LOW-BETA SUPERCONDUCTING RF CAVITY TUNE OPTIONS

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Abstract

The main method of the superconducting RF cavity frequency tuning is a resonator wall deformation. Since the highest frequency sensitivity on the geometry change is an accelerating gap variation, the "standard" place of deformation tuning force application in different cavity types are the cavity beam ports.

A series of low-beta cavities (HWR, spoke-type) with different options of tuning has been investigated. Every option is compared with beam port displacement. The problem of resonator frequency shift self-compensation caused by external pressure fluctuations is discussed.

INTRODUCTION

The possibilities to use different options of the cavity tuning beside wall deformations using movable plungers have been already discussed elsewhere [1-2]. These plungers can be installed either in the region of maximal magnetic volume or in electric. By their insertion into the cavity the plungers change the volume occupied by the field. The disadvantages of using such plunger are the low frequency shift like by IPN Orsay magnetic plunger [1] or rather complicated IFMIF electrical plunger design [2]. Here we investigate half-wave resonator (HWR) and spoke cavity tuning by their wall deformations in different places than beam ports.

HALF-WAVE RESONATOR TUNING

To use effectively the outer conductor wall for cavity tune deformations the central part of HWR is made asymmetric with plane surface on one side (Fig. 1). This plane surface is used for deformations.

Figure 1: HWR (β=0.166, 175 MHz) tuning by central part deformation.

To achieve higher tune sensitivity this plane surface can be slightly deformed inwards of the cavity outer

conductor diameter. This shift of the plane wall inside the cavity is characterized by parameter „ddpl". The surface deformation is simulated by a subtraction of ball volume of the radius ball_r. Here „dtune" is a penetration of tune ball inside the cavity beyond plane surface (beyond ddpl). The results of simulations are df/dtune = 50 kHz/mm for ddpl=10 mm and df/dtune = 70 kHz/mm for ddpl=20 mm (Fig. 2).

The plane tune surface is nearly free from RF current (it is similar to the bottom plate in QWR). It means that to minimize microphonics caused by df/dp on this surface one can consider the vacuum on both sides of the tune plate. The cooling of tune plate will be made through helium in the tune stick and through surrounding helium vessel.

Figure 2: HWR (β=0.166, 175 MHz) tune simulation results.

The different option of HWR tune can be considered for the cavity of rather high β=0.53 and frequency 322 MHz.

Figure 3: HWR (β=0.53, 322 MHz) geometry.

The use of HWR with β=0.53 makes accelerating gaps large and cavity short in vertical direction (Fig. 3). These result in the reduction of frequency sensitivity by beam port deformations (zbport) and higher cavity frequency sensitivity on its height (H). Fig. 4 shows the results of cavity frequency dependence on resonator length (df / dH = -1326 kHz/mm) and on the length of the beam port (df /

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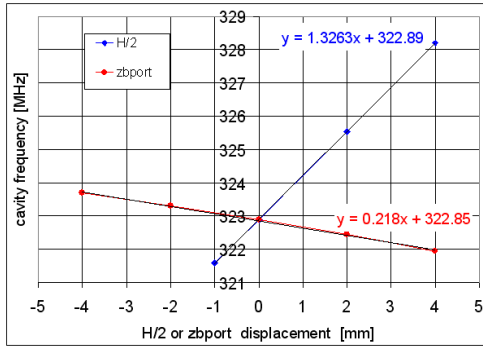d(zbport) = 218 kHz/mm). Here the positive direction of displacements is inwards of the cavity.

Figure 4: HWR (β=0.53, 322 MHz) simulation results.

Since the sensitivity of the cavity frequency to the HWR length is more than 5 times higher to compare with accelerating gap change, there is an idea to investigate the possibility of the cavity tune by deformation of the dome surfaces but not beam ports.

To allow easier deformations of the dome, the dome geometry has been changed from completely round into mainly plane (Fig. 3, ANSYS geometry). The cone region of the central electrode has been replaced by cylindrical. The deformation of dome plate was simulated with the torus subtraction from HWR volume. The result is df / ytune = 536 kHz/mm.
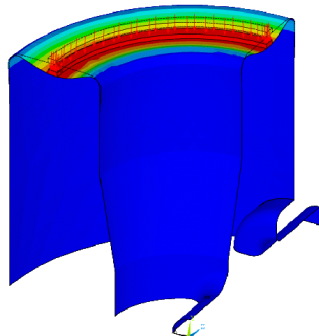
Figure 5: HWR (β=0.53, 322 MHz) dome deformation.

