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COMMISSIONING OF THE NORMAL CONDUCTING CAVITIES FOR LEReC PROJECT*

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Abstract

To improve RHIC luminosity for heavy ion beam energies below 10 GeV/nucleon, the Low Energy RHIC electron Cooler (LEReC) is designed and is currently under commissioning at BNL. The linac of LEReC consists of a DC photoemission gun, a 704 MHz superconducting radio frequency (SRF) booster cavity, a three-cell 2.1 GHz third harmonic cavity for RF curvature correction, a single-cell 704 MHz cavity for energy de-chirping and a 704 MHz deflecting cavity for diagnostic line. In this paper, we present the commissioning of three normal conducting cavities mentioned above.

INTRODUCTION

A bunched beam electron cooler called LEReC [1] has been designed and is under construction at the Relativistic Heavy Ion Collider (RHIC) to significantly improve the collider luminosity at energies below 10 GeV/nucleon to map the QCD phase diagram, especially to search the QCD critical point.

The electron linac of LEReC consists of a DC photoemission gun, one 704 MHz SRF booster cavity [2], and four normal conducting cavities: a 2.1 GHz third harmonic cavity, a 704 MHz cavity [3-5], a 9 MHz cavity, and a 704 MHz deflecting cavity on the beam diagnose line for longitudinal energy spread measurement. The 704 MHz SRF booster cavity accelerates 400 keV bunches from the DC gun near the top of the RF wave, with an accelerating voltage up to 2.2 MV. The booster also introduces an energy chirp for ballistic stretching of the bunches in a beam transport section. The remaining curvature of the bunch in longitudinal phase space is then corrected by decelerating the beam in the 2.1 GHz third harmonic cavity, so that the bunch is nearly linear in phase space. After the 30-meter long transport section, the bunch is still short enough so that the energy chirp can be removed with the normal conducting 704 MHz cavity.[6]

The 2.1 GHz cavity is a three-cell cavity operating at 2.112 GHz. It delivers an accelerating voltage up to 250 kV, at 9 kW power dissipation in the cavity walls, and 21.2 kW maximum power from the beam (decelerating). The 704 MHz cavity is a single-cell structure operating at 704.0 MHz that delivers a voltage up to 251 kV, at 9.5 kW power dissipation in the cavity walls, and 13.4 kW maximum power to the beam (accelerating). The 704 MHz deflecting cavity is a single-cell structure operating at 704.0 MHz that delivers a voltage up to 50 kV, at 150 W power dissipation in the cavity walls, and the power goes to the beam can be ignored since it works at zero phase and only limited number of electron bunches go into the diagnose line per second. In this paper, we describe the commissioning of these three normal conducting cavities.

CAVITY COMMISSIONING

The 2.1 GHz cavity was measured using network analyzer. At 2.1127 GHz, cavity unloaded Q was at 2.0e4, FPC Q_{ext} was at 2.0e4, critically coupled to the cavity. Pickup coupler 1 Q_{ext} was at 1.25e8 and pickup coupler 2 Q_{ext} was at 2.71e7. Cavity R/Q was calculated to be 175.1 Ω in circuit definition.

The RF window was first tested at JLab using 12.1 kW amplifier at 1.5 GHz. An IR camera was used to monitor the temperature on the ceramic, and 8 thermal sensors were attached outside the RF window to monitor the temperature on the stainless-steel frame. The highest temperature on the ceramic was 161.6 °C, and on the stainless-steel was 109.6 °C. The RF window was installed on a JLab530 to WR430 transition piece with two knobs so that it can be tuned to match the new working frequency at 2.112 GHz. The S-parameter results with optimized knob locations are shown in Figure 1.

