

# DUBNA-MINSK SRF TECHNOLOGY DEVELOPMENT STATUS REPORT

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## Abstract

In 2011 Dubna-Minsk collaboration started an activity on the development and manufacture the series of 1.3 GHz superconducting Nb cavities in the enterprises in Belarus. The current status of this work is presented in this report.

Main EM characteristics of the cavity were calculated and the shop drawings for cavity fabrication were developed. Two test-benches were assembled for RF-tests of the cavities at room temperature and at liquid helium temperature. The measured SWR was about 1.01 due to special matching device developed for that. This measurement technique was applied to the single-cell cavity from FNAL at power level nearby 10 mW. Measured resonant frequency was about 1.27 GHz, while the measured Q-factor was  $2.8 \cdot 10^4$  at room temperature and more than  $10^8$  at liquid helium temperature.

To evaluate mechanical properties of sheet Nb and of model materials (Cu and Al), a number of tests were made. Series of half-cells were fabricated of Al to test the technique of hydraulic deep-drawing that will be used in production of Nb cavities. The modes for electron-beam welding of sheet Nb were explored and the first welding seams were tested. The method of chemical treatment of cavities was also elaborated.

## INTRODUCTION

At present we can state that collaboration of leading research centres of Belarus in tight cooperation with JINR in the field of SRF technology is established. The aim of this activity is to develop the technology of production of 1.3 GHz superconducting niobium RF cavities which meets the ILC requirements ( $Q > 10^{10}$ ,  $E_{acc} > 35$  MV/m). First production series of 1.3 GHz superconducting niobium single-cell cavities will start in Minsk by 2015. After the tests in Minsk and Dubna these cavities will be presented to the international ILC community for expertise. On the beginning of works on the project was announced at the Conference on Accelerators RuPAC-2012 [1], where our report was praised by Russian and foreign specialists.

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## CAVITY CALCULATIONS

In the beginning of the activity, main EM characteristics of Tesla-shape 1.3 GHz cavity were recalculated with special attention given to the higher order oscillations' modes, and the shop drawings (Fig. 1) of a single-cell cavity were developed [1,2]. Now, we represent a clone where the only difference is that there is an elliptical conjugation in the cavity's iris region.

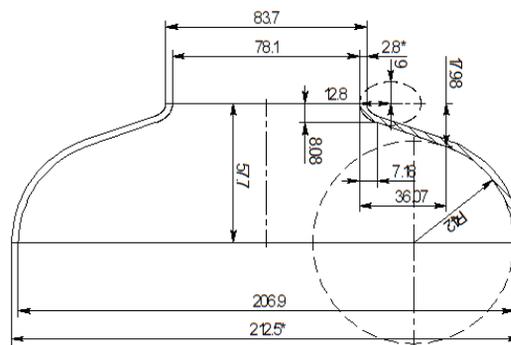


Figure 1: Shape of half-cell.

It was found out, by simulations, that elliptical conjugations allows reducing the maximum electric field strength at the cavity wall by 7-10 %. For the purpose of that computer simulations, the special software package, CEDR [3] was developed in BSUIR.

## RF-TESTS OF THE CAVITY

### Coupling Device

To make test of the cavities at low power level of RF signal, a unique coupling device was developed and manufactured by specialists from INP BSU. The shop drawing of the device is shown in Fig. 2. This device itself is a loop providing for a magnetic coupling of the cavity with the source of RF signal, and allows for matching adjustment of feed of power of the signal by rotation and/or by modifying the loop length. Combination of these two techniques of adjustment allows getting very good matching of the source with the cavity: the measured value of SWR was about 1.01 at the resonant frequency so that about 99.9 % of RF power was transmitted to the cavity.

