HIGHER ORDER MODE INVESTIGATION OF SUPERCONDUCTING CH STRUCTURES AND STATUS OF THE CH PROTOTYPE CAVITY [*]

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Abstract

H-Mode cavities (IH-DTL, IH-RFQ, 4-Vane-RFQ) have been developed sucessfully during the last decades for a large variety of applications in the field of ion acceleration [1]. The CH- or Crossbar H-structure is a new H-Mode drift tube structure operating in the TE_{210} mode. This structure is currently under development at the IAP in Frankfurt, Germany. This type of cavity is an excellent candidate for the use in future high current applications like IFMIF or XADS with beam currents of up to 125 mA [2][3]. For these applications superconducting operation is very attractive. The overall plug power consumption is lower and the use of larger apertures can reduce the risk of activation significantly. Due to the possible superconducting operation it is important to investigate the higher order modes (HOM) in such a cavity. In this paper, we present the first results of the HOM analysis and give a status of the development of the superconducting CH cavity prototype.

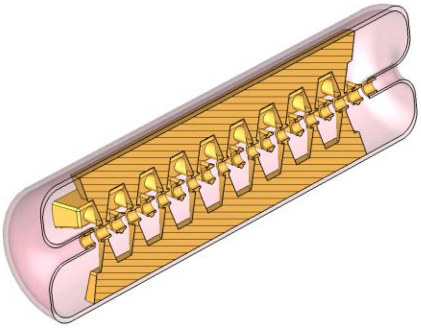

Figure 1: View of the prototype of the superconducting CH cavity which is presently under construction.

INTRODUCTION

Existing H-Mode cavities can be operated only at room temperature. Many future projects require cw operation. Normal conducting structures are limited in the gradient because of power losses.

Due to its mechanical rigidity the CH-structure can be realized for room temperature as well as for superconducting operation. Together with the use of the KONUS beam dynamics [4] long lens-free sections and therefore superconducting multicell structures like the CH-cavity become possible. The reasonable energy range is between 3 and 150 A·MeV and a frequency between 150 and 800 MHz can be used.

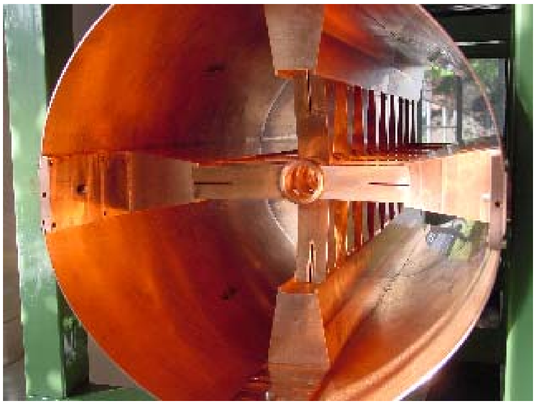

Figure 2: View into the CH copper model. The characteristic crossed stem construction of the CH cavity is clearly visible.

Figure 1 shows the prototype of a 19-gap superconducting CH-structure which is presently under construction. The operating frequency is 352 MHz and the β is 0.1.

HOM ANALYSIS

Theory

Inside a cavity the beam can gain energy due to longitudinal electric on axis fields. On the other side, every higher order mode with electric field on or near the axis could in priciple be excited by the beam. Higher order mode excitation can lead to beam instabilites and to additional power losses. Besides the frequency of the higher order modes the R/Q value is one of the most important quantities:

$$R/Q = \frac{\left|\int E_z(z) \exp\left(i\omega z/\beta c\right) dz\right|^2}{\omega W}, \qquad (1)$$

where W is the stored energy. The geometric shunt impedance R/Q measures the level of excitation of higher order modes. For cw applications, significant voltages can be generated only if a Fourier beam component is within the bandwidth of HOM.

