FIRST CRYOGENIC TEST OF THE SUPERCONDUCTING CH-STRUCTURE

H. Podlech, C. Commenda, H. Klein, H. Liebermann, U. Ratzinger, A. Sauer
IAP, Universität Frankfurt/Main, Germany

Abstract

The superconducting **C**rossbar-**H**-type **CH**-structure is a novel multicell drift tube cavity operated in the $H_{21(0)}$-mode. It is well suited for protons and ions in the low and medium energy range from 5 AMeV to 150 AMeV [1]. A 19-cell, β=0.1 prototype cavity has been developed and built [2]. Several cryogenic tests have been performed in the new cryogenic rf laboratory at the IAP in Frankfurt. The quality factor at low field was $5.7{\cdot}10^8$. An effective accelerating voltage of 3.8 MV in cw operation has been achieved for this cavity.

Figure 1: The superconducting CH-protype cavity.

INTRODUCTION

The development of superconducting cavities for the low and intermediate energy range has been a vital research area in recent years [3]. The maximum number of accelerating gaps was between one and four. If energy variability is not an issue as for driver accelerators it is advantageous to use multicell cavities which can increase the real estate gradient significantly while the total number of cavities with their support systems is reduced considerably [4].

The **C**ross-bar-**H**-mode (**CH**)-Structure is the first superconducting low and intermediate energy multicell cavity which has been built and tested. The cavity has a lenght of 105 cm and a diameter of 28 cm. For the production 2 mm thick bulk niobium sheets with a RRR-value of 250 have been used. Table 1 summarises the main parameters of the CH-prototype cavity.

f	MHz	360
β		0.1
length	cm	104.8
diameter	cm	28
number of gaps		19
R_a/Q_0	Ω	3180
G	Ω	56
$(R_a/Q_0) \cdot G$	Ω^2	178000
E_p/E_a		$5.2^{\#}$
B_p/E_a	mT/(MV/m)	$5.4^{\#}$
W	$mJ/(MV/m)^2$	$92^{\#}$
material		bulk niobium
RRR		250

Table 1: Parameters of the superconducting CH-ptotoype cavity. $^{\#}$Values based on the "$\beta\lambda$"- definition with a used length of 9.5$\beta\lambda$.

CRYOGENIC TESTS

A cryogenic laboratory including a clean room has been established in Frankfurt for the development of superconducting rf-structures. The first cold test of the CH-structure has been performed in July 2005. Figure 2 shows the superconducting CH-structure before diving into the vertical cryostat. To save helium the system has been pre-cooled with liquid nitrogen. Figure 3 shows the measured frequency as function of the average cavity temperature during the cool down. The solid line represents the simulated frequency as function of the temperature assuming a homogeneous contraction of the whole cavity.

By varying the pressure in the cryostat between 0.3 and 1 bar the sensitivity of the cavity against pressure variations has been measured. Figure 4 shows the result of this measurement. The sensitivity df/dP is 250 Hz/mbar at T=77 K.

When beginning with rf conditioning the cavity showed some multipacting at very low power levels ($P_f \approx \mu W$). The most efficient way for the conditioning was to sweep over the resonance with a power of about 10 W and a span of 500 Hz. After several multipacting barriers have been conditioned within a few hours the coupling strength β and the Q-value a low field levels have been determined. The loaded Q-value Q_L was $1.13 \cdot 10^8$ and β was 4. This resulted in an intrinsic Q-value Q_0 of $5.7 \cdot 10^8$ which gives a

Figure 2: The superconducting CH-cavity ready for the first cold test in the vertical cryostat.

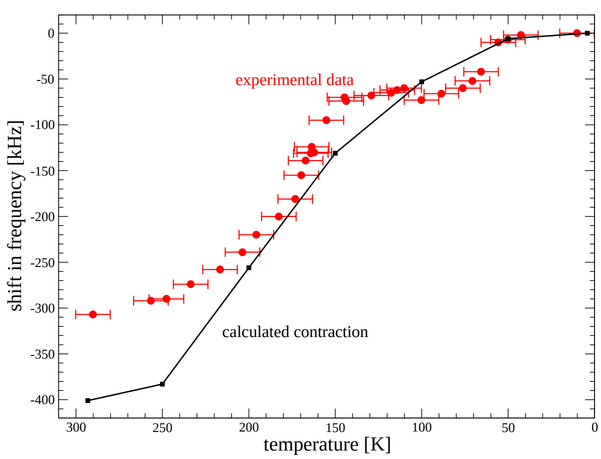

Figure 3: Measured frequency shift during the cooldown. The solid line represents the simulated frequency shift due to the contraction of the material.

total surface resistance R_s of 96 nΩ. With a BCS-value of 49 nΩ and a magnetic resistance of 4 nΩ a cavity residual resistance of 43 nΩ has been obtained. Figure 5 shows the typical rf signals of the CH-structure during the cold test. It can clearly be seen that the cavity is over-coupled.

