NUMERICAL COUPLING ANALYSES OF B*ERL*inPRO SRF GUN*

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Abstract

B*ERL*inPro is an approved ERL project to demonstrate energy recovery at 100 mA beam current by pertaining a high quality beam. These goals place stringent requirements on the SRF cavity (1300 MHz, β=1) for the photoinjector which has to deliver a small emittance 100 mA beam with at least 1.8 MeV kinetic energy while limited by fundamental power coupler performance to about 230 kW forward power.

The gun cavity features 1.4 lambda/2 cell resonator.

We present results of mechanical structure developments of SRF gun. The main purpose of the whole structure optimisation was the design of the gun helium vessel together with the tuner and stiffening rings to provide the simple construction for structure tuning with minimization of the cavity frequency dependence on external pressure. During the resonator tuning and external load structure deformations the cavity field profile variation along the beam path should stay within 5%.

INTRODUCTION

The B*ERL*inPro ERL will be a prototype facility demonstrating energy recovery with a 100 mA beam at 50 MeV beam energy while preserving a normalized emittance of better than 1 mm mrad @77 pC bunch charge at a pulse length of 2 ps or less [1]. SRF guns, which are supposed to be implemented in accelerator design, represent a merging of the well-established normal conducting RF technology and superconductivity, the dissipated RF power is reduced by several orders of magnitude and CW operation for high average currents can be realized. The high beam brightness will be achieved by inserting a high quantum efficiency normal conducting semi-conductor cathode within the SC environment of the cavity.

The final RF and beam dynamics gun cavity investigations feature 1.4λ/2 cell resonator (1300 MHz, β=1, Fig. 1). In this paper we describe only the results of the mechanic design of the cavity together with liquid helium vessel using an RF optimised geometry published elsewhere [2]. HZB B*ERL*inPRO SRF gun cathode insert design based on geometry of Forschungszentrum Dresden-Rossendorf [3]. Since this SRF gun is under operation for already several years, an evaluation of its structural properties was taken into account as the basis for the most optimal B*ERL*inPRO SRF gun mechanical design.

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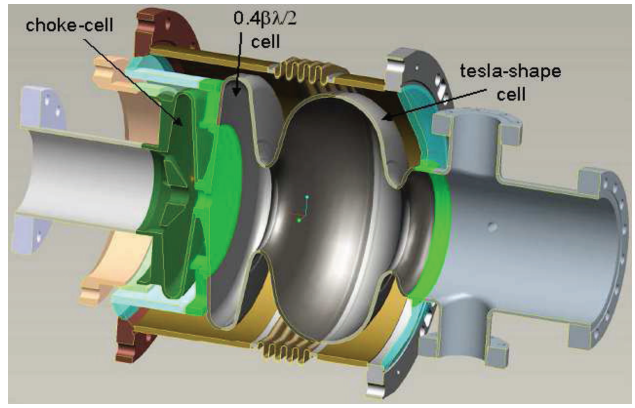

Figure 1: Schematic view of HZB B*ERL*inPRO SRF gun cavity in helium vessel.

A sequential coupled field analysis (RF/Structural/RF) is used to predict the frequency shift due to cavity deformations using the ANSYS codes. The same meshed model was used for all types of simulations. Such procedure together with ability to exchange the results between different types of simulations allows getting the highest simulation accuracy to be obtained.

GUN CAVITY INVESTIGATIONS

The main concern by the gun cavity mechanical design is to keep an accelerating field distribution along the beam path unchanged. The possible reasons of this field profile change can be any deformations caused by external loads applied to the structure like helium pressure or resonator tuning. To start investigating field profile variation against these external loads the simulation model was limited by only half-cell, TESLA-cell and beam pipe (Fig. 2).