The more realistic simulations of the cavity tune are by the dome region and beam port deformations (Fig. 5).
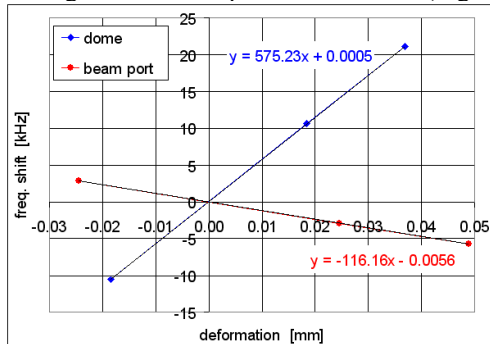
Figure 6: HWR (β=0.53, 322 MHz) tune simulation results.

We applied the tune pressure on the surface of dR = 10 mm wide for dome deformation. It resulted in df / dy = 575 kHz/mm, which is in very good agreement with torus

subtraction simulations). The pressure for beam port deformations was applied on beam pipe aperture. The result is df / dz = -116 kHz/mm (Fig. 6).
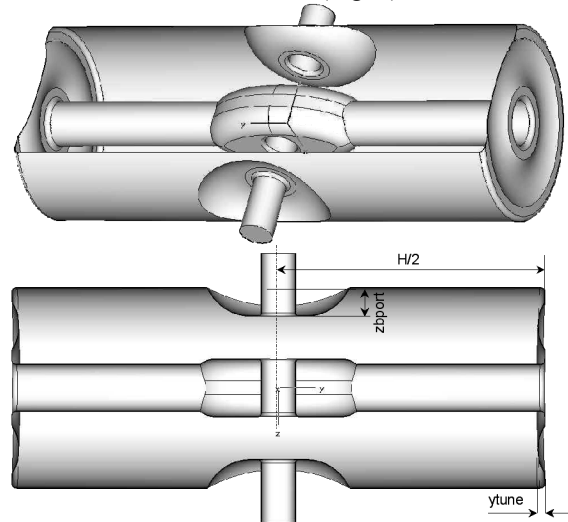
Figure 7: HWR (β=0.166, 175 MHz) tuning by dome deformation.

For HWR with lower β=0.166 and frequency 175 MHz (Fig. 7) the frequency dependence on cavity height and accelerating gap length is about the same (Fig. 8). Still the choice can be made in favour of dome tuning option since it allows saving space between cavities along the beam path.
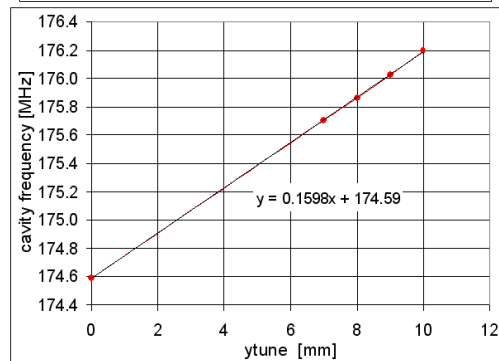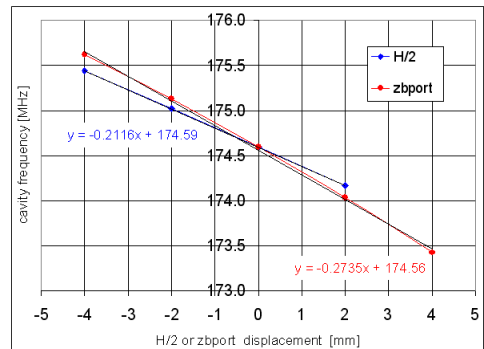

Figure 8: HWR (β=0.166, 175 MHz) tune simulation results.