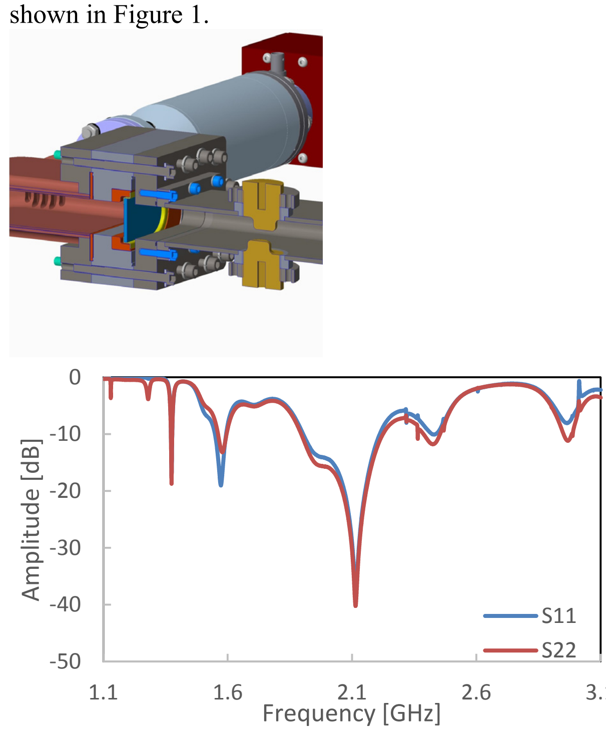

Figure 1: (top) RF window with two tuning knobs (yellow) to tune the frequency from 1.5 GHz to 2.1 GHz; (bottom) S-parameter of the JLab530 RF window with tuning knobs.

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During the conditioning of the 2.1 GHz cavity, the valve between 704 MHz superconducting radiofrequency (SRF) booster cavity and the 2.1 GHz cavity was closed to prevent possible contamination to the SRF booster cavity by vacuum spikes produced by the conditioning of the 2.1 GHz cavity.

The cavity resonant frequency was scanned by changing the tuner position, with nominal frequency at 2.112 GHz, the tuner shifts the frequency in a -0.7 MHz to +1.3 MHz range. Due to the design issue of the 2.1 GHz amplifier, only half of the power was used. With 6 kW out of the amplifier modules, 5 kW power was introduced into the cavity. The 2.1 GHz cavity was conditioned to 180 kV, with RF window stainless-steel frame temperature at 52.1 °C, the connection between beam port and cavity body at 36.8 °C, and tuner port blending area at 33.5 °C.

During the conditioning of the 2.1 GHz cavity, there were some vacuum activities that cannot be conditioned away. Further conditioning was done by ramping the amplifier's output power up and down, thus cavity voltage can be scanned. During this procedure, Inphase-Quadrature (IQ) loop was used to automatically adjust the tuner location to keep the cavity frequency constantly at 2.112 GHz. The condition showed that the cavity voltage cannot be maintained while ramping down the amplifier's output power, and vacuum activities appeared with this effect, as shown in Figure 2 top and middle. The vacuum activity appeared at around 150 to 160 kV, however it was not associated with this certain field level since during the power ramping up it did not appear. The only difference between power ramping up and power ramping down is that the tuner movement was in opposite direction in these two cases. An independent measurement was done by using Phase Lock Loop (PLL) without IQ, and then scan the tuner position up and down while monitoring the cavity resonant frequency at low field level (around 0.5 kV). Result is shown in Figure 2 (bottom). In this plot we found there is a backlash, which get corrected after tightening the motor belt. While moving the tuner out of the cavity, cavity resonant frequency decreased monotonically, and while moving the tuner into the cavity, a few "dead bands" appeared. Further investigation on the tuner actuator showed that there was a mechanical "dead band" while moving the tuner into the cavity, due to the distortion of the guiding rods and threads. To repair it, it was suggested by the vendor that the cavity should not be kept under vacuum (back fill with clean nitrogen), thus decision was made that the actuator will be fixed after this LEReC run. And a temporary fix was made by applying a "dead band" on the PLL phase error so that even the cavity resonant frequency gets detuned by a certain amount, the tuner is not going to move. Instead, amplifier is forced to provide more power to maintain the cavity accelerating voltage.

For the 704 MHz warm cavity, at 703.75MHz, cavity unloaded Q was at 3.38e4, FPC Q_{ext} was at 1.43e4, pickup coupler 1 Q_{ext} was at 1.12e8 and pickup coupler 2 Q_{ext} was at 9.08e7. Cavity R/Q was calculated to be 126.7 Ω in circuit definition.

