SLAC RF GUN PHOTOCATHODE TEST FACILITY*

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Abstract

A RF gun photocathode test facility has been commissioned at SLAC. The facility consists of a S-band gun, high power RF, a UV drive laser and beam diagnostics. Here we report on the capabilities of the facility demonstrated during commissioning. Currently the facility is being used to study in-situ laser processing of copper photocathodes. In the future the facility will be used to study fundamental gun and photocathode performance limitations and enhancement strategies. Eventually it is envisioned to integrate a load lock and plug into the gun enabling the evaluation of high performance surface sensitive semiconductor photocathodes and the incorporation of ex-situ surface science analytical techniques.

INTRODUCTION

The Accelerator Structure Test Area (ASTA) at SLAC has been reconfigured to study RF gun photocathode performance. The 1.2 m thick concrete vault now contains a replica of the first 1.4 m of the LCLS injector, including the spare LCLS gun. The motivation for this is that LCLS operations have previously suffered from unexpected variations in photocathode quantum efficiency, emittance, and lifetimes. As a result a program was initiated to develop robust procedures for photocathode exchange and in-situ surface processing. The immediate goal is to demonstrate reliability. By performing these experiments in a dedicated test facility regular LCLS operations are not affected.

Photocathode Processing

LCLS photocathodes (Fig. 1) are fabricated from high-purity copper. The recipe varies but normally they first undergo a dry hydrogen braze at 950 °C followed by a diamond fly-cut to a final surface roughness < 10 nm RMS. Then they are vacuum fired at 650 °C for 24 hours, welded to their base flange, and then vacuum fired again for another 24 hours at 550 °C. Once the photocathodes are installed, RF processing occurs until full power operation is achieved without breakdown. At this point the QE of a given photocathode can vary from 1×10^{-6} (low) to 6×10^{-5} (high) under nominal operating conditions. To increase QE in-situ techniques such as laser-processing and RF plasma cleaning are being developed.

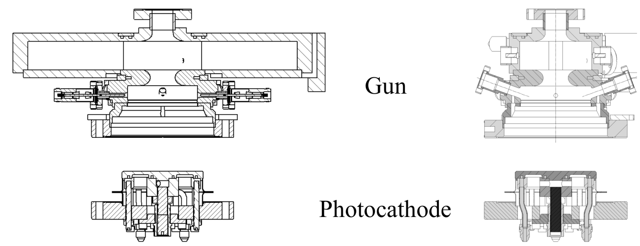

Figure 1: Cross-sections of LCSL photocathode and gun.

INSTRUMENTATION

Gun

The LCLS gun (Fig. 2) is a 1.6 cell racetrack shaped cavity with symmetrical RF feeds and field probes. Field gradients of 115 MV/m can generate greater than 3 nC pulses at 6 MeV. Gun performance in ASTA however is intentionally limited to hundreds of pC at 5.5 MeV. The gun is bakeable to 150 °C and can achieve 4×10^{-10} torr vacuum in operation. The gun assembly includes a solenoid, bucking coil, and transverse correctors. The ASTA installation also includes UV transport, RF waveguide and diagnostics (Fig. 3).

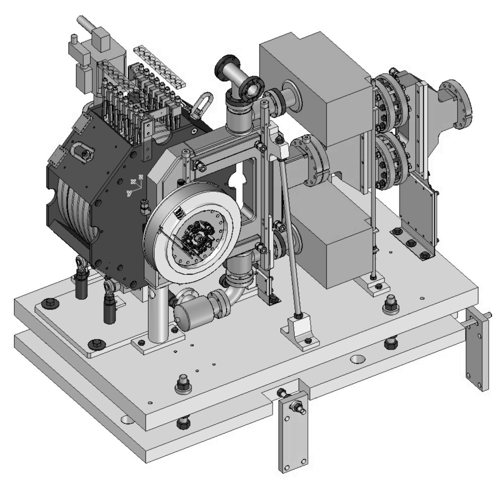

Figure 2: Gun assembly.

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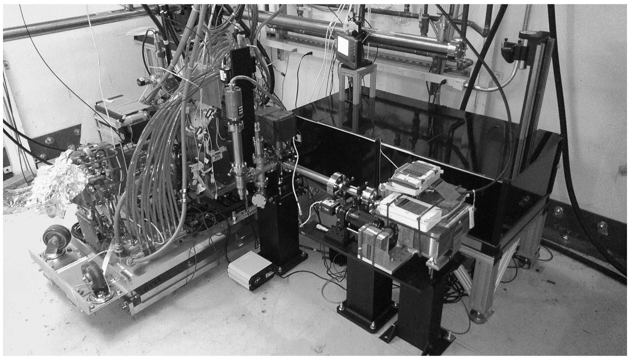

Figure 3: ASTA vault.

