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DESIGN AND CHARACTERISTICS OF CRYOSTAT FOR TESTING OF LOW-BETA 325 MHz HALF-WAVE RESONATORS

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Abstract

Design of the cryomodule prototype for testing low-beta 325 MHz half-wave cavities is currently in the process at INP BSU. The cryomodule allows performing intermediate vacuum-, temperature-, and rf-tests during the fabrication of half-wave resonators. The first experimental results of cryomodule cooling down to liquid nitrogen temperatures are presented and discussed. The pressure and temperature control allows us to estimate the main cooling/heating characteristics of the cryostat at different operation stages. The presented test cryomodule will be used for further development and production of superconductive niobium cavities for the Nuclotron-based Ion Collider fAcility (NICA) injector.

INTRODUCTION

The first stages of the fabrication process and properties control of superconductive cavities for high energy particle acceleration are performed at room temperature. The intermediate rf-measurements allow to control of the resonant frequency during initial "warm" tests [1]. Since the niobium-based cavities operate at liquid helium temperatures their resonant frequency significantly differs from intermediate room temperature measurements. The complexity of the half-wave resonators(HWR) geometry and a large number of welds make it difficult to estimate the shrinkage and frequency shift when the resonators are cooled to cryogenic temperatures.

The difference between the cavity's resonant frequency at room and at cryogenic temperatures is one of the most important experimental parameters related to the fabrication of resonators. To determine this parameter, it is necessary to develop a test cryostat that provides temperature and vacuum conditions close to the operational characteristics in the particle accelerator.

The test cryostats are widely used for research purposes in the manufacture of resonators [2, 3]. The present communication is devoted to the cryostat design for testing of low-beta 325 MHz half-wave resonators. In the next sections, we will discuss the main features of the cryostat design and the most important results obtained from a preliminary experiment on cooling to liquid nitrogen temperature.

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TEST CRYOSTAT DESIGN

The test cryomodule should be designed to effectively perform intermediate vacuum-, temperature- and rf-tests of HWR. Additionally, the geometrical parameters of the cryostat should provide enough space to test different types of frequency tuning systems and other support devices like power coupler, field probe antenna, etc.

The proposed concept of test cryostat consists of standard cryogenic parts [4, 5] including stainless vacuum chamber, liquid nitrogen (LN_2) inputs, liquid helium (LHe) inputs, rf inputs for cavity electromagnetic response measurements, LN_2 shield, etc. The model of the cryostat with a cavity inside is presented in Fig.1 (a-b).

In Fig.1(b) the vacuum chamber providing a protective vacuum (residual pressure ~ 10^{-6} bar) around the resonator. The main heat flux from the environment is screened by a LN_2 shield. It is cooled by a liquid nitrogen subsystem (blue pipes in Fig.1(b)). The integrated helium vessel of HWR is connected to the liquid helium subsystem (yellow pipes in Fig.1(b)). The cavity is mounted inside the cryomodule using two thin stainless steel spokes that are attached to the top cover of the cryostat. The spokes pass through the nitrogen shield and have good thermal contact with it.

The proposed system has an inner length $L = 830$ mm and an inner diameter of $D = 890$ mm. The peripheral devices (power coupler, frequency tuning system, etc.) can also be partially located in the additional volume of the side pipes.

In Fig.2 (a,b) are presented fabricated cryostat and thermal LN_2 shield inside them.

LN_2 shield was fabricated from 3mm thick aluminium type AMc. The copper pipe of the LN_2 system was brazed to the cylindrical part of the LN_2 shield to provide good thermal contact. The outer surface of the LN_2 shield was covered by multilayered thermal isolation. The shape of the copper pipe of the LN_2 system provides gaseous nitrogen to the area of cryogenic inputs on the top of the cryomodule. Vacuum, rf, and electrical inputs are located on the right side of the cryostat.

In the next section, we present the first experimental results of cryostat temperature and pressure tests.

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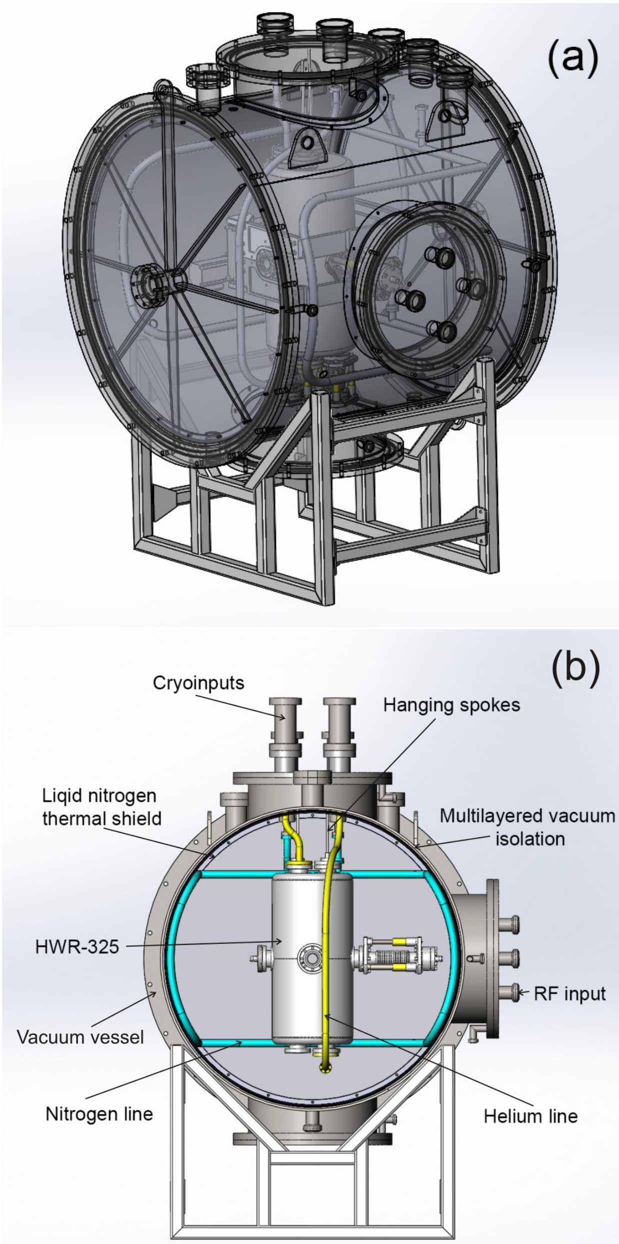

