FIRST TESTS OF THE SUPERCONDUCTING CH-STRUCTURE *

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Abstract

The CH- or Crossbar H-structure is a new H-mode drift-tube structure operating in the TE_{210} mode. Due to its mechanical rigidity room temperature as well as superconducting cavities can be realized [1]. A superconducting version of the CH-structure has been development at the IAP in Frankfurt, Germany. To prove the promising results optained by simulations a 19-cell, 352 MHz ($\beta = 0.1$) prototype cavity has been designed and built. This CH-prototype is the first superconducting low energy multi-cell cavity for the acceleration of protons and ions. The cavity has been tested at room temperature with an rf power of up to 300 W cw and 2 kW pulsed. We present the first tests of the cavity as well as mechanical simulations.

Table 1: Parameters of the sc CH-structure

parameter	value
Gaps	19
Length	1048 mm
Diameter	280 mm
Frequency	359 MHz
R_a/Q_0	3180 Ω
G	56 Ω
$(R_a/Q_0)\cdot$ G	178000 Ω^2
Q_0 (R_s=150 nΩ)	$3.7\cdot10^8$
E_p/E_a	6.16
B_p/E_a	7.94 mT/(MV/m)
W	155 mJ/(MV/m)^2
P @ E_a=3.2 MV/m	9 W

INTRODUCTION

Figure 1: The superconducting CH-structure.

All existing H-mode cavities (4-Vane-RFQ, IH-DTL and IH-RFQ) can be realized only for room temperature operation due to a lack of mechanical stability. The CH-structure has enough mechanical stiffness for the superconducting operation. With the use of the KONUS beam dynamics [2] which reduces the transverse defocusing of

the beam long lensfree sections can be realized. The disadvantage of other superconducting low energy cavities like spoke or half wave resonators is the small energy gain and low real estate gradient. Due to the negative synchronous phase it is neccessary to focuse the beam frequently. Together with the required shape of the cavities this leads to more drift spaces than in CH-structures. Additionally, due to the β-profile the CH-structure has always the optimum transit time factor unlike 2-gap structures. The CH-structure is the first efficient low energy multi-cell structure with respect to real estate gradient and energy gain per cavity. It is especially suited for driver accelerators with a fixed velocity profile like XADS [3] or IFMIF [4].

Figure 1 shows the superconducting CH-structure before the final welding of the end cells. The cavity has been fabricated by the company ACCEL [5] from 2-3 mm thick bulk niobium sheets with an RRR-value of 250.

CAVITY PARAMETERS

Table 1 shows the main parameters of the superconducting CH-cavity. The measured frequency is about 7 MHz above the design value because of the weld shrinking of the tank by 2.5 mm. Assuming a total surface resistance at 4.5 K of 150 nΩ the expected Q-value is $3.7 \cdot 10^8$. The required rf power is 9 W to reach the design gradient of 3.2 MV/m which corresponds to a cavity voltage of 3.36 MV. The peakfield ratio is 6.16 for the electric and 7.94 mT/(MV/m) for the magnetic field. This leads to moderate values (E_a=3.2 MV/m) for the electric and magnetic

peak fields of 20 MV/m and 25 mT, respectively. To calculate these values, the total length of the cavity has been used.

After the fabrication of the cavity the field profile has been measured (see fig. 2). It could be demonstrated that it is possible to obtain a sufficient flat field distribution in superconducting CH-structures. The field distribution has been optimized by changing the capacitance along the cavity locally.
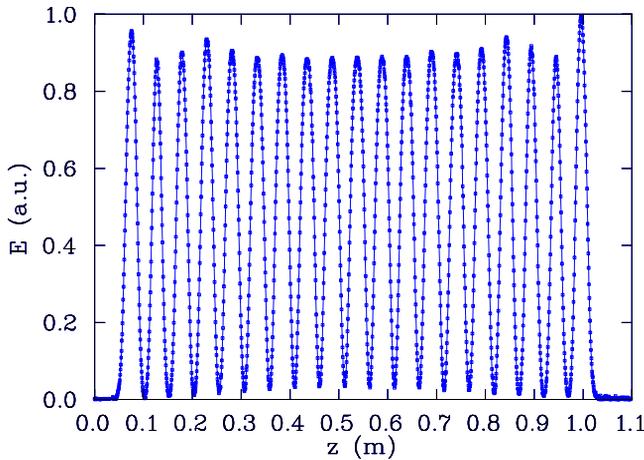
Figure 2: Measured distribution of the electric field after the final welding.

