STATUS OF THE SUPERCONDUCTING CH-STRUCTURE

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Abstract

The CH-Structure which has been developed at IAP in Frankfurt is the first superconducting multi-cell drift tube cavity for the low and medium energy range between 5 and 150 MeV. The prototype cavity which has been built consists of 19 accelerating cells and has an operation frequency of 360 MHz (see fig. 1). The cavity has been tested for several times, gradients of up to 4.7 MV/m have been achieved in cw operation. Presently the limitation is field induced quenching. To localize possible field emitting sites a detailed X-ray analysis has been performed. One main emitter could be identified. Additionally, warm measurements have been performed to test the tuning concept of the cavity. A tuning sensitivity of 400 kHz/mm has been measured.

INTRODUCTION

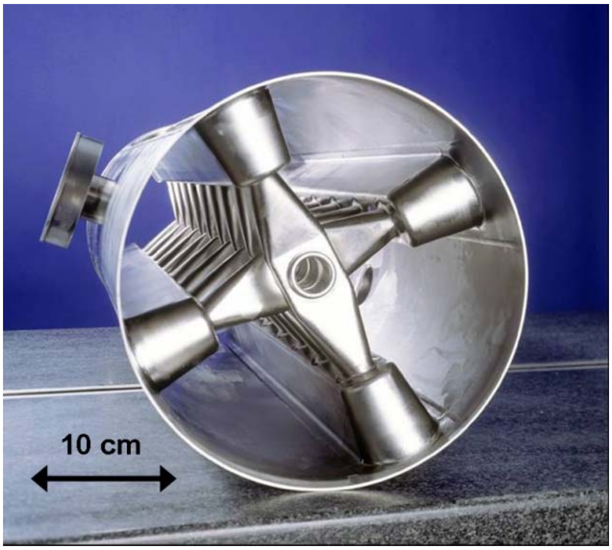

Figure 1: The superconducting CH-structure developed at IAP in Frankfurt. The prototype cavity has 19 accelerating cells, the geometrical β is 0.1, the operation frequency is 360 MHz.

The CH-structure is a multi-cell cavity and belongs to the family of H-mode cavities which are operated in an H_{n1}-mode. This new structure has been named CH-structure because of its cross-bar geometry and the H_{21}-mode.
The CH-geometry leads to a very rigid geometry which makes the realization of room temperature as well as superconducting cavities possible [1, 2] . The operation frequency between 150 and 700 MHz makes this cavity attractive for proton and light ion driver linacs in the low and medium energy range. This multi-cell cavity would increase the filling factor significantly when compared to conventional superconducting 2-gap cavities like quarter- or half-wave resonators. Additionally, the number of subsystems would be reduced, which generally increases the accelerator reliability.

CRYOGENIC TESTS

The superconducting CH-cavity has been tested several times in the cryogenic laboratory in Frankfurt. Effective gradients of 4.7 MV/m ($\beta\lambda$-definition) have been achieved which corresponds to electric peak fields of 25 MV/m and to an accelerating voltage of 3.7 MV, respectively (Fig. 2) [3]. The Q-value at low field level was $5.7 \cdot 10^8$ which corresponds to a total surface resistance of 96 nΩ. The residual resistance was 43 nΩ.

Presently the limitation is field emission induced quenching. Above a peak surface field of 20 MV/m strong field emission has been observed. The X-ray distribution has been measured with Thermo-Luminescence Dosemeters (TLD). In a first step the detectors have been placed outside the cryostat in the warm region. The asymmetric distribution along the cavity indicated the existence of field emitters. But the resolution was insufficient because of the large distance to the beam axis (50 cm) where the maxium fields occur [3]. In a following cryo test 24 TLD-cards have been placed directly on the cavity surface in the helium bath. Two rows of detectors have been placed at the girder between the stems. The distance within one row be-

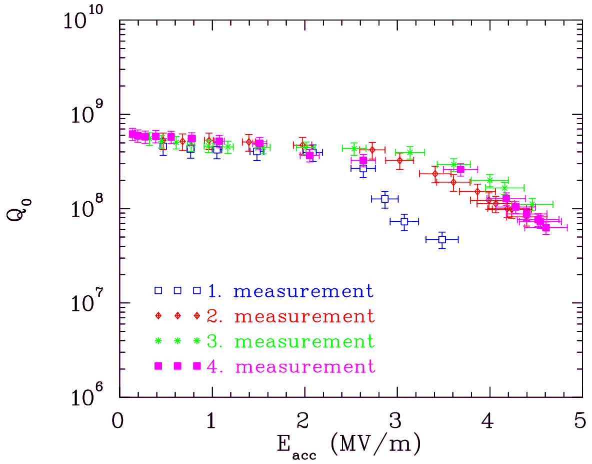

Figure 2: Measured Q-value as function of the effective acclerating gradient E_a. The maximum achieved gradient of 4.7 MV/m ($\beta\lambda$-definition corresponds to an accelerating voltage of 3.7 MV.

