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***Update on the CeC PoP 704 MHz 5-cell cavity  
cryomodule design and fabrication***

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# UPDATE ON THE CeC PoP 704 MHz 5-CELL CAVITY CRYOMODULE DESIGN AND FABRICATION\*

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## Abstract

A 5-cell SRF cavity operating at 704 MHz will be used for the Coherent Electron Cooling Proof of Principle (CeC PoP) system under development for the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. The CeC PoP experiment will demonstrate the new technique of cooling proton and ion beams that may increase the beam luminosity in certain cases, by as much as tenfold. The 704 MHz cavity will accelerate 2 MeV electrons from a 112 MHz SRF gun up to 22 MeV. This paper provides an overview of the design, the project status and schedule of the 704 MHz 5-cell SRF for CeC PoP experiment.

## INTRODUCTION

The 5-cell 704 MHz SRF linac is being designed and fabricated in collaboration between BNL and Niowave. It will be the main 20 MeV electron accelerator for CeC PoP experiment under construction in RHIC at BNL [1]. The delivery of the 704 MHz SRF linac to BNL is scheduled for the end of June 2015. The 704 MHz SRF linac will be installed and ready for commissioning at the beginning of 2016 RHIC Run. An update on the layout of the fundamental power coupler, the tuner test results, the final buffer chemical polishing (BCP) and high pressure rinse (HPR) results, and the fabrication progress of several components including the completion of the helium vessel, magnetic shields, heat shield, cryogenic components and the ASME Code stamped cryostat are presented in this paper.

## 704 MHz COMPONENTS DESIGN

### Fundamental Power Coupler

The 704 MHz SRF cryomodule [2] is powered by a coaxial coupler capable to deliver up to 20 kW CW RF power to the SRF cavity. The final model of the fundamental power coupler is shown in Fig. 1.

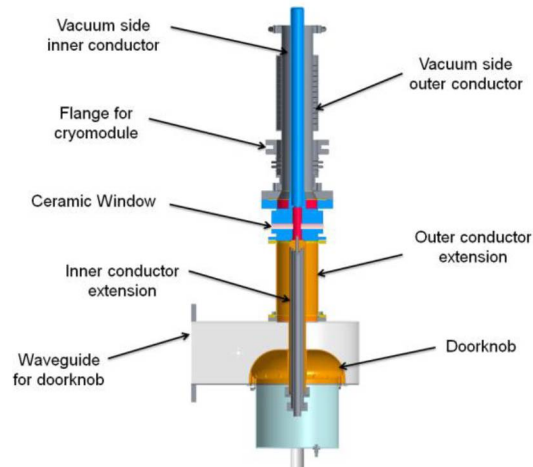


Figure 1: Fundamental power coupler design layout.

The FPC utilizes a coaxial RF window/antenna assembly from Toshiba Electron Tubes & Devices Co. [3], similar to the one currently in service on the 5-cell SRF cavity at the BNL's R&D ERL facility. On the vacuum side of the assembly, the outer conductor is a copper plated stainless steel tube with cooling channel used as a heat intercept and the inner conductor (antenna) is made of OFHC copper. The coaxial alumina window assembly has two instrumentation ports on the vacuum side: one for vacuum gauges the other one for an arc detector. The vacuum side outer conductor of the coaxial line will be cooled by 5 K helium gas, the vacuum side of the inner conductor will be cooled by air and the RF window will be cooled by water.

On the air side, the water-cooled inner extension is made of OFHC copper and the outer extension is made from copper-plated stainless steel. The FPC is coupled to a rectangular WR1150 waveguide via a waveguide doorknob transition supplied by Advanced Energy Systems, Inc. (AES) [4]. Custom conflat RF gaskets are used on all the outer conductor joints to provide good RF contact and at the same time a UHV joint.

## TUNER MECHANISM

### Mechanical Tuning System Design

The BNL3 cavity mechanical frequency tuning system was designed based on a tuner that has been successfully

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implemented at HZDR in Germany for their superconducting RF Photo-Injector [5]. A detailed layout of the tuner mechanism is shown in Fig. 2 below.

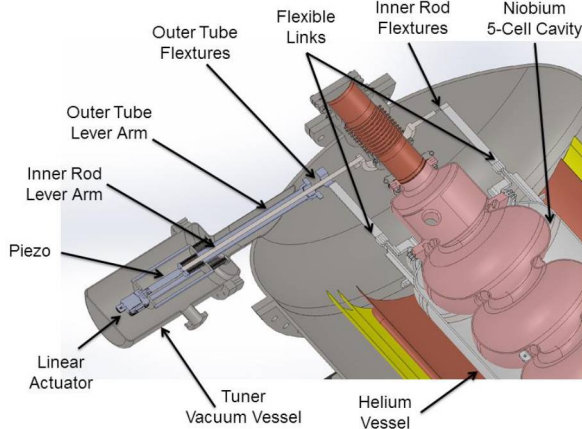


Figure 2: Detail design of mechanical tuning system.

The tuner mechanism consists of an inner rod lever arm and an outer tube lever arm that move in opposite directions, using the linear actuator or the piezo. As a result of the motion described above, a bending moment is applied on each flexible link. The tuner flexible links transform the lateral motion of the rod and the tube into an axial motion at the cavity cells that varies their length. In order to prevent any plastic deformation to the 5-cell cavity, the design was modified by adding a mechanical stop that will restrict that travel of the stepper motor lead screw. The tuning sensitivity of the cavity was calculated to be 171.6 kHz/mm and the tuning range needed is 78 kHz, resulting in a motion range of 0.454 mm in one direction along the beam axis.