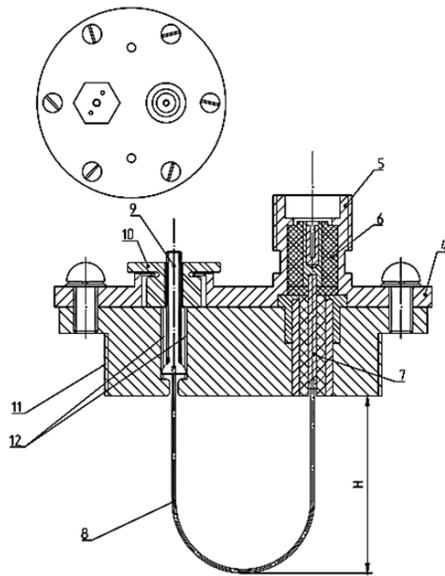


Figure 2: Coupling device.

### Room-Temperature RF-Measurements

To support Dubna-Minsk collaboration in performing experiments and development technique of RF-measurement, FNAL kindly provided a single-cell Nb cavity for its usage as an etalon to test techniques of measurements. This cavity was used to make all the measurements in our experiments.

The tested parameters were two. The resonant frequency,  $f_0$  was measured to test the cavity's geometry accuracy. The resonator's quality-factor,  $Q$  was measured to test the manufacturing quality of the cavity.

Room temperature RF-tests with etalon cavity from FNAL were made by using 3 different methods and equipment sets; the results of these different experiments were consistent well with each other.

At the first method, a signal generator with manual frequency tuning was used, and the resonant frequency was directly measured by a digital frequency meter; the measured value of resonant frequency was found  $f_0 = 1.273$  GHz.

The second technique was based on the measurements of power of falling (from a generator) and of reflected (from the resonant cavity) waves. With this technique, we found the resonant frequency was at 1.273 GHz at the value of standing wave ratio (SWR) less than 1.07.

In the third scheme, the vector network analyser Agilent E5071c-1E5 with high-stability of time-base reference generator was used. Nowadays, the vector analysers of such kind are universal instruments to measure Q-factor. Commonly, with a vector network analyser, the resonance frequency is measured at the minimum level of  $S_{11}$  (complex coefficient of reflected power) and the Q-factor is defined by measurement of reflected power as a function of sweep frequency. The usage of this modern high-precision instrument allows getting a good accuracy, and we found the resonant frequency  $f_0$  at 1.27297 GHz while the quality factor,

$Q$  was 28193. With this measurement technique we also got quite good matching – measured SWR was about 1.01. This measuring technique was also applied to the cavity in its superconducting state in the cryogenic tests.

### Cryogenic RF-Measurements

A stand for performing tests of the cavity's parameters at cryogenic temperatures was built and successfully tested in SSPA SPMRC NASB. Its cryogenic system demonstrated high stability over time that allowed performing such measurements at the temperatures of about 4.2 K for about four hours continuously.

Table 1: 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

Parameters of cryogenic setup are shown in Table 1. The results of RF-measurements (Fig. 3) of the cavity at the temperature of liquid helium showed that the superconductivity in the cavity was reached during the experiment. We have a first estimate the cavity's  $Q$  in the state of superconductivity. Its value not less than  $10^8$  at the input power of RF source nearby 10 mW. With the stand's upgrade with the external source of ultra-high stability time base we expect to achieve the ability to measure Q-factor up to  $10^{10}$ .



Figure 3: Stand for RF-tests at 4.2 K.

During cryogenic tests there was detected instability of the shape of the resonant curve, namely, the attenuation went up and down every 10-15 seconds from -120 dB to -60 dB. In our opinion the reason of this is the local boiling of film of helium on the surface of coupling loop and non-Nb parts of the cavity resulting their heating by surface current. This phenomenon will be studied in more detail during future cryogenic tests.

## CAVITY MANUFACTURING

### Choose of Nb-Material

We have considered the possibility of using of niobium material from manufacturers of Russia and Kazakhstan. It has been found that samples from both manufacturers do

not meet the requirements for SC cavities: the measured value of  $RRR$  was 40 for the samples from Russia and 60 for the samples from Kazakhstan. Therefore, we decide using Nb plates from an approved manufacturer from China (NOTIC) with  $RRR > 300$ .

Previously we did measurements of  $RRR$  in DESY but nowadays we developed equipment set for  $RRR$ -measurements in Minsk.

