DEVELOPMENT OF SUPERCONDUCTING CH CAVITIES*

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Abstract

At present, two superconducting (sc) CH cavities are under development at the Institute for Applied Physics (IAP) of Frankfurt University. The construction of a sc 325 MHz CH cavity with 7 cells and an envisaged design gradient of $5\ \mathrm{MV/m}$ is almost finished. It is planned to test this cavity with beam at GSI Universal Linear Accelerator (UNILAC), Darmstadt to show its performance as a candidate for the UNILAC upgrade. Furthermore, the 217 MHz CH structure with 15 accelerating cells and a real estate gradient of $5.1\ \mathrm{MV/m}$ will be the first cavity of the new sc continuous wave (cw) LINAC at GSI. This proposed cw LINAC is highly requested to fulfil the requirements of nuclear chemistry and especially for a competitive production of new Super Heavy Elements (SHE). To demonstrate the cavity capabilities under a realistic accelerator environment, a full performance test by injecting and accelerating a beam from the GSI High Charge Injector (HLI) is planned in 2013/14. The current status of both sc CH cavities is presented.

MOTIVATION

Since in the future the existing UNILAC at GSI will be used as an injector for FAIR (Facility for Antiproton and Ion Research), beam time availability for nuclear chemistry and especially for SHE production will be very limited. For this reason a new sc cw LINAC at GSI is desired by a broad community of future users [1]. The layout of this heavy ion LINAC (see fig. 1) was worked out at the Institute for Applied Physics (IAP) at Frankfurt University [2]. The main acceleration of approximately 35 MV will be provided by nine sc multi-gap CH cavities operated at 217 MHz. At present, the first cavity of the proposed cw LINAC is under development. As a first step, a full performance test is planned to demonstrate the cavity capabilities by injecting and accelerating a beam from the 1.4 AMeV GSI HLI in 2013/14. Furthermore, for the FAIR project a higher beam intensity as well as an improved beam quality is required, which can not be provided by the existing UNILAC at the moment. Hence, it needs a upgrade of the present UNILAC, especially of the Alvarez-DTL part. The construction of a new sc 325 MHz prototype CH cavity at RI (Research Instruments GmbH, Bergisch Gladbach, Germany) is almost finished. In order to show its performance as a suitable candidate for the UNILAC upgrade, it is planned to test this cavity with a 11.4 AMeV beam at the UNILAC in 2012.

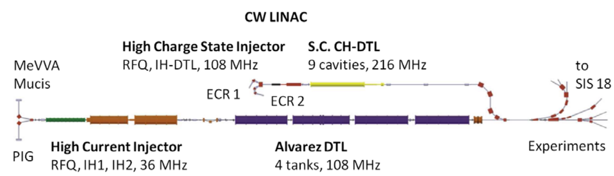

Figure 1: Future layout of the new sc cw LINAC (top) in parallel to the existing GSI UNILAC (bottom).

STATUS OF THE 325 MHZ CH CAVITY

The sc 325 MHz CH cavity (see fig. 2) is designed and optimized for high power applications, consists of 7 accelerating cells and has a design gradient of $5\ \mathrm{MV/m}$ [3]. Its frequency is the third harmonic of the Alvarez-DTL.

Inclined end stems inside of the cavity lead to a homogeneous field distribution due to their increased inductance. This allows a very compact longitudinal design of the cav-

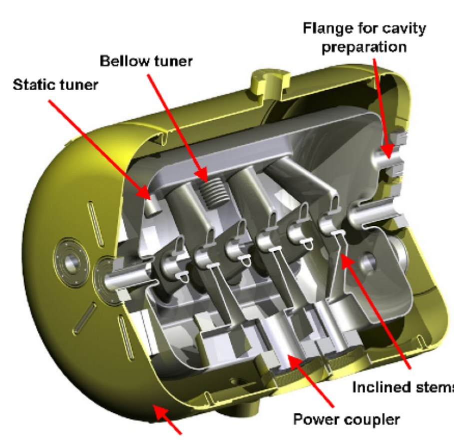

Figure 2: Design of the sc 325 MHz CH cavity.