RF Power

A 5045 S-band klystron operating at 2856 MHz delivers RF power to the gun (Fig. 4). The klystron is designed to produce 65 MW peak power in 3.5 µs RF pulses at 180 Hz . The beam voltage is 350 kV, perveance is 2.0 $\mu A/V^{1.5}$ and average power is 41 kW. Typical operating conditions in ASTA are 1.5 µs pulses at 120 Hz with 10 MW delivered to the gun. Low level RF chasses handle synchronization based on a 119 MHz fiducial and event codes arriving from an EVG shared with the LCLS (Fig. 5). Diagnostics include gun probes, directional waveguide couplers and vacuum and temperature monitoring.

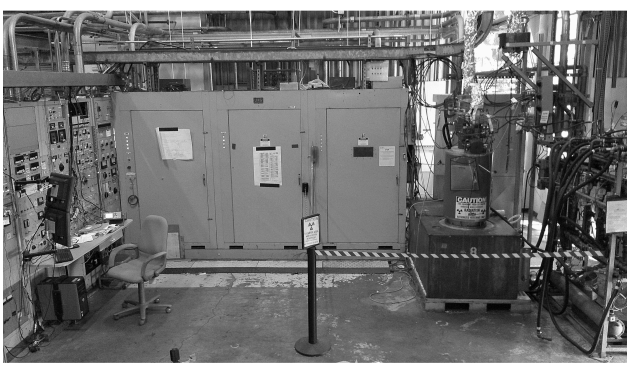

Figure 4: Klystron and modulator.

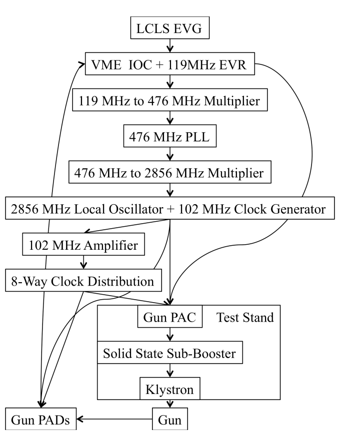

Figure 5: RF power diagram.

Drive Laser

The drive laser (Fig. 6) starts with a 68 MHz mode-locked Ti:Sapphire oscillator outputting 400 mW of IR at 760 nm in a 30nm bandwidth (68 MHz is a sub-harmonic of 2856 MHz). This is stretched, amplified and then compressed to generate 3 mJ pulses. The regenerative amplifier is pumped by a 120 Hz, Q-switched, diode-pumped solid-state frequency-doubled yttrium lithium fluoride laser at 527 nm. After the compressor the frequency is tripled to 253 nm using two nonlinear crystals. A conversion efficiency of 10% gives 0.3 mJ in 1.5 ps FWHM transform limited pulses. The Gaussian transverse profile is then magnified by a zoom telescope and apertured by an iris. The iris is imaged on the photocathode with de-magnification of 4:1. The imaging system is designed to produce a flat-top transverse profile. An extra removable lens also permits focusing the beam to 30 um for laser processing. Typically up to 20 µJ/pulse arrives at the photocathode after transport. The power can be increased by changing iris size and magnification at the expense of beam uniformity. The power can also be decreased by rotating a half-wave plate behind a thin-film polarizer following the tripler. The beam power and transverse profile are monitored using beamsplitters, power meters and a virtual cathode camera. A scanning cross-correlator is used to measure the pulse length. The system is locked to 476 MHz low level RF via a PLL and a PAD/PAC system that adjusts the timing with respect to the RF (Fig. 7).

Figure 6: Laser lab.

