses are kept constant, we get particle losses at about I_e > 30 emA in longitudinal direction at positive RF phase angles. If the voltage amplitude is increased in the percentage range the particle losses can be reduced again and the beam current can be further increased.

In that example with I_e = 70 emA the voltage amplitude in the first tank was increased by 1,5 %, in the second tank by 3 %, all magnetic field gradients were increased by 1,5 %.

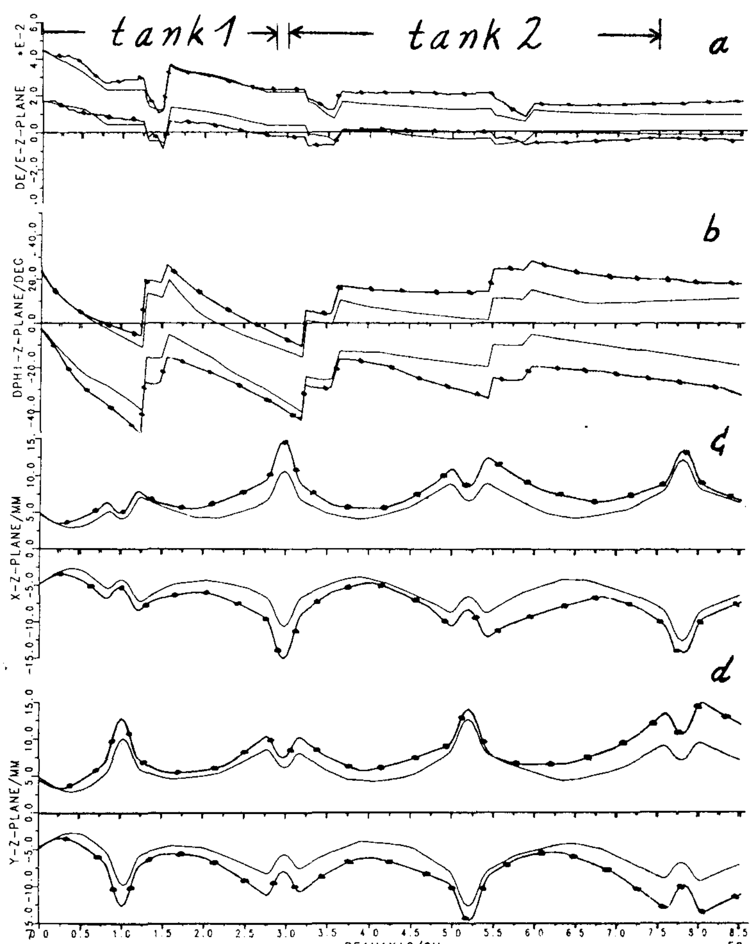

Fig. 4: Preliminary results of space charge investigations on that special type of accelerating structure.
Parameters: 2 tanks; f_r = 108 MHz; W_i = 0,6 MeV/u; W_f = 2,4 MeV/u; q/A = 0,084; E_{eff} = 2,7 MV/m;
The injected ellipses in phase space have areas ε_{tr} = 30 π mm mrad, ε_{long} = 100 keV/u deg.
—•—: beam envelopes at I_e = 70 emA;
——: beam envelopes at I = 0 emA;

References

[1] E. Nolte, G. Geschonke, K. Berdermann, R. Oberschmid, R. Zierl, M. Feil, A. Jahnke, M. Kress and H. Morinaga, Nucl. Instr. and Meth. 158 (1979) 311.

[2] E. Nolte. R. Geier, W. Schollmeier and S. Gustavsson, Nucl. Instr. and Meth. 210 (1982) 281.

[3] U. Ratzinger, E. Nolte, R. Geier, N. Gärtner and H. Morinaga Nucl. Instr. and Meth. A 263 (1988) 261.

[4] J. Klabunde, These proceedings.