Development of IH-Cavities for the Munich Accelerator for Fission Fragments (MAFF)

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Abstract

The linear accelerator for the new Munich high flux reactor FRM II (MAFF) which is under design [1,2] will deliver intense beams of very neutron-rich fission fragments of up to 10^{12} particles per second with final energies between 3.7 and 5.9 MeV/u in order to perform experiments for structure investigations and production of long living heavy elements [3]. In order to obtain an efficient acceleration in a short LINAC charge breeding of the 1+ ion beam from the reactor to a q/A ~ 0.2 and bunching of the continuously produced radioactive ions according to the duty cycle of 10% are required. The overall length of the LINAC is restricted to 20m. Thus structures with high shunt impedances and high effective accelerating field like the IH-structure will be used to reach energies at the Coulomb barrier. In order to gain a high flexibility in the final energy with only two small cavities the properties of 7-gap IH-structures are under examination at the Munich tandem laboratory and will be presented. In addition the concept of an IH-cavity driven RFQ structure [4] at 101.28 MHz as the first acceleration stage will be shown as well.

1 THE MAFF LINAC

In fig.1 the overview of MAFF is shown. The singly charged radioactive ions from an target ion source inpile [5] will be mass separated inside the reactor hall and then guided to the experimental hall. The overall length of the LINAC is restricted to 20m, because the space of the experimental hall is limited by the reactor fence. Thus charge breeding of the intense radioactive ion beams in order to enhance the charge to mass ratio to q/A>0.16 and bunching of the continuous 30 keV beam from the inpile source has to be done. The best scheme will be determined in the framework of the European charge breeding network. To achieve adequate final energies close to the Coulomb barrier a LINAC has been proposed which is described in [6] and [7]. The first acceleration stage is an IH-RFQ which accelerates the ions from 2.5 keV/u to 300 keV/u (fig.2). The matching to the following drift tube LINAC is done by a magnetic quadrupole triplet lens and an RFQ buncher (super-lens)[4]. The booster LINAC consists of three IH cavities which will accelerate the ions up to 5.4 MeV/u. The two 7-gap IH-resonators will be able to vary the final energy between 3.7-5.9 MeV/u due to acceleration and deceleration at different injection energies.