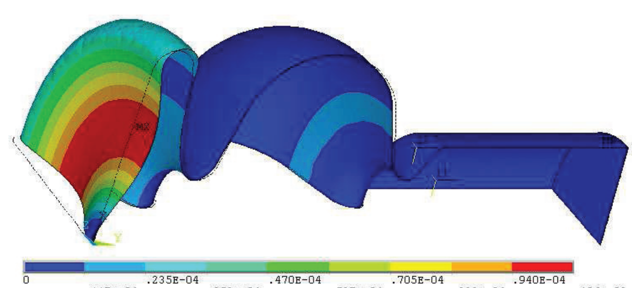

Figure 2: Cavity deformations under 1 bar external pressure.

According to numerical simulations the resonator tuning sensitivity is about 1.6 MHz/mm that requires tuning force of 800 N/mm at the cavity project wall thickness 3 mm. For these simulations initial field profile in 0.4-cell is 2% lower than in TESLA cell. By tuning this cavity applying a force at the beam pipe a field profile changes by 2% at 0.049 mm beam pipe shift.

GUN CAVITY WITH CHOKE STRUCTURE IN HELIUM VESSEL

The complete gun structure for the mechanical simulations includes TESLA-shape main cell, 0.4 $\beta\lambda/2$ cell and cathode-choke model situated in helium vessel. Fig.3 shows geometry of HZB B*ERL*inPRO SRF gun simulation model and its mechanical constraints.

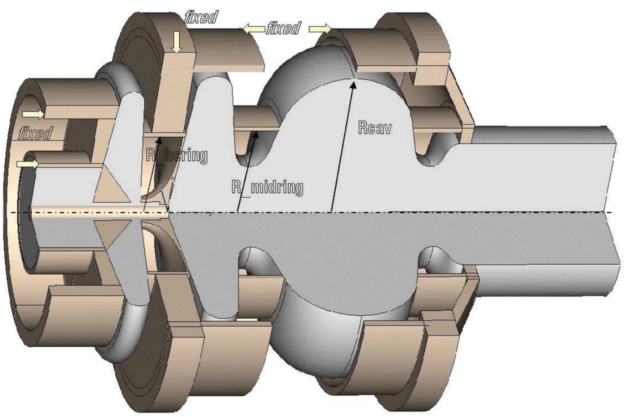

Figure 3: SRF gun simulation model.

A cavity frequency shift is defined mainly by the deformation of the half-cell walls, especially by the right wall at the side of mid-cell. The other wall is well stiffened by the half-cell ring and rigid iris geometry.

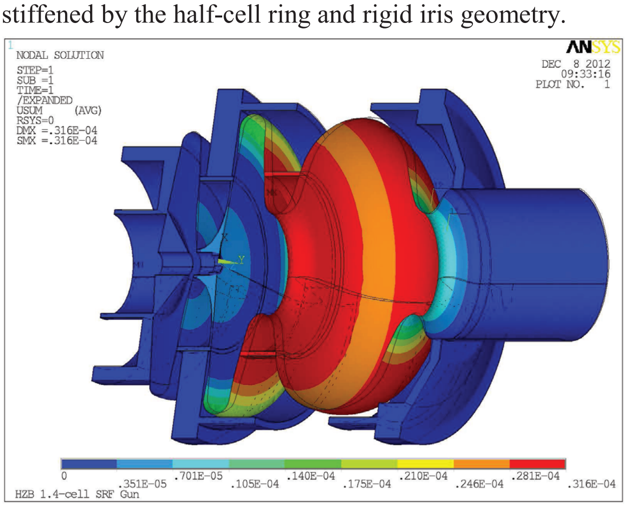

Figure 4: Deformations of gun cavity and choke structure in helium vessel under 1 bar external pressure.

The change of the magnetic field prevails an electric field change that results in the positive sign of the frequency shift. An installation of the mid-ring results in the lower half-cell deformation and, what is more important, much bigger additional deformation of the mid-cell (Fig. 4). The net effect results in the bigger system capacitance that reduces the frequency shift (Fig. 5). An additional end-cell ring works in the opposite direction reducing deformations of mid-cell, which results in the frequency shift increase. Using mid-ring together with half-cell ring allows reaching the compensation effect of frequency shift caused by electric and magnetic field change. An electrical accelerating field distribution along the structure axes (beam path) was changed within 1% after 1 bar external pressure application.

