High Current IH Structures

U. Ratzinger
GSI, Gesellschaft für Schwerionenforschung mbH
P.O. Box 110 552, D-64220 Darmstadt, Germany

Abstract

The application of the beam dynamics of Combined Zero Degree Synchronous Particle Structures on high current heavy ion acceleration is demonstrated. The adaptation of such a drift tube structure to a RFQ is discussed, especially for the case of high A/q-values and low beam velocity. A very compact solution which seems to be feasible especially in case of the IH structure is presented.

A new design for the GSI high current injector needed to fill the synchrotron SIS up to the space charge limit is described.

1 INTRODUCTION

The IH structure is used as heavy ion accelerator behind a RFQ at the new GSI High Charge State Injector (ECR ion source) successfully [1]. An extended 3 tank system behind a RFQ has been completed recently for the CERN Lead LINAC [2]. It accelerated the design ion 208 Pb^{25+} from 250 keV/u to 4.2 MeV/u. The intensity is around 50 eμA. The beam dynamics of Combined Zero Degree Synchronous Particle Structures [3] makes an important contribution to the high efficiency of these structures.

Ion sources like CHORDIS [4] and MEVVA [5] generating beam currents of several pmA in one charge state and pulse lengths of more than 100μs are limited in the charge state to $q \leq 4$. At present high current heavy ion beams are requested to fill heavy ion synchrotrons like SIS [6] up to the space charge limit. Linac studies in the field of Heavy Ion Inertial Fusion especially concentrate on beams with A/q $\sim$ 200 and beam currents around 100 mA. A first study about the use of IH structures for a fusion linac was described in ref. [7].

This paper especially concentrates on the coupling of the RFQ with the IH structure and presents a design study for the new high current injector at GSI.

2 BEAM CURRENT INCREASE AT THE UNILAC

Earlier studies about the UNILAC current upgrade project were described in ref. [8]. Two stripping processes along the linac were planned in that scenario, which combined a 27 MHz RFQ for A/q $\leq$ 130 with the UNILAC-Wideröe tank 2 at W_i = 216 keV/u. The latest design replaces the whole 4 tank Wideröe section with W_i = 11.7 keV/u, W_f = 1.4 MeV/u and A/q $\leq$ 25 by a 2 tank IH structure at f = 36 MHz with W_i = 120 keV/u, W_f = 1.4 MeV/u, A/q $\leq$ 65. The two existing 300 kV high voltage platforms will be kept at their original positions to inject the beam out of ion sources like CHORDIS and MEVVA into the linac. Additionally the large reservoir of PENNING ion sources may be used there furtheron, especially in case of lower intensity demands. It even seems feasible to keep the high duty cycle of up to 25% for the new linac in the 'PENNING-mode', as the A/q-values are about a factor 2.5 higher resp. the rf power losses by a factor of 6.25 lower in that case. The complete new 1.4 MeV/u injector including a 36 MHz RFQ up to 120 keV/u will not need more length than the present set up though the voltage gain has to be enlarged by a factor 2.5 due to the change in the charge state from $^{238}U^{10+}$ out of the Pennning source down to $^{238}U^{4+}$ out of the MEVVA source. This becomes possible as the IH structure was tested successfully up to averaged effective accelerating field strengths as high as 6 MV/m. At the same time the four existing Wideröe amplifier chains with $P_{rf} \leq$ 800 kW each will be sufficient to drive the two IH cavities. By that way the additional stripping process at 216 keV/u as described in ref. [8] is no more necessary. The gas stripper at 1.4 MeV/u has to be used furtheron to adopt the beam to the Alvarez section which is designed for A/q $\leq$ 9. Taking into account an additional stripping process behind the UNILAC to get highest energies out of the synchrotron the current demands for the new injector are around 2 pmA for Uranium, it is 8 emA $^{238}U^{4+}$ at 1.4 MeV/u. The design presented has a current limit at around 20 mA, caused by the lens apertures of the first and second magnetic quadrupole lenses.

3 ADAPTATION RFQ-IH

In case of the 'High Charge State Injectors' described in ref. [1] and [2] with beam intensities below 100 eμA and A/q values below 9.5 the IH linac was coupled with the RFQ by the sequence: Magn. Quadrupole Triplet (Doublet) - Rebuncher - Magn. Quadrupole Doublet.

At high beam intensity and high A/q-values this sequence makes problems mainly because of the following contradiction:

- The drift lengths RFQ-Rebuncher and Rebuncher-IH should be short because of space charge effects.
- The magnetic lenses need more length due to the higher A/q value.