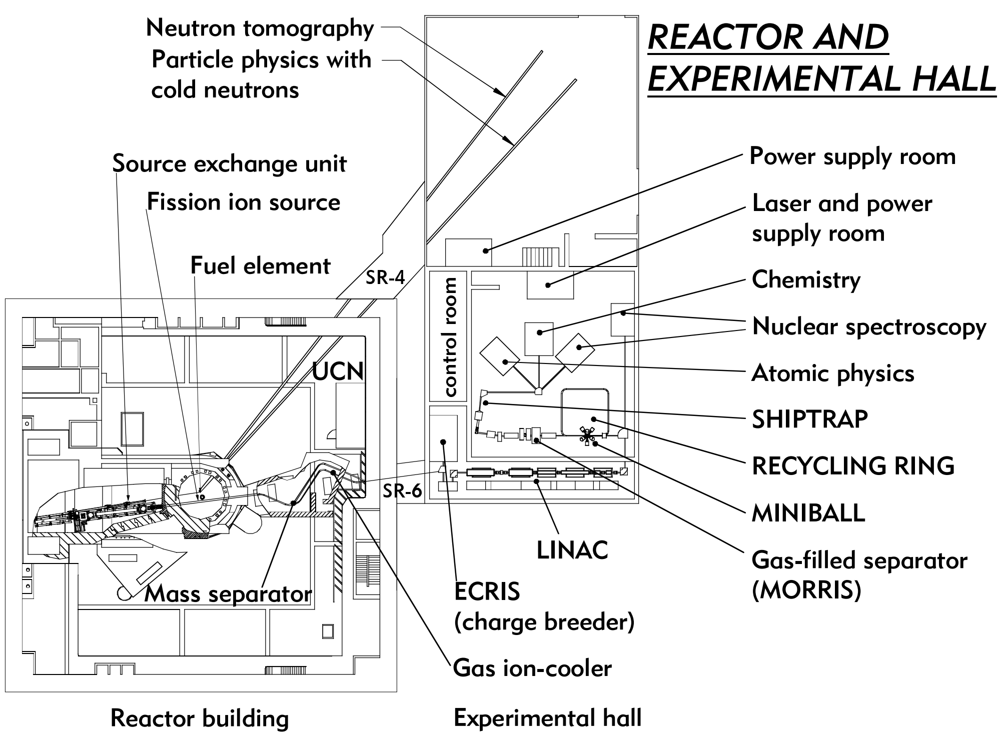

Figure 1: Overview drawing of MAFF

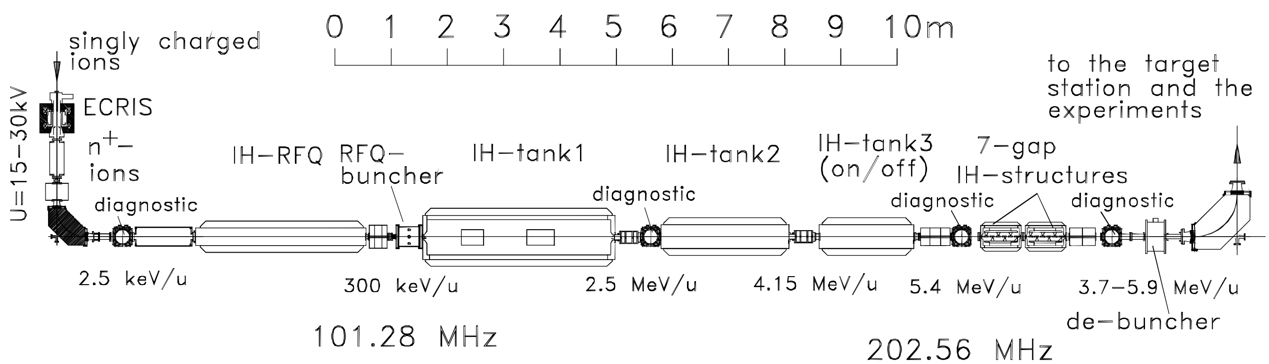

Figure 2: Layout of the MAFF LINAC.

2 IH-RFQ CAVITIES

2.1 The IH-RFQ

The RFQ of the MAFF LINAC shall benefit from the advanced concept of an IH-mode driven quadrupole structure which allows indirect electrode cooling and provides a higher shunt impedance in comparison to the 4-rod structure. This concept which is used at the GSI-HSI [8] at 36 MHz will be examined for MAFF at its limiting frequency of about 100 MHz [9]. The acceptance of the RFQ is about 0.6 π mm mrad at 2.5 keV/u, the final energy about 300 keV/u. The electrode design and the exit emittances are comparable to the REX-RFQ [10].

2.2 The RFQ buncher structure

A short IH-RFQ bunching structure will be used to match the beam phase spread from the RFQ to the IH-tank 1. Due to space restriction this short matching section which preserves the good beam quality has been chosen instead of two triplet lenses with a drift tube re-buncher, which is used at REX-ISOLDE. In front of the RFQ buncher a quadrupole triplet is used for transverse matching. Table 1 shows the design parameters of this small "super-lens" from MAFIA calculations.

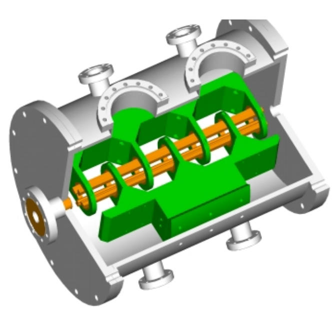

Figure 3: Technical lay-out of the RFQ buncher

The resonator tank is shown in fig.3. The resonators is a cylinder where two massive ridges are welded to the superficies surface. The ridges carry the electrodes via copper rings, which will fit into the stems. The design is similar to the GSI super-lens.

Table 1: Design parameters of the RFQ-buncher

Stem Distances [cm]	6
Stems	7
Q_0	8276
Length [cm]	50
Inner Diameter [cm]	32
Frequency [MHz]	101.3
Rp-value [kΩm]	211

3 THE BOOSTER LINAC

The booster LINAC, which consist of three IH-cavities, has to deliver beams with a maximum energy of 5.4 MeV/u. Table 2 shows the key parameter of the cavities which are relevant for the particle dynamic calculations of the structures. With a maximum effective voltage of 32.2 MV this booster LINAC provides only 1 MV lower acceleration voltage in comparison to the CERN lead LINAC. For the three tanks the ''Combined zero degree synchronous particle structure' (KONUS) [4] is used which guarantees maximum acceleration efficiency.

Table 2: Design parameters of the booster tanks for particle dynamics calculations

	Final E	**Ueff**	**L**	**Gap no.**
Tank 1	2.5 MeV/u	13.9 MV	3.8 m	40
Tank 2	4.15 MeV/u	10.4 MV	2.1 m	34
Tank 3	5.4 MeV/u	7.9 MV	2 m	25

Beam dynamics calculations with LORASR have been performed, in order to determine the right gap voltage distribution, the injection emittances and the beam quality after the booster. A small phase spread after this part of the LINAC is mandatory, because the excitation function for the production of very heavy elements by heavy ion fusion reaction require an energy spread below 0.1%. In Fig.4 the beam dynamics calculations of tank1 and 2 of the booster are shown. In comparison to the lead LINAC the phase drift of the particle bunch in the high energy sections of tank1 is much smaller. The particles stay in the vicinity of the 0^{o}-synchronous particle and where the energy gain is maximum due to the fact that their A/q is larger than in case of the lead LINAC (A/q=8.2). Tank2 shall deliver an acceleration gain of 1.65 MeV/u over only 2.1 m length. Thus a rather long 0°-Section of 24 gaps has been foreseen. In fig.4b the development of the energy and phase spread is shown. Both remain stable in the long acceleration section. The phase spread of about 25° will be reduced in the buncher section of tank3.