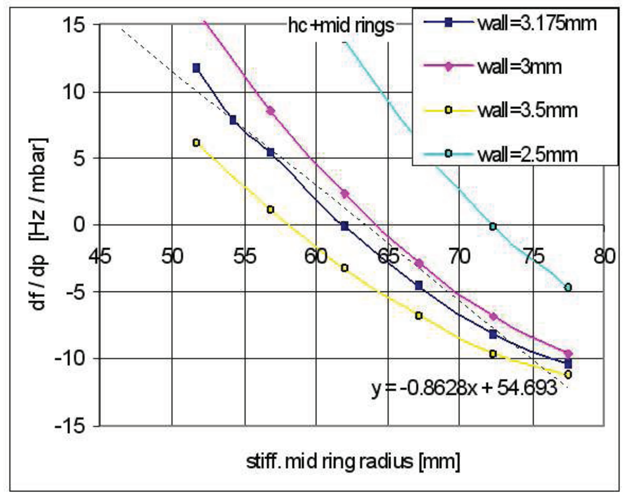

Figure 5: Simulation results of gun cavity and choke structure frequency shift under 1 bar external pressure depending on resonator mid-ring position.

The ring position dependence on the cavity wall thickness (Fig. 6, Table 1) is about (-1.09 Hz/mbar/0.1mm).

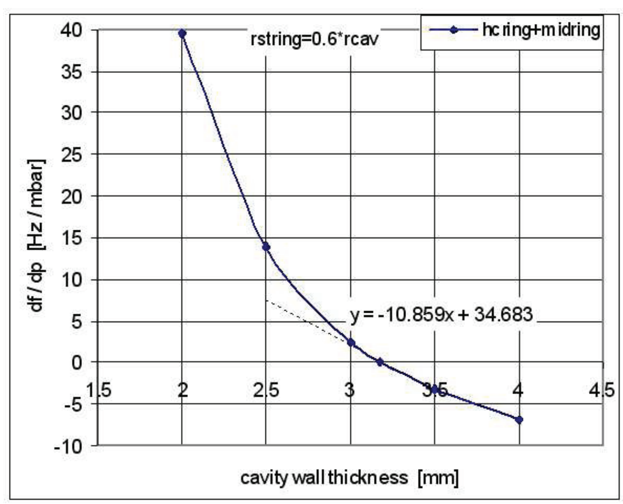

Figure 6: Simulation results of gun cavity and choke structure frequency shift under 1 bar external pressure depending on resonator wall thickness.

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Table 1: Gun Cavity Simulation Results

df/dp vs wall thickness	-1.09	Hz/mbar/0.1mm
df/dp vs mid-ring position	-0.86	Hz/mbar/mm

The coaxial tuner that should be installed around the helium vessel is supposed to be implemented to provide the structure tuning. The gap in the outer cylinder of the helium vessel is simulating the slot of the tuner. In the simulation model the tuning force is applied at one side of the tuning slot keeping the other fixed. Different from the 1 bar deformations the tuning deformations are mainly related to the TESLA cell. The required tuning force is about 7.5 kN/mm at 3 mm cavity wall thickness (Fig. 7).

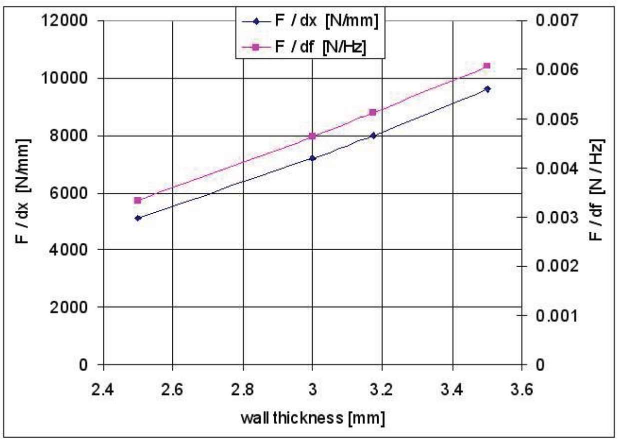

Figure 7: Tuning simulation results of gun cavity and choke structure in helium vessel.

