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FIRST HORIZONTAL TEST RESULTS OF THE HZB SRF PHOTOINJECTOR FOR bERLinPro

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Abstract

The bERLinPro project, a small superconducting RF (SRF) c.w. energy recovery linac (ERL) is being built at Helmholtz-Zentrum Berlin in order to develop the technology required for operation of a high current, 100 mA, 50 MeV ERL. The electron source for the accelerator is a 1.4 cell SRF photoinjector fitted with a multi-alkali photocathode. As part of the HZB photoinjector development program three different SRF photoinjectors will be fabricated and tested. The photoinjector described herein is the second cavity that has been fabricated, and the first photoinjector designed for use with a multi-alkali photocathode. The photoinjector has been built and tested at JLab and subsequently shipped to HZB for testing in the horizontal test cryostat HoBiCaT prior to installation in the photoinjector cryomodule. This cryomodule will be used to measure the photocathode operation in a dedicated experiment called GunLab, the precursor to installation in the bERLinPro hall. This paper will report on the final results of the cavity installed in the helium vessel in the vertical testing dewar at Jefferson Lab as well as the first horizontal test in HoBiCaT.

INTRODUCTION

Helmholtz-Zentrum Berlin (HZB) has set out on a program to build a superconducting RF (SRF), high average current, Energy Recovery Linac (ERL) designed to operate at an electron beam energy of 50 MeV with 100 mA average current.[1] The ERL is designed to study the physics of the operation of a high current ERL in a number of different modes. This includes operation with bunch charges ranging from a few pC to 77 pC and repetition rates that range from low repetition rate burst modes up to c.w. operation at 1.3 GHz. This wide range of operating conditions will place great demands on many of the components of the ERL, and will certainly test the limits of the SRF photoinjector.[2]

In order to help mitigate the risks associated with operation of the SRF photoinjector HZB has set out on a multi-cavity photoinjector R&D program.[3] Four different SRF photoinjectors will be built and tested in order to gain experience with different aspects of the photoinjector operation. The first two photoinjectors in the development program were designed to utilize a lead photocathode and the results of these tests can be found in references 4-7.[4-7] The first photoinjector suitable for bERLinPro, called Gun 1.0, has been fabricated by Jefferson Lab and the preliminary data reported on previously.[8] This cavity is designed to utilize an independently cooled cathode stalk which will allow for the installation of a high quantum efficiency multi-alkali, CsK_2Sb, photocathode, suitable for generation of a 100 mA electron beam. In this paper we will report on the helium vessel welding and final test results in the JLab VTA as well as the first horizontal test results obtained at HZB in the HoBiCaT horizontal test cryostat.

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HELIUM VESSEL WELDING AND FINAL VERTICAL TEST RESULTS

Following the cavity fabrication at JLab the cavity was processed and tested a number of times in an attempt to achieve the required operating gradient and quality factor for bERLinPro. Due to the new cavity design and the fact that this cavity was the first article produced, several challenges were encountered and the performance after 8 vertical tests was less than desired.[8] Due to schedule constraints the decision was made to attach the helium vessel to the cavity to progress the program. The titanium helium vessel was electron beam welded to the cavity while the cavity was kept under the static vacuum to avoid contamination of the inside of the cavity during the welding process. A photograph of the cavity following the helium vessel welding is shown in figure 1, with the cut-away of the cavity inside shown in figure 2.

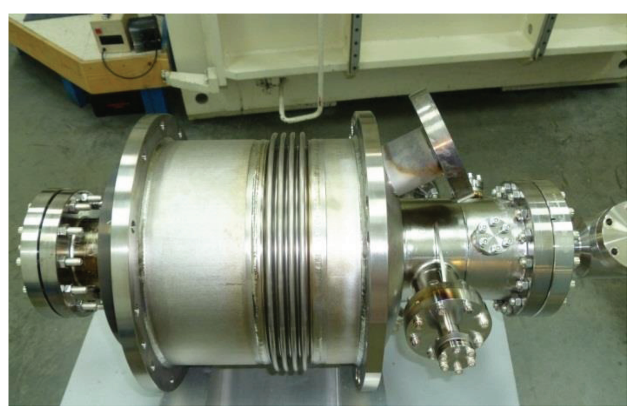

Figure 1: The SRF photoinjector for bERLinPro.

After the helium vessel welding and leak checking was complet the field flatness and frequency of the cavity were measured and found to be in very good agreement with the estimated values expected after the welding. The

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field flatness was measured to be 95% while the frequency had decreased by 300 kHz. The field profile is such that there is less stored energy in the half cell then the full cell, a favourable condition for operations as it reduces the peak field on the cathode stalk, thus potentially helping to reduce field emitted stray electrons.

