DUBNA-MINSK ACTIVITY ON THE DEVELOPMENT OF 1.3 GHZ SUPERCONDUCTING SINGLE-CELL RF-CAVITY

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Abstract

In 2011 Dubna-Minsk collaboration started an activity on the development and manufacture the series of superconducting niobium cavities in the enterprises of Belarus. First results of this work are presented.

Simulation code for calculation of EM characteristics, the synthesis of geometric dimensions and profile of SC niobium RF-cavity with the ability to find and research the higher order oscillations modes is developed. The calculations of single-cell and 9-cell cavity were made: the ratio of the maximum electric field on the cavity axis to an average accelerating field is 2 within 1%; a geometric factor equal to 283 Ohm.

Half-cells will be made by hydraulic deep drawing and welded by electron-beam. Stamping tool for hydraulic deep drawing and technological tools for probing and perfection of modes of EBW of two half-cells is designed and is in production. Mechanical properties of niobium and model material (Cu, Al) were investigated.

Cryogenic system for low temperature RF tests of SC single-cell cavity is manufactured and successfully tested at 4.2 K.

Coupling device for RF measurement is developed and manufactured – measured standing wave ratio is 1.01-1.07. Warm RF tests with etalon single-cell cavity unit were made using 3 different equipment sets and results are consistent with each other: fundamental frequency – 1.273 GHz, quality factor (warm) – $28 \cdot 10^3$.

INTRODUCTION

Since 2007 Joint Institute for Nuclear Researches officially jointed to ILC project and proposed Dubna area as a site for ILC accelerator [1]. The key technology of ILC accelerator is using of superconducting RF cavities for acceleration of electrons and positrons. R&D for superconducting radiofrequency technology is a high-priority and global technical challenge for the ILC and leading accelerators centers involved in this activity.

Nowadays in frame of ILC project several tasks are fulfilled in JINR laboratories and one of them is aimed at the creation of the series of superconducting niobium cavities in collaboration with the leading research centers in Republic of Belarus. First Dubna-Minsk superconducting 1.3 GHz single-cell niobium cavities will be manufactured in Minsk by 2015. After the tests in Minsk and Dubna these cavities will be presented to international ILC community for expertise.

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COMPUTER SIMULATIONS

Group of specialists from Belarus State University of Informatics and Radioelectronics has developed a program complex CEDR [2] for simulations and optimization of electrodynamic processes in non-regular RF systems including ohmic losses in the surface. Developed simulation code allows finding all the electromagnetic characteristics of the single-cell and multi-cell RF cavity, its optimal geometry and dimensions.

Table 1: Calculated EM characteristics of the cavity

Parameter	ILC requirements	BSUIR results
f_0	1.3 GHz	1.3 GHz
E_{peak}/E_{acc}	2	2.026
B_{peak}/E_{acc}	4.26 mT/MV·m	4.731 mT/MV·m
G	270 Ω	283 Ω
k_{sell}	1.87 %	1.94 %

RF-calculations of the main electromagnetic characteristics of a single-cell and a nine-cell cavity were made and higher order oscillation modes were investigated [3-5]. Basing on the results of calculations we find the optimal shape of the cavity which provides maximum accelerating gradient on the cavity axis with minimal electric and magnetic field on the surface. Results of these computer simulations in comparison with ILC requirements [6] are presented in Table 1. As a result of simulation the conceptual draw of half-cell – the base detail for cavity manufacturing was made (Fig.1).

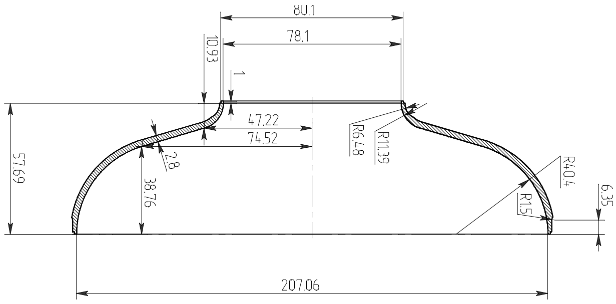

Figure 1: Conceptual draw of the half-cell.

