RECENT DEVELOPMENTS ON SUPERCONDUCTING CH-STRUCTURES AND FUTURE PERSPECTIVES

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Abstract

Worldwide there is an increasing interest in new high intensity proton and ion driver linacs with beam powers up to several MW. A very challenging part of these accelerators is the low and medium energy section up to 100 MeV. Depending on the duty cycle room temperature or superconducting options are favoured. In both cases the Crossbar-H-mode (CH)-structure developed at the IAP in Frankfurt is an excellent candidate. Room temperature as well as superconducting prototype cavities have been developed and tested successfully. A superconducting 19 cell low energy CH-cavity at 360 MHz reached effective gradients of 7 MV/m corresponding to an accelerating voltage of 5.6 MV. This cavity could be used for high intensity, cw operated linacs like accelerator driven systems (ADS, EUROTRANS) or the international fusion material irradiation facility (IFMIF). Recent developments of this new type of a multi-cell drift tube cavity, tests of the prototypes and future plans will be presented.

INTRODUCTION

The CH-cavity is operated in the H_{21}-mode and belongs to the family of H-mode cavities like the IH drift tube cavity and the 4-vane RFQ. Due to the mechanical rigidity of the CH-cavity room temperature (r.t.) as well as superconducting (s.c.) versions can be realized [1]. For higher duty cycles or even cw operation superconducting solutions become more favourable because of a lower plug power consumption and higher achievable gradients [2]. In many cases the rf linac efficiency and compactness can be increased significantly by the use of multi-cell cavities.

360 MHZ PROTOTYPE CAVITY

The superconducting CH-protoype cavity (f=360 MHz, β=0.1, 19 cells) has been tested successfully in Frankfurt. After a second chemical surface preparation gradients of 7 MV/m corresponding to an effective voltage of 5.6 MV have been achieved (Fig. 1). Presently the cavity is being prepared for tests in a horizontal cryostat which is equipped with a slow and a piezo based tuner system. The basic principle of the tuner is an elastic deformation of the cavity by applying an external force at the end flanges of the tank [3]. This changes the width Δx of the end gaps and the gap capacitance. Tests at room temperature have been

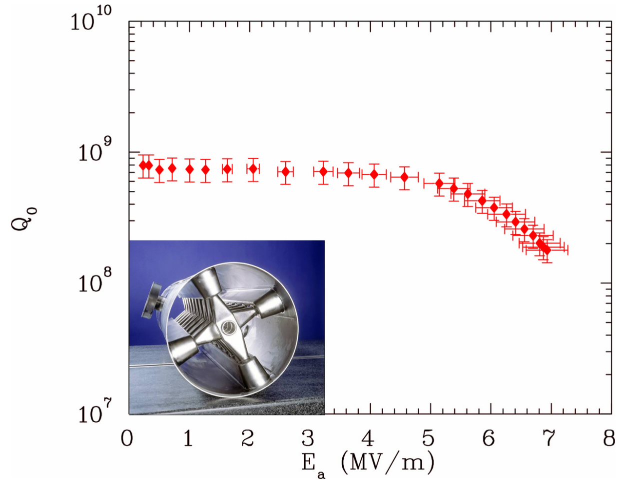

Figure 1: Measured Q-value of the superconducting CH-prototype cavity. Effecitve gradients of 7 MV/m have been achieved.

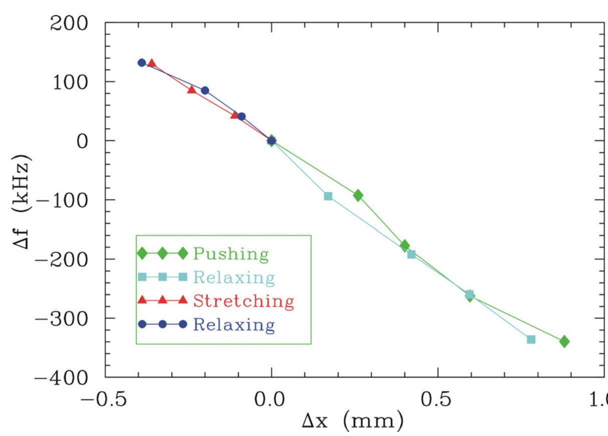

Figure 2: Measured frequency shift as function of the cavity deformation.

performed. The measured frequency tune shift is Δf/Δx = 400 kHz/mm (see fig. 2). The change of field distribution according to the deformation of the tank has been measured by using the bead pull method. The experimental results are in good agreement with MWS simulations. The effect is mainly concentrated on the end cells of the structure, where a maintainable maximum field variation of 10% within the tuning range was observed [1]. The fast tuner will be used to operate the cavity at constant frequency. It

