

SUPERCONDUCTING CH-CAVITY DEVELOPMENT

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Abstract

The superconducting CH-Cavity (Crossbar H-Mode) is the first multi-cell drift tube cavity for the low and medium energy range of proton and ion linacs. At the Institute for Applied Physics (IAP), Frankfurt University, a 19 cell, $\beta = 0.1$, $f = 360$ MHz prototype cavity has been tested successfully with a voltage of 5.6 MV and gradients of 7 MV/m. Two new, optimized CH-cavities are currently under development at IAP. One cavity ($f=325.224$ MHz, $\beta=0.1545$, 7 cells) is determined as an upgrade for the GSI Unilac. This will allow first beam tests with a CH-cavity. The second one ($f=216.816$ MHz, $\beta=0.059$, 15 cells) is a prototype for the cw operated heavy ion linac at GSI. It will be the first of nine s.c. CH-structures, that will form this linac. The construction of the 325 MHz 7-gap CH-cavity has started at Research Instruments (RI, Bergisch-Gladbach). The new cavity design has an optimized geometry regarding tuning possibilities, high power RF coupling, minimized end cell lengths and possibilities for surface preparation. After low power tests it is planned to test the first cavity with a 10 mA, 11.4 MeV/u beam delivered by the Unilac at GSI. Both cavities have a constant β -profile and will use a new tuning system, which is currently under investigation concerning rf and mechanical performance.

THE 325 MHz CH-CAVITY

Many large international projects with high requirements regarding beam power and quality (e.g. EUROTRANS (EUROpean Research Programme for the TRANsmutation of High Level Nuclear Waste in an Accelerator Driven System) [1] and spallation neutron sources) ask for new linac concepts. The superconducting CH-cavity is an appropriate candidate for those requirements because it reduces the number of drift spaces between cavities significantly compared to conventional low- β ion linacs [2]. Along with KONUS beam dynamics, which decreases the transverse rf defocusing and allows the development of long lens free sections, this yields high real estate gradients with moderate electric and magnetic peak fields. A 19-cell, superconducting 360 MHz CH-prototype has been developed and successfully tested in the past. Gradients of up to 7 MV/m, corresponding to an effective voltage gain of 5.6 MV were reached [3]. For future operations a new design proposal for high power applications has been investigated. The new cavity will be operated at 325.224 MHz, consists of 7 cells, $\beta = 0.1545$ and has an effective length of 505 mm.

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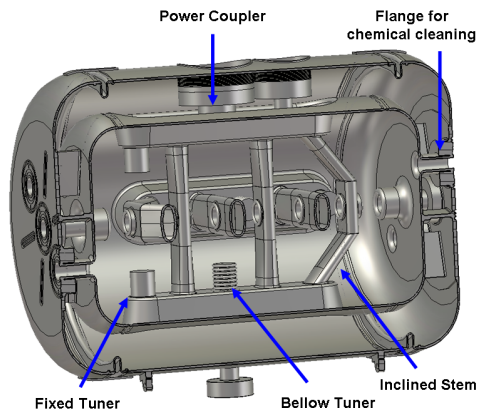


Figure 1: Final design of the superconducting 7-cell CH-Cavity (325.224 MHz, $\beta = 0.1545$)[4].

The most important changes in comparison to the CH-prototype are:

- inclined end stems
- additional flanges at the end caps for cleaning procedures
- two bellow tuner inside the cavity
- two ports for large power couplers through the girders

These elements can be seen in Figure 1.

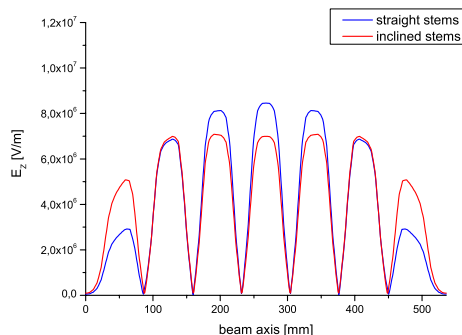


Figure 2: Field distribution for different stem and adapted girder geometries.