### Hydraulic Deep Drawing

Manufacturing of the cavities' half-cells is assumed to be by the hydraulic punch-free deep drawing. Schematically, this method is shown on Fig. 4. PhTI NAS of Belarus has equipment for this technology and also reach experience in this deal.

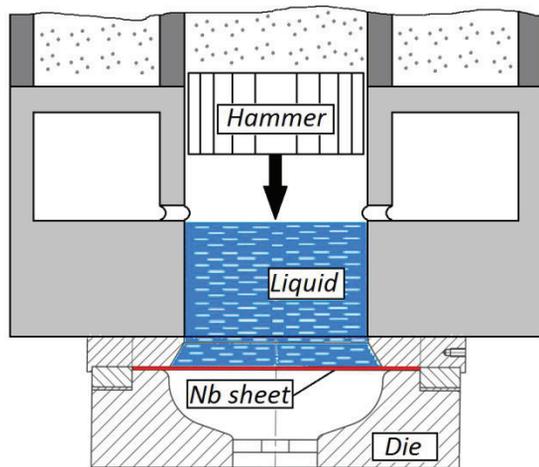


Figure 4: Scheme of hydraulic deep drawing.

Usage stamping with a liquid instead of a standard solid die allows avoiding the possible mechanical damage of the inner cavity surface.



Figure 5: First half-cells made of aluminium by hydraulic deep drawing in Minsk.

At present, the stamping tool for hydraulic deep drawing is in production. With the use of first tool set for stamping, we have got first experimental samples (Fig. 5) of the cavity's half-cells that are manufactured of Al.

### Electron-Beam Welding

Also PhTI NASB has reach experience in the field of electron-beam welding (EBW). Currently, they continue to test electron-beam welding of sheet niobium at various conditions to qualify them. They has already fixed the EBW regime for getting the welded joint of sheet Nb (Fig. 6) with the sagging of the seam less than 0.5 mm.

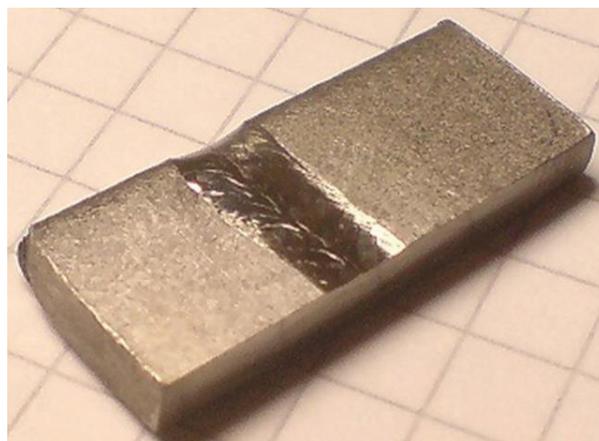


Figure 6: Sample of EBW of niobium in Minsk.

Quality of the obtained welding seams is tested. At present we have significant reduction of  $RRR$  from 400 to 100-300 in the neighbourhood of welding seam, as well as an increased concentration of carbon in the welding seam and the increased concentration of oxygen in the heat affected zone. These drawbacks would be eliminated with the upgrade of vacuum system of the EBW-machine.

### Chemical Treatment

Chemical treatment of niobium on different stages of cavity manufacturing also will be made in the PhTI which has the developed technological infrastructure for chemical processing of materials. Nowadays, a series of experiments on the buffered chemical polishing (BCP) of Nb goes on. Also conducted the research of modes of BCP, and the equipment set for electropolishing is under development.

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### REFERENCES

- [1] N. Azaryan et al., "Dubna-Minsk Activity on the Development of 1.3 GHz Superconducting Single-Cell RF-cavity," RuPAC'12, St. Petersburg, September 2012, WEPPD023, p. 602 (2012).
- [2] 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, Issue 2, pp. 150-162, 2012.
- [3] S.V. Kolosov, A.A. Kurayev, A.V. Senko, "The simulation code CEDR," IVEC-2010, USA, Monterey, pp. 115-116 (2010).