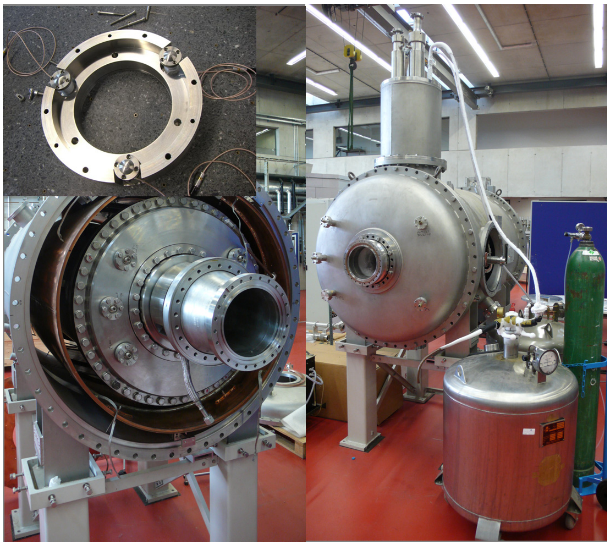

Figure 3: Horizontal cryostat with piezo tuner.

consists of three piezo elements with an expected stroke at 4 K of 3.5 μm which corresponds to a frequency shift of ±700 Hz. Figure 3 shows the horizontal cryostat and the piezo tuner. First test with liquid nitrogen haven been performed for leak tests.

A NEW 325 MHZ CH-CAVITY

The superconducting CH-cavity is an excellent candidate for high power applications because it reduces the drift space between cavities significantly compared to more conventinal solutions like Spoke-type cavities. To fullfil the requirements for high power applications the geometry of the sc CH-cavity has been optimized (Fig. 4). The stem orientation has been changed to accomodate sufficient large power couplers into the girder. The stems of the end cells are inclined. This increases the inductance in the end cells and increases the electric on-axis field without long end drift tubes which have been used before. This has great advantages for the beam dynamics of high intensity linacs. The drawback of inclined stems is an increased magnetic peak field of 13 mT/(MV/m). On the other hand, typical gradients of 5 MV/m lead to still modest values of 65 mT.
To reach the design frequency internal tuners it is planned to use cylindrical tuners. During the fabrication the frequency is measured and will be changed by 5 cylinders (r=15 mm). After this tuning process the tuners are welded into the girder. This procedure has been tested successfull with the first prototype cavity [1]. Additionally, two membran tuners with r=25 mm are foreseen. One tuner will act as a slow tuner to compensate temperature and pressure effects. The other tuner will be driven by a piezo to control fast frequency changes. Figure 5 shows the simulated frequency shift as function of the tuner height above the girder H_T using all tuners simultaneously. The experience with the first prototype cavity showed that a good surface preparation is essential for the performance of the cavity.

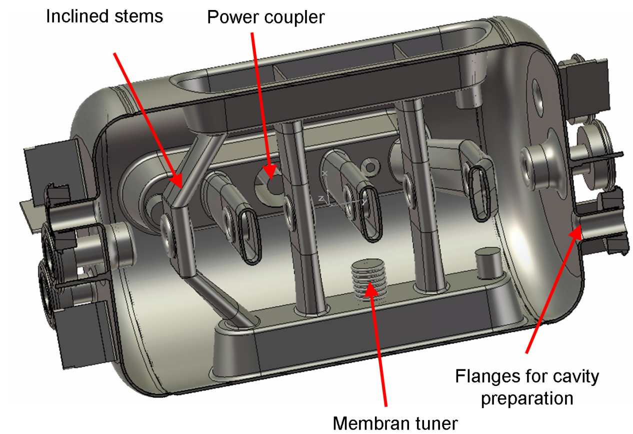

Figure 4: Geometry of the new superconducting 325 MHz CH-cavity.

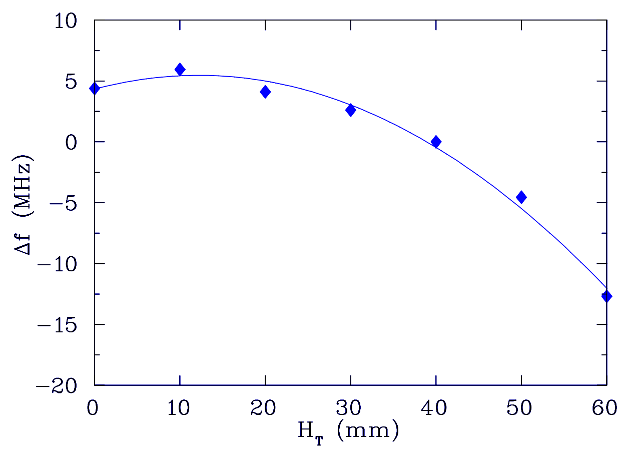

Figure 5: Frequency shift as function of the tuner height using all tuners simultaneously.

