97249

ANL-HEP-CP-98-94

High Power Test Results of the First SRRC/ANL High Current L-Band RF Gun

C.H. Ho, S.Y. Ho, G.Y. Hsiung, J.Y. Hwang, T.T. Yang,
Synchrotron Radiation Research Center, No.1 R&D Road VI, Hsinchu 30077, Taiwan
M. Conde, W. Gai, R. Konecny, J. Power, P. Schoessow
Argonne National Laboratory, 9700 S. Cass Avenue, Argonne, Illinois 60439, USA

Abstract

A joint program is underway between the SRRC (Synchrotron Radiation Research Center, Taiwan) and ANL (Argonne National Laboratory, USA) for developing a high current L-band photocathode rf guns. We have constructed an L-Band (1.3 Ghz), single cell rf photocathode gun and conducted low power tests at SRRC. High power rf conditioning of the cavity has been completed at ANL. In this paper we report on the construction and high power test results. So far we have been able to achieve > 120 MV/m axial electric field with minimal dark current. This gun will be used to replace the AWA (Argonne Wakefield Accelerator)[1] high current gun.

1 INTRODUCTION

The generation of high gradients (> 100 MV/m) in wakefield structures requires a short pulse, high intensity electron drive beam. The goal of the AWA is to demonstrate high gradients and sustained acceleration of charged particle beams using wakefield methods. The main technological challenge of the AWA program is the development of a photoinjector capable of fulfilling these requirements. The laser photocathode source was designed to deliver 100 nC bunches at 2 MeV to the drive linac. The photocathode gun is a single cell standing wave cavity with designed peak field of 90 MV/m on the cathode[2]. However, due to surface contamination and damage during the initial rf conditionong of the original gun, the peak electric field on axis is only limited to 55 ~ 65 MV/m rather than the designed field 92 MV/m due to the severe dark current beam loading[3].

A collaboration between SRRC and ANL has been established to construct a new L-band single cell photocathode rf gun and associated test stand. The goals of this collaborative research effort are to characterize the beam produced by this gun, and to study high field breakdown phenomena, dark current, and quantum efficiencies of various photocathode materials.

2 FABRICATION AND COLD TESTING

The gun cavity structure is shown in Figure 1. The cooling channel is built inside the cavity body instead of just attaching it to the outer surface. The cavity is also equipped with a tuner and a field strength monitor.

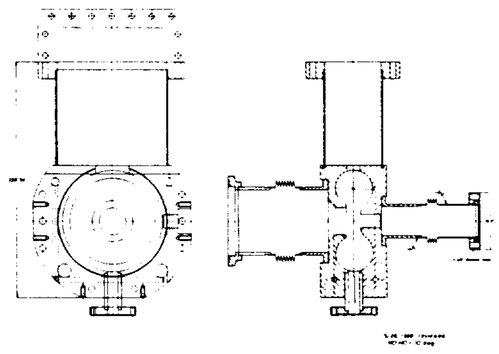


Figure 1: Assembly drawing of the gun cavity

The cavity was CNC machined several times to reach the correct resonant frequency and critical coupling. The cavity surface (mounted on a rotating stand) was then polished using 3M Imperial Lapping Films (60, 40, 30, 15, 12, 9, 5, 3, and 1 micron) and then Buehler Micropolish II Alumina Suspensions (1, 0.3 and 0.05 micron).

The cavity components were brazed together in a vacuum furnace in several stages to allow the joining of various components. After brazing and applying Vac Seal to eminent possible small leaks around the joints between the WR-650 waveguide and the cavity, it was vacuum tested using a Helium leak detector (Balzers HLT 160) and found to be Helium leak tight to better than 10^{-10} standard c.c./sec. However, it was found that the resonant frequency had been shifted down by 2.5 MHz and the

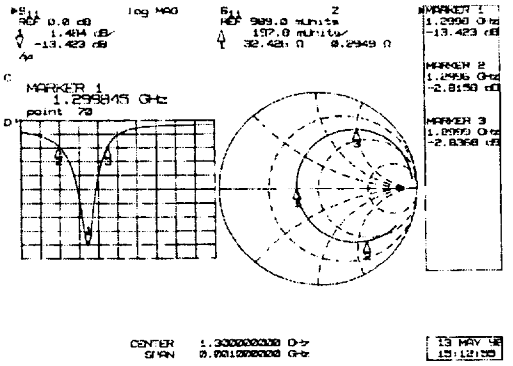


Figure 2: Reflection coefficient of gun cavity measured

Submitted to the proceedings of the XIX International Linac Conference (LINAC'98) Chicago, IL, August 23 - 28, 1998.

using HP8510C network analyzer.

coupling coefficient shifted from 1 (critical coupling) to around 1.5 (over coupled). The frequency shift is corrected back to 1.3 GHz using the tuner. Figure 2 is the measured plot in atmosphere and room temperature from the HP 8510C network analyzer after the cavity was installed and tuned at ANL. The measured unloaded quality factor is around 13000, while the URMEL prediction for the unloaded quality factor is around 15000.

