STATUS OF THE DEVELOPMENT OF A SUPERCONDUCTING 352 MHz 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 [2]. This structure is currently under development at the IAP in Frankfurt. Due to its mechanical rigidity the CH-structure can be realized for room temperature as well as for superconducting operation. In this paper we present the status of the development of the first superconducting CH-cavity prototype.

INTRODUCTION

Present H-mode structures are all operated at room temperature. Many future accelerator projects require cw operation. But the achievable gradients of room temperature cw operated H-mode cavities are limited due to power losses and cooling problems.

The use of the KONUS beam dynamics [3] allows to realize long lens free sections and makes superconducting multi cell cavities for low and medium beta beams possible. The superconducting CH-cavity can be realized in the frequency range between 150 and 800 MHz, the beam energy can be chosen between 5 A·MeV and 150 A·MeV which corresponds to a β range from 0.1 to 0.5.

The CH-structure can be used for proton as well as for ion beams. But it seems to be epecially attractive for future high current proton linacs like XADS [4] or deutron linacs like IFMIF [5].

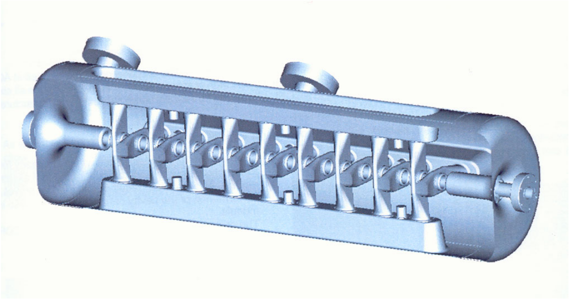

Figure 1: View of the 352 MHz superconducting CH-cavity prototype which is currently under fabrication at the ACCEL company, Bergisch Gladbach, Germany.

DESIGN AND PRODUCTION OF THE CH-CAVITY

A superconducting CH-cavity prototype is under development to demonstrate the capabilites of this new structure (see fig. 1). The cavity has been designed using the program Microwave Studio [6]. The main design issues were the optimization of the field distribution and the minimization of the electric and magnetic peak fields. The field distribution along the beam axis has been optimized by changing the length of the drift tubes and keeping the cell length constant [7].

The electric peak field E_p/E_a is 6.59. This means that the CH-structure will be limited most likely by field emission. Assuming an accelerating gradient of $E_a = 3.2\ MV/m$ this results in a peak field of $E_p = 21\ MV/m$ which is still a moderate value. On the other side, the energy gain per length and per cavity of about 3.5 MeV for protons is much higher when compared to other structures like spoke resonators. The magnetic peak field of the CH-cavity is rather low, $B_b/E_a = 7.29\ mT/(MV/m)$. The maximum magnetic field at a gradient of $3.2\ MV/m$ is only $23.3\ mT$

The prototype cavity will be produced from 2-3 mm thick

Table 1: 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 [$k\Omega$]	3.22
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, 4.2K)	$1.5\cdot10^9$
Q_0 (R_s=150 nΩ)	$3.7\cdot10^8$
P @ E_a=3.2 MV/m [W]	9.5
material	bulk niobium
RRR	250
sheet thickness [mm]	2-3

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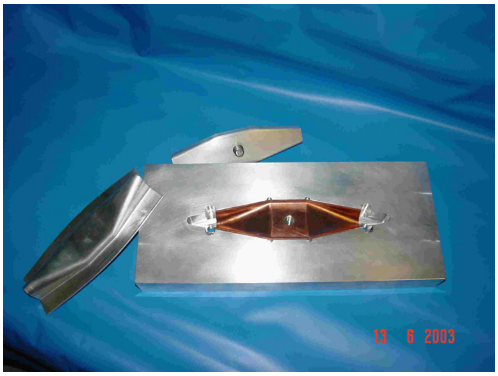

Figure 2: This photograph shows the dies and the first results of the deep drawing tests of the stems.

bulk niobium sheets with a RRR of about 250. The endcaps of the tank and of the girders will be produced by spinning whereas all other parts will be formed by deep drawing. The raw material has been already delivered and the production has been started (see fig. 2). The cavity is expected to be deliverd in the beginning of 2004.
To test the cavity, a new cryo laboratory has been established in Frankfurt. It is equipped with a 3 m long vertical cryostat, two 250 l transport dewars for the liquid helium, a helium recovery system and a class 100 laminar flow box and a magnetic shielding (see fig 3).

Figure 3: View into the new cryo laboratory in Frankfurt with a class 100 laminar flow box (background) and the 3 m vertical cryostat.

ROOM TEMPERATURE MODEL

A room temperature copper model of a CH structure has been built to validate the simulations and to investigate basic rf properties. The agreement between simulation and measuremt was excellent. A higher order mode study has also been started [9].

Due to the larger number of cells a CH cavity has a β-profile along the beam axis like normalconducting IH-structures. We modified the copper model and introduced a β-profile between β=0.085 and 0.12. This corrensponds to an energy gain of 3.5 MeV for protons. Changing the capacitance by changing the lenth of the drift tubes and gaps, respectively, it was possible to obtain a flat field distribution. The agreement between the simulation and measurement is very good. These investigations showed that it is possible to obtain a flat field distribution in a CH-cavity with a β-profile and without girder undercuts as applied in room temperature IH-structures and 4-vane RFQ's. Figure 4 shows the measured and simulated field distribution and figure 5 shows the length of the drift tubes and gaps which lead to these distributions.