Therefore four additional flanges, two located at each end plate are foreseen now to improve the thoroughness of the surface preparation (BCP, HPR).
The cavity has 7 cells and will be operated at 325.224 MHz. The β is 0.1585 which corresponds to 11.4 MeV/u. This gives the possibility to test the cavity with beam at GSI using the UNILAC as an injector. Figure 6 shows the distribution of the electric field along the beam axis. The cavity will be fully equipped with helium vessel and power coupler. It is expected to order the cavity at the end of this year. Table 1 summarizes the parameters of the cavity.

EUROTRANS

EUROTRANS is the EUROpean research program for the TRANSmutation of high level nuclear waste in an accelerator driven system. The driver linac has to deliver a cw 2.5-4 mA, 600 MeV proton beam to a spallation target. In the present reference design a CH-DTL has been proposed. This 17 MV injector consists of a 3 MV 4-vane RFQ, a

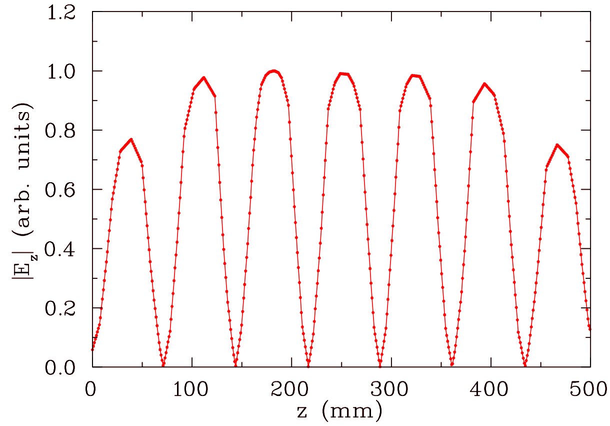

Figure 6: Simulated electric field distribution of the 325 MHz CH-cavity.

Table 1: Parameters of the sc 325 MHz CH-cavity

f (MHz)	325.224
β	0.1585
$L_{\beta\lambda}$ (m)	0.55
Aperture diameter (mm)	30
Accelerating cells	7
Tuner height (mm)	0-60
Tuner diameter (mm)	30/50
E_p/E_a	6
B_p/E_a [mT/(MV/m)]	13
G (Ω)	64
R_a/Q_0 (Ω)	1265
R_aR_s (Ω^2)	80000

room temperature 2 MV CH-cavity and 4 superconducting CH-cavities operated at 352 MHz [4]. Figure 7 shows the schematic layout of the injector. Each superconducting CH-cavity provides about 3 MV effective accelerating voltage. Between the superconducting cavities a sc solenoid for transverse focusing is foreseen. The effective gradient is 4 MV/m which results in modest peak fields. The cavity geometry has been optimized using the ideas which will be realized first in the 325 MHz prototype cavity. This leads to a cost effective and very compact linac design with excellent beam dynamics properties. The simulated emittance growth is only about 10% at a current of 5 mA [4]. Figure 8 shows the geometry of the first superconducting CH-cavity (left) and the simulated field distribution (right).

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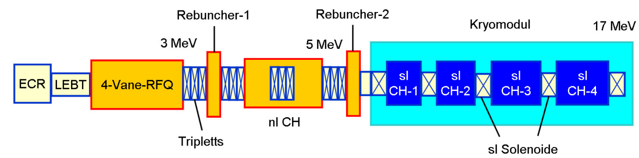

Figure 7: Schematic layout of the proposed 17 MV EUROTRANS injector which consists of a 4-vane RFQ, a room temperature CH-cavity and four superconducting CH-cavities.

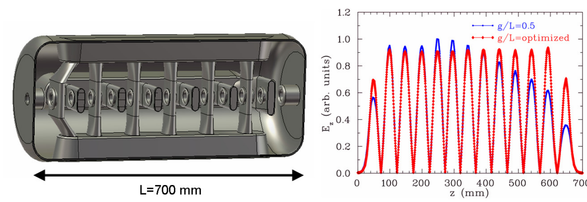

Figure 8: Geometry of the first superconducting CH-cavity for EUROTRANS (left) and the field distribution (right).

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