FIRST BEAM COMMISSIONING AT BNL ERL SRF GUN*

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Abstract

The 704 MHz SRF gun successfully generated the first photoemission beam in November of 2014. The configurations of the test and the sub-systems are described. The latest results of SRF commissioning, including the cavity performance, cathode QE measurements, beam current/energy measurements, are presented in the paper.

INTRODUCTION

The R&D ERL [1] at BNL is an electron accelerator designed for high average current, up to 350 mA. It serves as a test bed for future RHIC projects, such as eRHIC [2], Coherent-Electron-Cooling [3], and Low Energy RHIC Electron Cooler [4]. The 704 MHz half-cell SRF gun is designed to provide 0.5 A, 2 MeV electron beam. Commissioning of the SRF gun is being carried out in stages: without a cathode stalk (finished in early 2013), with a copper cathode stalk (finished in fall of 2013), and beam commissioning (started in mid-2014) [5, 6, 7]. The 704 MHz half-cell SRF gun has successfully generated electron beams in November of 2014. This paper discusses the first beam test results.

BEAM COMMISSIONING LAYOUT

Following the step-by-step commissioning plan, the first beam commissioning of the SRF gun was done with a straight beam line ending up at a faraday cup, instead of going through a Zig-Zag, a merging scheme for the high- and low-energy beams consisting of dipole magnets bending in the vertical plane designed to minimize emittance growth [8]. The beam line configuration is shown in Figure 1. The Cs_3Sb photocathode [6, 7] was deposited on the cathode stalk with copper substrate (a new cathode stalk will use Ta substrate) in the cathode deposition system located outside the ERL blockhouse. Then, the cathode stalk was moved to the ERL blockhouse inside a cathode transport cart and inserted into the SRF gun. A load-locked system is used for the connection between the SRF gun and the cathode transport cart. Following the 704 MHz half-cell SRF cavity, there is a high temperature superconducting solenoid (HTSS), a room-temperature HOM absorber (Now, instead of the absorber, a room temperature solenoid was installed there for better beam quality), a laser cross, an Integrated Current transformer (ICT), a Beam Position Monitor (BPM), a vertical and horizontal beam corrector, a beam halo monitor, a pepper pot beam emittance measurement, a beam profile monitor and a Faraday cup. The dipole magnet for bending electron beams to the Zig-Zag is locked out for the first beam tests.

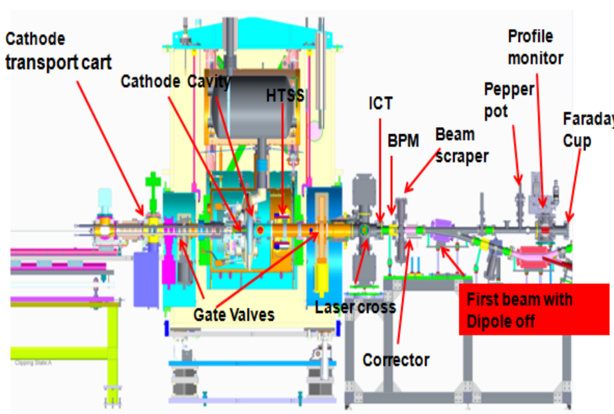

Figure 1: First beam commissioning configuration.

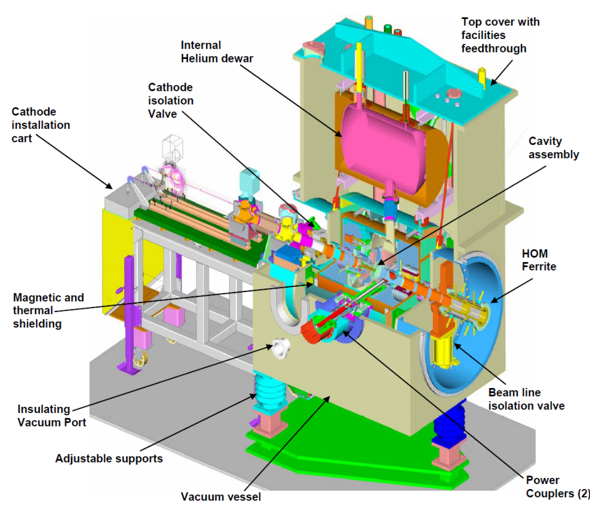

Figure 2: SRF gun cryomodule.