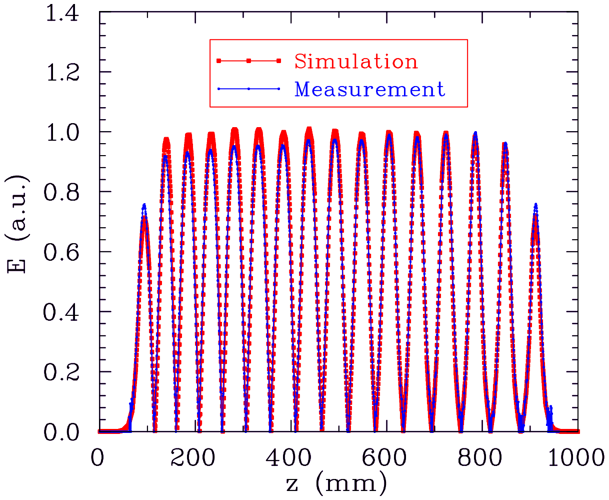

Figure 4: Simulated (red) and measured (blue) field distribution of the room temperature model with a β-profile between β=0.085 and 0.12.

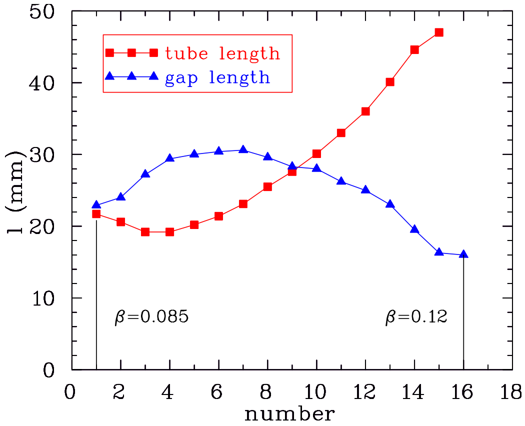

Figure 5: Required length of drift tubes and gaps to obtain the flat field distribution of figure 4.

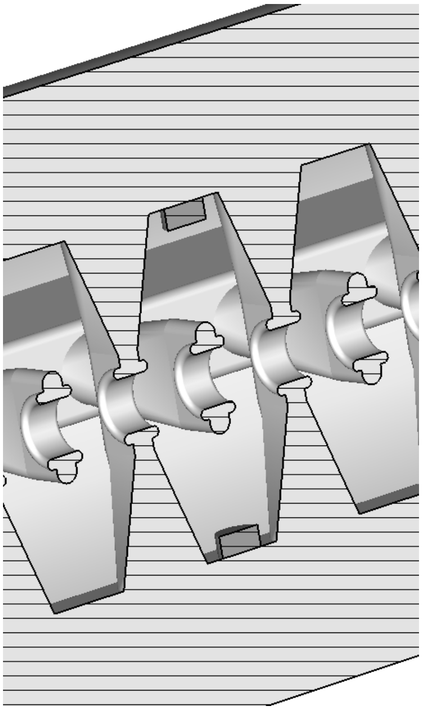

Figure 6: Tuning cylinder can be used to tune the frequency and the field distribution

FREQUENCY TUNING

Microwave Studio simulations have been started to investigate different tuning methods for CH-cavities. Figure 6 shows tuning cylinders which can be welded into the girders after the cavity production. A small height of the cylinder increases the frequency due to the decreased inductance. For a certain height the tuner decreases the frequency because of the increased capacitance. Figure 7 shows the frequency as funtion of the tuner height. These cylinders can also be used to optimize the field distribution. Another tuning method is to stretch and to squeeze the cavity end cells by a mechanical tuner. Figure 8 shows the frequency shift by changing the length of the end cells. The typical frequency shift is about 190 kHz/mm.

OUTLOOK

Presently the experimental setup is being prepared for the first test. As usual, it is foreseen to test the CH-cavity in a closed loop operation. In a next step, the development of a mechanical tuner is planned.

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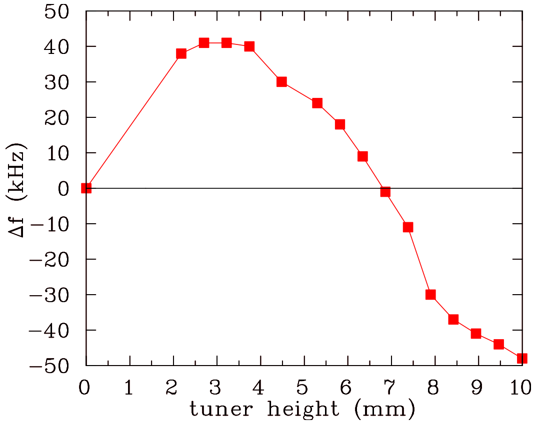

Figure 7: Simulated frequency shift of the cavity as function of the height of the tuning cylinders.

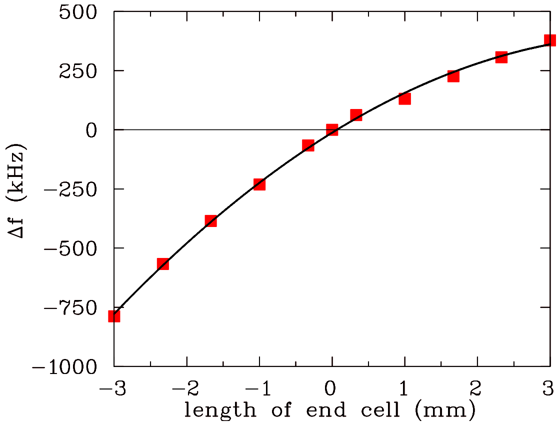

Figure 8: Simulated frequency shift as function of the length of the end cells.

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