Inclined end stems lead to a more homogeneous field distribution along the beam axis (see Figure 2) compared with straight stems because the magnetic high field volume and therefore the inductance are increased [5]. At the same time the longitudinal dimensions of the cavity can be reduced by about 20%-25% since an extended end cell is not

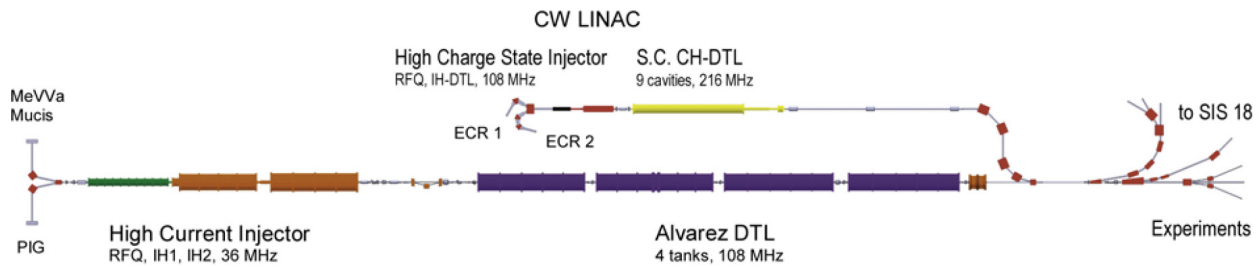


Figure 3: Schematic overview of the designed cw heavy ion linac (top) and of the existing GSI UNILAC (bottom).

needed for field flattening. Flanges at the tank caps provide an additional way to process the cavity surface with BCP (**B**uffered **C**hemical **P**olishing) and HPR (**H**igh **P**ressure **R**insing). In Table 1 the main parameters of the new cavity are summarized.

Table 1: Specifications of the 325 MHz CH-Cavity

β	0.1545
frequency [MHz]	325.224
no. of cells	7
length ($\beta\lambda$ -def.) [mm]	505
diameter [mm]	352.6
E_a [MV/m]	5
E_p/E_a	5.1
B_p/E_a [mT/(MV/m)]	13
G [Ω]	64
R_a/Q_0	1248
$R_a R_s$ [Ω^2]	80000

A new tuner system will be realized and tested: Four static tuners with a diameter of 30 mm and a height of up to 60 mm will adjust the frequency after fabrication. They are positioned between the stems and the height is fixed after adjustment. The possible frequency shift range is about ± 2 MHz. While the CH-prototype was tuned by pushing the end caps and by this varying the end cell of the resonator, the new cavity will use two bellow tuners (a fast and a slow one) inside the cavity. They will be placed on the girder between the stems and will be driven by a piezo and a step motor, respectively. The slow tuner adjusts the frequency after cooling the cavity down, while the fast one regulates the frequency during beam operation. A prototype of the bellow tuner has already been tested at room temperature. Further tests with a 6-cell membrane tuner prototype are foreseen for the next couple of weeks. In order to calculate the influence of the membrane tuner rf simulations have been performed. The height of the static tuners was kept constant while increasing continuously the height of the membrane tuner. Figure 4 shows that at a working point around 50 mm tuner height a shift of 150 kHz/mm is achievable, which is sufficient for fast tuning during beam operation.

It is planned to test the cavity with beam at the GSI Unilac at the exit energy of 11.4 MeV (see Figure 3, behind

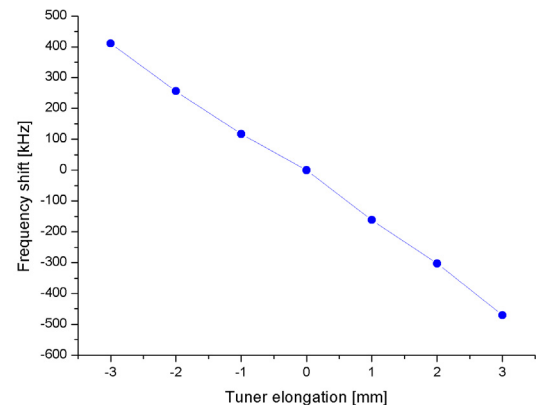


Figure 4: Tuning range of the bellow tuner.

the Alvarez section). The frequency of 325.224 MHz is the third harmonic of the Unilac.

