# A COUPLED RFQ-IH CAVITY FOR THE NEUTRON SOURCE FRANZ

M. Heilmann*, C. Claessens, D. Mäder, O. Meusel, U. Ratzinger, A. Schempp, M. Schwarz
IAP, Frankfurt University, 60438 Frankfurt am Main, Germany

*Abstract*

The Frankfurt Neutron Source at the Stern-Gerlach-Zentrum (FRANZ) [1] delivers neutrons in the energy range from 1 to 300 keV at high intensities. The neutrons are produced using the the $^7Li(p,n)^7Be$ reaction with 2 MeV protons. The linac accelerator cavities (Table 1) consist of a 4-rod-RFQ [2] coupled with an 8 gap interdigital H-type drift tube [3] section with a total cavity length of 2.3 m (Fig. 1). It accelerates the 120 keV beam to 2.03 MeV at a frequency of 175 MHz. The combined cavity will be powered by one RF amplifier to reduce investment and operation costs. The inductive power coupler will be located at the RFQ part. The coupling into the IH section is provided by direct inductive coupling within the cavity. The coupled RFQ-IH combination is investigated with CST-MWS-simulations [4] and by an RF model. The linac combination has to match the resonance frequency, flatness along the RFQ and the voltage ratio between both cavity sections. Beam operation will be cw (a few mA) and pulsed 250 kHz, 50 ns (up to 50 mA and beyond). The thermal cavity losses are about 200 kW and the cooling is the challenging topic.

## INTRODUCTION

The coupling of RF components is useful for accelerator developments to reduce the RF amplifier cost and profit from short drifts between accelerator structures and compact devices. In case of FRANZ the coupled system is an RFQ-IH-DTL with the same resonance frequency and both structures are coupled inductively. The coupled structures can be driven in 0 and $\pi$ mode. The coupled RFQ-IH-DTL combination is investigated for the 0 mode and a mode switch would need an extra drift between both structures. The coupled combination is investigated with simulations and by an 2:1 RF model to optimize the layout design of the RFQ-IH-DTL [6, 7, 8]

## COUPLED RFQ-IH COMBINATION

The inductive coupling connects through a large aperture the RFQ and IH-DTL. The coupled structures are optimized by simulations and by a 1:2 scaled radio-frequency dipole-IH model. The RFD-IH model has shown the functionality of the coupled combination [5]. In the coupled RFQ-IH system the resonance frequency, the balanced field distribution of RFQ electrodes (flatness) and the voltage ratio between both structures have to be matched. The challenge is the tuning of the coupled system, because only the resonance frequency can be tuned in the simulation to an

* heilmann@iap.uni-frankfurt.de

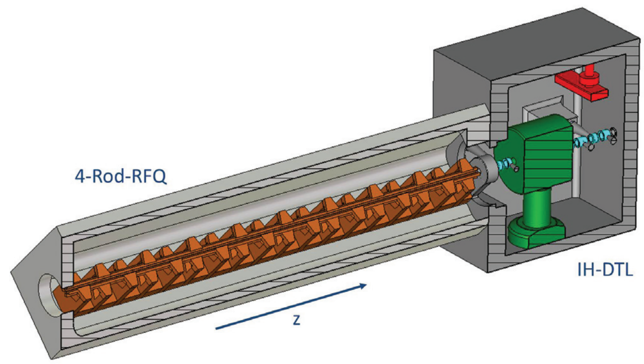


Figure 1: Cross sectional view of the coupled RFQ-IH-DTL combination for FRANZ. The RFQ is on the left side and the IH-DTL on the right. In copper color are the RFQ-electrodes and stems. The IH-drift tubes are colored in cyan, the magnetic quadrupole triplet lens is shown in green and in the dynamic tuner is represented in red.

