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 in Belarus. First results of this work are presented.

Simulation code was developed to compute EM characteristics, and to calculate the shape and geometric dimensions of SC niobium RF-cavity taking into account higher order oscillations modes. The calculations of a single-cell and 9-cell cavity were made: the found ratio of the maximum electric field on the cavity axis to an average accelerating field is 2 within 1%; the found geometric factor equals 283 Ohm.

Half-cells will be made by hydraulic deep drawing and welded by electron-beam (EBW). A stamping tool for hydraulic deep drawing of the half-cells and a set of technological tools for probing of EBW of two half-cells have been designed. Mechanical properties of niobium and model material (Cu, Al) were investigated.

Cryogenic system for low temperature RF tests of the SC single-cell cavity was successfully tested at 4.2 K.

Coupling device for RF measurement of the single-cell SC niobium cavity was synthesized and manufactured – the measured standing wave ratio is about 1.01-1.07. Warm RF tests with etalon single-cell cavity were made: fundamental frequency – 1.273 GHz, quality factor (warm) – $28 \cdot 10^3$.

INTRODUCTION

Since 2007 Joint Institute for Nuclear Researches officially joined the ILC project and proposed Dubna site for ILC accelerator [1]. The key technology of the ILC is the accelerator that uses superconducting RF cavities for acceleration of electrons and positrons. R&D in superconducting radio-frequency technology is of a high priority and makes a global technical challenge for the R&D organizations worldwide.

Nowadays, in the framework of the ILC project, JINR laboratories perform several tasks. One important task is creation of series of superconducting niobium cavities in tight collaboration with the leading research centers of Republic of Belarus. First production series of 1.3 GHz superconducting niobium single-cell 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 the expertise.

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COMPUTER SIMULATIONS

Group of specialists from Belarus State University of Informatics and Radioelectronics has developed a program package CEDR [2] for simulations and optimization of electrodynamic processes in non-regular RF systems including ohmic losses in the surface. The package allows finding all the electromagnetic characteristics of the single-cell and multi-cell RF cavity, and obtaining 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]. Thus, using the package, one can 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. The results of these computer simulations along with the ILC requirements [6] are presented in Table 1. In the Fig.1 we present the conceptual sketch of the calculated half-cell being the base detail for cavity manufacturing.

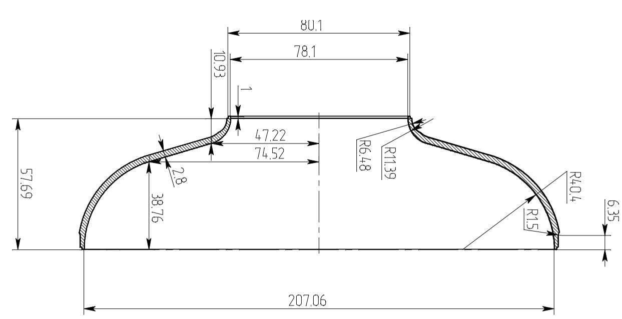

Figure 1: Conceptual draw of the half-cell.

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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. Stamping with usage of a liquid instead of some standard solid die stamping allows avoiding the possible mechanical damage of the inner cavity surface. At present, the stamping tool for hydraulic deep drawing is elaborated and placed in production.

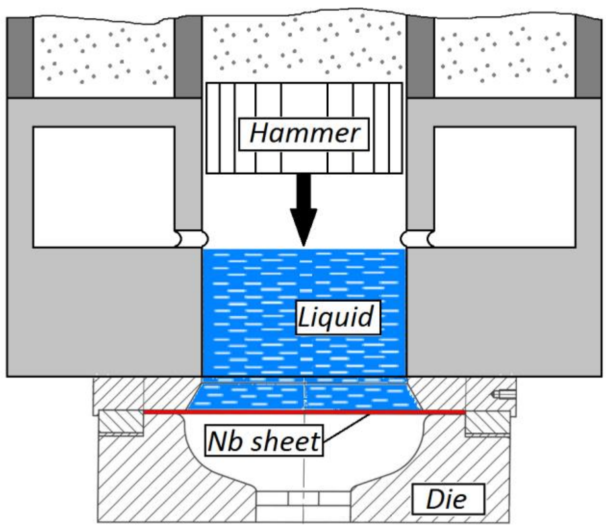

Figure 2: Scheme of hydraulic deep drawing.

In parallel, we consider the possibility of using of niobium material from Russia and Kazakhstan for the cavities manufacturing. It has been found that both materials do not meet the requirements for superconducting cavities: measured value of RRR was 40 for samples from Russia and 60 for samples from Kazakhstan. Therefore, we decide using Nb plates from an approved Nb manufacturer from China with *RRR*>300. Also we made a research of mechanical properties of Nb Cu, and Al to compare 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

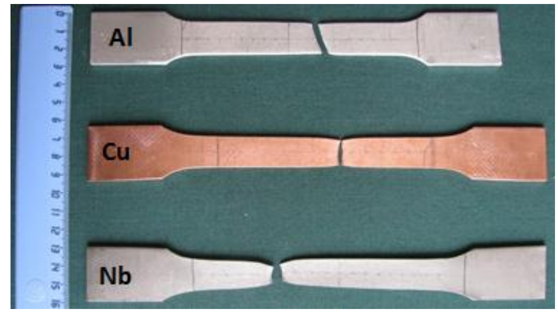

Figure 3: Nb, Cu and Al samples after tension test.

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 de-ionization 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 (Fig.5) is in production.

