ISBN: 978-3-95450-191-5 doi:10.18429/JACoW-SRF2017-MOPB009

PROGRESS OF 650 MHz SRF CAVITY FOR ERHIC SRF LINAC*

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Abstract

A high-current, well-damped 5-cell 647 MHz cavity was designed for ERL-Ring based eRHIC. Two prototype cavities were contracted to RI Research Instruments GmbH: one copper cavity with detachable beampipes for HOM damping study, and one niobium cavity for performance study. The performance study includes high-Q study for ERL-Ring eRHIC design and high gradient study for Ring-Ring eRHIC design. This paper will present the preliminary results of the HOM study, progress on Nb cavity fabrication and preparation for vertical test.

INTRODUCTION

An electron-ion collider, named eRHIC, is proposed by Collider-Accelerator Department at Brookhaven National Lab. A new electron accelerator will be built to provide polarized electron beams with an energy range from 5 to 18 GeV to collide with the existing polarized proton beams in RHIC. This electron accelerator will be placed in the existing RHIC tunnel and the SRF linac at IP2, where the length of the available straight section is 200m, as shown in Figure 1.

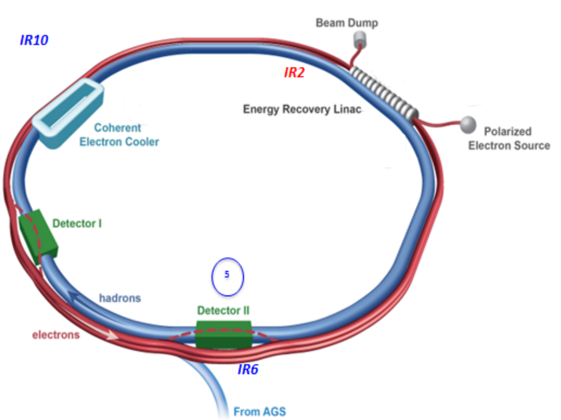

Figure 1: Layout eRHIC. Existing "Blue" hadron ring (center); Electron ring and SRF linac at IP2.

There are two technologies to build electron accelerator for eRHIC: one is to use ERL (Energy Recovery Linac) technology [1], which high current CW electron beam is accelerated by the same SRF cavities multiple times to reach a collision energy, and after colliding with, the electron energy is given back to the SRF cavities for the acceleration of following electron bunches; the other one is to use the storage ring technology [2], which electron bunches is accelerated by recirculating linac to the collision energy and injected into a storage ring to collide with proton beams. The design based on these two technology is called ERL-Ring eRHIC and Ring-Ring eRHIC, respectively.

The 5-cell 647 MHz cavity was originally designed for ERL-Ring eRHIC, which uses an enlarged beam tube to propagate all the HOMs but attenuate the fundamental mode. More detail of the cavity design can be found in reference [3]. A copper cavity was fabricated to study the performance of the HOM damping, and a niobium cavity is being fabricated to study post-processing and cavity performance. This paper will briefly describe cavity design, including the fundamental parameters and the different requirements of SRF cavity for ERL-Ring and Ring-Ring eRHIC. Then we will discuss the Cu cavity fabrication, and results of the HOM damping measurement and progress of the niobium cavity fabrication.

CAVITY DESIGN

Cavity Design for the ERL-Ring SRF Linac

The main objective for designing the 647 MHz 5-cell cavity was to damp well the HOMs, which includes both longitudinal modes and transverse modes. The 5-cell 647 MHz cavity uses the same idea of the previous BNL 5-cell cavities, i.e., enlarged beam tube to propagate all the HOMs but attenuate the fundamental modes. There is a taper at each side of the cavity to reduce the cross-talk between cavities and avoid RF heating on the cavity's gaskets. Figure 2 shows the Superfish code model of the cavity and its parameters are listed in Tab. 1.

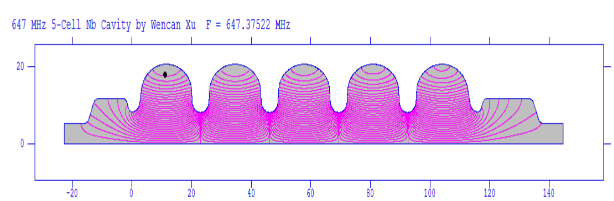

Figure 2: Superfish code model of BNL4 cavity.

During the cavity design, the loss factor, HOM damping capability was optimized to generate low monopole HOM power and increase the transverse beam-break-up (BBU) at the same time. More details of the cavity design are presented in reference [4].

Due to the wide range of the proton energy (40 GeV to 275 GeV), ERL-Ring SRF cavity is required to be able to tune up to 174 kHz. Following extensive mechanical-RF simulations [3], we decided that the wall thickness of the cavity would be 4.4 mm and there would not be any stiff-

* Work supported by LDRD program of Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886 with the U.S. DOE.
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ening rings between cells. This makes the cavity allow to tune 174 kHz with reasonable tuner load (205 lbs), and the cavity's maximum stress is below 7000 psi. Three tabs were welded to the middle of the cavity so that it can be tighten to the LHe vessel, so that the first mechanical mode of the cavity is transversal mode with frequency of 107 Hz. The Nb cavity model is shown in Figure 3.