BELLOW TUNER SIMULATIONS

One of the most innovative elements of the new cavity is the bellow tuner system. Besides rf simulations additional mechanical simulations have been performed using Ansys [6]. Several geometry lay-outs have been studied and finally a 6-cell membrane tuner with a wall thickness of 1 mm seems to be the best and most reliable solution. The fast tuner will be driven by a piezo signal with a bandwidth of up to several 100 Hz to compensate Lorentz-Force-Detuning (LFD) and Microphonics. Hence the mechanical tuner Eigenmodes have been simulated (see Figure 5). The first mode drops down to about 200 Hz. Taking account of prestress and 4 K temperature the real value will be higher.

THE 217 MHz CH-CAVITY

At GSI the design effort for a cw operated heavy ion linac has started. The linac will be used for the production of super heavy elements. It has to provide ion beams with a A/q of up to 6 and energies up to 7.3 AMeV. Above an energy of 3.5 AMeV the linac is fully energy variable.

Due to the required cw operation the main linac will be superconducting. The front end is the existing high charge state injector (HLI, 108.48 MHz, 1.4 AMeV) which

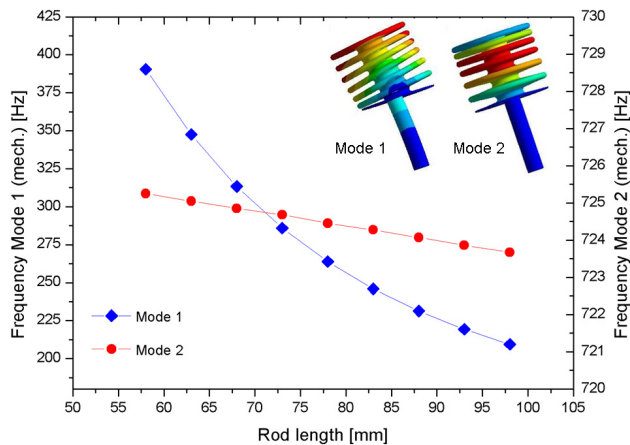


Figure 5: Bellow tuner schemes and the two lowest mechanical oscillations.

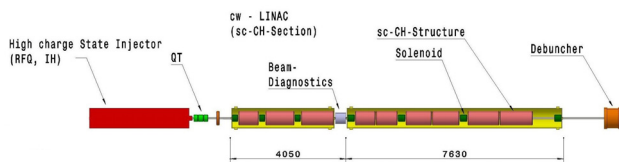


Figure 6: Schematic layout of the planned cw heavy ion linac.

is at present being upgraded for the required duty cycle. The main acceleration of approximately 35 MV will be provided by a superconducting linac consisting of 9 CH-cavities operated at 216.816 MHz (see Figure 6). The first superconducting CH-cavity (see Figure 7) is currently under design and it is planned to test it with beam in 2012. The geometrical properties are adapted to the 325 MHz CH-cavity and first rf simulation results could be achieved (see Table 2).

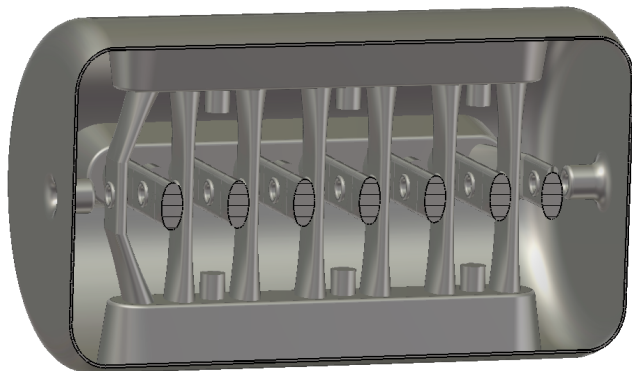


Figure 7: First design layout for the first cavity of the cw heavy ion linac.

Table 2: Parameter of the First s.c. CH-cavity of the cw Linac

β	0.059
Frequency [MHz]	216.816
No. of cells	10
Length ($\beta\lambda$ -def.) [mm]	613
Diameter [mm]	413
E_a [MV/m]	5.1

SUMMARY & OUTLOOK

The rf simulations of the 325 MHz sc CH-cavity for the GSI Unilac are completed and the fabrication process has started at Research Instruments. Additional thermal and mechanical simulations have yet to be performed to ensure smooth operation after cool down and during beam time. First simulations of the 217 MHz CH-cavity for the cw heavy ion linac at GSI have been started and production of the cavity is determined for early 2011.

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