Simulation and Measurements

For future high current applications it is necessary to determine all of the potentially dangerous modes with respect

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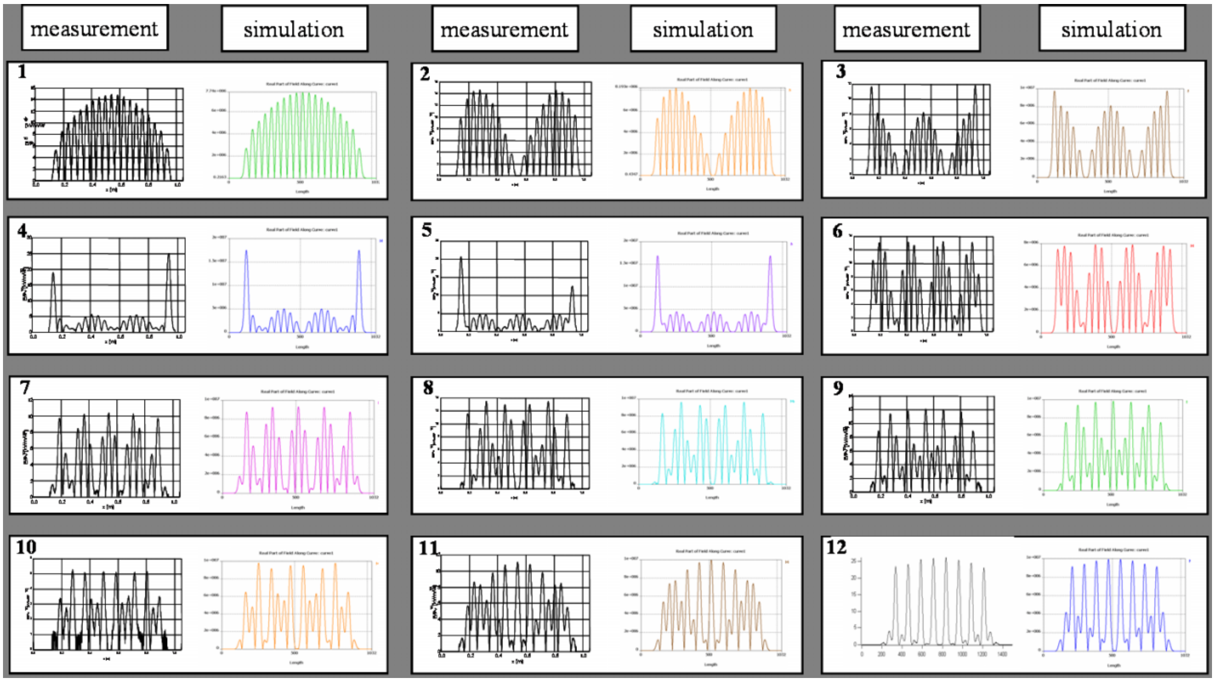

Figure 4: Distribution of the electrice field of the first 12 eigenmodes of the CH copper model.

to R/Q values, frequencies and additional power losses. In a first step we simulated a CH-cavity with Microwave Studio [5] to identify the higher order modes and to derermine their frequencies. A copper model of this cavity has been built to validate the simulations. It is a 19-gap copper model with a measured frequency of the basic mode of 289 MHz and with a β of 0.08. Figure 2 shows a photograph of this model resonator. The measurements have been performed using the bead perturbation method. A metallic bead with a diameter of 4.75 mm has been pulled through the resonator. The Figure 3 shows the experimental setup. Unlike to elliptical cavities, it is sufficient to measure on axis because every mode produces a longitudinal on axis electric field in CH-cavities. Due to the fixed velocity profile of CH-structures one has to determine the R/Q value only for the design β. In a first step the R_0/Q_0 values of the first 15 modes up to a frequency of 1 GHz could be determined. The agreement between the simulations and the measurements was excellent. The Figure 4 shows the measured and simulated field distributions of the first 12 modes. Table 1 shows the measured and simulated parameters of the model resonator. So far, the investigation shows that the simulations are accurate enough to determine potentially dangerous higher order modes in CH cavities. We found an interesting and potentially dangerous mode. Figure 5 shows the simulated field distribution of the basic mode (f=285 MHz) and of the 28th mode (f=1235 MHz). Both modes have a similar field distribution although the 28th mode has a frequency of almost 4.3 times the basic frequency. The investigation of the properties of this mode are still under way.