RF CONDITIONING

Figure 3: Experminetal setup for the room temperature rf conditioning of the CH-structure.
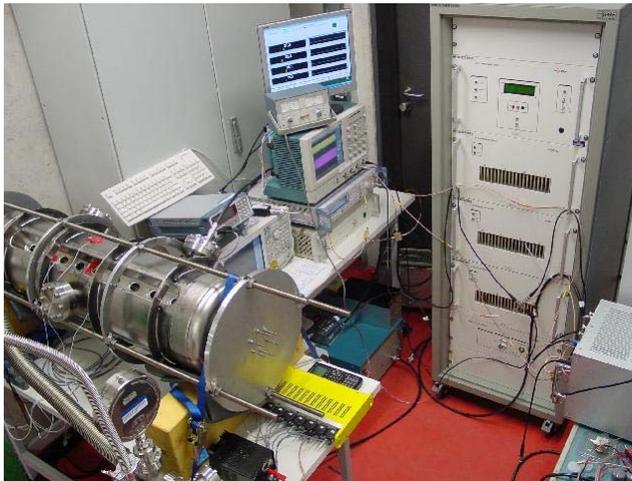
Although H-mode cavites typically don't show much multipacting it has been decided to condition the CH-structure at room temperature to reduce possible multipacting barriers. Figure 3 shows the experimental setup for the conditioning. A 2 kW rf-amplifier which can be operated pulsed as well as cw has been used. As input coupler a loop
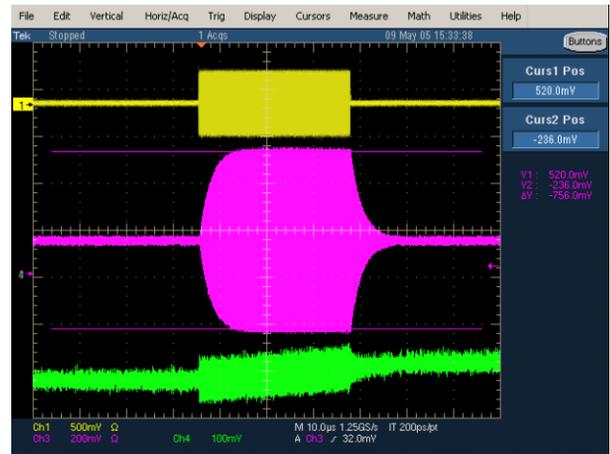
Figure 4: RF signals of the room temperture conditioning with 32μs, 2 kW pulses (forwarded power, resonator response and VCO-signal).

with A=6 cm^2 has been used. The pickup was a small coaxial coupler ($Q_{ext}=10^8$) which will be used as input coupler during the crygenic tests [6]. Figure 4 shows typical rf signals during the conditioning (forwarded power, pickup signal, VCO-signal). The forwarded power was 2 kW with a pulse length of 32 μs. Above 350 W some minor multipacting barriers have been observed. But they could be processed within one hour. The final pressure decreased from $6 \cdot 10^{-8}$ hPa before the conditioning to $2 \cdot 10^{-8}$ hPa. Additionally, a new 8-channel temperature measurement system (4 K-330 K) has been installed. The temperature has been measured at different positions on the surface of the CH-structure during an applied rf power of up to 300 W cw. Figure 5 shows the temperature as function of time for the different positions (top) and the CH-cavity with the marked temperature sensors (bottom). As expected, the temperatures close to the stems (position 2 and 3) are the highest because of the highest magnetic fields and surface currents, respectively. The observed frequency shift was about 3.8 kHz/K.