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ity since at the same time an extended end cell is not needed for field flattening. A flat field distribution results in an efficient acceleration and reduces the peak fields. In addition, an improved beam acceptance is caused by that design which is essential to avoid beam losses and activation of accelerator components.

Matching the design frequency during the fabrication process of a sc CH cavity is one major challenge. Regarding this, the tuning of the cavity will be done by capacitive tuners welded on the girders between the stems: four static tuners with a fixed height of up to 60 mm and with a diameter of 30 mm will be adapted accordingly during the fabrication to reach the design frequency. They will provide a frequency shift range of about ± 2 MHz.

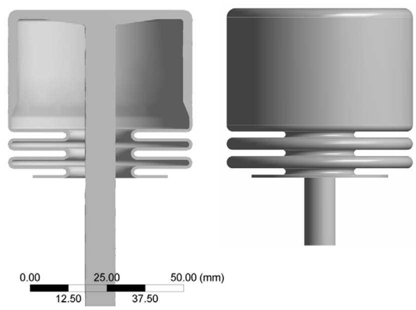

Figure 3: Final design of the 3-cell bellow tuner.

Additionally, two bellow tuners, driven by stepping motors are supposed to control the frequency during operation. These slow tuners will readjust frequency changes and pressure effects at 4.2 K. Furthermore, one of them is connected to a fast reacting piezo element and will be driven by a signal bandwidth of up to several hundred Hz to compensate limitations like microphonics and Lorentz-Force-Detuning. In order to calculate the frequency shift of the bellow tuners, several rf simulations have been performed. At a working point around 50 mm tuner height, a frequency shift of 150 $\mathrm{kHz/mm}$ is achievable. This is sufficient for fast tuning during beam operation. Besides the rf simulations, additional mechanical simulations have been performed, and within these simulations different tuner geometries have been studied [4]. Figure 3 shows the final design of the 3-cell bellow tuner with a wall thickness of 1 mm. In table 1 the specifications of the 325 MHz CH cavity are summarized while figure 4 shows the current status of several cavity components.

Table 1: Specifications of the 325 MHz CH cavity

β		0.16
RRR		>250
Frequency	MHz	325
Accelerating cells		7
Length ($\beta\lambda$-definition)	mm	505
Cavity diameter	mm	353
Accelerating gradient	$\mathrm{MV/m}$	5
E_p/E_a		5.1
B_p/E_a	$\mathrm{mT/(MV/m)}$	13
G	Ω	64
R_a/Q_0	Ω	1248
R_aR_s	$\mathrm{k}\Omega^2$	80

Figure 4: Deep-drawing of a girder component and an end cap of the cavity (top), final welded inclined stem and a straight stem without drift tube (bottom).

THE 217 MHZ CH CAVITY

The sc 217 MHz CH cavity (see fig. 5 top) should provide a real estate gradient of 5.1 $\mathrm{MV/m}$ by using 15 ac-