Table 1: Measured and simulated parameters of the CH copper model

Parameter	**Simulation**	**Measurement**
f (MHz)	285	289
length (cm)	104	104
diameter (cm)	34	34
gap number	19	19
β	0.08	0.08
R_a/Q (Ω)	1668	1690

Figure 3: Photograph of the experimental setup. In the center the CH r.t. model is visible.

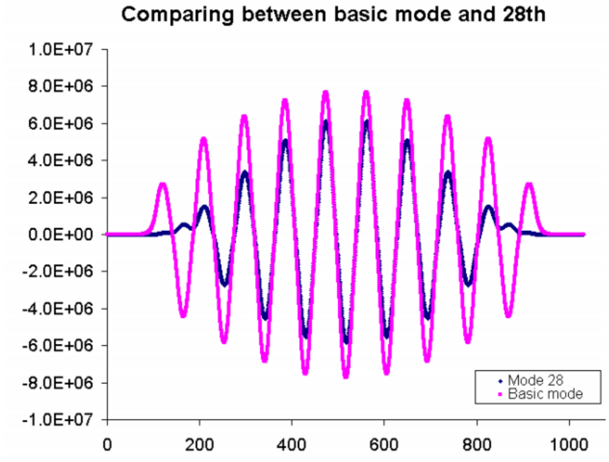

Figure 5: Comparison of the field distribution of the basic mode (285 MHz) and the 28th mode (1235 MHz).

Figure 6: The 3 m long vertical cryostat (center) and the class 100 laminar flow box (right) in the new cryogenic laboratory in Frankfurt.

PROTOTYPE STATUS

The cavity parameters have been optimized using Microwave Studio. The major issue was to minimize the electric and magnetic peak field to reduce the risk of field emission and thermal breakdown [6]. This type of cavity will be limited most likely by the electric fields whereas the magnetic peak fields have very moderate values. Table 2 summarizes the most important parameters of the superconducting prototype.

A design and engineering study has been performed in close cooperation with industry (ACCEL) to show the feasibility of the production of superconducting CH structures. After a call for tenders, the cavity has been ordered. The production of the cavity has already started, the used material is high RRR bulk niobium. After fabrication the cavity will be treated with Chemical Buffered Polishing (BCP) and High Pressure Rinsing (HPR). It is expected that the cavity will be delivered in January 2004.

Table 2: Parameters of the superconducting CH cavity prototype

f [MHz]	352
β	0.1
length [cm]	104.8
diameter [cm]	28
number of gaps	19
R_a/Q_0 [Ω]	1610
G [Ω]	56
E_p/E_a	6.59
B_p/E_a [mT/MV/m]	7.29
E_p @ E_a=3.2 MV/m [MV/m]	21
B_p @ E_a=3.2 MV/m [mT]	23.3
W [mJ/(MV/m)^2]	155
W @ E_a=3.2 MV/m [J]	1.58
Q_0 (BCS, 4K)	$1.6\cdot10^9$
Q_0 (R_s=100 nΩ)	$5.6\cdot10^8$
P @ E_a=3.2 MV/m [W]	13

The cavity will be tested in the new cryogenic laboratory at IAP in Frankfurt. The lab has been equipped with a 3 m long vertical cryostat and a class 100 laminar flow box (see fig. 6), a magnetic shielding, a helium recovery system and two 250 l transport dewars.

OUTLOOK

It is planned to continue the HOM analysis and to determine the Q_{ext} for different modes. A mechanical analysis using the program COSMOS will be performed to investigate the mechanical vibrations of the cavity. The setup for the cryo tests is beeing equipped and the rf control system is under development. In addition, investigations of a mechanical tuner have started.

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