ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPME059

PREPARATION OF THE COUPLED RFQ-IH-CAVITY FOR 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] will provide ultra-short neutron pulses at high intensities and repetition rates. The neutrons will be produced using the ^{7}Li(p,n)^{7}Be reaction induced by a proton beam. The 175 MHz IH-type drift tube linac with 8 gaps (Fig. 1) [2] succeeds a 4-rod-RFQ (Table 1) [3, 4]. Together they form a coupled linac combination with a length of 2.3 m and accelerate the protons from 120 keV to 2.03 MeV [5]. As the RF losses add up to 200 kW, the cooling of both accelerators is a central challenge [6]. The RFQ-IH combination is powered by a radio frequency amplifier, which couples the RF power into the RFQ. The two structures are connected via inductive coupling. The initial beam operation of the accelerators is configured for 50 mA in cw mode. The IH-components were fabricated, RF tuning measurements are underway. The RFQ and the IH-DTL will be conditioned separately and then be connected, aiming for a beam operation at the end of 2014. A main challenge in fabrication was the precise welding required for the water cooled drift tubes and stems.

Figure 1: Top view of the FRANZ IH-cavity. Between entrance and quadrupol triplet (aluminum dummy) are three gaps and between lens and exit are five gaps. On the side of the triplet the static frequency plungers (aluminum dummy) are shown.

* manuel.heilmann@email.de

INTRODUCTION

The coupling of RF components is an important topic to reduce RF amplifier costs. Therefore - with respect to high current beam dynamics - it is advantageous to use compact structures with short drifts between accelerating sections. The space charge forces of a high intensity beam is simple to handle in an energy region up to 2 MeV with a short accelerator. Coupled systems are present like a RFQ with a 2 gap rebuncher drift tube section for medical application development at the HICAT (Heavy Ion Cancer Therapy) center in Heidelberg, Germany or the first coupled CH-DTL cavity of the FAIR Proton Injector at GSI [7]. In ref. [8], the coupling of a RFQ with a IH-DTL was suggested and the first combined structures was realized in ref. [9]. The coupled combination for FRANZ consists of a 4-Rod-RFQ and a IH-DTL [10]. Both accelerators with their basically different mode of operation are coupled inductively with the same frequency. The operating frequency can be serve in 0- and π-mode and can be changed under adjustment of an extra drift. The 0 mode is investigated by CST-MWS-simulations [11] and using an 1:2 RFD-IH-DTL model [12, 13].

Table 1: Parameters of the 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
Shunt impedance	MΩ/m	69

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPME059

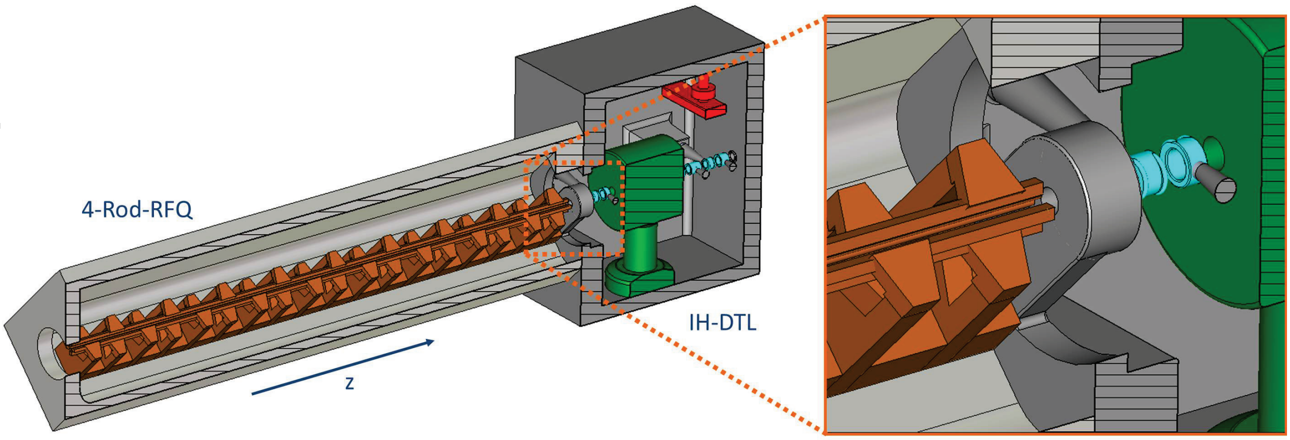

Figure 2: Cross sectional view of the coupled RFQ-IH-DTL combination for FRANZ with a zoom into the coupling area.

