A COUPLED RFQ-IH COMBINATION FOR THE NEUTRON SOURCE FRANZ*

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Abstract

The Frankfurt Neutron Source at the Stern-Gerlach-Zentrum [1] is driven by a 2 MeV proton linac (Table 1) consisting of a 4-rod-radio-frequency-quadrupol (RFQ) [2] and an 8 gap IH-DTL [3] structure. RFQ and IH cavity will be powered by only one radio frequency (RF) amplifier to reduce costs. The RF-amplifier of the RFQ-IH combination is coupled into the RFQ. Internal inductive coupling (Fig. 1) along the axis connects the RFQ with the IH cavity ensuring the required power transition as well as a fixed phase relation between the two structures. The main acceleration of 120 keV up to 2.03 MeV will be reached by the RFQ-IH combination with 175 MHz and at a total length of 2.3 m. The losses in the RFQ-IH combination are about 200 kW.

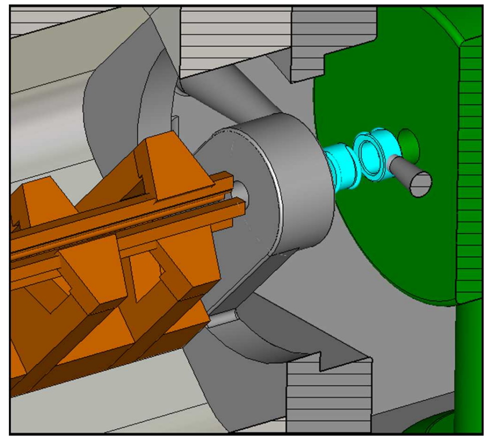

Figure 1: Coupling area between RFQ and IH-DTL.

INTRODUCTION

The coupling of RF-components is for new accelerator developments attractive to reduce the costs for RF-amplifier and using more compact devices.
Examples of coupled systems are already present or planned. In the development of the FAIR Proton Injector at GSI coupled CH-DTL cavities are planned and already under construction [4]. The example of an existent system is a coupled RFQ drift tube combination for medical application development at the HICAT (Heavy Ion Cancer Therapy) center in Heidelberg, Germany. At HICAT center a 4-Rod-RFQ with a 2 gap rebuncher is merged by Institute for Applied Physics, University Frankfurt [5].
Coupled systems, in this case RFQ and IH-DTL (Fig. 2) with the same resonance frequency can be driven in 0 and π-mode. A switch between the 0 and π-mode needs an extra drift. In case of the FRANZ-combination are shown the investigation for the 0-mode and the drift between RFQ and IH-DTL is 60 mm [6, 7].
The investigations on the inductive coupling between RFQ and IH-DTL for FRANZ are performed. Both cavities have the same resonance frequency and are coupled inductively over a special flange.

Table 1: Parameters of FRANZ-RFQ-IH Combination

Parameter	Unit	
Particle		Proton
Frequency	Mhz	175
Current	mA	50-200
RFQ Input-Energy	keV	120
IH-DTL Input-Energy	keV	700
IH-DTL Output-Energy	MeV	2.03
RFQ Losses	kW	139
IH-Losses	kW	75
RFQ $\epsilon_{in}^{trans.,norm.,rms}$	mm mrad	0.4
IH $\epsilon_{X,out}^{trans.,norm.,rms}$	mm mrad	0.9
IH $\epsilon_{Y,out}^{trans.,norm.,rms}$	mm mrad	1.09
IH $\epsilon_{Z,out}^{trans.,norm.,rms}$	mm mrad	5.2
RFQ - # of Cells		97
IH - # of Cells		8
RFQ - # of Stems		18
IH - # of Stems		6
RFQ - Aperture	mm	4
IH - Aperture	mm	22-24
RFQ - Dimension	mm	300x340x1825
IH - Dimension	mm	410x640x560
Coupling constant		0.03
Q - Factor		8000
Shunt impedance	MΩ/m	69

RFQ DESIGN

The RFQ beam dynamics is now fixed in detail, an average aperture of 4 mm for a 1.75 m structure with electrode voltage $U_{el} = 60\ kV$ is being build. The positions of the tuning plates for a balanced field distribution (flatness) were simulated with MicroWave Studio (MWS) [8]. The RFQ has 18 stems and tuning plates. The last tuning plate