The most important measurement was the determination of the intrinsic Q-value as function of the accelerating gradient (Fig. 6). The gradient depends on the length definition in a cavity. We used the "$\beta\lambda$"-definition: The length in a n-gap cavity is defined by $L_{\beta\lambda} = n(\beta\lambda)/2$. Using this definition a gradient of 4.6 MV/m has been reached (Fig. 6) in cw operation. This corresponds to an effective accelerating voltage including the transit time factor (T=0.8) of 3.8 MV. The gap voltage amplitude is in the range between 175 kV and 300 kV. Table 2 shows the accelerating gradient depending on the length definition.

Due to the pressure of the electromagnetic fields a fre-

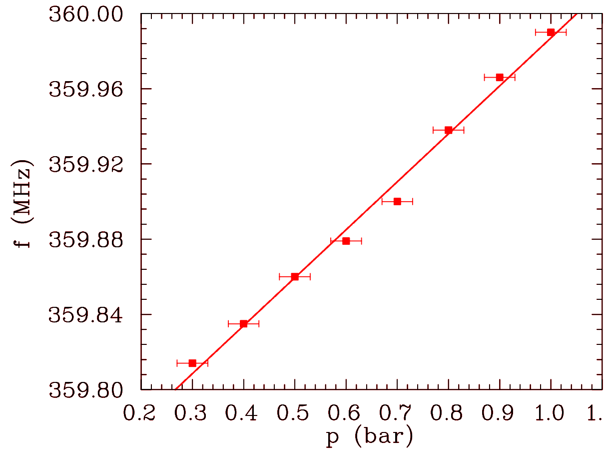

Figure 4: Measured frequency as function of the external pressure at T=77 K.

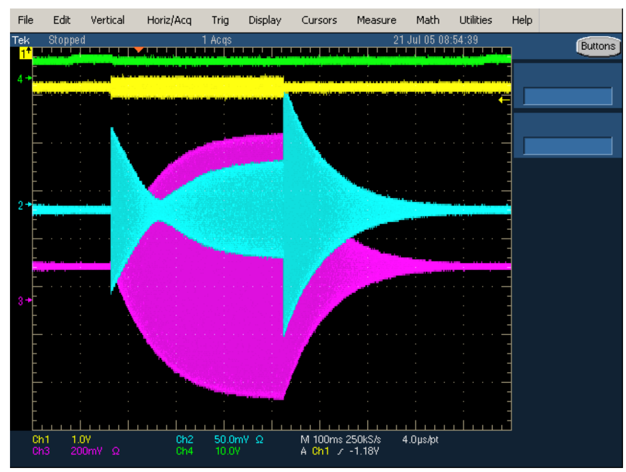

Figure 5: RF signals of the CH-cavity at low fields: Reflected signal (green), pickup signal (magenta) and forwarded signal (yellow). The time scale is 100 ms per division.

	L=active	L=9.5$\beta\lambda$	L=total
L (mm)	767	810	1048
E_a (MV/m)	4.9	4.6	3.6
U_a (MV)	3.8	3.8	3.8

Table 2: Accelerating gradient depending on the length definition in the CH-prototype cavity (T=0.8 included).

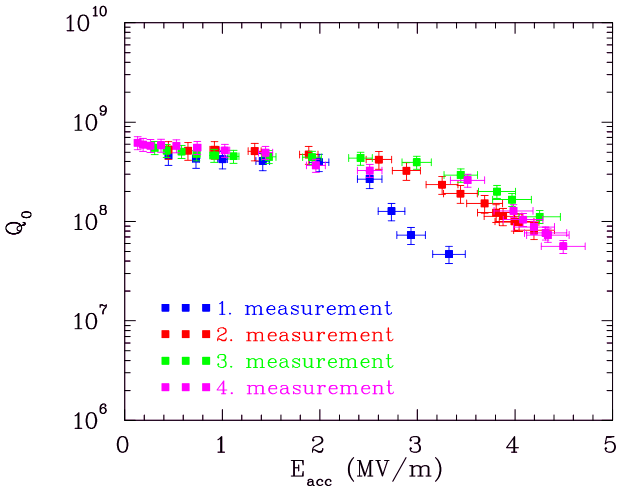

Figure 6: Measured unloaded Q-value Q_0 as function of the accelerating gradient E_a. For the gradient definition a length of $8.5\beta\lambda$ has been used.

