DUBNA-MINSK SRF TECHNOLOGY DEVELOPMENT. STATUS REPORT.

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BSU BSUIR SSPA SPMRC PhTI NASB DESY

1. INTRODUCTION

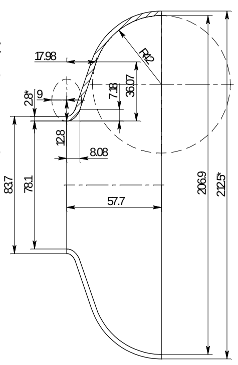
In 2011 Dubna-Minsk collaboration started an activity on the development and manufacture the series of 1.3 GHz superconducting Nb cavities in the enterprises in Belarus. The aim of this activity is to develop the technology of production of 1.3 GHz superconducting niobium RF cavities which meets the 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.

2. CAVITY CALCULATIONS

In the beginning of the activity, main EM characteristics of Tesla-shape 1.3 GHz single-cell and nine-cell cavity were re-calculated and higher order oscillation modes were investigated. For the purpose of that computer simulations, the special software package, CEDR was developed in BSUIR. 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.

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_{cell}	1.87 %	1.94 %



3. RF-TESTS OF THE CAVITY

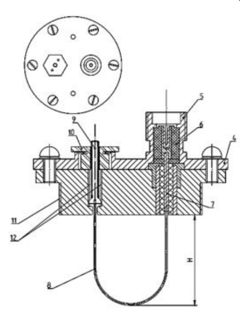
To support Dubna-Minsk collaboration in FNAL kindly provided a single-cell cavity of ultrapure niobium for its usage as an etalon unit.

Two test-benches were assembled for RF-tests of the cavities at room temperature and at liquid helium temperature. This measurement technique was applied to the single-cell cavity from FNAL at power level nearby 10 mW.

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 quality of cavity manufacturing.

3.1. Coupling Device

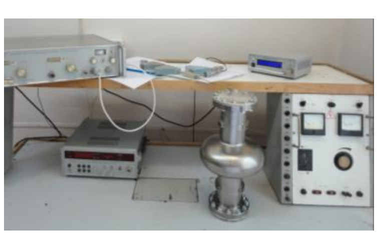
To make test of the cavities at low power level of RF signal, a unique coupling device was developed and manufactured by specialists from INP BSU. This device itself is a loop providing for a magnetic coupling of the cavity with the source of RF signal, and allows for matching adjustment of feed of power 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.

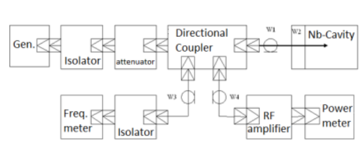


3.2. Room-Temperature RF-measurements

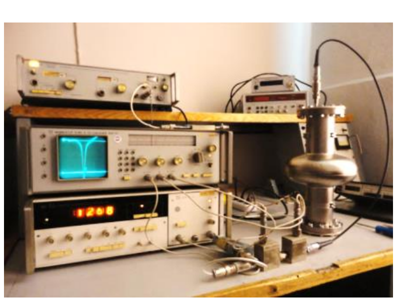
Room temperature RF-tests with etalon cavity from FNAL were made by using 3 different methods and equipment sets; the results of these different experiments were consistent well with each other.

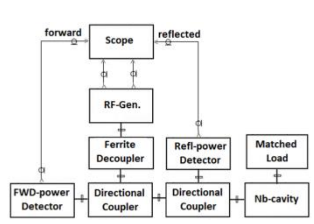
At the **first method**, a signal generator with manual frequency tuning was used, and the resonant frequency was directly measured by a digital frequency meter; the measured value of resonant frequency was found $f_0 = 1.273$ GHz.



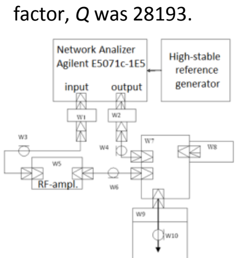


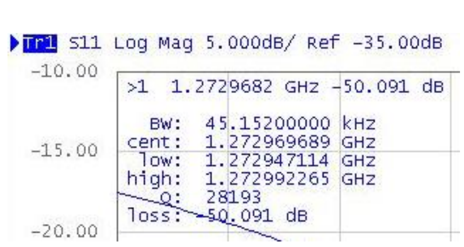
The **second technique** was based on the measurements of power of falling (from a generator) and of reflected waves. With this technique, we found the resonant frequency was at 1.273 GHz at the value of standing wave ratio (SWR) less than 1.07.





In the **third scheme**, the vector network analyzer Agilent E5071c-1E5 with high-stability of time-base reference generator was used. Resonance frequency is measured at the minimum level of S_{11} 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.





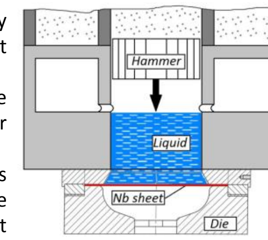
With this measurement technique we also got quite good matching – measured SWR was about 1.01.
This measuring technique was also applied to the cavity in its superconducting state in the cryogenic tests.

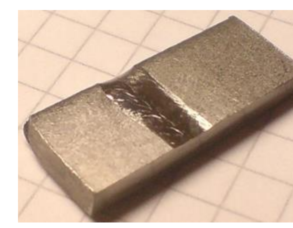
4. CAVITY MANUFACTURING

Manufacturing of the cavities' half-cells is assumed to be by the **hydraulic deep drawing**. PhTI NAS of Belarus has equipment for this technology and also reach experience in this deal.

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

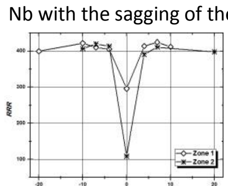
At present, the stamping tool for hydraulic deep drawing is in production. With the use of first tool set for stamping, we have got first experimental samples of the cavity's half-cells that are manufactured of Al.





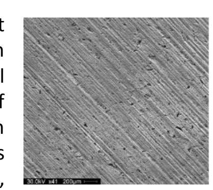
Also PhTI NASB has reach experience in the field of **electron-beam welding**. EBW setup in PhTI consists of vacuum chamber (ø1350×2500 mm), vacuum pumps and electron gun which provide the power of 15 kW with 250 mA current and 60 keV electron energy.

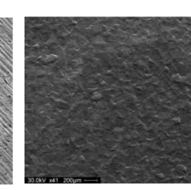
Currently, they continue to test EBW of sheet niobium at various conditions to qualify them. They has already fixed the EBW regime for getting the welded joint of sheet Nb with the sagging of the seam less than 0.5 mm.



Quality of the obtained welding seams is tested. At present we have significant reduction of *RRR* from 400 to 100-300 in the neighborhood 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 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.





Nb from NOTIC as delivered (left) and after BCP in PhTI (right)

Also 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.

3.3. Cryogenic RF-measurements

A stand for performing tests of the cavity's parameters in liquid helium 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.

The results of RF-measurements 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}.

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.