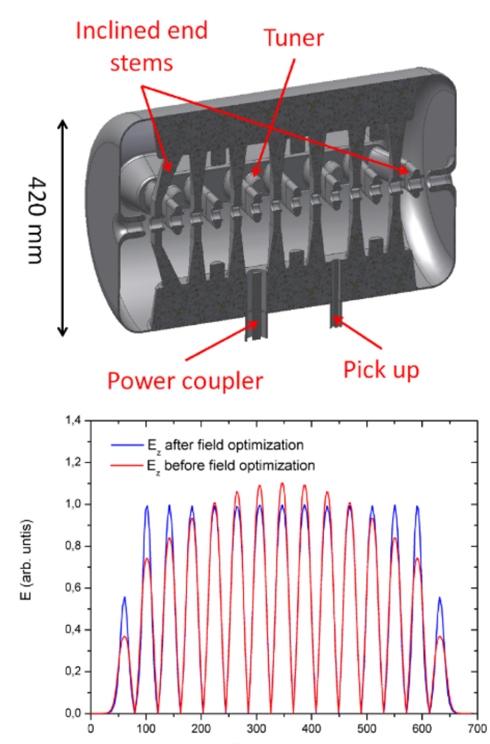

Figure 5: Side view of the sc 217 MHz CH cavity for the new cw LINAC at GSI (top) and E_z along the beam axis before and after the field optimization (bottom).

celerating cells at a total length of 690 mm [5]. It will be the first cavity of the new sc cw LINAC at GSI. In addition, the cavity will be operated with the special EQUUS (EQUidistant mUlti-gap Structure) beam dynamics [2].

The electric field distribution on beam axis was optimized by adjusting the gap-to-cell-length ratio (g/l) to reach a flat field distribution on beam axis as well as a high beam quality. Figure 5 (bottom) shows the simulated field distribution before and after the optimization. Applying the same tuning concept as used for the 325 MHz cavity, the 217 MHz CH cavity will be equipped with nine static tuners, one slow and two fast bellow tuners. Figure 6 shows the simulated tuning range of the nine static tuners with respect to the electric peak fields of the cavity. Based on this tuning range the working point for the static tuners has been chosen with the aim to maximize the frequency gain while keeping the tuner height and the electrical peak fields to a minimum. For an adequate frequency adjustment, a maximum height of 63 mm for the static tuners is foreseen which results in a frequency shift range of ±2 MHz as well.

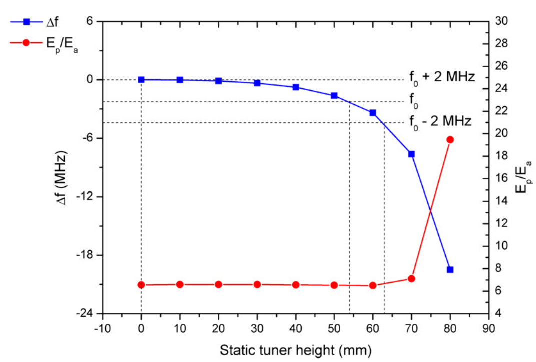

Figure 6: Simulated tuning range of the nine static tuners with respect to the electric peak fields.

Further rf, mechanical and multipacting simulations are in progress at the moment to determine the final geometry of the dynamic bellow tuners for the 217 MHz cavity. Table 2 shows the required frequency shift of the different tuner types while the main parameters of the cavity are summarized in table 3.

Table 2: Required frequency shift of the different tuner types for the 217 MHz cavity

Parameter	No.	Frequency shift
Static tuners	9	± 2 MHz
Fast tuners	2	±150 Hz/μm
Slow tuners	1	±150 kHz/mm

SUMMARY & OUTLOOK

The construction process of the sc 325 MHz CH cavity at RI is almost finished. It is planned to test the cavity with beam at the GSI UNILAC, Darmstadt in 2012. The rf design of the 217 MHz cavity for the new sc cw LINAC at GSI is completed. Further rf, mechanical and multipacting simulations concerning the cavity tuning are in progress at the moment. The fabrication process of the cavity will start within this year. A full performance test with beam at the HLI is foreseen to demonstrate the cavity capabilities in 2013/14.

Table 3: Main parameters of the 217 MHz CH cavity

β		0.059
Frequency	MHz	217
Accelerating cells		15
Total length	mm	690
Cavity diameter	mm	420
Accelerating gradient	MV/m	5.1
Effective gap voltage	kV	225
Voltage gain	MV	3.13
E_p/E_a		6.5
B_p/E_a	mT/(MV/m)	5.9
R_a/Q_0	Ω	3540

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