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FREQUENCY TUNING SYSTEM BASED ON MOBILE PLUNGERS FOR SUPERCONDUCTIVE COAXIAL HALF WAVE RESONATORS

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Abstract

The design of a prototype of the frequency tuning system (FTS) for superconductive coaxial half wave resonators (HWR) developed for the Nuclotron-based Ion Collider fAcility (NICA) injector is presented. The proposed system is based on mobile plungers placed in the technological holes in the end caps of the resonator. The FTS allows controlling the penetration depth of plungers, which is monotonically related to the resonant frequency shift of the cavity. The results of numerical simulations of the resonant frequency for a wide range of plunger parameters are presented and discussed. The most important parameters for effective frequency shift are estimated.

INTRODUCTION

The present communication is devoted to aspects of Frequency tuning system (FTS) design for half wave coaxial superconductive cavities, which are developed for the Nuclotron-based Ion Collider fAcility (NICA) injector. These cavities comprise the $\beta = 0.21$ accelerating section [1] and are operating at frequency 324 MHz. The model of the HWR is presented in Fig. 1.

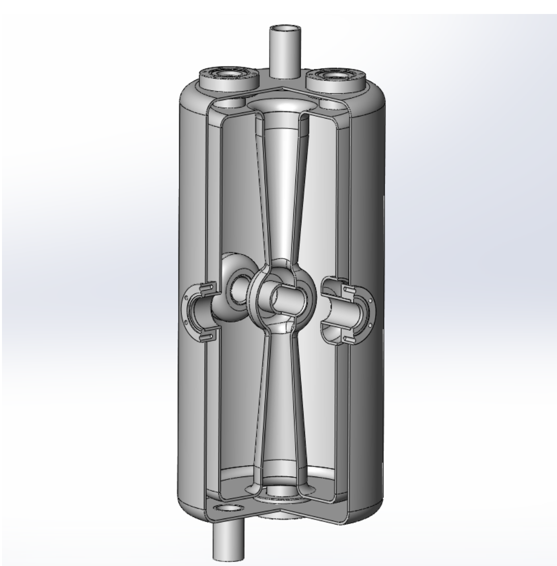

Figure 1: 324 MHz HWR cavity model.

The cavity in Fig. 1 was designed in a classical coaxial half-wave configuration [2, 3]. In the middle of the cylinder resonant cavity in the opposite sides there are locating 2 beam ports, input power, and antenna ports. At the end cups of the resonator, there are 4 technological holes of diameter $D = 30$ mm used for the chemical polishing of the internal surface of the cavity during the manufacturing process.

Frequency tuning system (FTS) is an important and essential part of the design of superconductive cavities used for particles acceleration. It should contain slow and fast tuners and operate at cryogenic conditions. The slow tuner subsystem is necessary due to the complexity of the HWR manufacturing process. Additionally, the slow tuner allows compensating the changes of HWR properties after cooling down and vacuuming. The fast tuner subsystem is used to minimize effects related to microphonics, helium fluctuations, Lorentz force etc.

The real-time frequency tuning and control may be organized in different ways. The most common and popular principles are:

(a) elastic mechanical deformation of cavity [4]. Applying mechanical force to the beam ports it is possible to change their distance to the central inner conductor and correspondingly shift the resonant frequency of the cavity.

(b) the mobile plunger in the electric field region [5]. The main part of this type of FTS is the capacitive plunger located in the electric field region of the HWR, usually perpendicular to the beam axis.

(c) the mobile plunger in the magnetic field region. This type of FTS was realized in practice for tuning of quarter wave resonator [6].

Traditionally the principle (a) is used for frequency tuning of HWR. The disadvantage of this type of FTS is the complexity of the design because FTS must operate in ultrahigh vacuum conditions, at a temperature near to 4.2K and effectively provide fast and slow tuning frequency. In the present communication, we propose to apply the concept (c) for the case of the coaxial half wave cavities and estimate the most important parameters for effective HWR frequency tuning.

