DEVELOPMENT OF A 217-MHz SUPERCONDUCTING CH-STRUCTURE*

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Abstract

To compete in the production of Super Heavy Elements (SHE) in the future a 7.3 AMeV superconducting (sc) continuous wave (cw) LINAC is planned at GSI. The baseline design consists of 9 sc Crossbar-H-mode (CH) cavities operated at 217 MHz. Currently an advanced cw demonstrator is under design at the Institute for Applied Physics (IAP) at Frankfurt University. The purpose of the advanced demonstrator is to investigate a new concept for the superconducting CH structures. It is based on shorter CH-cavities with 8 equidistant gaps without girders and with stiffening brackets at the front and end cap to reduce pressure sensitivity. One major goal of the advanced demonstrator is to show that the new design leads to higher acceleration gradients and smaller E_p/E_a values. In this contribution first simulation results and technical layouts will be presented.

INTRODUCTION

At the moment the demonstrator for the sc cw-LINAC at GSI is under construction and its successful beam operation will be the first milestone realizing the new sc cw-LINAC at GSI [1]. The advanced demonstrator which is presented here will be the second milestone for the sc LINAC at GSI. The sc LINAC will consist of the demonstrator as first cavity and 5 additional cryomodules with 2 CH-cavities per cryomodule [2, 3]. The design of the advanced demonstrator will be used for all 10 cavities in the sc cw-LINAC after the demonstrator. The cavity is designed and optimized for high power applications, consists of 8 accelerating cells and has a design gradient of 5 MV/m. Its frequency is the second harmonic of the High Charge Injector (HLI) at GSI, Darmstadt. Table 1 shows the main parameters of the sc 217 MHz CH-cavity and Figure 1 shows the Layout of the sc 217 MHz CH-cavity.

DRIFT TUBE DESIGN

The superconducting cavity for the advanced demonstrator has to reach high electric fields and high accelerating gradients. Without drift tubes the electric field on the beam axis is dropping rapidly in the first and last gap (Figure 2). To increase the field in the first gaps several simulations with CST-Microwave-Studio have been performed to determine the optimum drift tube length for the different gaps [4]. Figure 2 shows the electric field on the beam axis without drift tubes and with optimized drift tubes. The electric field in the first and last two gaps could be increased significantly wich results in higher accelerating gradients and better E_p/E_a values.

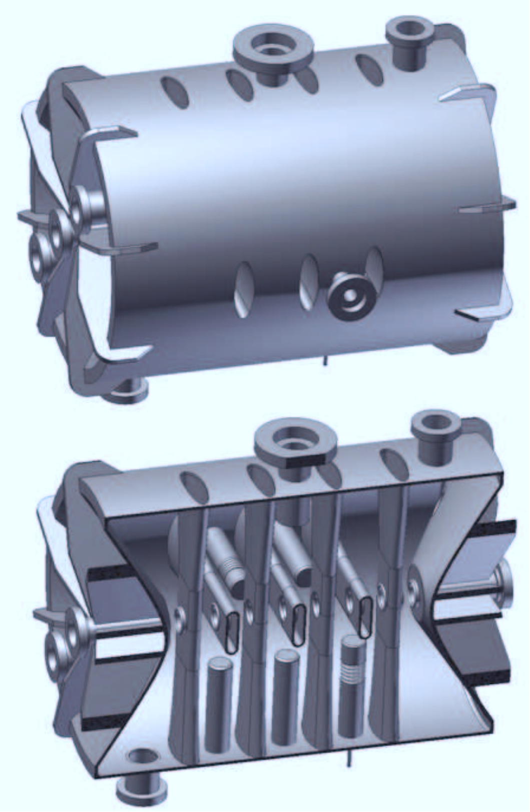

Figure 1: Layout of the sc 217 MHz CH-cavity.

The optimized drift tubes in gap 1 and 8 are 7 mm and in gap 2 and 7 2.5 mm long as shown in Figure 3

BUFFERED CHEMICAL POLISHING

One of the most important conditions for sc cavities is a good surface preparation without contamination wich can be achieved by the so called buffered chemical polishing (BCP). Two BCP treatments of at least 100 μm are planned for the sc CH-cavity after fabrication. Each processing step will change the frequency of the cavity so several CST-

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Table 1: Specifications of the 217 MHz CH-cavity

Parameter	Unit	
β		0.069
Frequency	MHz	215.5
Accelerating cells		8
Length ($\beta\lambda$-definition)	mm	381.6
Cavity diameter	mm	412
Cell length	mm	47.7
Aperture diameter	mm	30
Static tuner		3
Dynamic bellow tuner		2
Wall thickness	mm	3-4
Accelerating gradient	MV/m	5
E_p/E_a		5.2
B_p/E_a	mT/(MV/m)	8.5
G	Ω	51
R_a/Q_0		1045