COUPLED RFQ-IH-DTL COMBINATION

The inductive coupling connects the RFQ via a large aperture with the IH-DTL (Fig. 2). In the coupling hole is a xy-steerer between the RFQ-electrodes and the first IH-drift tube. The functionality of the inductive coupling has been investigated by simulations and with a 1:2 scaled Radio Frequency Dipol (RFD)-IH-DTL model [12]. The challenge of this inductively coupled combination is to match the resonance frequency of the system, a balanced field distribution at the RFQ electrodes (flatness) and the voltage ratio between RFQ and IH-DTL [6, 13] together at the same time. The coupled system can be tuned individually in both structures by several tuners. The experience with the scaled model has shown that the IH-DTL needs the possibility to be adjusted within a large frequency range.

IH-DTL MEASUREMENTS

The first measurements of the IH-DTL were performed in February 2014 with a non-copper plated stainless steel structure (all components). The module components of the IH-DTL are electrical connected with an aluminum metallic sealing. An aluminum dummy of the internal triplet lens was used for the frequency and field distribution measurements.

Frequency

The frequency can be changed in the IH-DTL with a dynamic and two static plungers. The static dummy plungers with a diameter of 50 mm are composed of aluminum slices with 10 mm in thickness and are located in the middle of the internal triplet. In operation the aluminum slices are replaced by a water cooled plunger with a fixed length for 175 MHz. The length of the static plungers was changed symmetrically to vary the frequency in a range of 175 MHz till 177 MHz. The dynamic plunger is mounted on the top flange behind the triplet and can tune the frequency in a range of ± 300 kHz. The investigations of the 1:2 scaled model have shown that the achievable frequency range in the IH-DTL must be large to optimize the voltage ratio in the coupled RFQ-IH-DTL combination (Fig. 3).

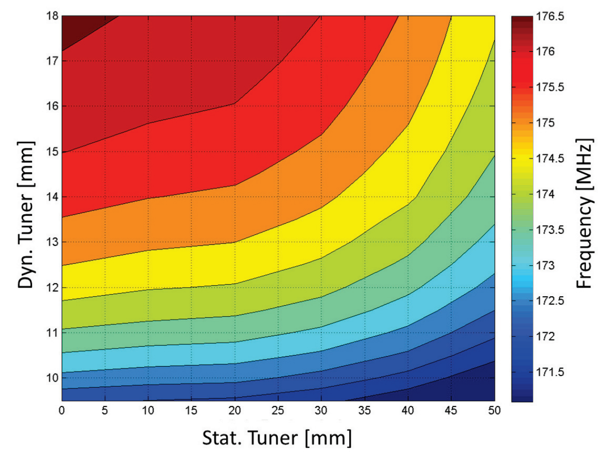

Figure 3: Measured frequency range of the non-copper plated IH-DTL depending on of the position of the plungers.

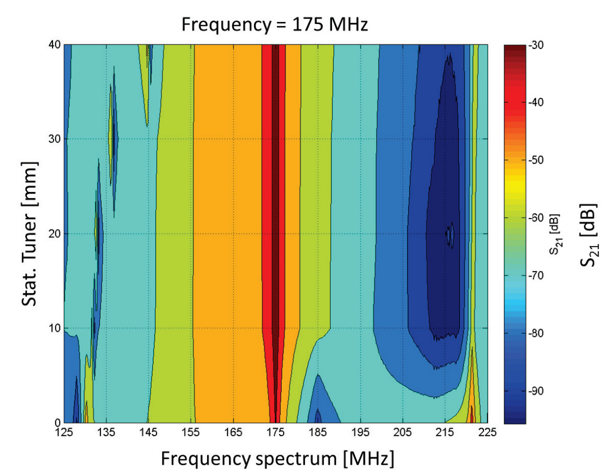

Figure 4: Measured frequency spectrum of the non-copper plated IH-DTL. No parasitic modes are located close to 175 MHz with operational plunger positions.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPME059

In the frequency spectra (Fig. 4) the neighbor modes for the fixed 175 MHz mode as a function of the length of the static tuner lengths are represented. There is a large frequency spacing between 175 MHz and the higher order surrounding modes.

