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SRF AND RF SYSTEMS FOR LEReC LINAC *

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Abstract

The Low Energy RHIC electron Cooling (LEReC) is under development at BNL to improve RHIC luminosity at low energies. It will consist of a short electron linac and two cooling sections, one for blue and one for yellow rings. For the first stage of the project, LEReC-I, we will install a 704 MHz superconducting RF cavity and three normal conducting cavities operating at 9 MHz, 704 MHz and 2.1 GHz. The SRF cavity will boost the electron beam energy up to 2 MeV. The warm cavities will be used to correct the energy spread introduced in the SRF cavity. The paper describes layouts of the SRF and RF systems, their parameters and status.

INTRODUCTION

One of the highest priorities for the RHIC experimental program is to map the QCD phase diagram at center-of-mass collison energies below 20 GeV (γ = 10.7). However, at present the RHIC luminosity at these energies does not provide sufficient statistics. It was proposed to apply bunched beam electron cooling to significantly increase the luminosity. The Low Energy RHIC electron Cooling is under design at BNL [1].

There are two options under consideration for the LEReC electron linac: one based on a DC photoemission gun and another based on an SRF photoemission gun. During the first phase of the project, LEReC-I, electrons will be accelerated only to kinetic energies from 1.6 to 2 MeV. As the DC gun option was chosen as the baseline, in this paper we present only SRF and RF system parameters relevant to this option of LEReC-I.

The linac will be located in the RHIC tunnel near the Interaction Point 2 (IP2) where it will benefit from sharing cryogenic system and some RF infrastructure with the coherent electron cooling proof-of-principle experiment [2]. The linac will include a Cornell-type DC photoemission electron gun [3] operating at 400 kV. The gun will be followed by a 704-MHz SRF booster cavity, and three normal conducting cavities operating at frequencies 9 MHz, 704 MHz and 2.1 GHz. The latter two cavities will serve for beam energy spread correction. The Phase I linac layout is shown in Figure 1 and RF system parameters are listed in Table 1.

The 9-MHz cavity is an existing spare cavity available from RHIC together with an RF amplifier. This cavity will be used in LEReC to compensate bunch-to-bunch energy variation inside the 30-car long bunch trains. This variation is due to beam loading effect in other cavities. Other RF systems are described below.

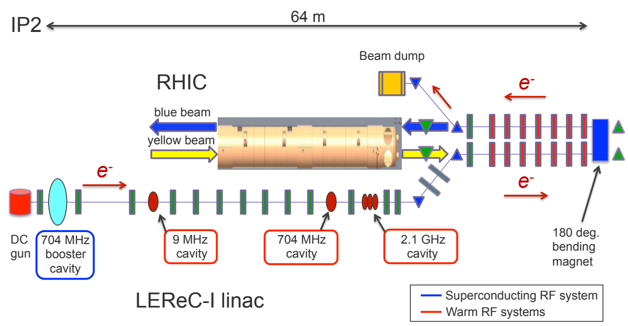

Figure 1: LEReC-I layout.

Table 1: Parameters of the LEReC-I RF Systems

Parameter	SRF booster	9 MHz	704 MHz	2.1 GHz
Cavity voltage	1.2 to 1.6 MV	3 kV	78 kV	7.5 kV
R/Q	96 Ω	190 Ω	247 Ω	487 Ω
Q_{ext}	5×10^5	35	2.6×10^4	1.09×10^4
Installed RF power	65 kW	1 kW	50 kW	10 kW

SRF BOOSTER

After generating a 400-keV beam in the DC gun, we need to boost its kinetic energy to 1.6 to 2 MeV. This will be achieved using a 704-MHz cryomodule converted from an SRF gun configuration to a booster cavity. At present, the cryomodule is installed in the R&D ERL at BNL and is under commissioning [4]. The SRF gun cavity has demonstrated very good performance, reaching its design voltage of 2 MV.

As soon as the R&D ERL beam experiments will be complete in 2016, the cryomodule will be removed and reconfigured to serve as a booster cavity for LEReC as illustrated in Figure 2. A photocathode stalk assembly will be removed and a specially designed beam pipe will be inserted in its place. In addition, the RF power coupling scheme will be modified to account much smaller beam loading in LEReC compared to R&D ERL. The booster will be powered from a 65-kW IOT-based high power RF amplifier.

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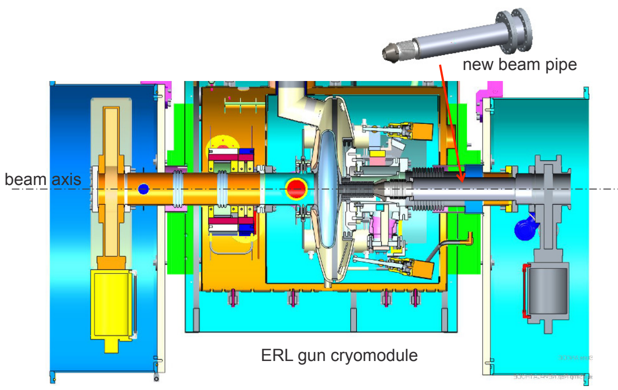

Figure 2: The ERL gun cryomodule converted to a LEReC booster cryomodule.