Table 1: Parameters of FRANZ-RFQ-IH combination at 140 mA (in brackets 50 mA) beam current.

| Parameter | Unit | |
|---|---|---|
| Particle | | Proton |
| Frequency | MHz | 175 |
| Current | mA | (50) 140 |
| RFQ Input-Energy | keV | 120 |
| IH-DTL Input-Energy | keV | 700 |
| IH-DTL Output-Energy | MeV | 2.03 |
| RFQ Thermal Losses | kW | 139 |
| IH Thermal 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 $\epsilon_{Z,out}^{trans.,norm.,rms}$ | keV ns | 5.2 |
| RFQ - # of Cells | | (97) 95 |
| 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 | 412x642x560 |
| Electrode voltage | kV | (61) 75 |
| Coupling constant | | 0.03 |
| Q - Factor | | 8000 |
| IH - Shunt impedance | MΩ/m | 69 |




ISBN 978-3-95450-122-9

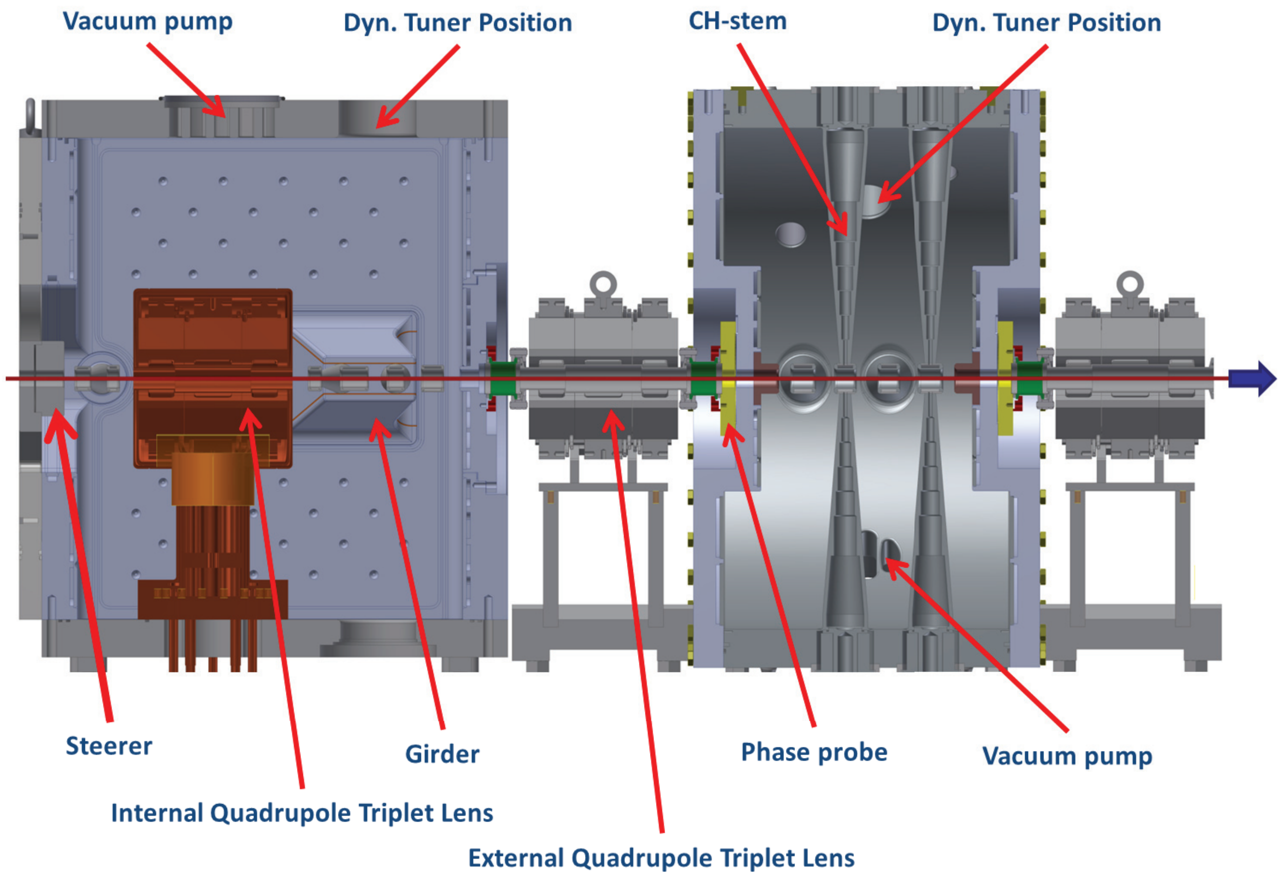


Figure 2: Cross sectional view of the construction layout of the IH-DTL and CH-ReBuncher with the three qudrupole triplet lenses for FRANZ. The acceptance is investigated for this sub-part of the LINAC section. The structures will be connected with a flanged bellow (green) and the phase probe (yellow) can be used for the time of flight.

accuracy of 1 %. The simulations are showing significant error bars for flatness and voltage ratio and deviated from the measurement.

The last cell of RFQ electrode is essential for the coupling. The RFQ output matcher must meet the acceptance of the IH-DTL. The orientation of the ellipses in xx' and yy' have a great impact on the further beam transport along the IH-DTL and down to the bunch compressor. Therefore, the steerer behind the RFQ will have the capability to act as a 'weak' quadrupole singlet additionally to improve the matching if needed.

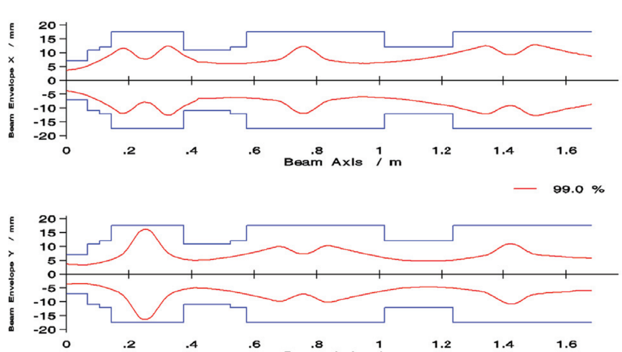


Figure 3: Beam envelope from the entrance of the IH-DTL to the end of the second external quadrupole triplet lens for 140 mA [9].