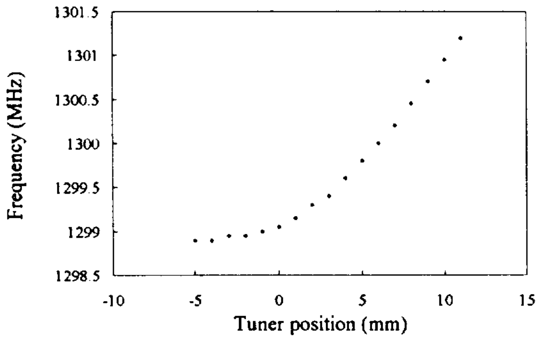


Figure 3: Measured resonant frequency dependence tuner position.

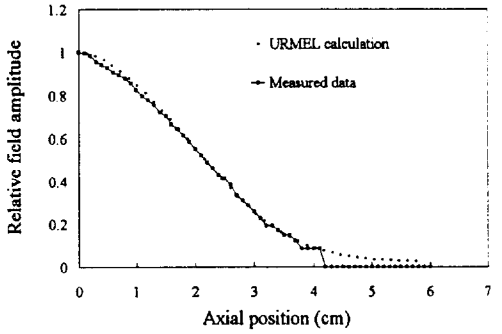


Figure 4: Longitudinal E-field profile on axis.

Figure 3 shows the measured frequency response to the tuner position (the tuning sensitivity is appear to be 1.8 MHz/cm in the linear region of the curve). Since the frequency is very sensitive to the cathode slug position, we use the tuner to fine tune the frequency. The cathode is held flush with the cavity inner surface to avoid arcing due to the discontinuity.

A ceramic bead of 2 mm diameter was used to perform the bead pull measurement. Figure 4 shows the longitudinal E-field profile along the central axis of the cavity from the bead pull measurement results and the URMEL prediction.

Bucking and focussing solenoids were also designed, constructed and measured at SRRC. The measured magnetic field profile is in close agreement with the POISSON calculation.

3 EXPERIMENTAL SETUP

The layout of the L-band rf gun test stand is shown in Figure 5. The whole system was first assembled and vacuum tested at SRRC and then shipped and installed at ANL in May, 1998. Two Molecular Drag pumps (16 CFM) and two oil free magnetic suspension Turbo Molecular Pumps (400 l/s) were used for roughing and baking. Two sputtering ion pumps (60 l/s) and one Non-Evaporable Getter (NEG) pump (500 l/s) were used to reach a base pressure of around 1.6 nTorr and maintain the pressure at around 13 nTorr during conditioning of the cavity.

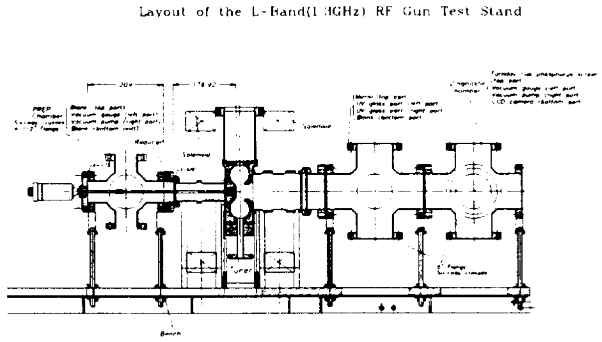


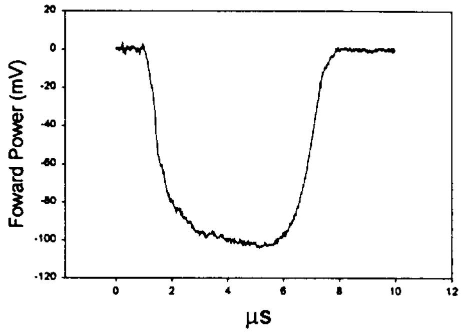
Figure 5: Layout of the L-band rf gun test stand.

4 HIGH POWER TEST RESULTS

RF conditioning of the gun proceeded smoothly. During the conditioning, the vacuum was kept under 50 nTorr and the occurrences of breakdown were kept to minimum. The forward, reflected rf power and dark current were also monitored continuously. Figure 6 shows the forward power to the gun with peak power of 2 MW. Figure 7 gives the reflected rf power and it shows almost no detuning of the gun due to the dark current.

