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COMMISSIONING OF SRF BOOSTER CAVITY FOR LEReC*

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Abstract

One important component for LEReC project is a 704 MHz booster cavity, which was modified from the BNL ERL 704 MHz SRF gun cavity. Within one and half year, the modification completed. The booster cavity cryomodule was successfully commissioned in mid-October 2017, and it was moved to LEReC location at RHIC tunnel 2 O'clock, where it has been serving routine operation since March 2018. This paper will report the configuration of the new cryomodule and its commissioning results.

INTRODUCTION

Low Energy RHIC Electron Cooling (LEReC) [1] aims to improve luminosity lifetime by counteracting Intra-Beam Scattering (IBS). The Energy scan of interest are 7.7, 9.1, 11.5, 14.6, 19.6 GeV, which requires corresponding kinetic energy of electron beam to be 1.6 – 2.6 MV. The energy gain is provided by SRF booster and a 400 kV DC gun. The 704 MHz SRF booster cavity introduces an energy chirp that causes ballistic stretching of the bunch as it drifts down the beam line. Additional RF systems (2.1 GHz, 704 MHz warm RF cavity, 9 MHz warm cavity) are employed to remove the energy chirp, longitudianl bunch curvature and bunch-by-bunch energy variation. Figure 1 shows the beamline layout LEReC.

The 704 MHz SRF booster cavity was converted from ERL SRF gun cavity [1]. The major conversion includes 1) convertion of the choke-joint cathode support to a beampipe, 2) retracting FPC for optimum coupling, 3) improvement of cryogenic plumbing for microphonics suppression, 4) change of beampipe HOM damper to coaxial line HOM damper, etc. This paper will describe the convertion of booster cavity and cryomodule, vertical test, commissioning results, and operation status of the booster cavity.

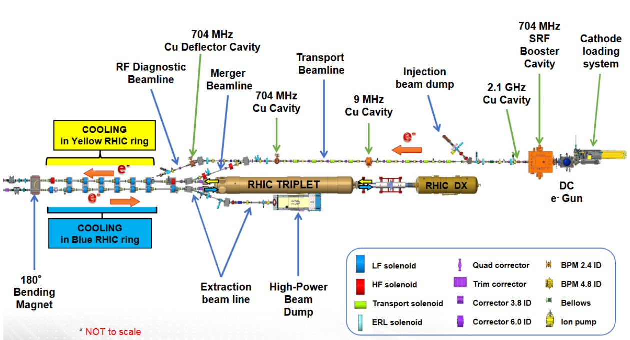

Figure 1: LEReC layout.

704 MHz SRF GUN CAVITY REVIEW

Before describing the modification, it is necessary to review the performance of the booster cavity as a gun cavity. Figure 2 shows the high current SRF gun cavity configuration. Two high power fundamental power coupler were used to deliver up to 1 MW RF power to the cavity. A choke-joint structure was used for photocathode support. Beam commissioning with this gun was carried out during end of 2014 to mid. 2015, which one can find more detail about the commission in reference [2]. One important point about the commission is that the cavity without cathode was able to reach CW 2.3 MV (although a lot of radiation), as shown in Figure 3. However, it kept quenching at around 1.6 MV after commissioning with cathode stalk a few month, which we believe that is due to cavity (near the cathode area) contamination by the either cathode stalk (Cu) or cathode (K_2CsSb). Due to tight schedule of LEReC and as the cavity reached 2.3 MV (shown in Figure 3), which is higher than the requirement of LEReC, we had sufficient confidence to convert the gun to LEReC booster.

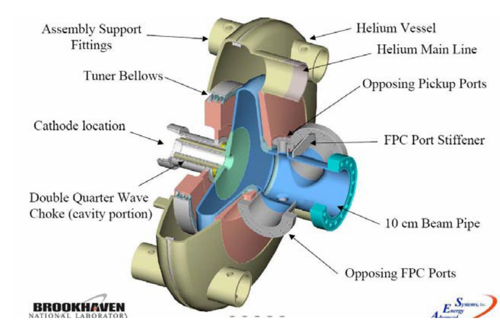

Figure 2: 704 MHz SRF gun cavity.