## BEAM DYNAMICS

The beam dynamics program LORASR simulates the RFQ output distributions with all gaps (IH-DTL, CH-ReBuncher) and magnets (Table 2) for 140 mA beam current. The transmission and output emittance at the end of the second external qudrupole triplet lens are optimized with the simulations. The MEBT (*M*edium *E*nergy *B*eam *T*ransport) technical design is shown in Fig. 2.

The envelope describes the maximum distance of the particle trajectories of the beam axis for 99 % of the particles (Fig. 3). The particle trajectories have a high filling degree in the aperture of the drift tubes and drift sec-

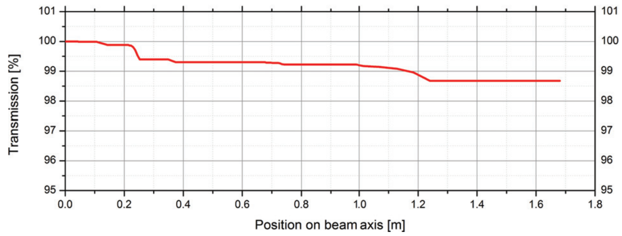


Figure 4: Beam transmission in the LINAC section for 140 mA. The beam losses at the end of the linac section are 1.4 % [9].

Table 2: Parameters of the ideal FRANZ-Quadrupole Triplets in LINAC-Section at 140 mA beam current [9].

| | Quadru-pole | Int. | 1. Ext. | 2. Ext. |
|---|---|---|---|---|
| Gradient [T/m] | a | 54.0 | 43.5 | 39.0 |
| | b | 51.5 | 49.0 | 46.5 |
| | c | 54.0 | 43.5 | 39.0 |
| Eff. Length [mm] | a | | 41 | |
| | b | | 61 | |
| | c | | 41 | |
| Current [A] | a | | 300 | |
| | b | | 440 | |
| | c | | 300 | |

tions of the accelerators at FRANZ, and particle losses are expected. In cw operation FRANZ will neutron activate probes with a few mA of proton driver beam. In pulsed operation (1 % beam duty factor), the beam has to match the acceptance of the bunch compressor [1]. Due to the available cost frame and space requirements this linac layout was an acceptable compromise to fulfill the requests of both operation modes. The beam transmission in the LINAC section is shown in Fig. 4 and the transverse output emittances are plotted in Fig. 5.