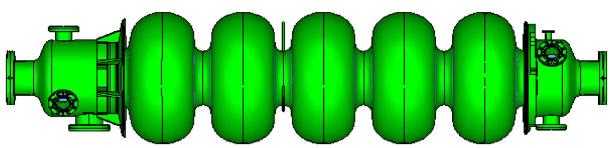

Figure 3: Engineering model of the cavity.

Table 1: BNL4 Cavity's Parameters

Parameters	BNL4 cavity
Frequency [MHz]	647.4
Number of Cells	5
Geometry Factor [G]	273
R/Q [Ω]	502
Bpeak/Eacc [mT/MV/m]	4.42
Epeak/Eacc	2.27
Coupling factor [%]	2.8
Cavity length [m]	1.68

Applied This Cavity to Ring SRF Linac

The main concern for designing the 647 MHz 5-cell The SRF requirements for ERL-Ring eRHIC and Ring-Ring eRHIC is significantly different. For ERL-ring, it requires the cavity operating CW at 16 MV/m with Q0 > 2e10, and well HOM damping for the high BBU threshold and HOM power [5]. However, the recirculating-linac requires high gradient operation at 26 MV/m with Q0>1e10, and only minimum HOM damping requirement, which can be done with conventional HOM dampers. In addition to that, the mechanical challenge for ERL-Ring cavity and Ring-Ring cavity is different as well, as ERL-ring cavity has to be tuned up to 174 kHz to match the energy of the proton beams (from 40 to 250 GeV), which forced us to give up the stiffness ring between cells for reasonable tuning load. As an injector for storage ring, there is not a cavity tuning issue for the Ring-Ring SRF linac, However, as the Lorentz detuning is proportional to the square of cavity voltage or gradient, the Lorentz detuning for pulse Ring-Ring SRF linac is about 60% higher than the CW SRF linac for ERL-Ring eRHIC (Lorentz detuning for CW is easy to overcome.), so stiffness rings is necessary for the cavity's Ring-Ring SRF linac application. So, to apply this cavity for Ring-Ring SRF linac, we will need to optimize the stiffness ring location to minimize the Lorentz detuning.

COPPER CAVITY

The main purpose of a copper prototype cavity is to carry out HOM studies. As shown in the Fig 4, the end beam-pipe end group is detachable so that we can attach any type of HOM couplers to study the HOM damping results.

Due to the large cell-to-cell coupling (2.8%) and tight cavity shape tolerance (< +/-0.3 mm), the cavity's field flatness is 89% as fabricated, and it required little tuning to reach 98.2% of field flatness. The cavity's fundamental mode spectrum and field flatness is shown in Fig 5.

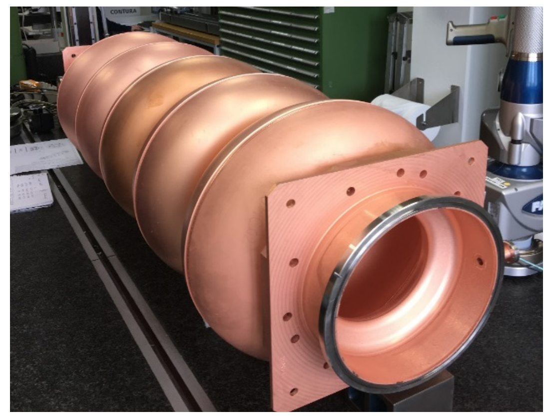

Figure 4: The copper cavity model with detachable end-group.

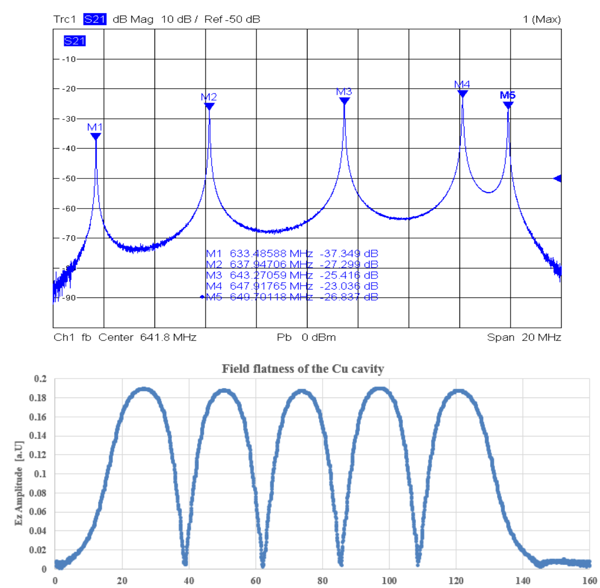

Figure 5: Cu cavity's fundamental spectrum (Top) and the field flatness after it's tuned in RI (Bottom).