704 MHz SINGLE CELL CAVITY

A single cell 704-MHz copper cavity is designed for an accelerating voltage up to 430 kV, which will be needed in Phase II of LEReC. Only 78 kV will be required for LEReC-I. The elliptical cell shape, shown in Figure 3, was optimized as reported in [5].

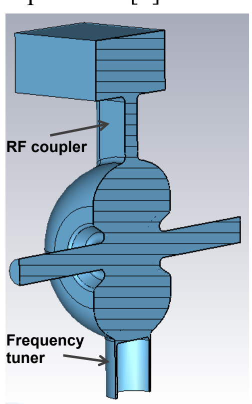

Figure 3: RF model of the 704-MHz cavity.

A plunger-type frequency tuner will provide a tuning range of more than 1.6 MHz. The cavity's Fundamental Power Coupler (FPC) consists of a coupling slot, a reduced height waveguide, and an RF window separating the cavity vacuum from WR1150 waveguide. The waveguide will connect the cavity to a 50 kW IOT amplifier. The RF window will be of the type developed originally at LBNL and further at Jefferson Lab [6]. The cavity's beam pipe aperture is 1.875″. The RF design is complete and the mechanical design is in progress. We expect to have the cavity fabricated within a year.

2.1 GHz 3-CELL CAVITY

A 3-cell 2.1-GHz copper cavity will provide an accelerating voltage up to 200 kV in Phase II, while requirements for LEReC-I, listed in Table 1, are more relaxed. The cavity, depicted in Figure 4, features magnetic cell-to-cell coupling via four slots in the inner walls and small nose cones are provided to maximize the shunt impedance [5]. A plunger-type frequency tuner delivers a frequency range of 4.5 MHz. A FPC is terminated by the CEBAF-type RF window [6]. A small ion pump is mounted on one side of the FPC, while a port on the other side (not shown in Figure 4) will be occupied by an arc detector. Two larger ion pumps are connected to 1.37″ ID beam pipes on each side of the cavity.

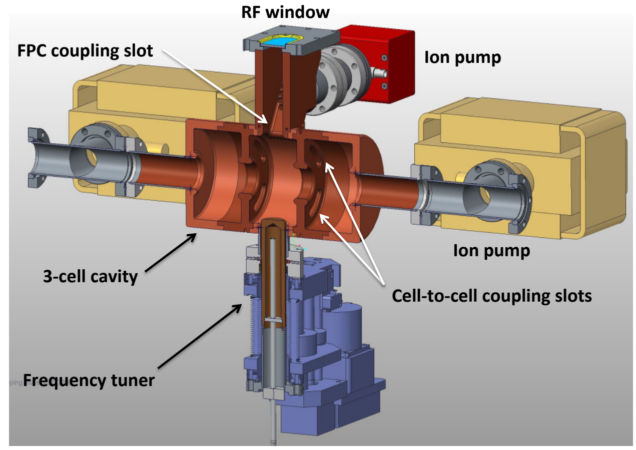

Figure 4: 3D cross section of the 2.1 GHz 3-cell cavity.

The cavity will be powered by a 10-kW solid state amplifier. The cavity design is complete and an order for its fabrication will be placed soon.

SUMMARY AND PLANS

LEReC-I will have a 704-MHz SRF booster and three normal conducting RF systems: a 9-MHz cavity for beam loading compensation, a 704-MHz cavity for beam energy spread correction, and a 2.1 GHz three-cell cavity for fine-tuning the energy spread. The 704-MHz SRF cryomodule is currently configured as an SRF gun and is under commissioning at R&D ERL. As soon at the ERL beam experiments are finished in 2016, the cryomodule will be converted into a booster cavity for LEReC. The 9-MHz system will be built from spare components available at RHIC. Finally, the other two normal conducting cavities are designed and their fabrication will begin soon with the goal to have the cavities available in mid-2016. High power RF amplifiers, circulators, loads, transmission lines, LLRF, etc. will be ordered as well. We plan to install the normal conducting RF systems in the RHIC tunnel during summer shutdown of 2016 and begin commissioning of the RF systems shortly thereafter.

REFERENCES

[1] A. Fedotov, "Bunched beam electron cooling for Low Energy RHIC operation", in *ICFA Beam Dynamics Newsletter* No. 65, p. 22 (December 2014).
[2] V. N. Litvinenko et al., "Present status of coherent electron cooling proof-of-principle experiment," *Proc. IPAC'14,* Dresden, Germany (2014), p. 87.
[3] J. Maxson et al., "Design, conditioning, and performance of a high voltage, high brightness dc

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photoelectron gun with variable gap," Rev. Sci. Instrum. **85**, 093306 (2014).

[4] Wencan Xu et al., "First beam commissioning at BNL ERL SRF gun," TUPMA049, these proceedings, IPAC'15, Richmond, VA (2015).

[5] B. Xiao et al., "Design of Normal Conducting 704 MHz and 2.1 GHz Cavities for LEReC Linac," WEPWI061, these proceedings, IPAC'15, Richmond, VA (2015).

[6] R. A. Rimmer et al., "A high-power L-band RF window," *Proc. PAC'01*, Chicago, IL (2001), p. 921.

[7] V. Nguyen, H. L. Phillips, and J. Preble, "Development of a 50 kW CW L-band rectangular window for Jefferson Lab FEL cryomodule," *Proc. PAC'99*, New York, NY (1999), p. 1459.