Field Distribution

The coupling loop for previous tests is mounted on the bottom flange behind the lens and the RF is coupled critical by a vector network analyzer (VNA). The scaled voltage distribution on the beam axis of the bead pull measurement is compared with the CST-MWS simulation (Fig. 5). The positions of the frequency tuners in the IH-DTL is L_{static} = 40 mm and $L_{dyn.}$ = 15.6 mm for a resonance frequency of 175 MHz. The field distribution in the first gaps of the IH-DTL shows a weak gap voltage, because the RFQ has not been coupled yet. In simulation (black line) the RFQ is connected to the IH-DTL to raise the voltage in the first gaps. The internal triplet dummy is screwed together from several single aluminum components with a low electrical connection to couple the gaps in front and behind at the internal lens dummy.

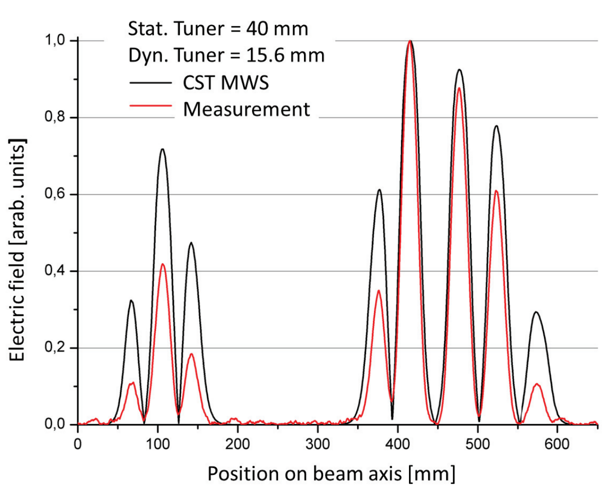

Figure 5: Electrical field distribution on beam axis in the non-copper plated IH-DTL with an aluminum triplet dummy and a resonance frequency of 175 MHz.

CONCLUSIONS

The coupled RFQ-IH-DTL combination is investigated in simulations and with a 1:2 scaled RFD-IH-DTL model with promised measured results. The results assist the optimization and design of the frequency range of the IH-DTL. The first measurements of the frequency range and field distribution on beam axis could be shown with the non-copper plated IH-DTL. The measurements will be repeated after coppering the IH-structure and with the 4-Rod-RFQ. After investigation of RF-properties during stand alone test, the measurements of the coupled structure is for seen. FRANZ has in first operation a 50 mA proton beam source with a 250 kHz chopper to realized a nuclear astrophysics program in Frankfurt for several years. The FRANZ upgrade will have a demanding beam current up to 140 mA for advanced experiments in future.

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, C. Zhang, The Driver Linac of the Neutron Source FRANZ, Proceedings of IPAC11 Conference, WEPS040, 2577 (2012).

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

[3] A. Bechtold, A. Schempp, M. Vossberg, Recent High Power RFQ Development, Proceedings of International Topical Meeting on Nuclear Research Applications and Utilization of Accelerators, 4-8 May, 2009, Vienna, Austria.

[4] M. Vossberg, A. Bechtold, C. Lenz, H. Podlech, A. Schempp, RF measurement during cw operation of an RFQ prototype, Proceedings of IPAC2013, Shanghai, China, WEPFI009, p. 2720 (2013).

[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 IPAC2013, Shanghai, China, THPWO017, p. 3797 (2013).

[6] 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 (2012).

[7] R.M. Brodhage, U. Ratzinger, G. Clemente, W. Vinzenz, First Coupled CH Power Cavity for the FAIR Proton Injector, Proceedings of IPAC2013, Shanghai, China, THPWO015, p. 3791 (2013).

[8] U. Ratzinger, High Current IH Structures, Proc. of the 1994 EPAC Conf., London, Vol. 1, p. 264 (1994).

[9] L. Lu, T. Hattori, N. Hayashizaki, Design and Simulation of C^{6+} hybrid single cavity linac for cancer therapy with direct plasma injection scheme, NIMA 688, 11 (2012).

[10] 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 (2008).

[11] CST MicroWave Studio, www.cst.de.

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

[13] M. Schwarz, Hochfrequenzabstimmung und Feldoptimierungen des gekoppelten 1:2 RFD-IH-Modells für FRANZ, Bachelor Thesis, Goethe-University Frankfurt, 2012.