ELECTRON EMISSION STUDIES IN THE NEW HIGH-CHARGE Cs_2Te PHOTOINJECTOR AT ARGONNE NATIONAL LABORATORY

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Abstract

A new L-band 1.3 GHz 1.5 cell gun for the new 75 MeV drive beam is being commissioned and will soon be operating at the Argonne Wakefield Accelerator (AWA) facility as part of the facility upgrade (see M. E. Conde, this proceedings.) The photoinjector is high-field (peak accelerating field $>$ 80 MV/m) and has a large Cs_2Te photocathode (diameter $>$ 30 mm) fabricated in-house. The photoinjector generates high-charge, short pulse, single bunches (Q $>$ 100 nC) or bunch-trains (Q $\approx$ 1000 nC) for wakefield experiments. Field emission from the Cs_2Te cathode is to be measured during RF conditioning and benchmarked against measurements from a copper cathode. Quantum efficiency (QE) will be measured in single and multi-bunch modes. Preliminary results are presented.

EMISSION STUDY PLAN AND GOALS

The AWA drive-gun will soon be operational, using high Quantum Efficiency (QE) Cs_2Te photocathodes fabricated in-house [1]. The primary function of the gun is to provide high-charge, short-pulse electron beams to drive wakefield structures [2]. As part of the turn-on process, we plan to do field emission and photoemission studies in the gun.

Part One: Field Emission Study

We plan to carefully measure and characterized the evolution of field emission from photocathodes (both Cu and Cs_2Te thin film on Mo) used during the two phases of RF conditioning. We will use the data to determine the relative impact of different factors influencing the level of field emission.

Part Two: Photoemission Study

Once conditioning is complete, we will measure and characterize photoemission from the Cs_2Te photocathode under various conditions. Using 2-10 ps, 248 nm wavelength laser pulses, we will analyze photoemission at high gradient to optimize the performance of the photocathode and the gun.

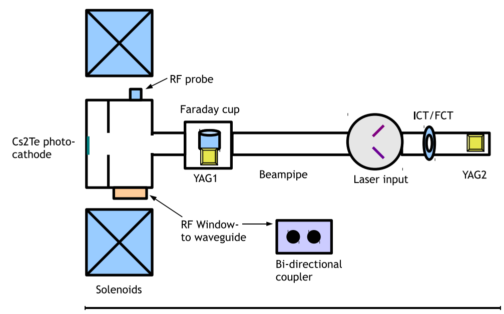

Figure 1: The L-band 1.5 cell photocathode gun with the relative positions of diagnostics to be used (cartoon - not to scale). The RF power input is measured near the RF window using a bi-directional coupler. The dark current is measured with a Faraday cup 58 cm from the cathode. The beam charge is measured using an Integrating Current Transformer (ICT). YAG(Ce) scintillating screens to image the beam and the dark current are available at two locations. In addition, an in-vacuum mirror at the Faraday cup location may be used to observe the photocathode and help to identify emission sites (not to scale).

EXPERIMENTAL SETUP

The beamline with the relative positions of diagnostics used for the experiments is depicted in a schematic shown in Fig. 1. RF power measurements were made using a dual-directional coupler connected in series in the waveguide just before the gun. The dark current was measured using a Faraday cup. The beam charge will be measured using a Bergoz Integrating Current Transformer (ICT) and Fast Current Transformer (FCT). Scintillator screens were used to image the beam and the dark current at two locations.

RF CONDITIONING

Initial RF Conditioning Procedure

The procedure followed for RF conditioning of the gun was:

1. begin with low RF power coupled into the gun
2. run at 1 Hz RF repetition rate until negligible arcing

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3. increase the repetition rate to 2 Hz and run until negligible arcing occurs, repeat at 5 Hz
4. lower the RF power level slightly and run at 10 Hz for several minutes
5. incrementally increase the RF power level
6. repeat this procedure many times until the target power level of 14 MW is achieved or exceeded.

Using YAG1 to image the dark current at the Faraday cup, the solenoids were scanned and set to ensure dark current measured was primarily from the cathode surface. We measured the threshold for field emission based on the Faraday cup signal at each step of conditioning. Then we measured the dark current signal at the highest attainable field at each 10 MV/m step.

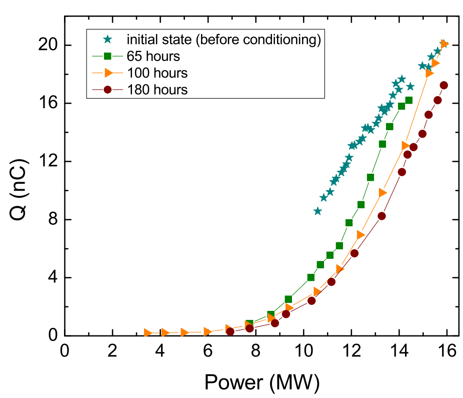

Figure 2: Initial conditioning with Cu cathode. Plot of charge measured with the Faraday cup vs. RF power into the gun. Dark current levels declined from the initial level at the operating point (12 MW) by 50% after conditioning. 12 MW input power provides a max field on the cathode of about 80 MV/m.