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PERFORMANCE OF THE SRF GUN

The SRF gun cryomodule is shown in Figure 2. It is built around the 704 MHz half-cell SRF cavity, including a quarter-wavelength choke-joint cathode insert, a pair of opposing fundamental power couplers (FPC) to deliver 1 MW of RF power, a high temperature superconducting solenoid (HTSS) to compensate space charge and a room-temperature ferrite HOM damper with a ceramic break. The gun was successfully commissioned and reached the design goal (2 MV in CW mode) without a cathode stalk insert [5, 7]. However, multipacting occurred during commissioning with a copper cathode stalk. The main reason for multipacting was distortion of anti-multipacting grooves during Buffered Chemical Polish (BCP) and high Second Emission Yield (SEY) in the stainless steel area of the choke joint. Details of multipacting in the choke-joint and its suppression are discussed in Reference [9]. After spending some time on conditioning mutipacting (to suppress it), we were able to operate the gun at 1.9 MV with 18% duty factor. The field stability was studied during cavity tests. The achieved amplitude stability is 2.3×10^{-4} (rms) and the phase stability was 0.035° (rms). While designing a new multipacting-free cathode stalk, we tried to use this cathode stalk to generate first electron beams.

PHOTO-CATHODE

Because the substrate of the cathode stalk is copper, the QE of Cs_3Sb was relatively low, 0.25% as measured in the cathode preparation chamber. However, after the cathode stalk was moved into the ERL block house and connected to the gun with a load-lock connector. The load-lock was baked out, the QE dropped to 3.5×10^{-4} (at room temperature) before it was inserted into the cavity. After the cathode was inserted into the cavity, the QE was measured as 1.2×10^{-5} with the cathode cooled by LN2. This drop was understood to be due to an increase in the workfunction at LN2 temperature [10].

BEAM STRUCTURE

The first beam test had to satisfy DOE's approval, "Commissioning Accelerator Safety Envelope (CASE) Credited Controls and Supports for ERL low power testing", which limited the beam power to below 70 W. The ICT was required to be used for beam current measurement. The beam structure, shown in Figure 3, had to satisfy ICT's response window.

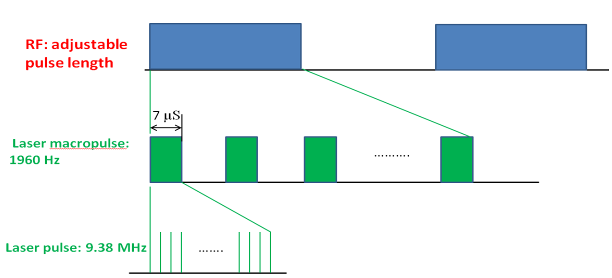

Figure 3: Beam structure of first beam test.

BEAM PARAMETER MEASUREMENTS

In November 2014, we successfully generated the first photoemission beam in the SRF gun and measured some of the beam parameters. Figure 4 shows the beam current measured by a Faraday cup with laser on and off. The beam current was 1.09 µA with only 38 nA dark current (laser off), and the bunch charge was 7.7 pC. The rms beam size was measured on the beam profile monitor as 1.4 mm, shown in Figure 5. A beam energy of 1.25 MeV was measured through steering and dipole magnets, consistent with the RF voltage.

Figure 4: Beam current (top), dark current (middle) and bunch charge (bottom) measured by Faraday Cup.