In fact, because this gun was over coupled after brazing, the loading from the dark current will move it toward critical coupling to some extent. Since the field monitor was not instrumented yet for this test, one can only estimate the surface field using the rf reflection coefficient and the dark current. For 2 MW forward power with no reflection, we have estimated the surface field at the cathode center to be 100 MV/m[2]. This is somewhat larger than the designed value of 92 MV/m at 1.5 MW. At 100 MV/m, dark current is about 13 nC per rf pulse, in comparison with the original AWA gun which is 40 -60 nC at ~ 60 MV/m.

Further rf conditioning has been done to further reduce the dark current and increase the axial electric field to 120 MV/m. With a few additional days of conditioning, we have increased the rf forward power to 3 MW, still with no dark current induced rf reflection, with the equivalent photocathode field of 117 MV/m. The peak electrical field on the nose cone is 152 MV/m. Measured dark current is 25 nC /pulse. This is a 40% above the designed field and should be able to provide improved performance over the original AWA gun. Figure 8 shows the dark current transported out of the gun versus the forward rf power (surface field). It clearly shows the exponential dependence of the surface field. Below 70 MV/m, no significant dark current was observed. However, it goes up quickly as the surface field increases.



Note. 100 mV = 100 MV/m on axis

Figure 6: Measured forward rf power to the gun. This is a scope trace that measures envelope of rf pulse with calibrated diode detector. The peak voltage corresponds to 2 MW peak rf power.

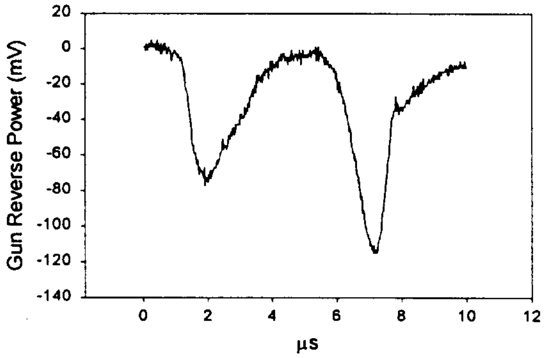


Figure 7: Reflected rf power from the gun. It shows that after the gun was filled, no reflection was observed.

5 SUMMARY

The first L-band rf gun cavity resulting from the joint collaboration between SRRC and ANL has been constructed, installed and conditioned. The high power test results are very encouraging. Input rf power was applied to rf cavity and increased from 100 kW level to 2 MW level within two days. Further conditioning increased the accelerating gradient in excess of 120 MV/m at the photocathode. The dark current measurement results show little effect of beam loading at this power level. We will replace the current AWA drive gun with this new gun, which should enable us to obtain shorter electron beams, and thus improve the gradients obtained in wakefield acceleration experiments.

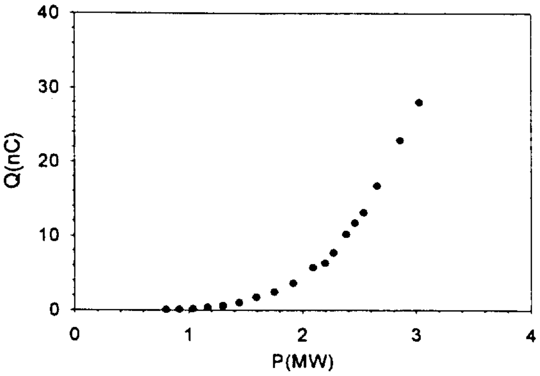


Figure 8: Measured dark current at the down stream against the surface field (forward rf power). It shows the exponential dependence and the maximum dark current observed was 30 nC at 120 MV/m (3 MW).

6 ACKNOWLEDGMENTS

We would like to thank Mr. T.T. Wu from ITRI for operating the vacuum brazing furnace. We would also like to thank Mr. M.H. Huang and Mr. C.H. Chang of SRRC for helping the construction of the solenoid, and Mr. F.Y. Lin and Dr. C.S. Hwang of SRRC for helping the measurement of the solenoid field profile. We would also like to thank the kind help from Mr. V. Svirtun, Mr. R. Nielson, and Dr. J. Noonan of ANL-APS, and Mr. R. Taylor of ANL-HEP during installation of the gun. This work is supported in part by the National Science Council (Taiwan) under contract No. NSC 87-2613-M-213-012, as well as by the Department of Energy (USA), Division of High Energy Physics, Contract No. W-31-109-ENG-38.

7 REFERENCES

[1] W. Gai et. al., in AIP Conf. Proc. 398 for the 7th Workshop on Advanced Accelerator Concepts Oct. 12-18, 1996, Lake Tahoe, California, p.116.
[3] C.H. Ho, PhD Thesis, UCLA, 1992.
[2] M. Conde et. al., to be appeared in Physical Review, Special Topics: Accelerator and Beam Physics, 1998.