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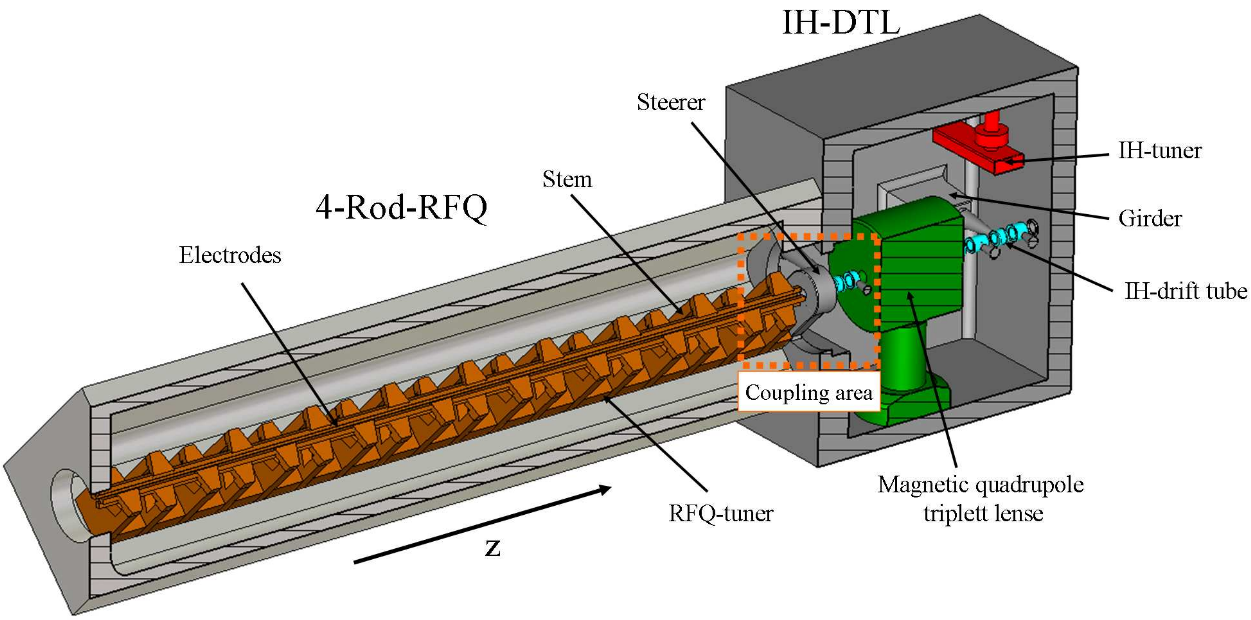

Figure 2: Cross sectional view of the coupled RFQ-IH-DTL combination for FRANZ. The 4-Rod-RFQ is shown left and the IH-DTL on the right side. In coppery are the RFQ-electrodes and stems, in the coupling area is in the gray the xy-steerer. The drift tubes are colored in cyan and the magnetic quadrupole triplet lens is shown in green. In the IH-DTL is represented in red the dynamic tuner.

is between the last stem and coupling flange. The field distribution is increased at the ends of the RFQ, if the RFQ is a stand-alone machine and the field is more flat at the end of the RFQ for the coupled structure. The tuning plates must be moved up in that region to flatten the field distribution again. The movement of the tuning plates changes the frequency, dynamic tuner and the tuning plates were used to get the right frequency. The tuning plates will be optimized with the Effect-Curve-method (EC) [9] for a faster flattening of the field distribution.

IH DESIGN

The IH-DTL has 3 gaps in front of and 5 gaps behind a focusing magnetic quadrupol triplet lens and the cavity accelerates the proton beam to the final energy of 2.0 MeV within a total length of 0.6 m. The beam dynamics were simulated with LORASR and the gap voltages are tuned with the LORASR values. The IH-DTL is optimized to decrease the power losses and to get maximum field concentration on beam axis. The IH-DTL has an expected power consumption of 75 kW and this energy must be transferred by the inductive coupling. The cooling for cw operation is a challenging topic, that is the reason why all components (drift tubes, stems, girders, walls, internal lenses) in the IH-DTL are cooled. For the cooling of the IH-structure 1,8 liters per second are needed.

COUPLED RFQ-IH COMBINATION

A scaled RFD-IH model [7] has shown the functionality of a coupled structure and helped to finally optimize the RF coupling and tuning between RFQ and IH-DTL. In Fig. 3 the magnetic fields are shown between RFQ and IH-DTL, these fields illustrate the inductive coupling. The preliminary coupling factor of $k \approx 0.03$ is simulated with MWS and is depending on voltage ratio. The voltage ratio is defined as the ratio of all IH-gap voltages and the RFQ-electrode voltages (Fig. 4):

$$V_r = \frac{U_{IH}}{U_{RFQ}} = 26 \quad (1)$$

A galvanic coupling was investigated and the coupling factor is only marginally larger than the coupling factor of the inductive coupling. In case of the galvanic coupling a galvanic coupling bridge is installed between the last RFQ-stem and the first IH-stem. A possible coaxial cooling in the bridge is too complex to cool the losses on this bridge for the benefit of a small growth of the galvanic coupling factor. The inductive coupling will be used.