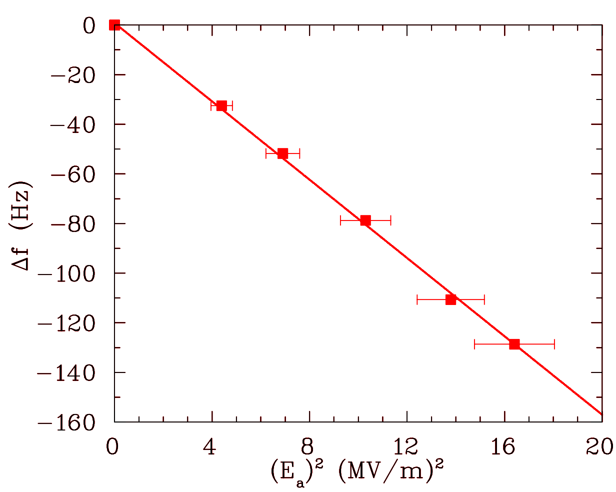

Figure 7: Measured Frequency shift due to Lorentz Force Detuning. The gradient is based on the $\beta\lambda$-definition.

quency shift of the cavity depending on the field level has been measured. This Lorentz Force Detunig (LFD) is proportional to the square of the field level. Figure 7 show the measurement of the LFD. A K-value of 8 Hz/(MV/m)^2 has been obtained ($\beta\lambda$-definition). This relatively high value is mainly caused by the use of only 2 mm thick niobium sheets for the cavity walls.

The electric peak field was 25 MV/m and the magnetic peak field was 26 mT, respectively. Above an electric peak field of about 20 MV/m strong field emission was observed. The X-ray distribution of the cavity has been measured with ^{6}Li/^{7}Li-detectors which have been placed outside of the cryostat in a distance of about 50 cm from the beam axis. Figure 8 shows the measured dose as function of the position of the detectors. The asymmetry in the distribution indicates the existance of field emitters.

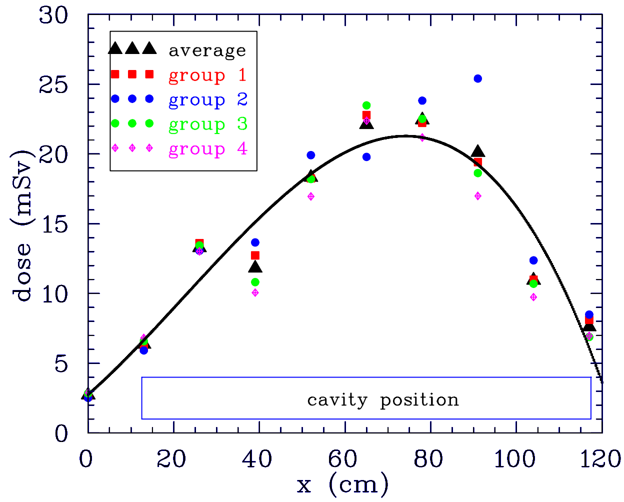

Figure 8: Measured X-ray distribution along the cavity.

SUMMARY AND OUTLOOK

The superconducting CH-structure is the first multi-cell cavity for the low and intermediate energy regime. A prototype cavity has been built and tested successfully. A gradient of 4.6 MV/m and an effective voltage gain of 3.8 MV have been achieved. Depending on a more detailed measurement of the X-ray distribution it is planned to do an additional surface preparation, either high pressure rinsing only or an addtional chemical treatment. At present a cryostat is being prepared for horizontal tests of the cavity.

ACKNOWLEDGEMENT

This work has been supported by GSI, BMBF contr. No. 06F134I, EU contr. No. EFDA/99-507ERB5005 CT990061 and EU contr. No 516520-FI6W. We acknowledge also the support of the European Community-Research Infrastructure Activity under the FP6 ”Structuring the European Research Area” program (CARE, contract number RII3-CT-2003-506395).
The authors would like to thank J. Festag and C. Pöppe, GSI for the support with the X-ray measurements.

REFERENCES

[1] U. Ratzinger, Habilitationschrift, Universität Frankfurt, 1998

[2] H. Podlech, H. Deitinghoff, H. Liebermann, H. Klein, U. Ratzinger, A. Sauer, R. Tiede, First Tests of the Superconducting CH-Structure, Proc. of the PAC05, p.3414-3416, 2005, Knoxville, TN, USA

[3] A. Facco, Low and Medium Beta SC Cavities, Proc. of the EPAC04, p.142-146, 2004, Lucerne, Switzerland

[4] H. Podlech, Development of Room Temperature and Superconducting CH-Structures, Proc. of the LINAC04, p.28-32, 2004, Lübeck, Germany