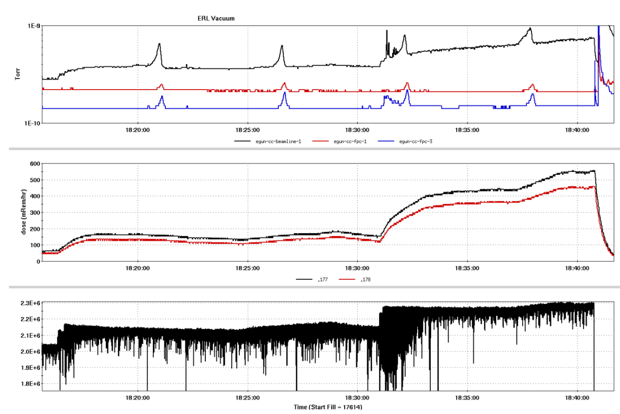

Figure 3: 704 MHz SRF gun cavity reached 2.3 MV prior to cathode commissioning.

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CONVERSION TO BOOSTER

Beamline Conversion

Figure 4 (top) shows conversion from choke-joint cathode support to a beam pipe. This is done by cut off the outer second ring of the choke joint, and weld a "dome' around the first ring of the choke joint or the beampipe of the booster cavity. Eighteen 0.375 inch holes are drilled to connect between the new dome with helium vessel. A conical beampipe transits the cavity to a beampipe with RF shield and particular trapping function.

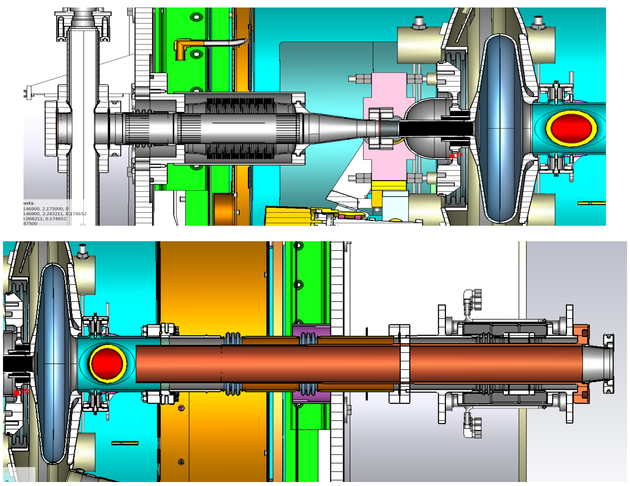

Figure 4: Booster cavity beamline configuration. Top: upstream, Bottom: downstream.

The downstream conversion involves the modification of HOM damper design [3]. In SRF gun, the HOM damper is a warm beampipe Ferrite HOM absorber, which is not sufficient to damp the trapped TM011 mode. Damping TM011 mode is very critical for LEReC because the energy spread for LEReC should be better than 5E-4 at the cooling area. So, an idea with coupling the HOM out of the cavity through a coaxial line and damp the HOM with ferrite at room temperature was developed and worked out. In Figure 4 (bottom) shows the downstream beamline of the booster cavity.

FPC Modification

The FPC coupling factor was 5.5E4 in the gun, which is optimized for 1 MW beam loading. However, the maximum beam power for LEReC is 120 kW, so the RF power source for LEReC is two 65 kW IOT tubes. The coupling factor of booster cavity was optimized to be 1.7E5. This coupling factor assumed the Q_0 at maximum voltage should be better than 7E8, and peak-to-peak microphonics should be smaller than 200 Hz. Based on simulation, each coupler has to retract 5 mm from the original position, which is realized by a thicker gasket spacer. The maximum RF field on the pringle increases about 20%, but still way below the break down level.