CAVITY MANUFACTURING

Manufacturing of the half-cells will be made by the hydraulic punch-free deep drawing. Schematically this method is shown on Fig.2. Using of liquid instead of standart solid die stamping allowed avoiding the possible damage of the cavity shape. Specialists from PhTI NAS of Belarus have a reach experience in this deal. Nowadays stamping tool for hydraulic deep drawing is developed and is in production.

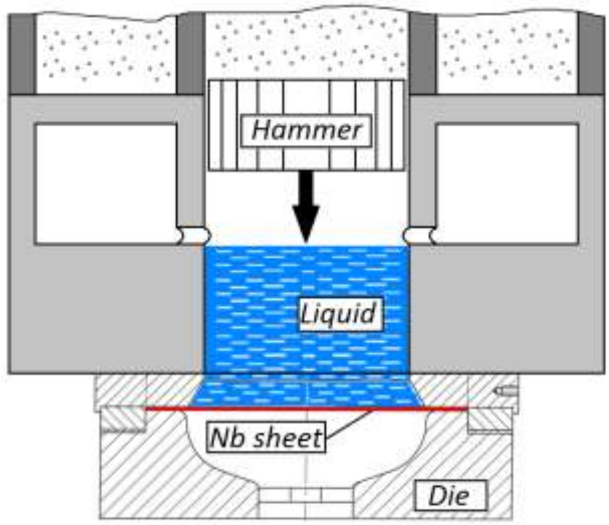

Figure 2: Scheme of hydraulic deep drawing.

We investigate the possibility of using of Russian and Kazakhstan niobium material for cavity manufacturing and find that this material does not meet the requirements for superconducting cavities: measured value of *RRR* was 40 for samples from Russia and 60 for samples from Kazakhstan. So we resolve to use an approved Nb manufacturer from China with *RRR* > 300. Also we made a research of mechanical properties of niobium material and model materials (Cu, Al) were made to investigate their drawability (Table 2, Fig.3).

Table 2: Mechanical properties of Nb, Cu and Al

Material	**Tensile Strength, N/mm^2**	**Yield Strength, N/mm^2**	**Elongation, %**
Al	119 117	40-50	38.7 33.5
Cu	219 220	70-80	55 57
Nb	168 164	70-80	55 58

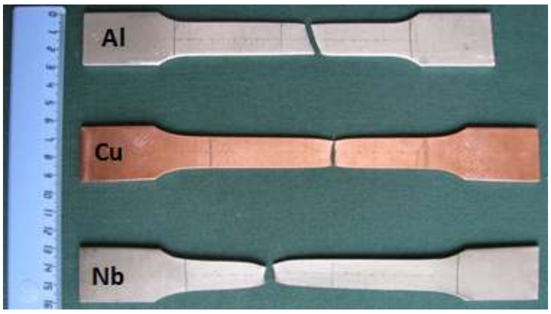

Figure 3: Nb, Cu and Al samples after tension test.

PhTI has all necessary equipment for hydraulic deep-drawing of half-cells, electron-beam welding and developed infrastructure for chemical processing of the materials, equipment for x-ray photoelectron spectroscopy and deionizer to obtain ultrapure water for cavity rinsing on different stages of the manufacturing. EBW setup (Fig.4) consists of vacuum chamber (ø1350×2500 mm), vacuum pumps and electron gun which provide the power of 15 kW with 250 mA current and 60 keV electron energy.

Figure 4: Equipment for electron-beam welding.

Using of EBW technics allows obtaining a deep narrow weld with low impurity contamination. Technological tool for probing and perfection of modes of electron-beam welding of two half-cells is designed (Fig.5) and is in production.

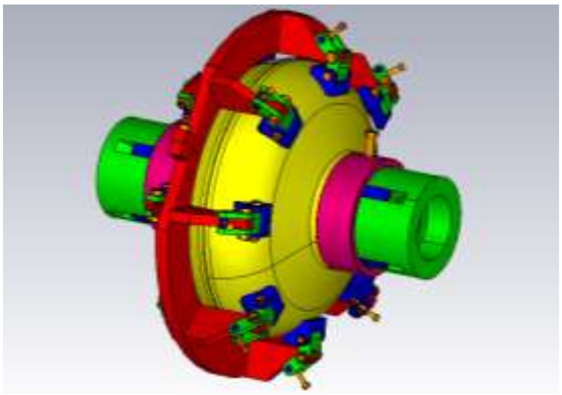

Figure 5: Design of EBW tool.