The tuning simulations with variation of the tuning force were provided to control the field profile dependence during tuning (Fig. 8). According these simulations the tuning force of 1 kN is required for about 200 kHz frequency shift with the field profile change of about 3%.

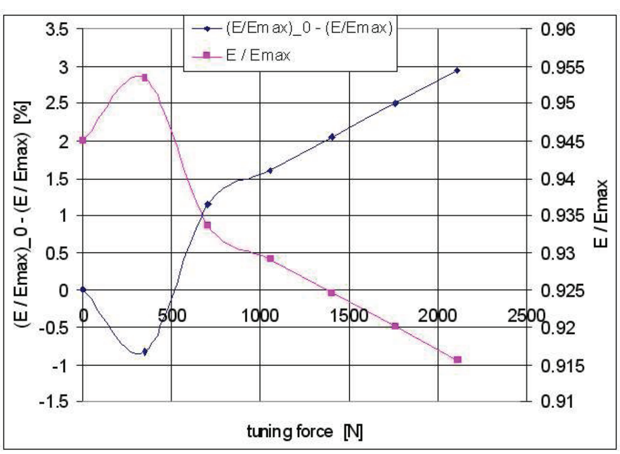

Figure 8: Electrical field profile change by gun cavity tuning.

There is a possibility to omit the mid-cell stiffening ring. An idea is to make half-cell wall as thin as the other cavity walls to ensure bigger its flexibility. This wall will be deformed inwards of the half-cell volume changing stored electrical field energy providing the compensation of the magnetic field energy change resulting in the df/dp=0. The other requirement that should be fulfilled for this region design is a well-constrained half-cell iris providing a permanent cathode position relative to half-cell. This requirement is satisfied by the compensation of the possible half-cell iris displacements by the pressure applied at the choke-cell walls (Fig 9).

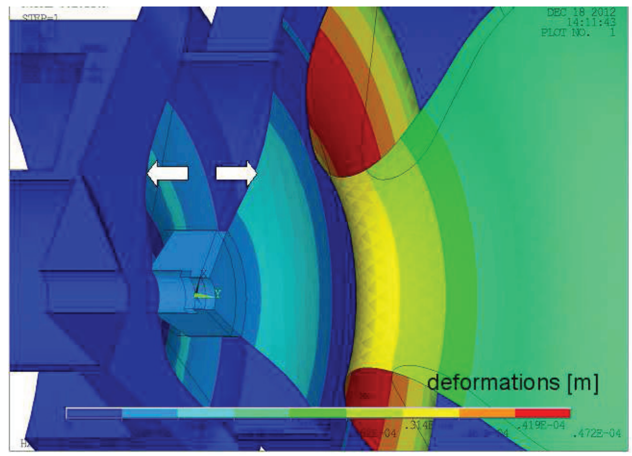

Figure 9: Deformations of gun cavity and choke structure without mid-cell ring in helium vessel under 1 bar external pressure.

CONCLUSIONS

HZB B*ERL*inPRO SRF gun cavity mechanical design was investigated to keep an accelerating field distribution along the beam path unchanged. The final structure should provide an electrical field profile change within 3% caused by the cavity tuning or unstable helium pressure. Several options of the resonator stiffening schemes can provide the balance of electrical and magnetic energy change securing the minimal sensitivity of the resonant frequency to fluctuations in helium pressure and to ensure that the slow tuner providing the target tuning range.

REFERENCES

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