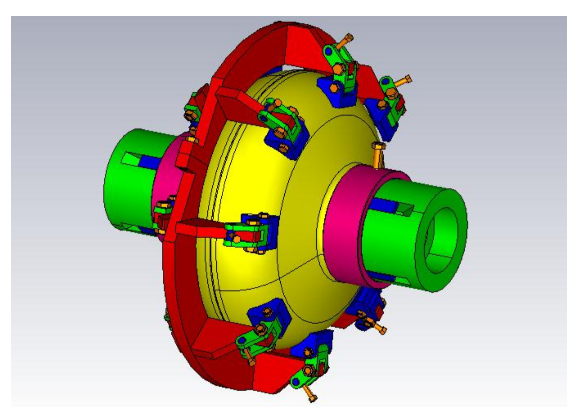

Figure 5: Design of EBW tool.

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STANDS FOR RF MEASUREMENTS

RF stand for cavity room temperature characteristics measurements at 100 mW power level is elaborated 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 presented in Fig.6.

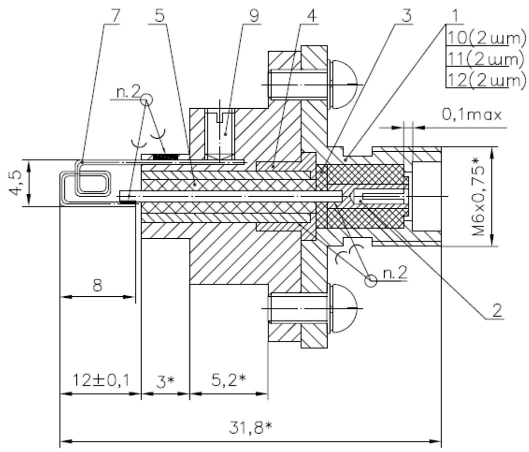

Figure 6: Shop draw of coupling device.

Warm RF tests with etalon cavity from FNAL were made by using 3 different methods and equipment sets; the results were well consistent with each other: fundamental frequency - 1.273 GHz, quality factor (warm) - 28193. The RF stand for the room-temperature RF-measurements of the FNAL niobium cavity during the tests is presented in Fig.7.

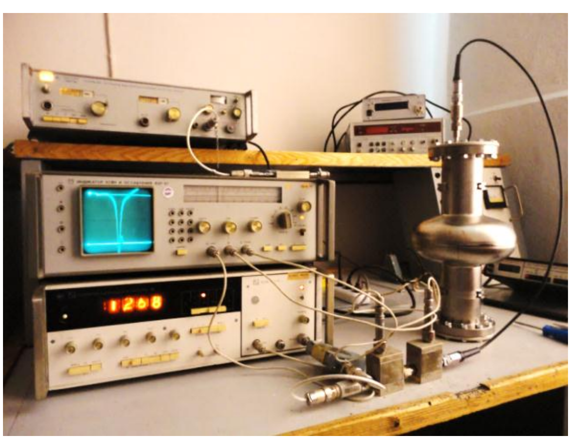

Figure 7: Room-temperature measurements of etalon cavity unit.

Equipment for RF-measurements at liquid helium temperature is elaborated and placed in production. Cryogenic setup is manufactured and successfully tested at operation temperature 4.2 K. The 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 in Fig.8.

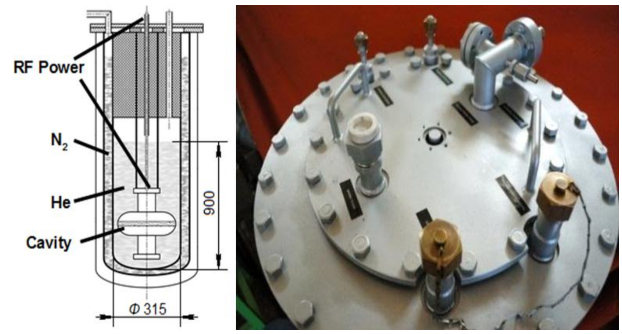

Figure 8: Scheme of the low-temperature RF stand and photo of the dewar.

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 with etalon cavity will start soon.

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We would like to thank our colleagues from FNAL who have kindly supply our research with etalon single-cell niobium cavity and our colleagues from DESY as well who provide us with valuable information on the cavity production technology. We would like to thank personally Xenia and Waldemar Singer from DESY.

REFERENCES

[1] A.Dudarev et. all, “Dubna Site Investigation - An Evaluation of a Proposed Site for the International Linear Collider near Dubna, Moscow Region, Russia”, ILC REPORT-2010-026, 2010.

[2] Kolosov S. V., Kurayev A. A., Senko A. V. “The simulation code CEDR”, IVEC-2010, USA, Monterey. P.115-116.

[3] N.S. Azaryan et al., “Computation of Single Cell Superconducting Niobium Cavity for Accelerator of Electrons and Positrons”, Physics of Particles and Nuclei Letters, vol. 9, No. 2, 2012.

[4] Kolosov S. V., Kurayev A. A., Senko A. V., “Calculation of Nine Section Resonator for Line Collider”, 21st Int. Crimean Conference “Microwave & Telecommunication Technology” (CriMiCo’2011), p.267, Sevastopol, 2011.

[5] N.S. Azaryan et al., “Superconducting Niobium Cavity for ILC Accelerator”, XVI Conference of Young Science and Specialists (AYSS`12), p.79, JINR, Dubna, 2012

[6] ILC Reference Design Report, 2007.

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