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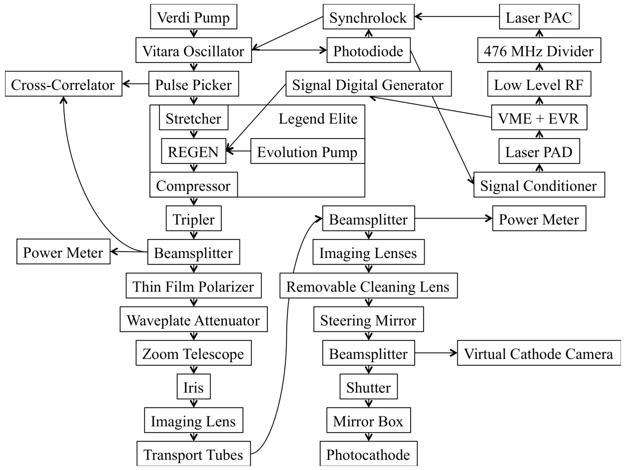

Figure 7: Drive laser diagram.

Beam Diagnostics

Current beam diagnostics (Fig. 8) include a camera for optical imaging of the photocathode (Figs. 9,10), two calibrated cold cathode vacuum gauges, an RGA, a YAG screen for beam position and emittance measurements and faraday cup for measuring beam current. The configuration is the same as that used in the LCLS injector.

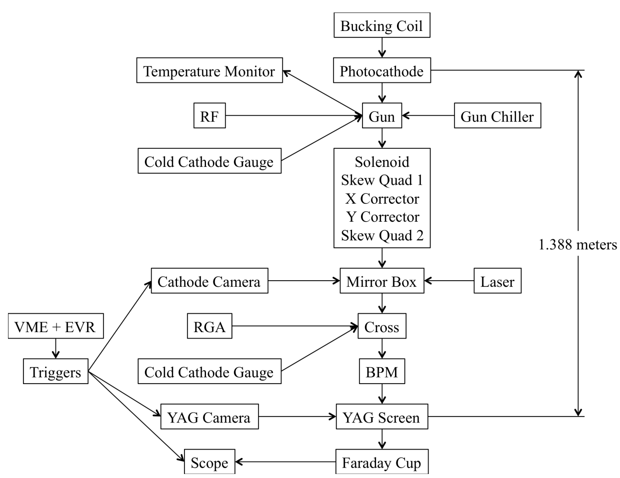

Figure 8: Beam diagnostics diagram.

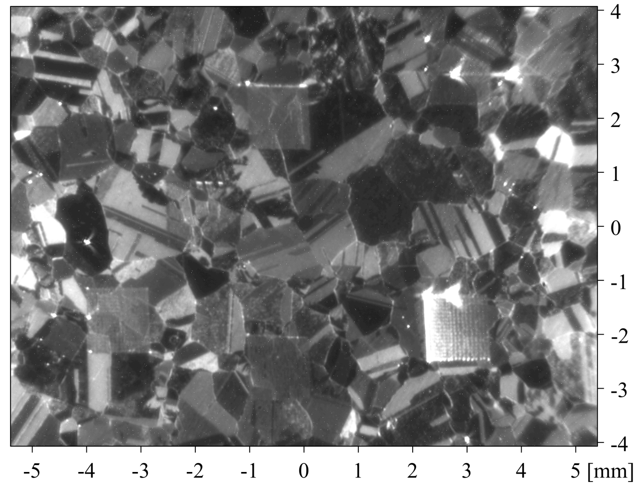

Figure 9: 30° incident light image of a photocathode after laser processing.

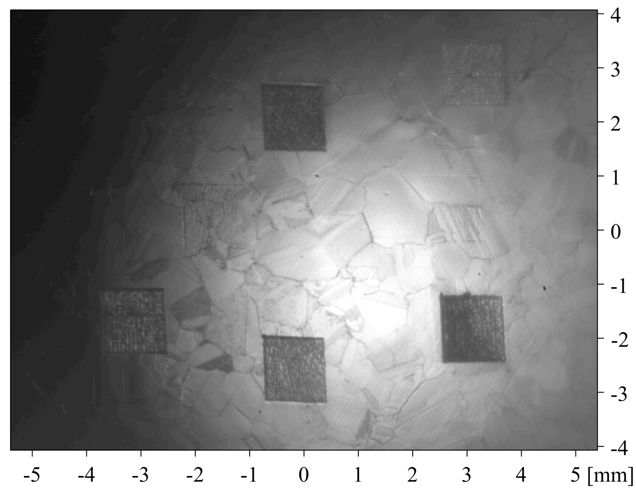

Figure 10: 90° incident light image of a photocathode after laser processing.

RESULTS

QE Measurements

Current QE in the LCLS is 10^{-4} at 250 pC of charge after laser processing. During ASTA commissioning charges up to 250 pC and QE up to 10^{-4} have been measured. Additionally 2d QE maps with spatial resolution sufficient to resolve both naturally occurring and deliberately induced QE variations have been obtained (Fig. 11).