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tween two detectors was $\beta\lambda$. The other row was shifted by one cell length longitudinally. Figure 3 (lower part) shows the arrangement of the X-ray detectors. The upper part of figure 3 shows the measured X-ray distribution along the cavity. The resolution is increased significantly. It shows clearly the existence of one main emitting site close to the cavity center. The distance between the field emitter and the origin of the X-rays cannot be more than one cell length in a low-β multi-cell structure. This means that the emitter is located in the cavity center close to the beam axis. The cavity has been sent to ACCEL for a mild chemical treatment (20 μm) and high pressure rinsing to remove the emitter and to increase the maximum achievable fields.

Table 1: Main parameters of the superconducting CH-prototype cavity

cavity type	s.c. CH
Material	bulk niobium
No. of accelerating cells	19
β_{geo}=v/c	0.1
frequency (MHz)	360
Length (mm)	1048
R_a/Q_0 (Ω)	3180
G (Ω)	56
R_aR_s (Ω^2)	180000
E_a, $\beta\lambda$-def., (MV/m)	4.7
U_a (MV)	3.7
Q_0 (low fields)	$5.7 \cdot 10^8$

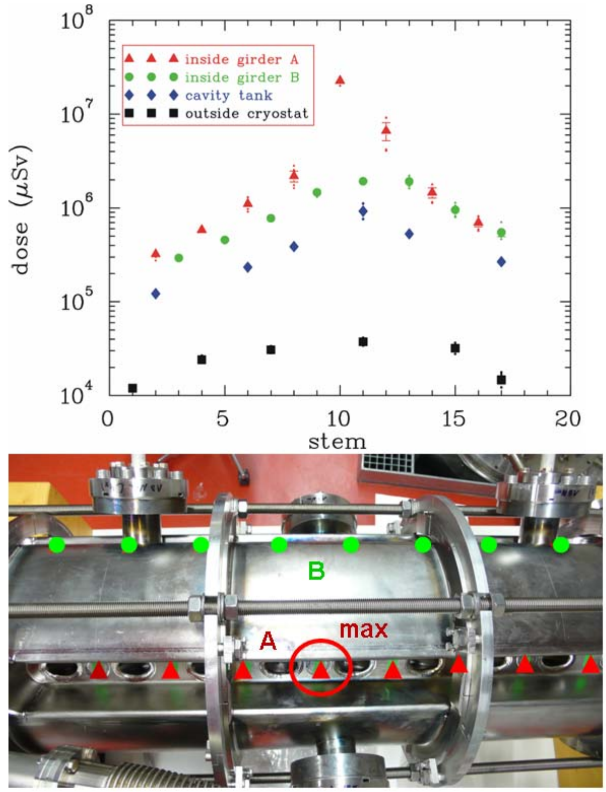

Figure 3: Top: Measured X-ray dose along the CH-structure. Bottom: Location of the TLD-X-ray detectors inside the girder of the cavity.

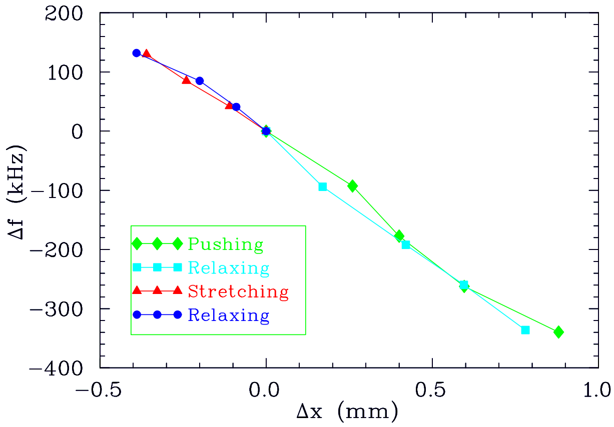

Figure 4: Frequency shift Δf as function of the deformation Δz of the end cell. The measurement has been performed at room temperature.

FREQUENCY TUNING

All previous tests of the cavity in the vertical cryostat have been carried out in a vertical cryostat with variable frequency to follow detuning effects under operation conditions. A horizontal cryostat is being prepared to test the cavity with a slow and a fast tuner. The basic principle of tuning is a deformation of the cavity by applying a longitudinal force at the end flanges causing a gap width variation at the end cells and thus a capacity change here.