PRELIMINARY RESULTS

Part one of the study is underway. We present some preliminary results from RF conditioning. In Fig. 2, Faraday cup charge vs. RF power coupled into the gun is plotted for several times relative to the start of the conditioning process with the Cu cathode. In Fig. 3, the Fowler Nordheim plots are presented. The field enhancement factors (β) derived from the plots following the type of analysis detailed by Wang and Loew [3], indicate that the field enhancement decreased by almost 10% after an additional 115 hours (about 3.5 weeks). Conditioning of the gun was interrupted for additional beamline installation (part of the on-going AWA facility upgrade), but will resume soon.

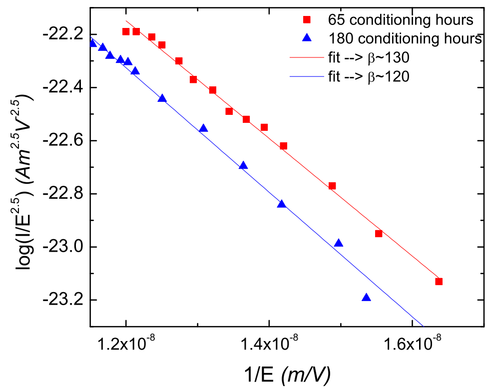

Figure 3: Fowler-Nordheim plots for the Cu cathode at two different points in the conditioning process. The field enhancement factors (β) derived from the plots indicate that the field enhancement decreased by almost 10% after an additional 115 hours of conditioning.

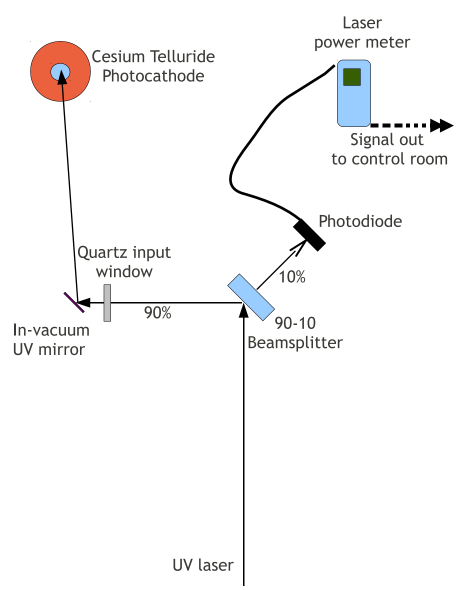

Figure 4: The experimental setup for measuring laser input power for the planned photoemission studies in the gun. The laser power measurement will be correlated with the ICT signal for shot to shot QE measurements.

PLANNED PHOTOEMISSION STUDIES

As soon as the gun is conditioned, we will begin the photoemission studies. Photoemission measurements to be made using the experimental setup sketched in Figs. 1 and 4 include laser power measurements concurrent with beam charge measurements to analyze shot-to-shot variations in the laser or the QE and single bunch 100 nC charge and QE measurements.

We plan to make QE RF field dependence measurements by two methods: 1) by varying the peak RF power into the gun and 2) by varying the laser input phase with constant RF power. We intend to raster the cathode with the laser to probe the spatial uniformity and map the QE variations across the cathode. This QE map will assist us as we look for variations in QE vs. laser spot size. For the 1000 nC bunch train QE measurements we plan to generate from 4 to 16 bunches per train with 770 ps separation (1 RF period). We will look to see if there is any QE bunch-train position dependence. The diagnostics for the bunch-train measurements [4] include the Bergoz in-flange ICT (to measure total charge) with FCT (to resolve individual bunches) and a photodiode sensor (measure laser power per pulse). Throughout these experimental runs, we will be collecting data for QE lifetime studies on each photocathode we make and install.

SUMMARY

The AWA high-gradient, high-charge drive gun is expected to be operational soon. In order to understand the performance limitations of the new gun and photocathode, photocathode emission studies will be conducted during conditioning and initial operation. First we will be looking at the dark current and its effect on the high-gradient (80 MV/m) operation of the gun. Second, we will look at the photocathode performance in single bunch and bunch-train modes. In particular, we will study the the QE evolution and lifetime and the effect of different laser parameters and operational demands. Parameters of interest include laser spot size, bunch charge, charge uniformity through the bunch train and cathode QE uniformity. Results will be analyzed and used to optimize the photocathode drive gun operation.

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