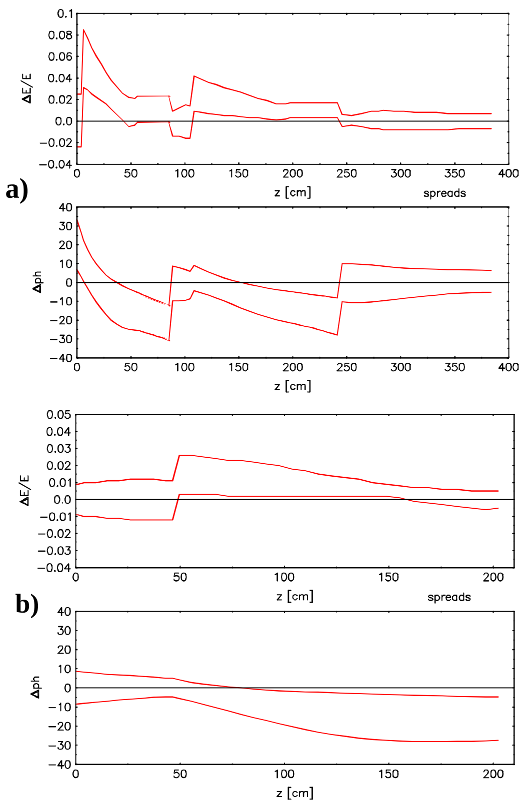

Figure 4: Development of the phase- and energy spread of the ions in a) tank1 and b) tank2 of the booster Linac.

4 THE 7-GAP IH-STRUCTURES

A central issue of the MAFF-LINAC are the 7-gap IH-cavities. For the beam dynamics calculations a total resonator voltage of 2.1 MV has been assumed. These calculations have been done with the LINAC programme of the MPI-K Heidelberg in dependence on the resonator voltage which correspond to the whole energy range of 3.7-5.9 MeV/u.

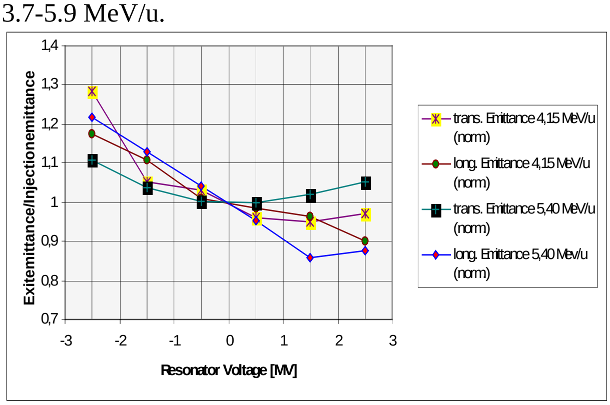

Figure 5: Calculations of the emittance growth of the beam in the 7-gap cavities in dependence on the voltage.

Thus the longitudinal and transverse emittance growth have been examined. The results are sketched in Fig.5. It shows that in the worst case of maximum deceleration at the lower injection energy of 4.15 MeV/u the emittance growth will stay below 30%. In longitudinal direction the worst emittance growth is about 20%, which is good enough for the requirements of the experiments.

MAFIA calculations have proposed a shunt impedance of about 150 MΩ/m and a quality factor of about 16000. Thus the possible resonator voltage could be increased to 2.5 MV, which would enhance the possible energy range as well. In order to examine the cavity of such an 7-gap IH-resonator a real size model was build, which is shown in fig.6. First measurement will be carried out in order to determine the gap voltage distribution in dependence on the undercut length, the possible tuning range and the rf-parameter (shunt impedance, quality factor). The model will deliver the geometry data for a 7-gap IH-power resonator

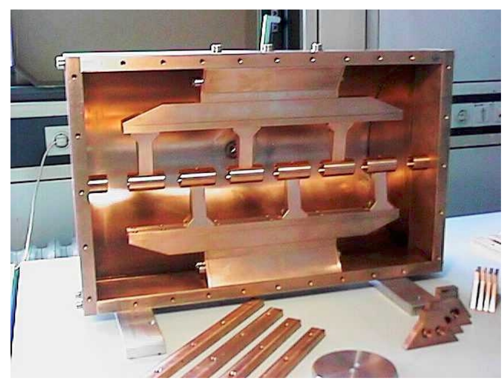

Figure 6: Picture of the model of a 7-gap IH-resonator.

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