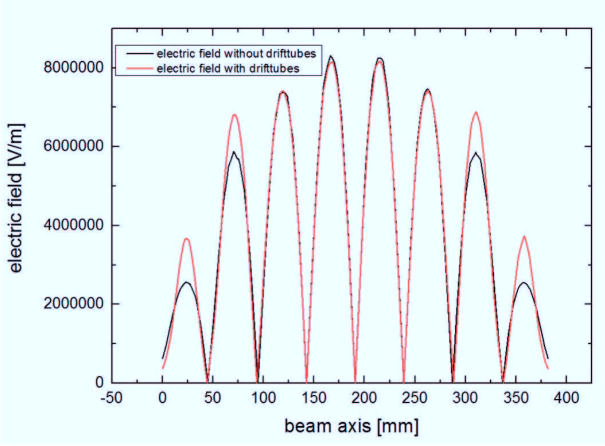

Figure 2: Field on the beam axis with and without drift tubes.

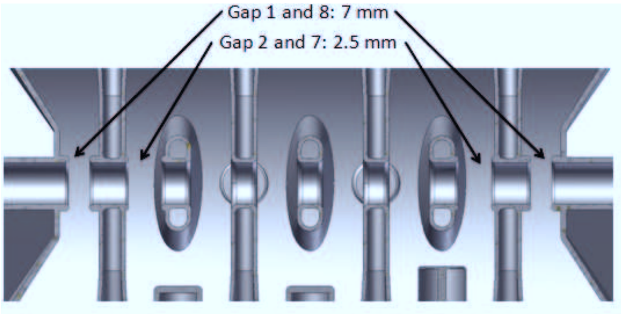

Figure 3: Optimized drift tubes for the sc CH-cavity.

simulations have been performed to estimate the frequency change of the cavity per 100 μm erosion through BCP. Experiences so far are showing an inhomogeneous effect through BCP treatment on the cavity. For example the interior of the cavity like stems and tuners are often more affected by the BCP than the cavity itself. To estimate the parts of the cavity which have been affected the most due to BCP treatment several CST-simulations have been performed were the BCP effect at the stems was increased by a factor of 1.5 or 2 in respect to the cavity. Additional simulations have been performed where only the stems or the cavity were treated with BCP to estimate the frequency influence of each part of the cavity. The results of these simulations are shown in Figure 4.

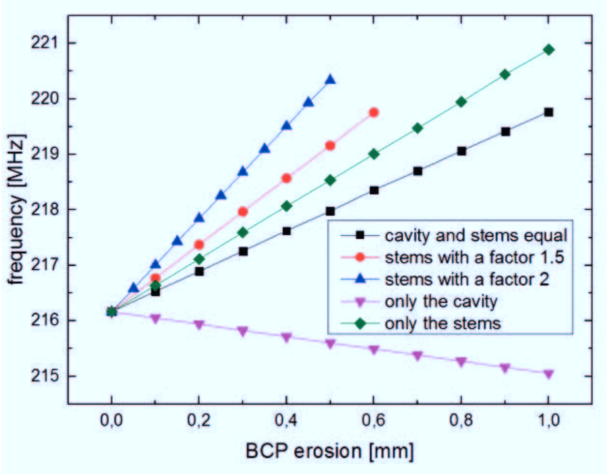

Figure 4: Frequency change through BCP erosion with various strength on various parts of the cavity.

The results of these investigations show that 100 μm erosion at the stems increase the frequency by ca. 470 kHz whereas 100 μm erosion at the cavity decrease the frequency by ca. 110 kHz.

BELLOW TUNER DEVELOPMENT

Previous CH-cavities have so called girders in which the stems are welded. This leads to high fabrication costs and extended fabrication duration. Additionally the girders reduce the mechanical stability of the cavity caused by a break of the cylindrical symmetry. The desgin of the advanced demonstrator without girders is cylindrically symmetrical which leads to significantly higher stability. Additionally the stiffening brackets at both ends of the cavity increase the mechanical stability of the cavity so that the pressure sensitivity is under 5 Hz/mbar.

Usually the dynamic tuning range for sc CH-cavities is covered by bellow tuners which are welded into the girders. For the design of the advanced demonstrator without girders a new type of bellow tuner has to be developed. The bellow tuner has to cover the whole area from the cavity wall to the region with high electric fields where the small tuner stroke of at most 1 mm can achieve enough frequency change for stable operation.