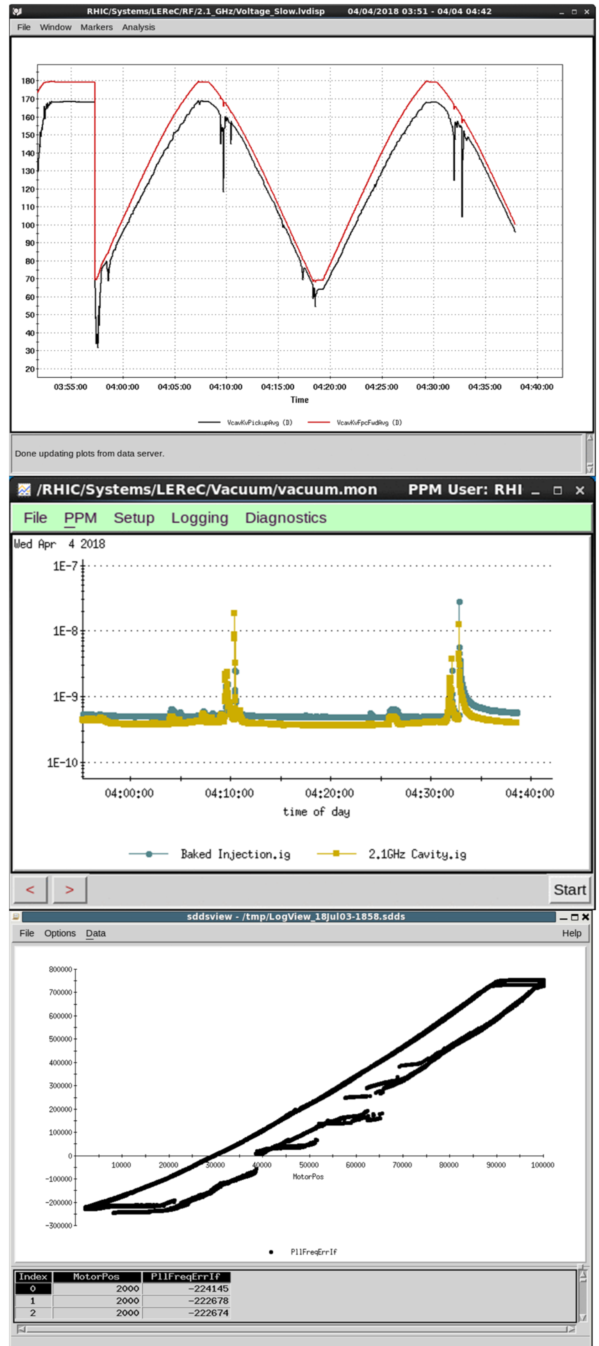

Figure 2: 2.1 GHz cavity conditioning, from top to bottom: (a) ramping amplifier output power up and down; (b) vacuum change during this procedure; (c) tuner position versus cavity resonant frequency.

The 704 MHz warm cavity was conditioned to 262 kV using 9.1 kW power with 1.35 kW reflected, with FPC port blending area at 41.2 °C, tuner port blending area at 35.3 °C, the connection between beam port and cavity body at 31.5 °C, cavity body temperature at 30.3 °C, and RF window at 30.6 °C. The FPC port blending area shows the highest temperature since it is the highest magnetic field region. The 704 MHz warm cavity uses an actuator similar to the one for 2.1 GHz cavity, measurement similar to Figure 2(c) was done for this cavity, and no backlash or

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"dead band" was found. Visual inspection was also done to the actuator while the tuner was moving, this system worked fine without any issue.

For the 704 MHz deflecting cavity, unloaded Q was at 1.24e4, FPC Q_{ext} was at 1.22e4, critically coupled to the cavity. There is only one pickup coupler on the cavity, with Q_{ext} at 1.86e5. Cavity R/Q was calculated to be 750 Ω in circuit definition.

The 704 MHz deflecting cavity was first measured on an optical table using wire-stretching technique to find the electric center, and to measure the deflecting field uniformity with possible beam trajectories that are parallel to the electric center [7, 8]. The cavity was then installed in the RHIC tunnel and was conditioned to 90 kV using 490 W power.

CONCLUSIONS

In this paper, the commissioning of three normal conducting RF cavities were presented: the 2.1 GHz cavity, the 704 MHz normal conducting cavity and the 704 MHz deflecting cavity.

For the 2.1 GHz cavity, the RF window was first high power tested at JLab using a 12.1 kW 1.5 GHz klystron amplifier, and then it was installed on a JLab530 to WR430 transition piece and was tuned to work at 2.1 GHz. The cavity was conditioned to 180 kV using 6 kW out of the amplifier modules, with highest measured temperature on the RF window stainless-steel frame at 52.1 °C.

For the 704 MHz cavity, it was conditioned to 262 kV using 9.1 kW power with 1.35 kW reflected, with highest measured temperature on the FPC port blending area at 41.2 °C.

The 704 MHz deflecting cavity was first measured using wire-stretching technique, and it was then conditioned to 90 kV using 490 W power.

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