STATUS OF THE SPARC PHOTOINJECTOR

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Abstract

The SPARC Project is starting the commissioning of its photo-injector. RF gun, RF sources, RF network and control, power supplies, emittance meter, beam diagnostics and control to measure the RF gun beam have been installed. The photocathode drive laser has been characterized in terms of pulse shape and quality. We will report also about first tests made on RF gun and on the emittance meter device. Additional R&D on X-band and S-band structures for velocity bunching are in progress, as well as studies on new photocathode materials. We will also discuss studies on solenoid field defects, beam based alignments and exotic electron bunch production via blow-out of short laser pulses.

BEAM MEASUREMENTS WITH EMITTANCE METER

The first phase of the SPARC project [1] consists in characterizing the electron beam out of the photoinjector at low energy before the installation of the three accelerating sections. The experimental layout for this phase of the project is shown in Fig. 1.

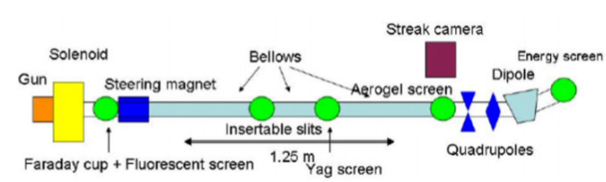

Figure 1: Block diagram for first phase of SPARC photoinjector commissioning.

In order to study the first few meters of beam propagation, where space charge effects and plasma oscillations dominate the electron dynamics, a new sophisticate diagnostic tool was installed and commissioned, the movable emittance-meter [2]. The SLAC/BNL/UCLA 1.6 cell S-band RF gun was conditioned up to > 10 MW, corresponding to a field of 120 MV/m. The particular design of the emittance-compensating solenoid, with 4 different coils inside the magnetic yoke, allows a unique study of how different magnetic field configurations affect the electron beam dynamics, in particular varying (in sign and absolute values) the current setting independently for each coil power supply. The results of these findings are reported in Ref. [3].

The electron beam is created illuminating the cathode using a state-of-the-art laser system capable of producing flat-top laser pulses via an acousto-optics crystal for pulse-shaping [4]. The optical system that delivers the UV pulse onto the cathode creates the uniform transverse profile by truncating the tails of the beam distribution with an iris and compensates for the 72 degrees incidence undesirable effects of beam ellipticity and amplitude front-tilt by imaging the plane of a 3560 lines/mm grating onto the cathode [5].

With a laser-based cleaning process we were able to improve the quantum efficiency both in absolute value and uniformity and reach a level of 10^{-4} over a region of 2.5 mm around the cathode center (see Fig. 2).

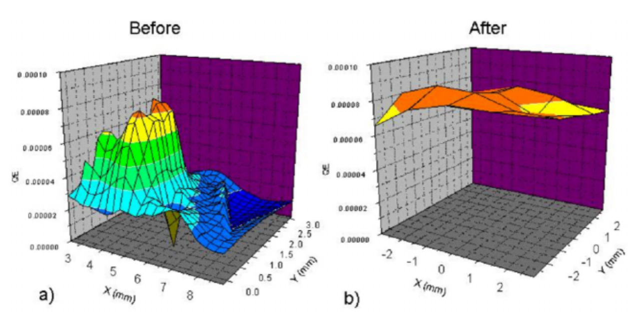

Figure 2: Quantum efficiency map before (a) and after (b) the laser cleaning procedure.

Figure 3 shows the beam energy and energy spread measured varying the launch phase of the laser pulse. The differences between the low and high charge case are due to longitudinal space charge effects (including the image charge at the cathode) and to the wakefield effects in the long bellows. The maximum beam energy of 5.65 MeV corresponds to a peak field in the gun of 120 MV/m, in complete agreement with RF power measurements.

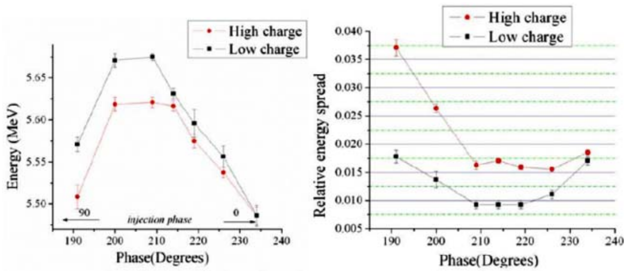

Figure 3. Beam energy and energy spread as functions of the launching phase.