Figure 4 shows the frequency shift Δf measured at room temperature as function of the deformation of both end cells Δz of the cavity. The tuning sensitivity is about 400 kHz/mm. By applying a force at the end flanges of the cavity in good approximation only the end cell geometry and the end cell gaps are effected. Changing the end cell gaps leads to a change in the electric field distribution of these gaps. From rf-simulations a maximum field variation of about 10% by pushing both end flanges by about Δz=1 mm has been expected. These estimations have been well confirmend by experimental results. Figure 5 shows the electric gap field distribution along the CH-cavity for different end cell variations Δz. Squeezing of the end cells leads to an increase of the field distribution in the first and last gap whereas the field in the inner gap remains unaffected. This behavior has been predicted by Microwave Studio simulations [4]. To squeeze both end cells by 1 mm an external force of about 5000 N is necessary. Beside the slow tuner a fast piezo tuner is being developed to fix the cavity frequency. The piezo crystals which will be used will provide a maximum shift of 5 μm on each side which correspond to a maximum frequency shift of about 2 kHz. The force of the axial slow device is transmitted across the

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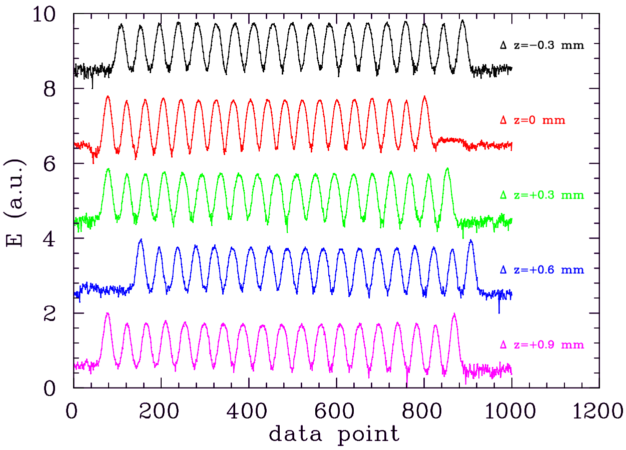

Figure 5: Measured field distribution along the CH-cavity for different end cell deformations Δz. An field enhencement of about 10% has been observed for a Δz of 1 mm on each side. The field of the inner gaps is unaffected.

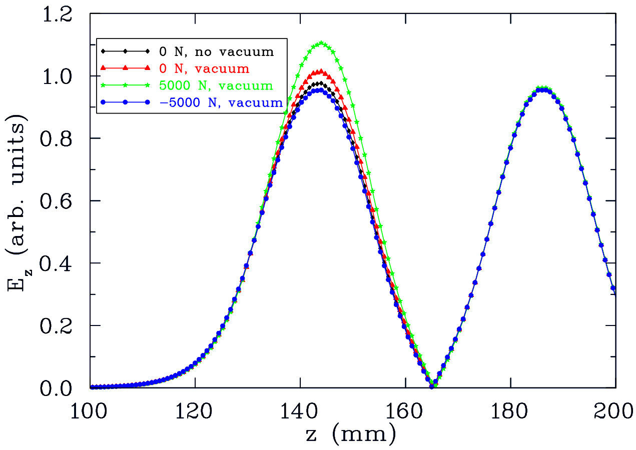

Figure 6: Microwave Studio simulation of the electric field when changing the end cell geometry due to a slow tuner. Only the field in the end cells is changed which could be experimentally validated.

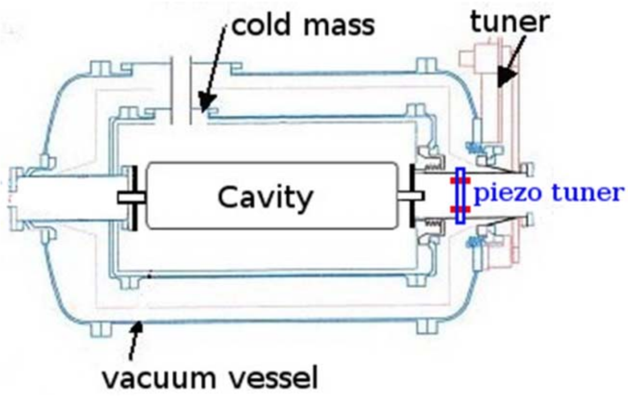

Figure 7: Cut through the horizontal cryostat with the positon of the tuner sytem.

piezos, which helps trying to avoid mechanical resonances and shearing that could destroy the piezos. Since the translation of the piezos is clearly a function of temperature, we carried out some preliminary experiments both at room temperature and at 77 K (liquid nitrogene) and found that the longitudinal range is about half of the original one at 293 K. Figure 7 shows a cut through the horizontal cryostat and the planned location of the tuner system.

SUMMARY AND OUTLOOK

The superconducting CH-prototype cavity has been tested successfully with achieved gradients of up to 4.7 MV/m. A detailed X-rax analysis showd a main field emitter. The cavity has been sent for a new surface treatment to overcome the present limitation due to field emission. Warm tests have been performed to tune the cavity. Presently a horizontal cryostat is being prepared to test the CH-structure with a slow tuner.

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