FTS DESCRIPTION

The technological holes in the end caps of the resonator are used for effective chemical polishing of the internal niobium surface. After the polishing process, they are closed

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for further operation in vacuum. We propose to use them for HWR resonant frequency control by placing mobile plungers inside. By varying of plungers penetration depth inside the cavity volume it is possible to change the effective distance between HWR end caps and themselves tune the frequency. Due to symmetry reasons, we start with 2-plungers FTS configuration presented in Fig. 2.

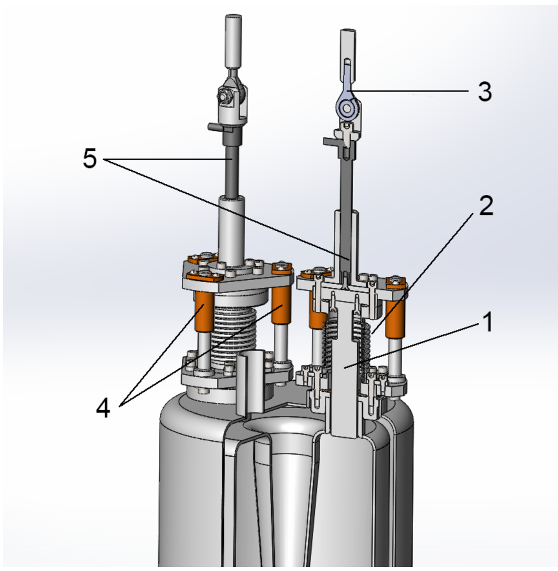

Figure 2: Concept of the Frequency tuning system based on mobile plungers in the end cups holes of HWR.

In Fig. 2 the plungers (1) are fixed on flexible bellows (2), which can be deformed by applying force from motor outside the cryostat using a system of levers (3). Due to three cylindrical guides (4), the possible movement of the bellows and plungers is limited only by the direction along its axis.

Fast frequency tuning works in series to the slow one and realized by using piezoactuators (5) suitable for operation in UHV conditions and cryogenic temperatures. The piezoactuators are installed on the bellow end flange, so its force is directly applied to the plunger. The similar configuration was used in [7] for frequency tuning of **Tesla-type cavities**.

THE ELECTROMAGNETIC RESPONSE SIMULATION

The HWR electromagnetic response simulation was carried out using CST Studio Suite 2016. The two-port configuration was chosen. The ports were located at the end of input power pipe and the antenna pipe. Inside of input power and antenna pipes were placed central conductors (Fig. 3) with diameter, corresponding to 50 Ohm characteristic impedance.

In considered FTS the most important parameters affecting the resonant frequency are plunger diameter D, plunger edge rounding radius r, and plunger penetration depth beyond the face plane ΔL (Fig. 4). Preliminary calculations immediately showed that the frequency is practically independent of the rounding radius r. In all presented below simulation results, the parameter r was taken equal to 0.1 mm.

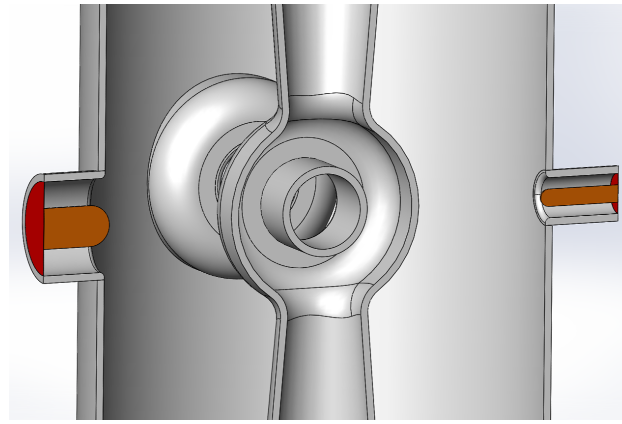

Figure 3: The two-port configuration for HWR electromagnetic response simulation.