### Test Results

The mechanical tuning system was fabricated, assembled and successfully tested at Niowave Inc. on the cavity at room temperature. The components used for the tuner test, consisted of all the internal parts described in Fig. 2. These components shown in Fig. 3 below will be used in the final assembly of the cavity into the cryomodule.



Figure 3: Tuner test setup.

The full range of the tuner was tested by measuring the push/pull displacement between the lever arms versus the

cavity deflection near the attachment locations of both flexible links onto the Niobium cavity as shown in Fig. 4.

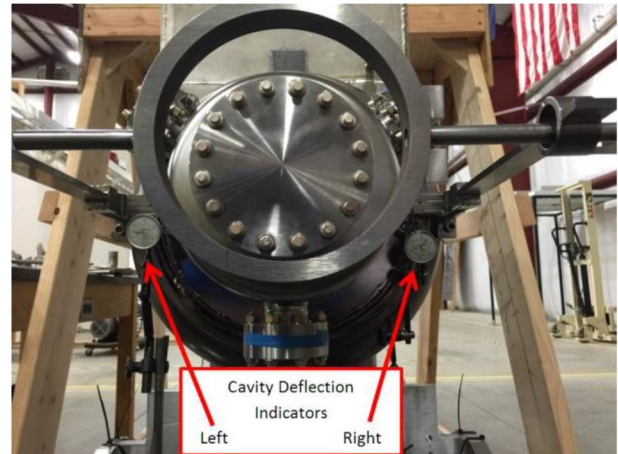


Figure 4: Dial indicators for deflection measurements.

The data shown in Fig. 5 below was taken about the cavity's free-state, where no load was applied on the cavity (cavity deflection = 0.0000 in).

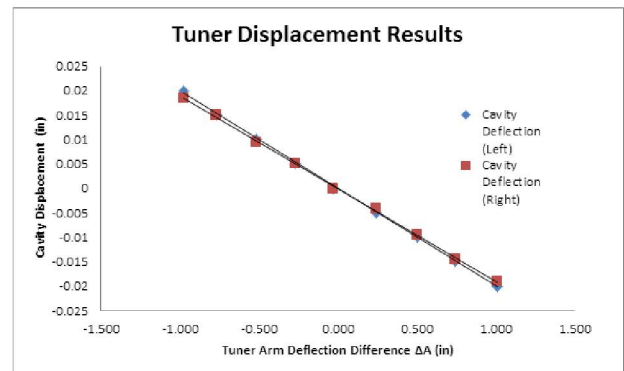


Figure 5: Tuner test results of the BNL3-2 cavity at room temperature.

The results show that the cavity is tuned linearly with the actuator displacement. Also, the displacement on the left and right side of the cavity were approximately equivalent to within 0.5 thousands of an inch, which implies that the tuning will be uniform across the cavity. The tuning ratio of tuner arm deflection to cavity displacement was calculated to be 24.8:1.

## FABRICATION

### BCP and HPR

Prior to the vertical testing at BNL [6], the 5-cell cavity was etched. In order to re-clean the cavity RF surface before the assembly into the cryomodule, Argonne National Laboratory (ANL) performed a complete cycle of processing. ANL started with buffered chemical polishing, proceeded through high-pressure water rinse, and hermetic clean assembly of all the components. The total surface removal at the ends of the cavity was measured to be 41 microns using an ultrasonic thickness gauge. The internal surface as photographed

immediately after BCP and rinsing with deionized water is shown in Fig. 6.



Figure 6: 5-cell cavity RF surface after BCP.

The surface appeared visually to be free of stains with a uniform matt finish silver color. During the two days of HPR the cavity was flipped vertically a total of 8 times in order to provide uniform HPR over the RF surface.

### *Cryomodule Assembly*

The 704 MHz SRF cryomodule for CeC PoP is being built by Niowave. The fabrication and purchase of most components have been completed. The ASME Code stamped vessel, the magnetic shields, the heat shield, and the piping system installations are shown respectively in Figures 7, 8, and 9 below.



Figure 7: ASME Code stamped vessel.



Figure 8: Magnetic and heat shields.

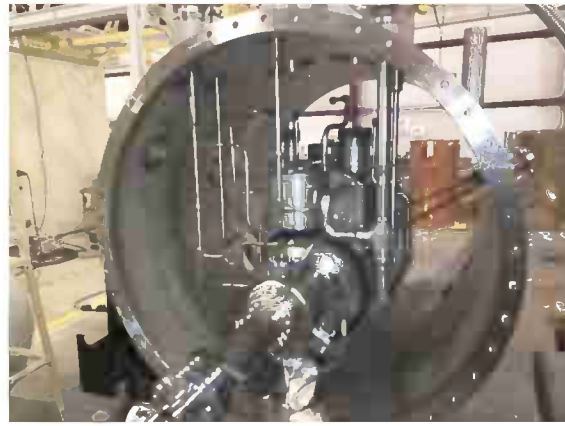


Figure 9: Piping system and He vessel installation.

## **CONCLUSION**

The tuner system, the cryogenic components, the heat shield, magnetic shield and the FPC make the mechanical design a challenging task. The pre-survey of the helium vessel in the cryostat and the inspection of the piping and instrumentation were completed in April at Niowave. The fabrication of most components is completed. BNL and Niowave are working closely to finalize the installation of all the components inside the cryostat. The tuner and cold test is schedule for the end of May at Niowave. The 704 MHz SRF linac is scheduled to be installed during the RHIC summer shutdown 2015.

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