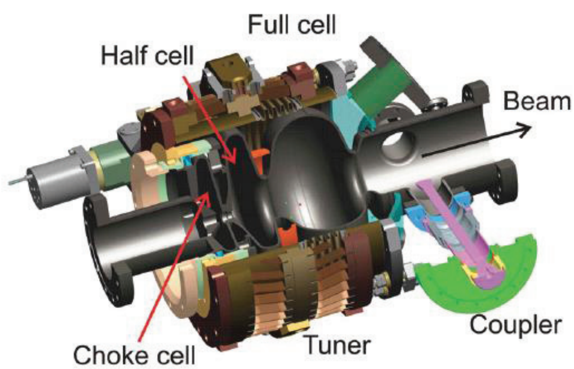

Figure 2: The cutaway view of the SRF photoinjector for bERLinPro.

After the bench RF measurements were completed the cavity was returned to the cleanroom, high pressure rinsed and re-tested. The test results for the cavity in the helium vessel are shown in figure 3, and were a significant improvement over the last test of the bare cavity. While the last test of the bare cavity only reached E_0 = 15 MV/m (where E_0 is the peak on axis electric field) with a low field Q_0 of 2.0e+9, the performance now reaches 28 MV/m with a low field Q_0 of 7.0e+9. Following this successful test the cavity was removed for the dewar, kept under vacuum, and shipped to HZB for further testing.

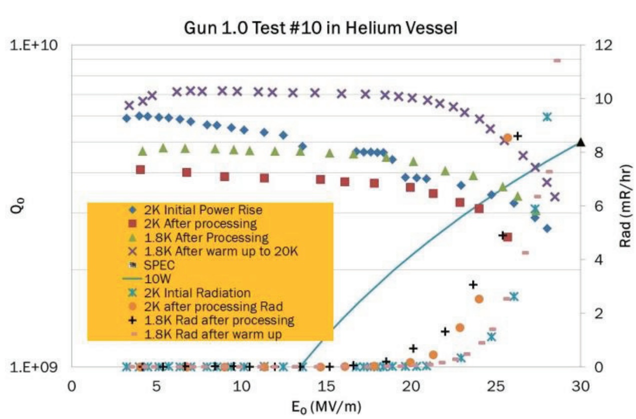

Figure 3: The vertical RF test results from the JLab VTA at 1.8 and 2K for the cavity in the helium vessel. The accelerating field E_0 is the peak on axis electric field, the most relevant measure for a photoinjector.

HZB HORIZONTAL TESTING

After the cavity arrived in Germany, a support system was designed and the cavity was installed in HoBiCaT, the horizontal testing cryostat at HZB. A picture of the cavity in HoBiCaT is shown in figure 4. In this configuration only the helium vessel is filled with liquid helium, better reproducing the cryomodule configuration, as compared to the vertical dewar tests where the entire cavity is submerged. Additionally, the cavity is restrained with threaded rod in-lieu of the tuner for this test. The local magnetic shielding has not been installed at this stage, so only the single layer of magnetic shielding inside of HoBiCaT is used. This has been demonstrated in the past to provide satisfactory shielding of the earth's magnetic field, and in the "long" position where the cavity is installed the earth's magnetic field was measured to be less than 2 μT on average.[9]

Figure 4: A photo of the gun cavity installed in HoBiCaT.

After connecting the cavity to the helium supply and recovery system, and establishing active vacuum pumping the cavity was cooled down to 1.8K for RF measurements. The cavity test proceeded much like the last JLab test with signs of multipacting at ~ a gradient of 3 MV/m and 10 MV/m and then a smooth power rise to 20 MV/m where another multipacting barrier was encountered that required pulsed RF processing for ~ 20 min. After this time the cavity went to ~ 30 MV/m where it appears to quench. All of these measurements are in excellent agreement with the results from JLab, confirming that the shipping of the cavity from JLab to HZB did not have any negative impact on the cavity performance.

The center frequency measured at HZB in the constrained orientation is 1299.262 MHz, approximately 384 kHz below the frequency measured in the VTA at JLab. The pressure sensitivity, df/dp for the cavity in this constrained configuration was measured from 4K down to 1.8K for comparison to simulations carried out by Zaplatin.[10] Unfortunately the tested configuration and the simulated configuration are different, but the simulated results relative to the measured results for the unconstrained cavity agree very well. Table 1 lists the calculated df/dp compared to the measured df/dp from HoBiCaT.

