FIRST MEASUREMENTS OF A COUPLED CH POWER CAVITY FOR THE FAIR PROTON INJECTOR

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Abstract

For the research program with cooled antiprotons at FAIR a dedicated 70 MeV, 70 mA proton injector is required. The main acceleration of this room temperature linac will be provided by six CH cavities operated at 325 MHz. Each cavity will be powered by a 2.5 MW klystron. For the second acceleration unit from 11.5 MeV to 24.2 MeV a 1:2 scaled model has been built. Low level RF measurements have been performed to determine the main parameters and to prove the concept of coupled CH cavities. For this second tank technical and mechanical investigations have been performed to develop a complete technical concept for manufacturing. In Spring 2011, the construction of the first power prototype has started. The main components of this cavity were ready for measurements in fall 2011. At that time, the cavity was tested with a preliminary aluminum drift tube structure, which will allow precise frequency and field tuning. This paper will report on the recent technical developments and achievements. It will outline the main tuning and commissioning steps towards that novel type of proton DTL and it will show very promising results of the latest measurements.

INTRODUCTION

The proton linac for FAIR is mechanically grouped in two tanks, each having a length of about 10m. Based on the actual design the first tank will consist of 3 coupled CH-cavities. Between both tanks there will be a diagnostics section with an additional rebuncher inside.

Further investigations have shown that a simplified layout of the 2nd section of the proton linac will be an improvement. In that case, three simple CH cavities without a coupling cell will be used, reducing the triplet lens number by three and simplifying the cavity layout a lot.

THE COUPLED PROTOTYPE CAVITY

Fig. 1 shows the prototype cavity which corresponds to the second coupled cavity. The low energy part consists of 13 gaps, followed by the coupling cell and by the 14 gap high energy part. The whole cavity has an inner length of about 2.8m and an inner diameter of about 360mm.

The coupling cell has a length of $2\beta\lambda$ and hosts the focusing triplet lens within one large drift tube. The intertank sections will also house triplet lenses as well as beam diagnostics, as shown in Fig. 2. They mechanically connect neighbored cavities.

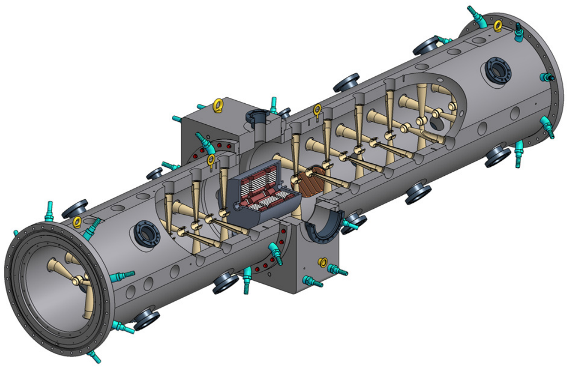

Figure 1: 3D-View of the coupled prototype cavity.

Table 1: Parameters of the Coupled CH Prototype Cavity

no. of gaps	13 + 14 = 27
frequency [MHz]	325.2
energy range [MeV]	11.7 - 24.3
beam loading [kW]	882.6
heat loss [MW]	1.35
total power [MW]	2.2
Q_0-value	15300
eff. shunt impedance [MΩ/m]	60
average E_0T [MV/m]	6.4 - 5.8
Kilpatrick factor	2.0
coupling constant [%]	0.3
aperture [mm]	20
total inner length [mm]	2800
inner diameter [mm]	180 / 217 / 182

MECHANICAL DESIGN

Intertank Unit and Cavity End Cell

The concept based on two 10m long tanks leads to very tight tolerances with respect to the surface finishing of the tank flanges as well as with respect to the transverse alignment against the beam axis. To control mechanical deformations by gravity or stress the linac will be mounted on a rail system - as practiced at the GSI Unilac. Alternatively, each tank could be mounted precisely on a robust support and then be aligned via a 3-point adjusting device with respect to the beam axis.

The neighbored cavities will be connected by an intertank unit. It consists of a quadrupole triplet housed in a drift tube and mounted into a rectangular massive frame which provides the end flanges for the neighbored cavities at the same time. No bellow connection along the beam

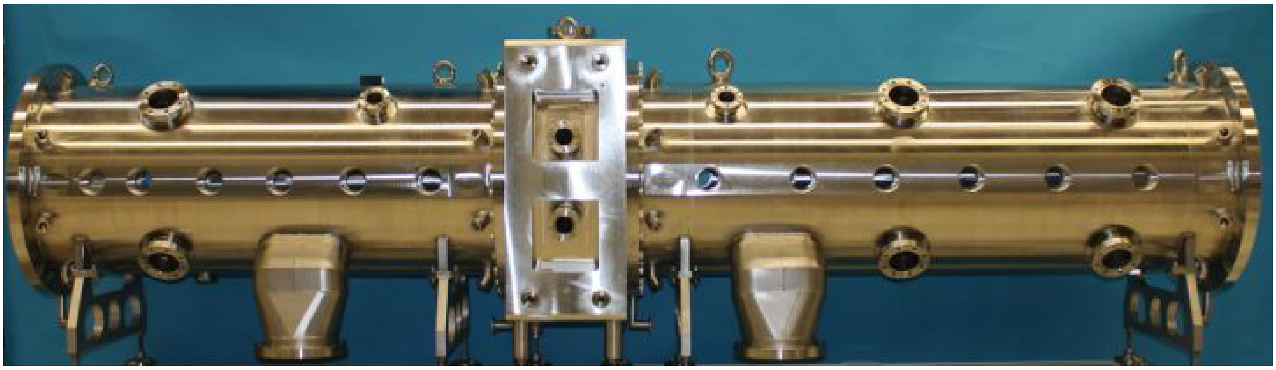

Figure 2: Side view of the proton linac power prototype after first assembly.

line is foreseen in that concept within each 10m section.