The problem could be overcome by a tool focusing in both transversal and in the longitudinal dimension at the

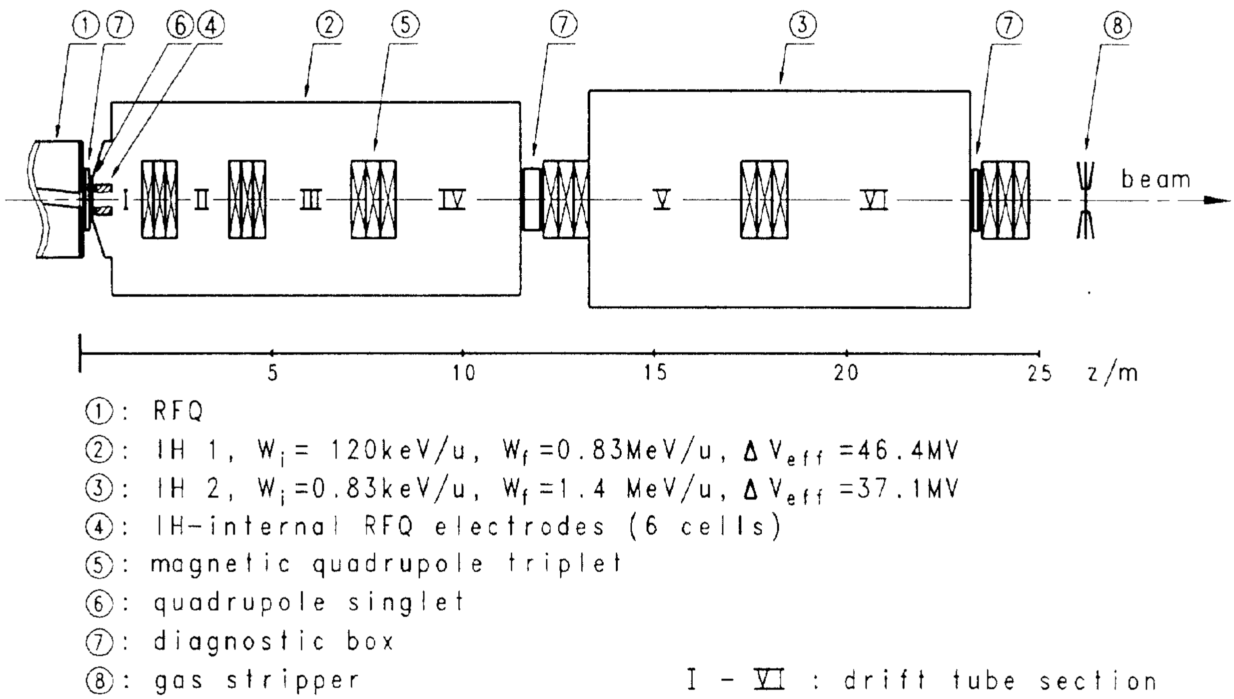

Figure 1: Scheme of the 36 MHz IH linac design.

same time: That is a short RFQ with larger aperture, positioned after a short drift (diagnostic box) behind the main RFQ tank. The IH structure should follow immediately behind that 'adapter RFQ'. One example was studied for the parameter set W = 120 keV/u, A/q = 65, I $\leq$ 20 mA. It is described in chapter 4 and shown by fig. 2.

4 THE 36 MHZ HIGH CURRENT IH LINAC DESIGN

After first investigations on a 27 MHz/54 MHz-design [6] the rf frequency of 36 MHz (one third of the Alvarez rf frequency) was chosen as a compromise between high current limit ($\rightarrow$ lower frequency) and moderate IH tank dimensions ($\rightarrow$ higher frequency). The transition from the RFQ to the IH structure is at 120 keV/u.

The LORASR beam dynamics calculations were performed with an injected bunch of constant particle density ρ and ellipsoidal shape. The rms emittance values are $\varepsilon_{n,x} = \varepsilon_{n,y} = 0.1 mm \cdot mrad, \varepsilon_z = 0.7 keV/u \cdot ns$. Fig. 1 shows the array from the end of the RFQ tank down to the beam focus at the gas stripper with a beam diameter around 6 mm. The increase in normalized rms emittance along the IH structure is calculated to be around 5 % at zero beam current, 40 % at 10 emA and 60 % at 15 emA for each of the 3 phase space areas at 100 % beam transmission.

The adaptation of the beam out of the RFQ to the IH structure is done after a drift of 28 cm with a magnetic quadrupole singlet and a 6 cell RFQ structure integrated in the IH tank as shown by fig. 2 and excited in the H_{11}-mode. An aperture diameter of 16 mm will be sufficient for the electrodes, their length will be around 40 cm. The present 6 cell design uses a synchronous rf phase of -60^0 and a modulation factor of 2, the voltage between electrodes is up to 400 kV. Investigations about the rf behaviour of an IH tank with a high capacitive load at the front end caused by the RFQ electrodes have still to be done. It also should be checked whether the main 36 MHz RFQ structure could profit from that type of 4 rod structure. The water cooling is easy as shown already for the IH drift tube structure. The distance between stems can be chosen very small in that mode compared to other 4 rod designs, giving higher precision in the electrode alignment.

The aperture diameters of the 6 quadrupole triplets range from 30 mm to 45 mm, the magnetic gradients from 74 T/m to 50 T/m. The length of the completed triplet lenses range from 0.8 m to 1.25 m. The rf power losses will be around 800 kW for each tank.

Fig. 3 shows the position of the bunch centre in rf phase and energy relatively to the synchronous particles in the mid plane of each gap centre along the accelerating sections I to VI. Each section consists of a rebunching unit (6 cell RFQ in section I resp. 4-7 gaps at ϕ_s = -35^0 in sections II-VI) followed by a 0^0 synchronous particle section with 10-16 gaps, where the bunch is injected with an excess in energy and an rf phase around 0^0.