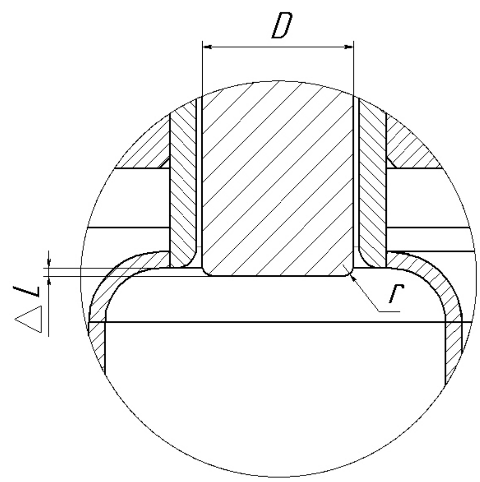

Figure 4: The most important parameters of FTS plungers.

Results of typical simulation of the amplitude of transmitted trough HWR signal S_{21} without plungers (dashed line) and with plungers of diameter $D = 29.6$ mm and various penetration depth ΔL (solid lines) are presented in Fig. 5.

From Fig. 5 we can clearly see the monotonic dependence of resonant frequency on plungers penetration depth. In case of Fig. 5, the frequency sensitivity is equal to $\Delta\nu/\Delta L \approx +24$ kHz/mm.

Another important parameter of plungers is their diameter D. Results of simulation of S_{21} with plungers of fixed length and varied diameter are similar to in Fig. 5. Generally, the increase of D leads to increase of resonant frequency.

To obtain a general overview we varied ΔL in the range from -3 to 4 mm and D in the range from 8 to 30 mm and calculated resonant frequency. The results are presented in Fig. 6.

Thus, the analysis of Figs. 5-6 shows that the use of two plungers allows to monotonously changing the frequency

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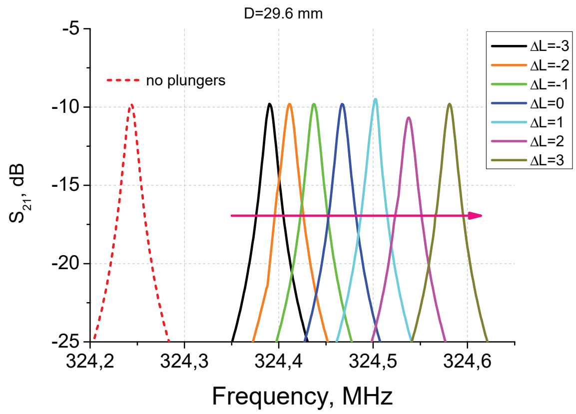

Figure 5: The simulated frequency dependencies of S_{21} of HWR without plungers (dashed line) and with plungers of diameter D = 29.6 mm and various penetration depth ΔL (solid lines).

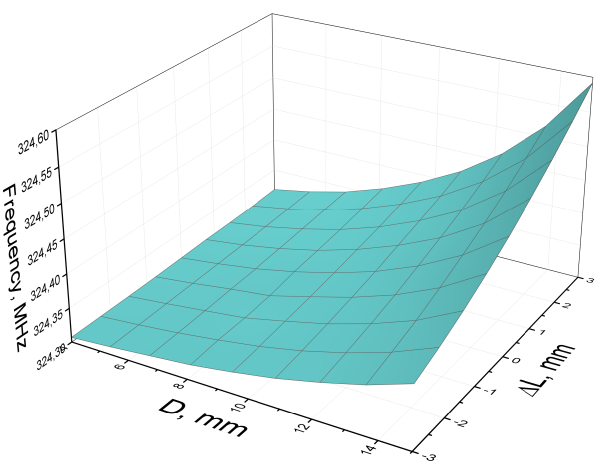

Figure 6: The dependence of resonant frequency on plunger diameter D and penetration depth ΔL.

of the HWR by changing their penetration depth for a wide range of plunger diameters.

CONCLUSIONS

The developed FTS includes slow/fast tuner parts and is more compact and simple in comparison to traditional mechanical systems, which deform reversibly the HWR by applying the force on the beam ports. The numerical simulation of FTS with a wide range of parameters shows monotonous dependence of the resonant frequency of the HWR on plungers penetration depth. The proposed concept will be proved during the manufacturing process of niobium HWR cavities [1] for NICA project.

ACKNOWLEDGEMENTS

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