Within the intertank units space is narrow. Therefore a special cavity end cell geometry was developed, that allows to mount diagnostics, such as beam position monitors, next to the quadrupol lense inside the RF free region.

To make this kind of layout possible several changes of the mechanical and RF design had to be performed. Of capital importance were the inclined stems as well as a special end shape of the cavity wall to shield the RF free region against the accelerating section.

Drift Tube Sections

It has been demonstrated successfully by a 8-cell prototype cavity [1, 2, 3] that the drift tube stems can be welded into the tank wall at the inner surface. To avoid large holes in the outer tank, special techniques were developed to integrate long drift tubes with modest transverse stem diameters. Additional care must be taken to limit longitudinal stress along the stem caused by temperature differences between tank wall and drift tube structure. Therefore a special end shape was developed which prevents the stems from rupturing in case of temperature variation.

With respect to the cooling system a stem and drift tube geometry was developed which allows to produce the stems in two single parts. The stems are produced hollow as a unibody piece in which only the drift tube has to be inserted. This technique makes it possible to stick to the very tight tolerances for the stem alignment.

New camera assisted welding techniques make it possible to weld the stems with very high precision.

MEASUREMENTS

Mode Spectrum

After production of the main parts the prototype was assembled at Frankfurt University using an aluminum dummy drift tube structure for tuning. First measurements took place in Dec. 2012 and were performed without any tuners. Table 2 shows that the simulated frequencies are very close to the measured frequencies. The failure is only about 1%. Because the prototype is only equiped with inductive acting tuners the simulations were made for frequencies slightly lower than the final operational frequency. This gives extra safety for the tuning, even if inaccuracies would occur during the manufacturing. In the next step all above mentioned tuners were installed and the frequency tuning was performed. The first resonant mode was step by step pushed up in frequency until the design region was reached. The frequency of this mode is 324.9 MHz by now. Pushing the frequency further up is not necessary at this point, because by evacuating and copper plating the frequency will again raise a little.

Table 2: Comparison Between Simulated and Measured Frequencies of the First Two Resonant Modes

Simulated [MHz]	Measured [MHz]
324.4	323.7
325.3	324.6

Figure 3 shows the measured mode spectrum including the frequencies of the first two modes. The large distance between the two modes of about 1 MHz gives a coupling constant of 0.3. This is of great importance when you consider the effect of the beam in the finished prototype. One has to ensure that the klystron does not excite the next higher mode during power ramping. Considering the save and robust design this effect is not possible. Also the main tuner in the coupling cell acts differently on the first two resonant modes, which ensures the spacing of the modes even in case of temperature changes.

Field Distribution

Nearly all inductive tuners which were used to tune the frequency have an effect on the field distribution on the beam axis. Only one tuner in the coupling cell has no effect on the field within the accelerating sections.

This means, that after frequency tuning one has to look at the field distribution in a second step. Using the same inductive tuners as with the frequency tuning it is possible to do a rough voltage tuning considering that the effect of different tuners has to be inverse to each other in terms of frequency. The final position of these plungers are now

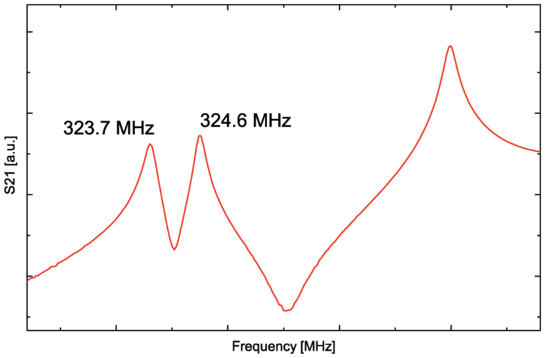

Figure 3: Measured frequency spectrum of the CCH power prototype.

very moderate. This means, that the plungers are leaping into the cavity between 5 and 15 cm.

Tuners always act on a large region within the cavity and are therefore not capable to reach high precision. Final results will be gained by manipulating the g/L ratio. this means, that the lengths of different drift tubes have to be changed. This is possible because of the dummy drift tube structure that was installed in the beginning. With this technique the local gap voltages can be in generally varied up to +-20.

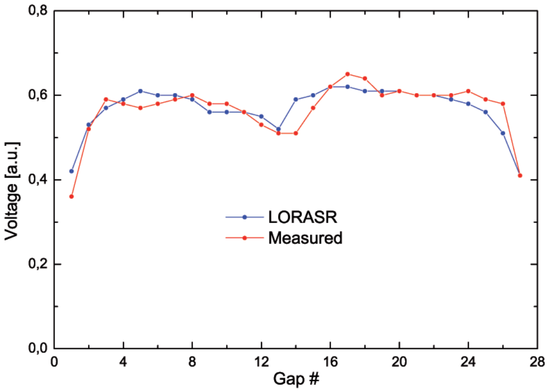

Figure 4: Comparison between measured and simulated voltage distribution of the CCH power prototype.

Fig. 4 shows the latest measured and normalized voltage distribution in comparison to the target voltages which were calculated by the beam dynamics code LORASR. Still this distribution is not final but yet it show no changes in transmission according to the beam dynamics simulation. This again proves the save and robust design of the coupled CH cavity.

CONCLUSION

This paper has shown the process of building and tuning a complex cavity according to a reliable RF design. It was proven that the applied techniques for manufacturing and tuning are capable of building up a working prototype. Refering to the latest measurements that have been shown this novel type of DTL can be considered as a serious alternative to the conventional DTL.

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