NIOBIUM CAVITY

Cavity Fabrication

The niobium cavity is undergoing fabrication at RI [6]. As a prototype cavity, we required the tolerance to be as tight as 0.3 mm of cavity shape deviation. Usually, two to three forming steps must be carried out to reach this tolerance. Due to the grain direction, usually the deviation over the cross-section is not uniform. However, this small

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lack of uniformity can be reduced by the EB welding setup. The cavity is expected to be completed by the end of June. Following with that, we will carry out various post-processing and vertical tests to study its SRF performance.

Plan of Post-processing

The original goal of the cavity processing is to study various post-processing methods to reach 18 MV/m with Q_0~3x10^{10}, which is the goal for the ERL-Ring eRHIC SRF linac. For the first round of post-processing, we will follow the typical cavity processing procedure as shown in Figure 6 : 120 um heavy BCP, 600 C bake out for 10 hours, 20 um light BCP. The first post-processing will be done by RI, and the cavity will be sent to BNL under vacuum directly for vertical testing. The next processing will be based on the results of the first test. As EP has been proved to be beneficial for cavity gradient, and cavity gradient of 25 MV/m is required for Ring-Ring eRHIC SRF linac, we will try to do EP on the cavity later on.

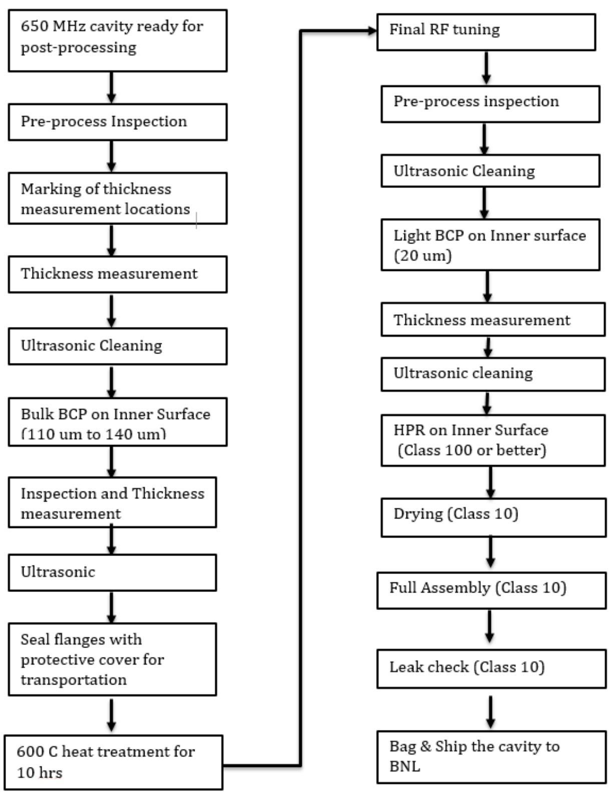

Figure 6: First post-processing procedure.

Preparation of the Vertical Test

The cavity will be tested at the BNL vertical test facility, which is an above ground VTF and has a limit on the total height of the objects to be tested. The vertical test configuration is shown in Figure 7. A fixed FPC is installed on the cavity's FPC port and a pickup antenna is on the cavity's pick up port. To minimize the RF loss, all HOM ports and beam pipe ports are sealed with Cu disc gaskets, with a venting hole. The estimated total RF loss on the all ports @ 20 MV/m is about 0.2 watt.

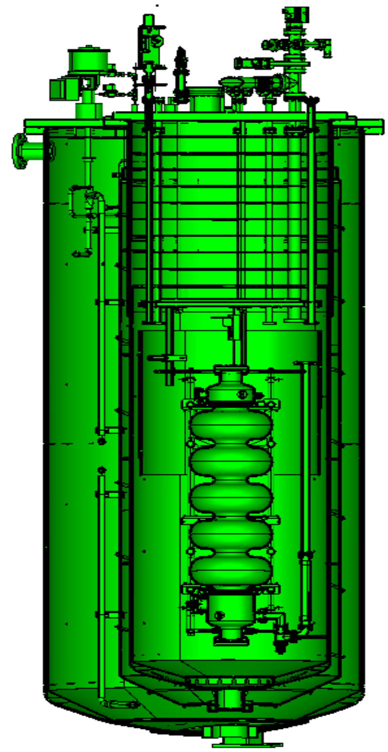

Figure 7: Vertical test dewar layout with a 5-cell 650 MHz cavity.

SUMMARY

We presented the progress on the 650 MHz cavity prototypes. The copper cavity has been shipped to BNL for HOM studies, and the niobium cavity is going to complete within this month. Various post-processing steps will be carried out for high Q studies for the ERL-Ring SRF linac and for high gradient study for Ring-Ring eRHIC SRF linac.

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