MECHANICAL ANALYSIS

A mechanical analysis using ANSYS [7] has been done to determine the deformation due to the external air pressure. It has been found that additional stabilization rings (see fig. 3 and 4) were neccessary to stabilize the cavity. In a second step, the mechanical eigenmodes have been calculated. The first 6 modes with support are shown in figure 6. The frequencies are between 146 and 417 Hz which means that the CH-cavity is a stiff structure. Table 2 shows the first five calculated mechanical resonances of the CH-structure without and with mechanical support.
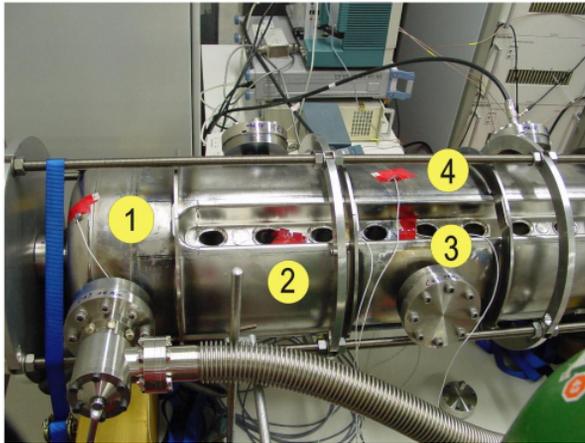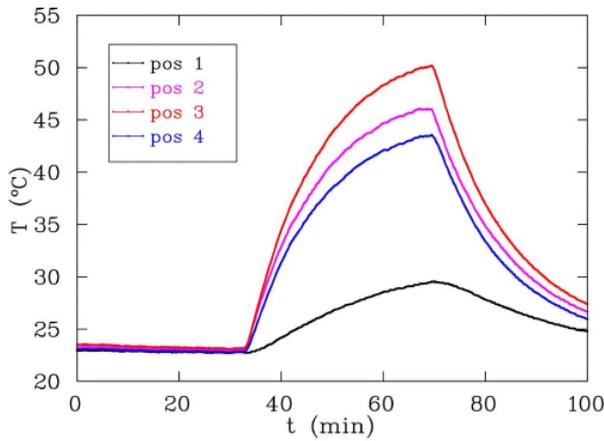
Figure 5: The temperature has been measured at 4 different positions with an rf power of 300 W cw.

Table 2: The first mechanical resonances without and with support.

mode	without support	with support
1	229 Hz	146 Hz
2	259 Hz	228 Hz
3	316 Hz	345 Hz
4	377 Hz	385 Hz
5	532 Hz	415 Hz

SUMMARY AND OUTLOOK

The superconducting CH-structure has been delivered to the University of Frankfurt and first room temperature measurements have been performed successfully. In a next step, cold tests with helium are planned to demonstrate the performance of the CH-structure. Additionally, simulations with respect to lorenz force detuning, frequency shift during cool down and the determination of the stress due to a mechanical tuner will be performed.
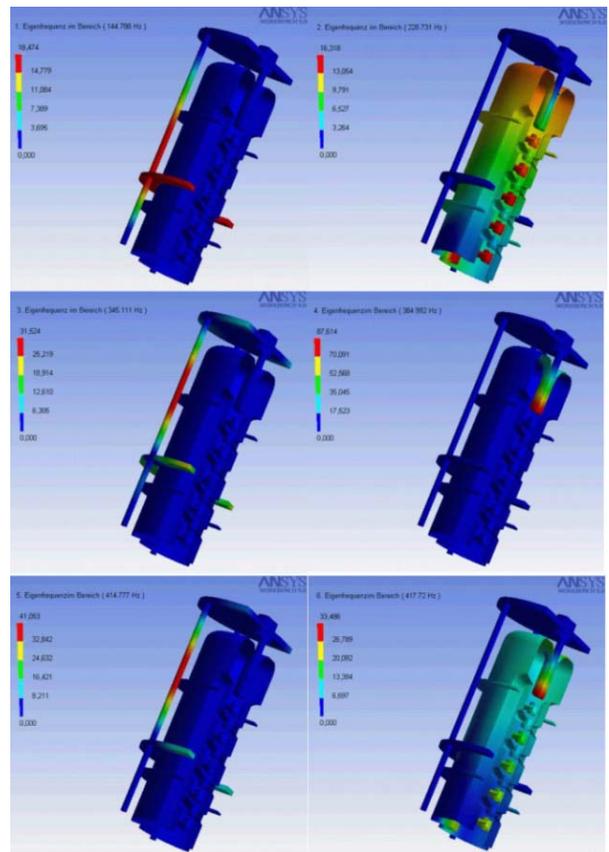
Figure 6: The first six mechanical eigenmodes of the superconducting CH-structure calculated with ANSYS.

ACKNOWLEDGEMENT

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