## CONCLUSIONS

The coupled RFQ-IH-DTL combination for FRANZ shows promising results in simulations and in model measurements on the 1:2 scaled RFD-IH model. The last components of the accelerators should be fabricated during 2013. The 50 mA proton source is ready for operation. Running in of the LEBT has started, including the 250 kHz chopper, to match the beam into the RFQ acceptance.

## REFERENCES

[1] U. Ratzinger, B. Basten, L.P. Chau, H. Dinter, M. Droba, M. Heilmann, L. Lotz, D. Mäder, O. Meusel, I. Müller, Y.C. Nie, D. Noll, H. Podlech, A. Schempp, W. Schweizer, K. Volk, C. Wiesner and C. Zhang The Driver Linac of the Neutron Source FRANZ, Proceedings of IPAC12 Conference, WEPS040.

[2] A. Bechtold, A. Schempp, M. Vossberg, Recent High

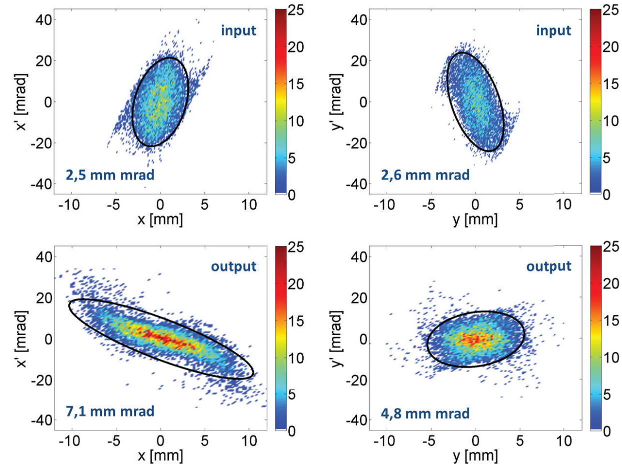


Figure 5: Cluster plots of the input distribution in front of the IH-DTL and output distribution at the end of the second external qudrupole triplet lens for 140 mA [9], emittance values for 95 % effective emittance ellipses are plotted.

Power RFQ Development Proceedings of International Topical Meeting on Nuclear Research Applications and Utilization of Accelerators, 4-8 may, 2009, Vienna, Austria.

[3] U. Ratzinger, Effiziente Hochfrequenz-Linearbeschleuniger für leichte und schwere Ionen, Habilitationsschrift, Goethe Universität Frankfurt, 1998.

[4] CST MicroWave Studio, `www.cst.de`.

[5] M. Heilmann, D. Mäder, O. Meusel, U. Ratzinger, A. Schempp, M. Schwarz
A Coupled RFQ-IH Cavity for the Neutron Source FRANZ, Proceedings of LINAC2012, Tel-Aviv, Israel, THPB008, p. 858

[6] A. Bechtold, U. Bartz, G. Clemente, M. Heilmann, P. Kolb, H. Liebermann, D. Mäder, O. Meusel, H. Podlech, U. Ratzinger, A. Schempp, C. Zhang, A coupled RFQ-drift tube combination for FRANZ, Proceedings of LINAC08, Victoria, Canada, MOP001, p.46.

[7] D. Mäder, Kopplung der Beschleunigerkavitäten RFQ und IH-DTL am FRANZ-Projekt, Master Thesis, Uni. Frankfurt, 2011.

[8] M. Schwarz, Hochfrequenzabstimmung und Feldoptimierung des gekoppleten 1:2 RFD-IH-Modells für FRANZ, Bachelor Thesis, Uni. Frankfurt, 2012.

[9] U. Ratzinger, privat communication, 2011




ISBN 978-3-95450-122-9