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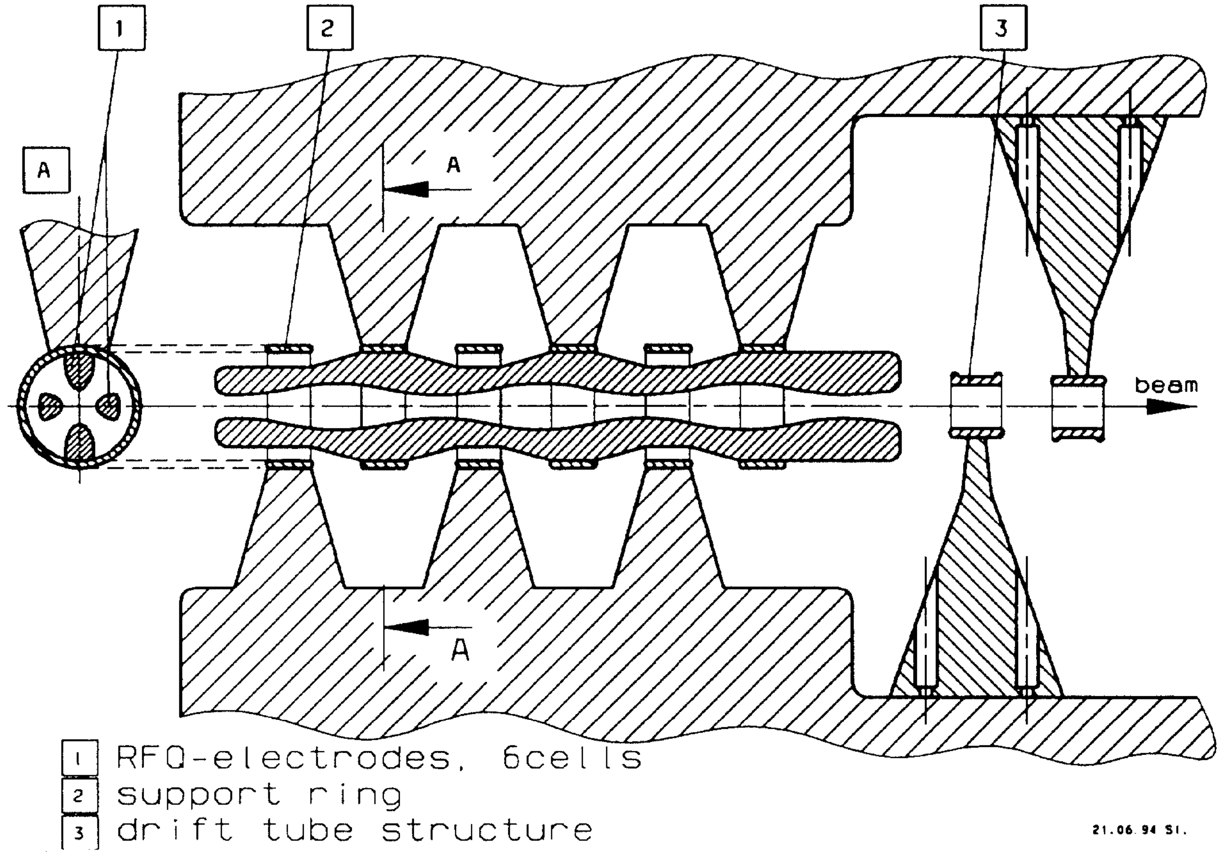

Figure 2: RFQ electrodes integrated at the front end of IH tank 1 to provide the beam adaptation.

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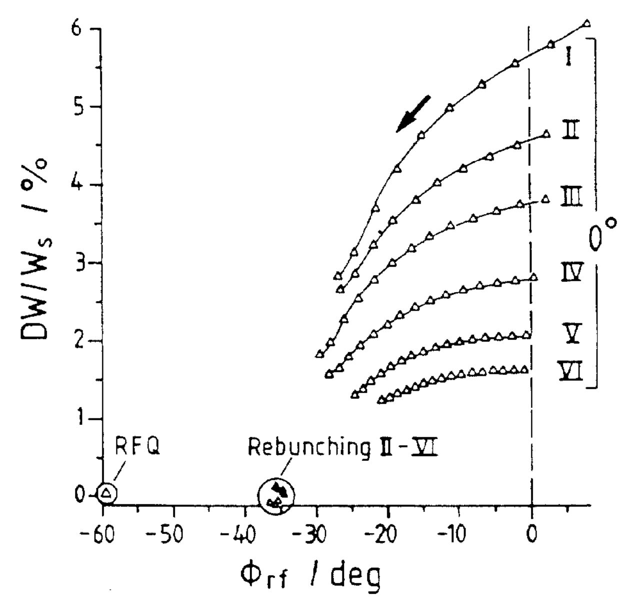

Figure 3: Position of the bunch centre in energy and rf phase in each gap centre along the IH structure.