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Table 1: The pressure sensitivity (df/dp) (Hz/mbar) measured in the vertical testing dewar (VTA - unrestrained) compared to the restrained case in HoBiCaT and simulations from ANSYS® for 3 mm Nb sheet material. It should be noted that the simulated restrained condition is different from the experimental configuration. Further tests will allow for measurement of the simulated case

Simulation		VTA	HoBiCaT
Unrestrained	Restrained with Tuner		Restrained with threaded rod
	0 Hz/mbar		150 Hz/mbar
-550 Hz/mbar		-561 Hz/mbar	

A plot of the cavity quality factor versus gradient for the final power rise in HoBiCaT is shown in figure 5. The cavity should be capable of delivering a 2.3 MeV electron beam for the experiments in GunLab, the demonstration photoinjector beamline for the study of multi-alkali photocathode operation in the 1.3 GHz SRF photoinjector.

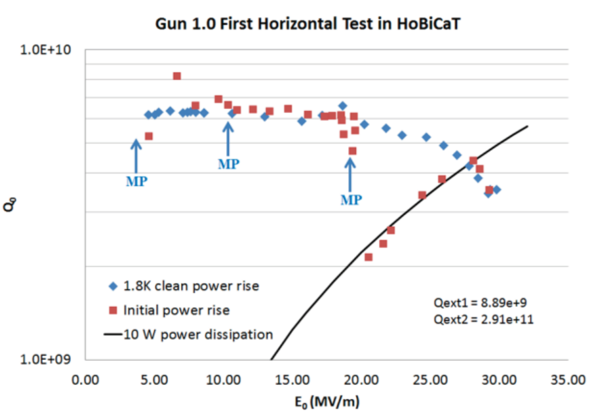

Figure 5: The first test results obtained for Gun 1.0 in HoBiCaT using the same RF coupler configuration as was shipped from JLab.

FUTURE PLANS

The cavity performance improvement after the helium vessel was attached to the cavity was a very pleasant surprise. The reproduction of this performance at HZB following shipment from JLab has further convinced us that the cavity will be well suited for use in GunLab. Once the TTF-III RF power couplers are conditioned and ready for operation they will be mounted on the cavity, along with the Petrov choke filter and the small gate valve and the cavity will be re-tested in HoBiCaT to confirm that the assembly was done in a particle free manner and that the performance of the cavity has not been compromised. After this key milestone has been met the remainder of the cold mass, the beampipe with the superconducting solenoid as well as the large gate valve, will be attached in the cleanroom and then the cold mass will be moved to the cryomodule assembly area for installation into the GunLab cryomodule. The cryomodule assembly should take place in Q4 of 2015 with GunLab operations ready to begin in Q2 2016.

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REFERENCES

[1] J. Knobloch, et al., "Berlinpro - Addressing the Challenges of Modern Erls (a Status Report)", ICFA Newsletter, 58 p. 118 (2012).
[2] A. Neumann, et al., "SRF Photoinjector Cavity for Berlinpro", IPAC'13, Shanghai, China, p. 285 (2013).
[3] T. Kamps, et al., "Status and Perspectives of Superconducting Radio-Frequency Gun Development for Berlinpro", Journal of Physics: Conference Series, 298 p. 012009 (2011).
[4] A. Burrill, et al., "RF Measurements of the 1.6 Celll Lead/Niobium Photoinjector in Hobicat", IPAC'13, Shanghai, China, p. 2313 (2013).
[5] J. Völker, et al., "Operational Experience with the Nb/Pb SRF Photoelectron Gun", IPAC'12, New Orleans, Louisiana, USA, p. 1518 (2012).
[6] A. Neumann, et al., "SRF Photoinjector Tests at Hobicat", SRF 2011, Chicago, IL USA, p. 962 (2011).
[7] R. Barday, et al., "Characterization of a Superconducting Pb Photocathode in a Superconducting Rf Photoinjector Cavity", PRST-AB, 16 p. 123402 (2013).
[8] A. Burrill, et al., "Processing and Testing of the SRF Photoinjector Cavity for Berlinpro", IPAC'14, Dresden, Germany, p. 2484 (2014).
[9] O. Kugeler, et al., "Adapting Tesla Technology for Future Cw Light Sources Using Hobicat", Review of Scientific Instruments, 81 p. 074701 (2010).
[10] E. Zaplatin, et al., "Numerical Coupling Analyses of Berlinpro SRF Gun", IPAC'13, Shanghai, China, p. 2328 (2013).