Figure 1: (a) The sketch of test cryostat model with a cavity inside, (b) the main parts and subsystems of the cryostat.

Figure 2: (a) Fabricated test cryostat, (b) the liquid nitrogen shield.

THE EXPERIMENTAL CHARACTERISTICS OF TEST CRYOSTAT

The initial experiments of cryostat temperature and pressure tests were performed without a cavity inside. In the center of the cryostat was placed the platinum resistance thermocouple. The data from this sensor was automatically saved every 3 seconds. Agilent TPS-Compact vacuum system was used for pumping out and pressure control.

The minimal achieved residual pressure inside cryostat at "warm" tests at room temperature was about $5.2 \cdot 10^{-2}$ Pa. The cooling down by adding liquid nitrogen makes it possible to reduce the residual pressure by two orders of magnitude. The minimal residual pressure achieved at temperature below 150 K was about $2.5 \cdot 10^{-4}$ Pa.

Figure 3 is presented the time dependence of temperature in the center of the cryomodule during the first LN_2 tests.

The first experiment began with evacuating air from the cryostat to the fore-vacuum level. After about 2 hours the pressure was about 0.2 Pa and liquid nitrogen began to flow smoothly into the LN_2 system. The intensive cooling at a maximal rate of about 1 degree per minute lasted for about 10 hours. Then the cooling rate was significantly slowed down. The minimal temperature achieved at first tests was -173°C. After about 18 hours the pumps and LN_2 input were

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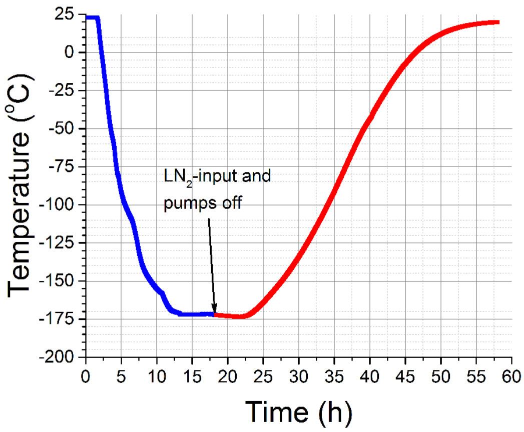

Figure 3: The time dependence of temperature in the center of the cryomodule during the first LN_2 tests.

turned off and the system began to heat up. The heating rate at the middle linear segment was about 0.15 degrees per minute. Heating time to room temperature was about 43 hours. The pressure with the pumps turned off rose to a level of about 0.3 Pa.

The minimal achieved temperature was about 22 degrees above the boiling point of liquid nitrogen. The cooling has slowed down at this point most probably due to some spaces in the multilayered insulation in the area of the end caps of the LN_2 shield. The effectiveness of the multilayer insulation, as well as their effective thermal contact with a cylindrical part, will be verified during the next tests experimentally and numerically.

CONCLUSIONS

The design of the cryostat for testing low-beta 325 MHz half-wave cavities is presented. During the first LN_2 experiments the minimal pressure $P = 2.5 \cdot 10^{-4}$ Pa and temperature $T = 173$°C in the center of cryostat were achieved after about 15 hours of cooling down. During the next steps, additional temperature sensors will be added to separate temperature control of the LN_2 shield. Also, the effectiveness of the multilayered insulation will be revised to decrease the minimal achieved temperature T. After that, the cryostat will be used for intermediate tests on the Nb prototype of HWR-325. Then the liquid helium subsystem will be developed and integrated inside. The presented results will be used for the further development and manufacturing of niobium cavities for the NICA project.

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REFERENCES

[1] D. Bychanok, *et al.*, ”Control of elec-tromagnetic properties during prototyping, fabrication and operation of low-beta 325 MHz half-wave resonators”, *J. Phys. D: Appl. Phys.*, 54(25), 255502, 2021, doi:10.1088/1361-6463/abf168.

[2] A. I. Sukhanov *et al.*, “Upgrade of the Fermilab Spoke Test Cryostat for Testing of PIP-II 650 MHz 5-Cell Elliptical Cavities”, in *Proc. 19th Int. Conf. RF Superconductivity (SRF'19)*, Dresden, Germany, Jun.-Jul. 2019, pp. 1124–1128. doi:10.18429/JACoW-SRF2019-THP091

[3] J.-L. Biarrotte, S. Blivet, S. Bousson, T. Junquera, G. Olry, and H. Saugnac, “Design Study of a 176 MHz SRF Half Wave Resonator for the SPIRAL-2 Project”, in *Proc. 11th Workshop RF Superconductivity (SRF'03)*, Lübeck, Germany, Sep. 2003, paper TUP02, pp. 269–273.

[4] Balshaw, N. ”Practical cryogenics and introduction to laboratory cryogenics.” 1996.

[5] J. G. Weisend II ”Cryostat Design”, Springer, 2016.