Several CST-simulations have been performed where parameters like the number of cells, cell length and gap distance have been optimized concerning Von-Mises-Stress and force needed for a tuner stroke of 1 mm. To investigate the attainable frequency change per mm several types of bellow tuners with different diameters were simulated. The attainable frequency change from the different bellow tuners can be seen in Figure 5 whereas the different types of bellow tuners are shown in Figure 6.

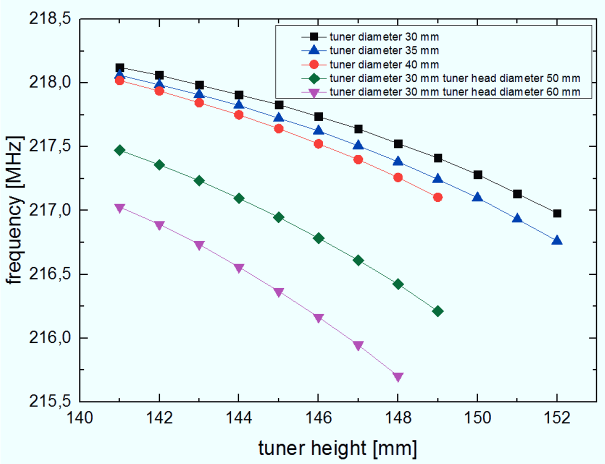

Figure 5: Frequency change through different bellow tuners.

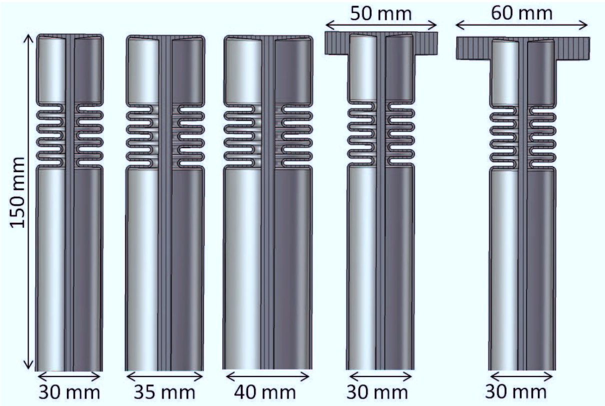

Figure 6: Layout of the different bellow tuners.

After these simulations concerning the attainable frequency change by the different bellow tuners several particle tracking simulations concerning multipacting have been performed with CST to investigate where multipacting might appear. It was found, that multipacting between the bellow tuner and the stem occured on several field levels with a tuner diameter of 40 mm or more. So the diameter was reduced to 35 mm to decrease the risk of multipacting between the stem and the tuner. To decrease the risk of multipacting in the cells of the bellow tuner itself the gap distance of each cell was set to 2 mm. By that the voltage per cell was increased to reach the upper voltage limit for multipacting at lower field levels than in the desired operation mode. So the only parameters to influence the needed force for a tuner stroke of 1 mm and the Von-Mises-Stress was the number of cells and the cell length. The simulation results shown in Figure 7 result in 5 cells with a cell length of 8 mm with a maximum Von-Mises-Stress of ca. 0.25 GPa and a force of ca. 480 N.

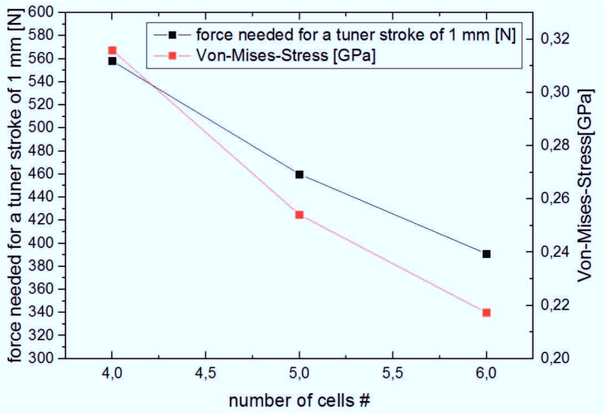

Figure 7: Von-Mises-Stress and force needed for a tuner stroke of 1 mm.

CONCLUSION

The short sc CH-cavities for the sc cw-LINAC are minimizing the technical risk for the operation at GSI and can also minimize the costs and construction effort. It was shown that the installation of drift tubes in the first and last two gaps increases the electric field on the beam axis significantly. The simulations concerning the influence of BCP on the different parts of the cavity are providing the possibility to estimate the frequency change per 100 μm erosion. The dynamic tuner concept without girders as a base for the tuner was investigated and optimized to operate at low risk and high frequency stability. The basic design of the presented short CH-cavity will also be used for the 17 MeV MYRRHA injector of the MAX-project with an adjusted geometry operating at a frequency of 176.1 MHz [5].

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