SPOKE CAVITY TUNING

The tuning method of spoke cavity is the beam port deformation. This changes a cavity capacitance and shifts

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resonance frequency. Since an accelerating gap is the region with the highest electrical field this method results in most effective cavity frequency tune. The frequency shift can be as high as hundreds kHz/mm depending on accelerating gap size. At the same time beam ports are most sensitive places for external pressure or Lorentz force detuning. This forces to stiffen beam ports as much as possible that results in tuning force enhancement. Such contradiction in cavity design can be solved with cavity tuning force applied at the end cup at higher radiuses. This automatically allows the complete beam port stiffening and release additional space between cavities at beam pipe regions. Fig. 10 shows one possible option to stiffen the beam port by ell-ring connected to the helium vessel end flange. The tune force is applied at the end ring.
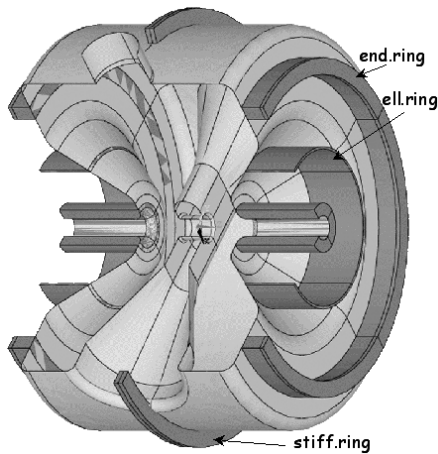
Figure 10: Spoke cavity (325 MHz, β=0.22).

The resulted deformations for the spoke cavity tune are shown on Fig. 11.
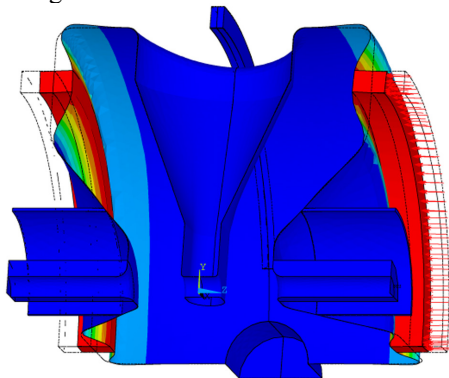
Figure 11: Spoke cavity (325 MHz, β=0.22) tune deformations.

The tune sensitivity of spoke cavity with resonance frequency 325 MHz and β=0.22 is about 320 kHz/mm.

Figs. 12-13 show a spoke cavity (325 MHz and β=0.1) in the helium vessel with the tune sensitivity by end cup deformation of about 1100 kHz/mm.
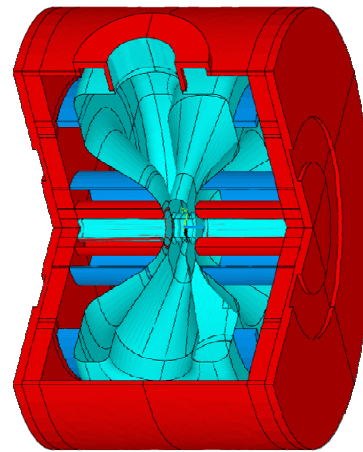

Figure 12: 5-cell cavity with reduced flange thickness region.

For an additional rough cavity frequency adjustment the helium end flange can be used. The flange thickness can be locally reduced for the certain radius range (Fig. 12). Dimensions of the region with reduced thickness should be defined together with the whole cavity-vessel design.
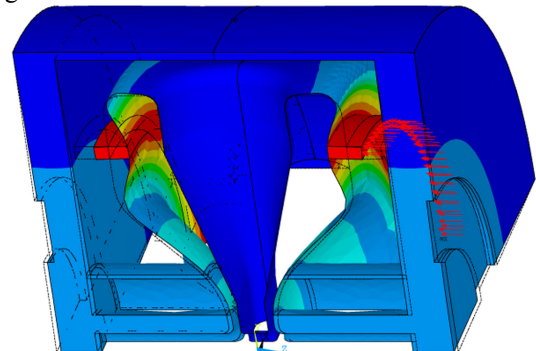

Figure 13: 5-cell cavity with reduced flange thickness region.

Depending on the radius of the cut, the inward force on the cavity walls will be either larger or smaller than the outward force on the end dish. Thus, the cavity will be either shortened or stretched. If to make an initial design with the thickness of this region smaller than it is required, the subsequent bridging of the region with plates of different thickness can provide the final adjustment of the frequency shift. This option can be easily used for subsequent structure adjustment after cavity-vessel fabrication (see also [3].).

REFERENCES

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[3] E. Zaplatin, "Project X Elliptical Cavity Structural Analyses," PAC11, New York, USA, 2011.