Cryomodule Modification

Comparing with SRF gun cavity, the majority additional heat load may come from two sources. The first one is heating by the beam loss or beam halo on the upstream beam pipe area. The worst scenario is all 20 kW beam power hitting on the upstream beampipe transition area for 20 µs, which will cause cavity quench. To avoid damage caused by beam loss, it is relied on cryogenic temperature sensors on the beampipe and He pressure sensor beam interlock. In Figure 5, it shows the cryogenic temperature sensor location, where three sensors were installed to the upstream transition area. The second one is the RF loss on the inner surface of the beam pipe and gasket, and radiation heat from the 300 K HOM inner conductor. To reduce the thermal radiation, the Cu surface was polished such that emissivity of the radiation is as low as 0.1. A 5 K cold anchor was added between cavity downstream flange and the first bellow. Eventually, the total heat load is reduced to 7.9 W, which is close to 7 W static heat load of the SRF gun cavity.

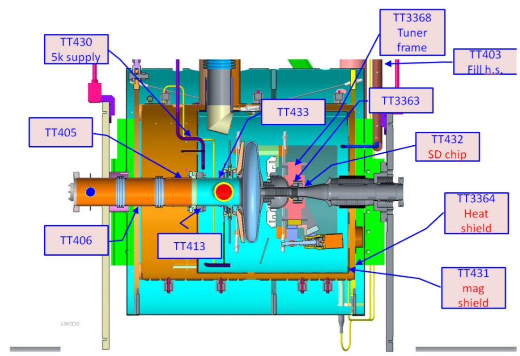

Figure 5: Temperature sensors on the booster cavity.

CRYOMODULE ASSEMBLY

Vertical Test of the Booster Cavity

The cavity was light BCP by ANL, and shipped to Jlab for vertical test. Two tests were carried out and HPR in between. The result of the last test is shown in Figure 6. The cavity reached 2.4 MV, and a field emitter lit up, somehow. After that the field emission onset is low at 1.6 MV. Due to tight schedule, and mainly because we are confident that we can condition through the field emission, the cavity was shipped to BNL for cryomodule installation.

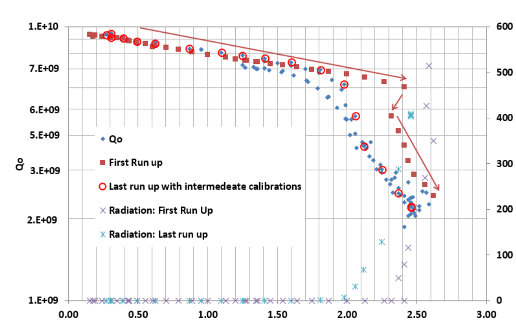

Figure 6: Vertical test results of booster cavity.

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Reconditioning of FPC

Two FPCs were taken apart, inspected and determined to be re-conditioned without any wet processing. The conditioning setup and procedure was similar to the original one used in 2012. As shown Figure 7, the FPCs were re-conditioned up to 120 kW in standing wave, which is double of the required maximum power.

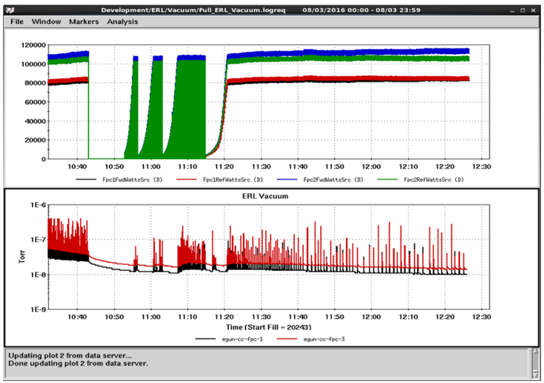

Figure 7: Reconditoning FPCs for LEReC.

Reinstallation of the Cryomodule

The cryomodule was assembled at BNL and moved to ERL blockhouse for high power RF test in summer 2017. Figure 8 shows the cavity in the clean room and cryomodule for high power test.

Figure 8: SRF booster cryomodule in ERL blockhouse.

COMMISSIONING RESULTS

Firstly, the booster cavity was commissioned in ERL Blockhase without HOM damper. Benefitting from the well-conditioned FPC before cryomodule installation, the cavity reached 2.2 MV smoothly, without much vacuum activity, arcing or tripping. Figure 9 shows the cavity commissioning results prior HOM injection. There was very small level the field emission at 2.2 MV. The static heat loss is about 6 W, and the dynamic loss at 2.2 MV is about 15 Watt, which corresponds to cavity quality of 4E9.