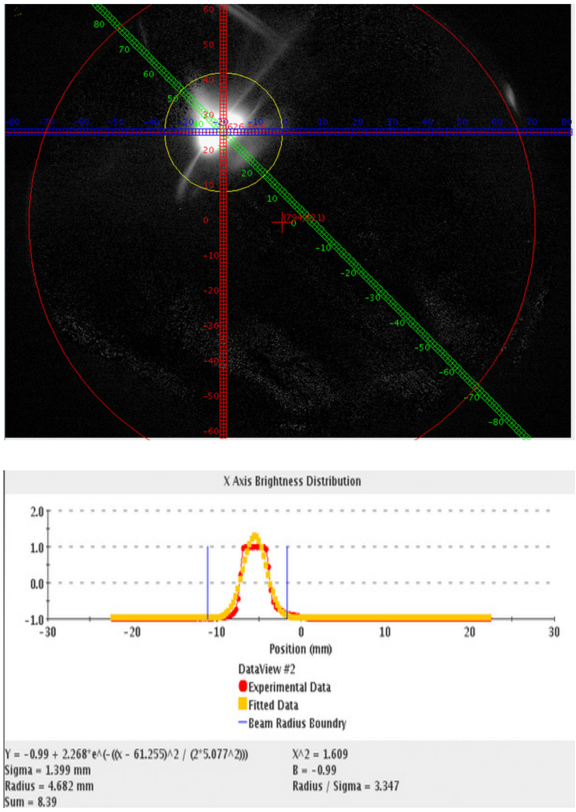

Figure 5: Beam size measured by beam profile monitor.

SUMMARY AND PLAN

The SRF gun for the R&D ERL is now in the commissioning stage, having received DOE approval to operate beyond the initial 70 W restriction. With a copper-substrate (low QE) cathode on the old cathode stalk, the first photoemission electron beam was successfully generated in November 2014. Some of the beam parameters were measured. This is a milestone for the SRF gun. There is no sign of cavity performance degradation due to operating with the photocathode.

A new multipacting-free cathode stalk with Ta tip was farbicated, tested and has shown truly multipacting-free performance. Beam tests with the new cathode stalk are in preparation.

REFERENCES

[1] I. Ben-Zvi, et al., "The Status of the BNL R&D ERL," ICFA Beam Dynamics Newletter, No. 58, August 2012, p. 151.

[2] E. C. Aschenauer, et al., "eRHIC Design Study: An electron-ion collider at BNL," http://arxiv.org/abs/1409.1633

[3] V. N. Litvinenko, "Coherent electron cooling – perfect tool for high luminosity RHIC and eRHIC," http://www.cad.bnl.gov/MAC/MAC_08/PDF/15_VL_CAD_MAC_February_2008.pdf

[4] A. Fedotov, "Bunched beam electron cooling for low-energy RHIC operation," ICFA Beam Dynamics Newsletter, No. 65, December 2014, p. 22.

[5] Wencan Xu, et al., "BNL SRF gun commissioning," Proc. SRF2013, Paris, France, 2013, pp. 155-158.

[6] D. Kayran, et al, "First test Results from SRF photoinjector for the R&D ERL at BNL" Proc. IPAC`14, Dresden, Germany, June 2014, pp.748-750.

[7] Wencan Xu, et al., "Beam Commissioning Program of the 704 MHz SRF Gun" Proc. LINAC2014, Geneva, Switzerland, 2014, pp. 70-72.

[8] Dmitry Kayran, and V. N. Litvinenko, "A Method of Emittance Preservation in ERL Merging System," Proc. 27th International Free Electron Laser Conference, Stanford, CA, 2005, pp. 644-647.

[9] Wencan Xu, et al., "Multipacting-free quarter-wavelength choke joint design for BNL SRF gun", these proceedings.

[10] E. Wang, et al. "Characterization of multi-alkali antimonide cathode at cryogenic temperatures," these proceedings.

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