TUNING CONCEPT

The tuning of the coupled system is the primary topic. In the linac combination the resonance frequency, flatness in the RFQ and the voltage ratio between the cavities have to match. The tank geometry can be adjusted in design phase for the frequency tuning and the voltage ratio can be

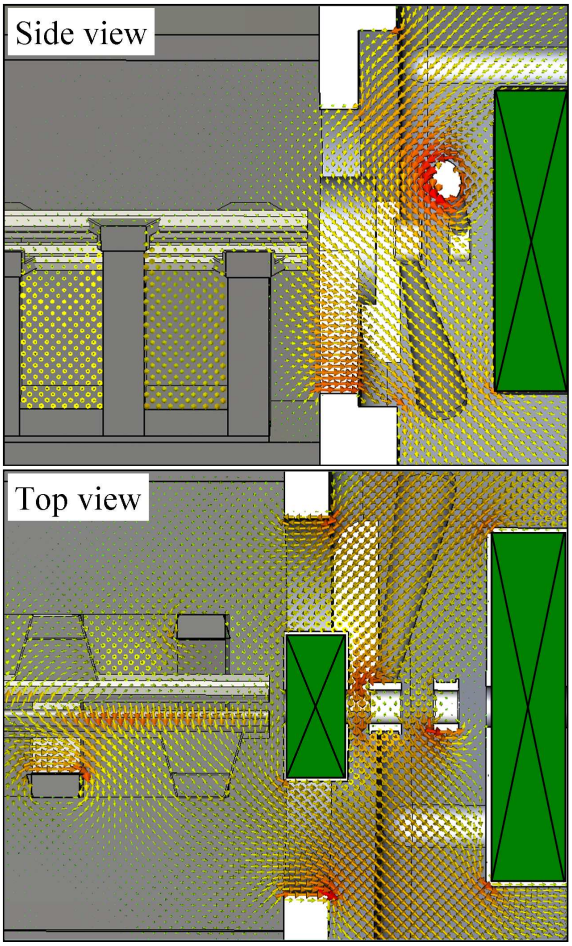

Figure 3: Side and top view on the coupling area. The RFQ is on the left and the IH-DTL is on the right side. The beam goes to the right direction. The arrows represent the magnetic fields and thus the inductive coupling. The inductive coupling connects the RFQ with IH-DTL.

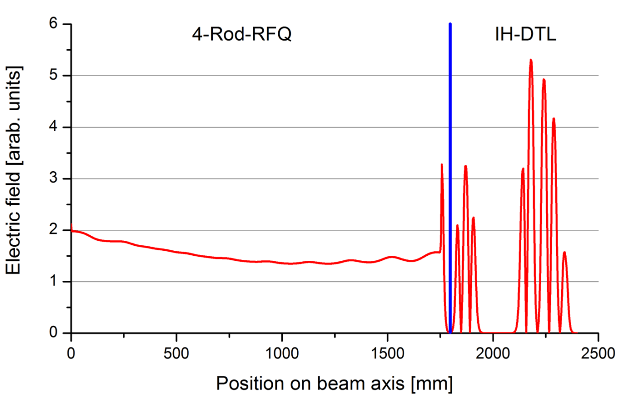

Figure 4: Field distribution on the beam axis along RFQ-IH-DTL combination. The blue line separates the both cavities. The voltage ratio must be 26 so that both accelerators have a strong field distribution and no cavity is suppressed. In this case the RFQ has no flatness of the RFQ field distribution.

adjusted to a certain point. The flatness in the simulation deviates from the measurement. Only the resonance frequency can be tuned to an accuracy of 1% in the simulation. The voltage ratio is dependent from the frequency and flatness of the RFQ field distribution. In operation the flatness of the field distribution and the frequency can be tuned with the variable tuning plates in RFQ. The frequency can also be tuned separately with the RFQ and IH tuner in each cavity.

CONCLUSIONS

The technique of coupled 4-rod-RFQ and IH-DTL cavities is possible and not only a theoretical concept. For the FRANZ project simulations with an RFQ-IH-DTL and a real 1:2 scaled model have proved that the coupling is functional between the cavities. The RFQ-IH-DTL cavities are under construction and the transmitter will be installed this month in the FRANZ experimental hall. The next step will be the flatness tuning of the RFQ field distribution for an optimal voltage ratio and thermal investigations of both cavities. At the end of 2012 both cavities will be conditioned and ready to boost protons to 2 MeV.

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