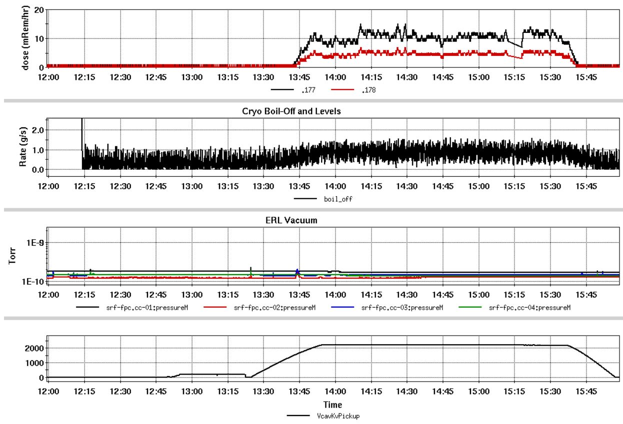

Figure 9: Booster cavity commissioning result before HOM insertion.

The HOM damper, shown in Figure 4 (bottom) was inserted in situ with a portable cleanroom. And the full-dressed booster cavity's test results are shown in Figure 10. The insertion was very successfully, the cavity ramped up the voltage very smoothly, and it only took two days to get to 2.2 MV. The field emission at 2.2 MV only increased slightly, comparing with the no HOM insertion case.

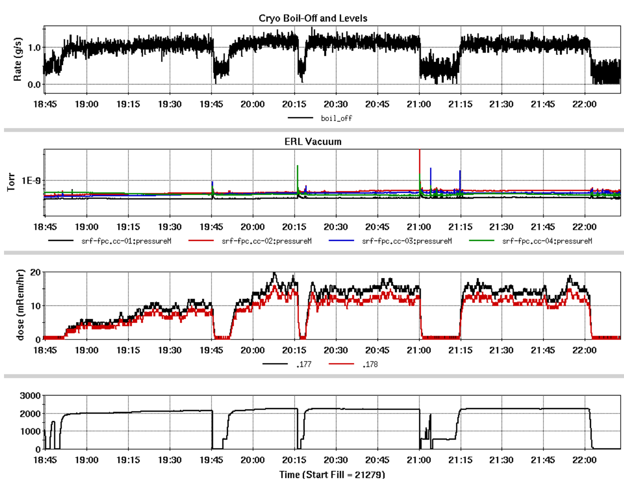

Figure 10. Booster cavity commissioning result after HOM insertion.

SUMMARY

LEReC booster cavity was successful converted from ERL SRF gun cavity. This paper reviewed the ERL SRF gun cavity tested results, discussed the conversion from SRF gun cavity to booster for LEReC, and presented the commissioning results. The booster cavity has been routine operating since it was installed in LEReC beam line.

REFERENCES

[1] A. Fedotov, M. Blaskiewicz, W. Fischer, *et al.*, "Accelerator physics design requirements and challenges of RF based electron cooler LEReC", in *Proc. 2016 North American Particle Accelerator Conf. (NA-PAC'16)*, Chicago, IL, USA, Oct. 2016. doi:10.18429/JACoW-NAPAC2016-WEA4CO05

ISBN: 978-3-95450-194-6 doi:10.18429/JACoW-LINAC2018-MOPO004

[2] Wencan Xu *et al.*, ``SRF Gun at BNL: First Beam and Other commissioning Results'', in *Proc. 17th Int. Conf. on RF Superconductivity (SRF'15)*, Whistler, BC, Canada, 13-18, 2015, pp. 1001-1005. doi:10.18429/JACoW-SRF2015-THAA03

[3] Wencan Xu *et al.*, "Design, simulation, and conditioning of 500 kW fundamental power couplers for a superconducting rf gun", *Phys Rev. ST Accel. Beams*, vol. 15, p. 072001, 2012. doi:10.1103/PhysRevSTAB.15.072001