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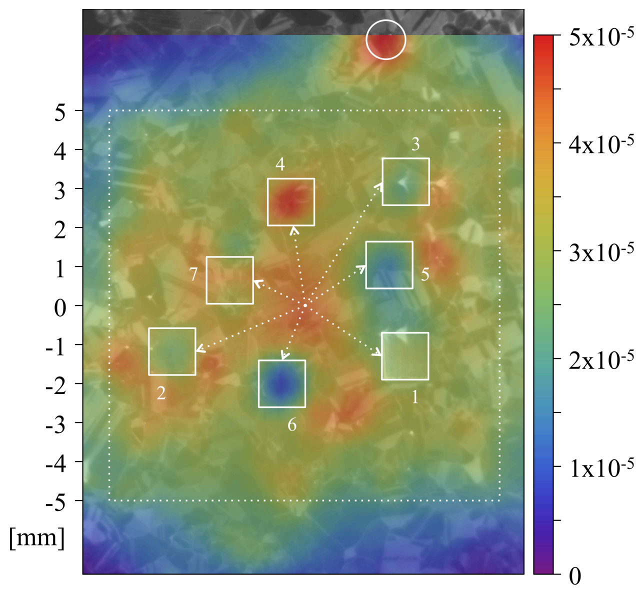

Figure 11: 2d QE map.

Emittance Measurements

Typical emittance in the LCLS is 0.3-0.4 µm at 150 pC of charge. Using the solenoid scan method preliminary measurements in ASTA of 0.3 µm at 1-2 pC have been recorded (Fig. 12). Emittance as a function of spot size has also been measured (Fig. 13). Reported values may change somewhat as the effects of instrumental resolution become clearer.

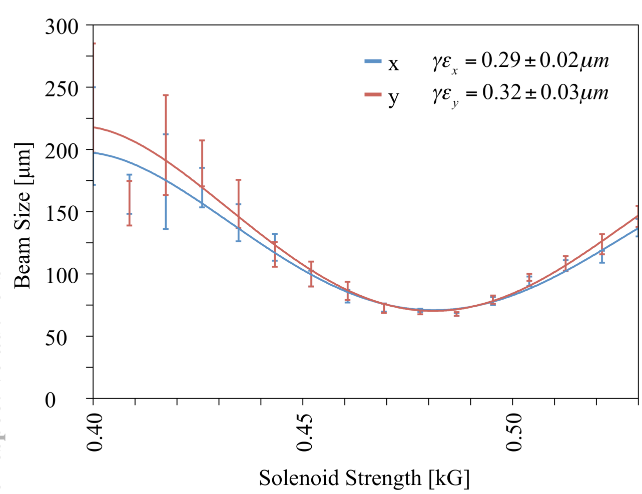

Figure 12: Emittance scan.

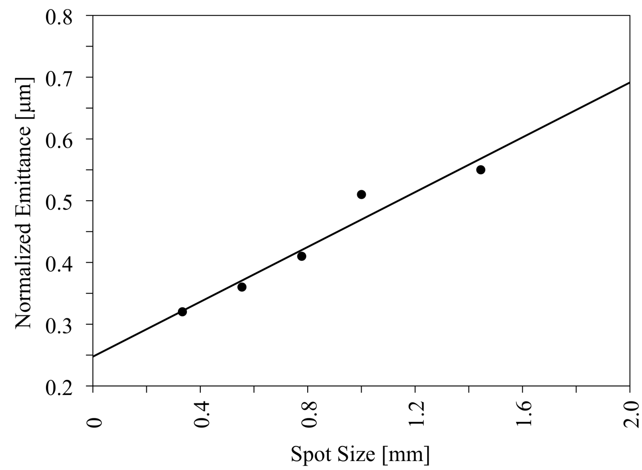

Figure 13: Normalized emittance.

CONCLUSIONS

A RF gun photocathode test facility has been commissioned at SLAC. The gun, high power RF, UV laser and beam diagnostics each perform as specified. QE and emittance measurements are also in line with expectation. Studies to optimize laser processing of copper photocathodes are underway. Results similar to those obtained in the LCLS have been reproduced. Once these studies have completed the facility will shift to study fundamental gun and photocathode performance limitations and enhancement strategies. Eventually it is envisioned to integrate a load lock and plug into the gun.

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