SRF SYSTEMS FOR THE COHERENT ELECTRON COOLING DEMONSTRATION EXPERIMENT*

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Abstract

A short 22-MeV linac under development at BNL will provide high charge, low repetition rate beam for the Coherent electron Cooling (CeC) demonstration experiment in RHIC. The linac will include a 112 MHz SRF gun and a 704 MHz five-cell accelerating SRF cavity. The paper describes the two SRF systems, discusses the project status, first test results and schedule.

INTRODUCTION

A Proof-of-Principle (PoP) experiment is under preparation at BNL to demonstrate feasibility of the Coherent electron Cooling (CeC) for future improvements of luminosity in high-energy hadron-hadron and electron-hadron colliders [1, 2]. During this experiment we aim to cool only one bunch in RHIC. This will require a high-bunch-charge (up to 5 nC), but low-repetition-rate electron beam. The bunch repetition frequency (78 kHz) is equal to the revolution frequency of ion bunches in RHIC. To generate such a beam, we are building a short 22-MeV superconducting linac [3]. The linac includes two SRF systems: a 112-MHz Quarter Wave Resonator (QWR) photoemission electron gun [4] and a 704-MHz booster cavity cryomodule. Two normal conducting bunching cavities [5] will provide velocity modulation to shorten electron bunches between the two SRF cryomodules. The linac layout is shown in Figure 1. In this paper we describe the two SRF systems, report on the project status and test results, and discuss testing and commissioning plans.

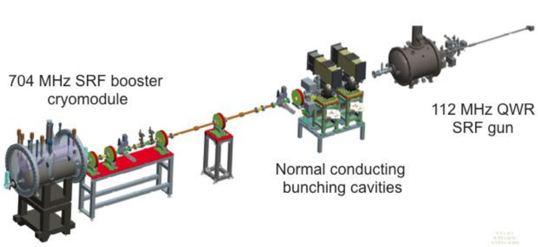

Figure 1: Layout of the CeC PoP linac.

112 MHz SRF GUN

A superconducting 112 MHz quarter-wave resonator was developed by collaborative efforts of BNL and Niowave, Inc. [6, 7]. The gun operates at 4.5 K with liquid helium provided from a quiet helium source via the cryomodule cryogenic tower. Assuming a residual surface resistivity of 10 nOhm and a residual magnetic field of 60 mG, we expect to achieve the cavity quality factor of 1.8×10^9. The QWR's center conductor geometry naturally accommodates a half-wavelength choke joint and allows mechanical decoupling of the cathode assembly from the niobium cavity [8]. A low-RF-loss photocathode stalk operates at room temperature. It is hollow, allowing inserting a small photocathode pack via a load lock system. Electron beam will be generated by illuminating a multi-alkali (CsK_2Sb or NaK_2Sb) photocathode with a green (532 nm) light from a laser.

The 112 MHz gun is equipped with a double-purpose fundamental RF power coupler / fine frequency tuning assembly [8]. The fine frequency tuning with a range of about 3 kHz will be used for remote frequency adjustment. It will complement a larger range (>78 kHz) tuner, which will be used only for an initial frequency set up. The mechanical design of the fundamental power coupler (FPC) is described elsewhere [9]. A focusing solenoid is placed on top of the FPC close to the cryomodule's beam exit flange.

After the first cryomodule cold test at Niowave in December of 2010 [6], the gun has undergone modifications for compatibility with installation in RHIC tunnel. The modified gun was cold tested again at Niowave in December of 2012 and February of 2013. During the test we have encountered multipacting zones at very low fields, which were processed only after we modified the RF input coupler to increase its coupling. After that we were able to proceed to higher fields, where several events occurred, presumably due to activation of an emitter first and then burning it out as we switched to pulsed RF power conditioning. Eventually, the gun reached an accelerating voltage of 0.92 MV, limited by an insufficient radiation shielding of the experimental set up. Figure 2 illustrates the gun cavity behavior during the cold test.

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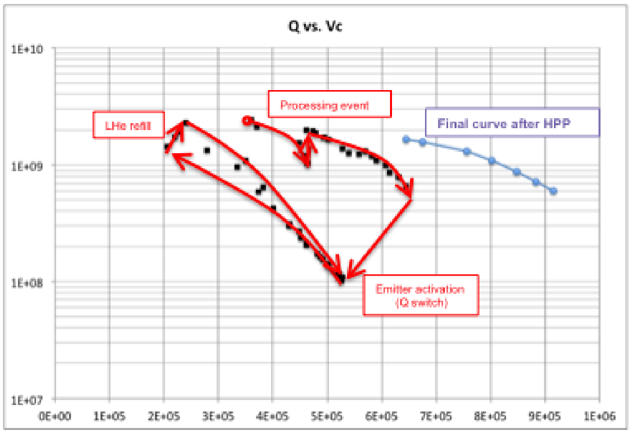

Figure 2: Q *vs.* V_c plot showing the gun cavity behavior during conditioning and the final curve.