STANDS FOR RF MEASUREMENTS

RF stand for cavity characteristics measurements at room temperature at a power level of 100 mW is created in INP BSU. Coupling device with Q of about 10^6 for RF measurement is developed and manufactured – measured standing wave ratio is 1.01-1.07. The shop-draw of the coupling device is shown on Fig.6.

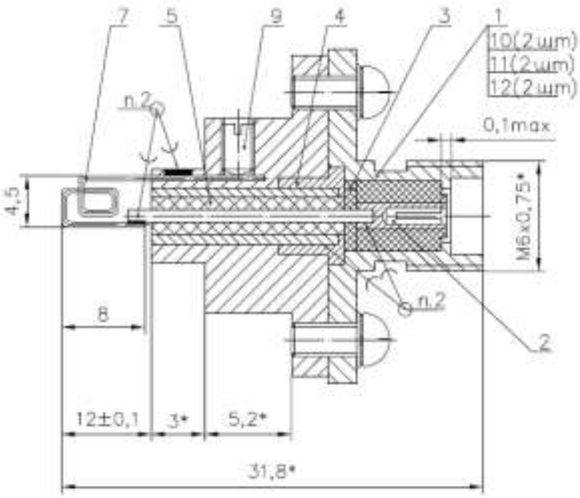

Figure 6: Shop draw of coupling device.

Warm RF tests with etalon cavity unit from FNAL were made using 3 different equipment sets and results are consistent with each other: fundamental frequency – 1.273 GHz, quality factor (warm) – 28193. On Fig.7 the room-temperature RF stand and the FNAL niobium cavity during the tests are shown.

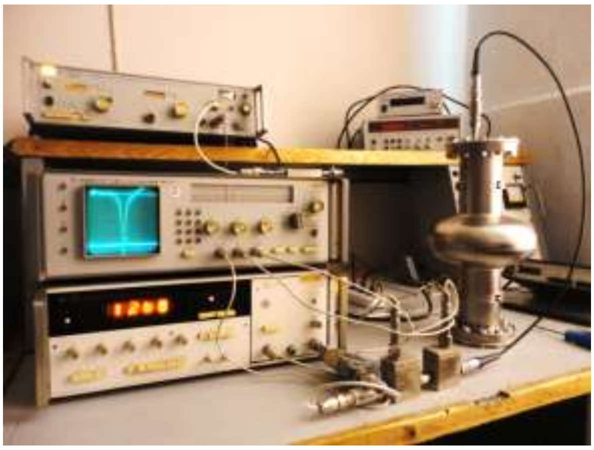

Figure 7: Room-temperature measurements of etalon cavity unit.

Stand for RF tests at liquid helium temperature is under construction. Cryogenic setup is manufactured and successfully tested at operation temperature 4.2 K. Parameters of cryogenic setup are presented in Table 3. Scheme of the stand for RF tests of the cavity at liquid helium temperature and photo of the helium dewar are shown on Fig.8.

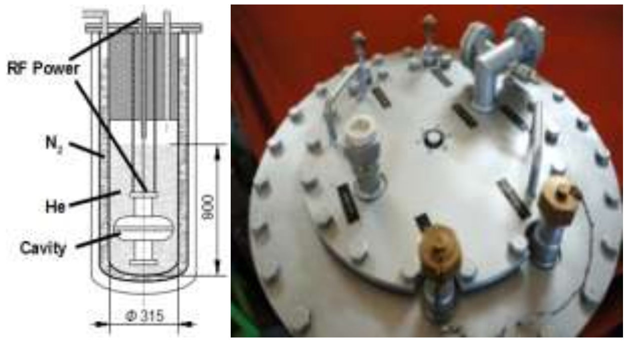

Figure 8: Scheme of the low-temperature RF stand and photo of the dewar.

Table 3: Parameters of cryogenic setup

Parameter	Value
Operating temperature	4.2 K
Helium vessel volume	70 l
Nitrogen vessel volume	25 l
Helium evaporating rate	0.65 l/h
Nitrogen evaporating rate	1.25 l/h

Low temperature RF tests of the etalon cavity we will start in nearest future.

ACKNOWLEDGMENT

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