After completion of the cold test, the gun cryomodule was shipped to BNL and is currently installed in the RHIC tunnel. The commissioning will begin as soon as cryogenic, photocathode transport, RF and other systems are ready, tentatively in January of 2014.

704 MHz BOOSTER CRYOMODULE

The 704 MHz booster cryomodule will house one 5-cell SRF cavity of the BNL3 shape [10-12]. The cavity will deliver an energy gain up to 20 MeV. It will operate at 2 K with an internal superfluid heat exchanger to better isolate the cavity from microphonic noise originated in the cryogenic system. The mechanical design of the cold mass is described elsewhere [13]. A sectional view of the cryomodule is shown in Figure 3. A fundamental RF power coupler (FPC) will be of a coaxial antenna type and will be able to transmit power up to 20 kW CW. The cryomodule design is being finalized and its production will begin soon at Niowave, Inc. with the delivery to BNL scheduled for summer of 2014. Table 1 lists main parameters of the booster system.

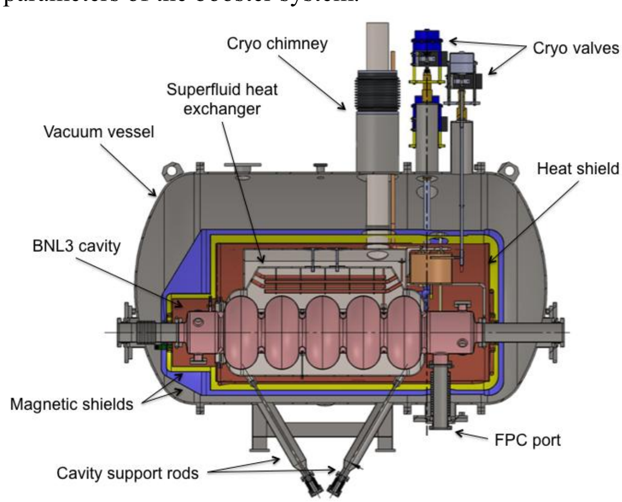

Figure 3: 704 MHz booster cryomodule for CeC PoP.

Two cavities have been fabricated: BNL3-1 by AES, Inc. and BNL3-2 by Niowave, Inc (Figure 4). Both cavities have undergone standard preparation for vertical acceptance tests (bulk BCP, vacuum bale at 600ºC for 10 hours, light BCP, HPR). The tests will be performed in October/November of 2013.

Table 1: Parameters of the 704 MHz SRF Booster

RF frequency	704 MHz
Maximum energy gain	20 MeV
R/Q	506 Ohm
Geometry factor	283 Ohm
Cavity Q_0 at 4.5 K	2×10^{10}
Cavity RF losses at 2.0 MV	37 W
Frequency tuning range	78 kHz
Q_{ext} of FPC, min.	2.8×10^{7}
Available RF power from solid state amplifier	20 kW

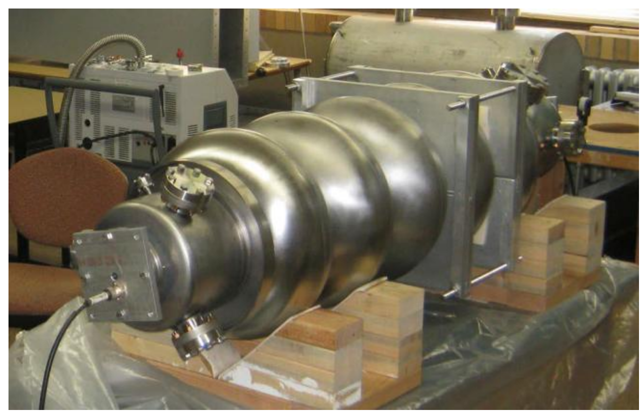

Figure 4: BNL3-2 cavity at Niowave, Inc.

SUMMARY

The SRF systems for the CeC PoP experiment have been designed. The 112 MHz SRF gun cryomodule has been fabricated and tested up to 0.92 MV, limited only by insufficient radiation shielding. It will be re-tested and conditioned to full voltage after installation in the RHIC tunnel is complete in January of 2014. This will be followed immediately by commissioning of the 2 MeV beam line. Two 704 MHz 5-cell cavities have been fabricated: one by AES, Inc. and one by Niowave, Inc. Both cavities went through standard cavity preparation cycle and will be vertically tested within two months. One of the cavities will be chosen for integration into the booster cryomodule. The booster cryomodule design is being finalized and its fabrication will begin soon at Niowave. Its delivery to BNL is scheduled for summer of 2014.

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