A longitudinal diagnostic, based on Cherenkov radiation produced by the beam passing through a 5 mm thick aerogel slab with index of refraction n = 1.017, was installed with the main purpose of studying the photoinjector response to hundreds femtosecond long laser pulses created by the Ti:Sa laser system (blow-out regime). A field-lens narrow band filtering optical system delivers the Cherenkov light to the entrance slit of a 2 ps resolution Hamamatsu streak camera enabling pulse length measurements. [6]. In Table 1 we report the beam parameters measured so far at low and high charge.

Table 1: SPARC photoinjector experiment parameters

Charge	200 pC	900 pC
Emittance	0.8 mm-mrad	2.2 mm-mrad
Energy	5.65 MeV	5.55 MeV
Energy spread	1%	2.6%
Pulse length	8 ps	12 ps

Using the emittance-meter we were able to observe clear indications of emittance oscillations driven by space charge forces in the drift downstream of the RF gun, in agreement to what expected from our theoretical model and numerical simulations (see Fig. 4).

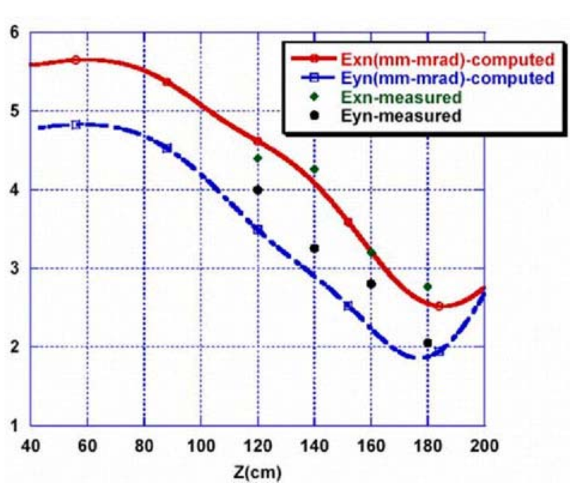

Figure 4. Measured emittance along z compared with Parmela simulations.

The 1-D pepper pot technique allows not only to measure the beam and the Twiss parameters, but also to reconstruct the phase space [7].

Here in Fig. 5 the phase space reconstruction in different positions, measured at low charge, 100 pC.

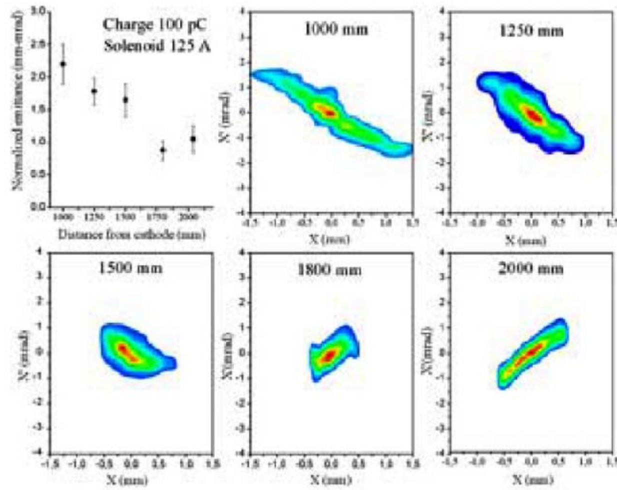

Figure 5: Phase space measure along the e-meter.

R&D ON PHOTOCATHODES

We investigated the deposition of high quality metal films directly on the RF gun cavity end plate, to be used as photocathodes.

Main aim of this study is to circumvent problems of RF breakdown shown at the metal junction by Mg disks inserted by press fitting in the end Cu plate of the gun. A key parameter determining the adherence of a deposited film is the kinetic energy of the particles impinging on the substrate. Therefore it is worthwhile to study alternative deposition processes with inherent higher particle energies, as pulsed laser deposition (PLD) and vacuum arc discharge.

The PLD deposition apparatus used in this study is made up of an UHV chamber containing the Mg target to be ablated and the substrate to be coated. A powerful laser beam from a XeCl excimer laser (pulse duration 30 ns), impinges on the target and forms a plume of Mg vapor. The substrate is placed in the plume cone at a suitable distance from the target. Films with thickness from 0.2 to 2.5 microns, covered or not with thin protective layer either of graphite, palladium or silicon have been synthesized.

A computer controlled laser cleaning procedure has been implemented in order to clean the surface gradually and uniformly, thus allowing a controlled removal of the contaminated surface layers and avoiding pure film deterioration. Mg films grown by PLD either with or without protective layers gave remarkable results in terms of QE, ranging from 1.4 x 10^{-4} up to 7.9 x 10^{-4} at low dc electric field (1 MV/m). Figure 6 shows the results of the laser cleaning process.

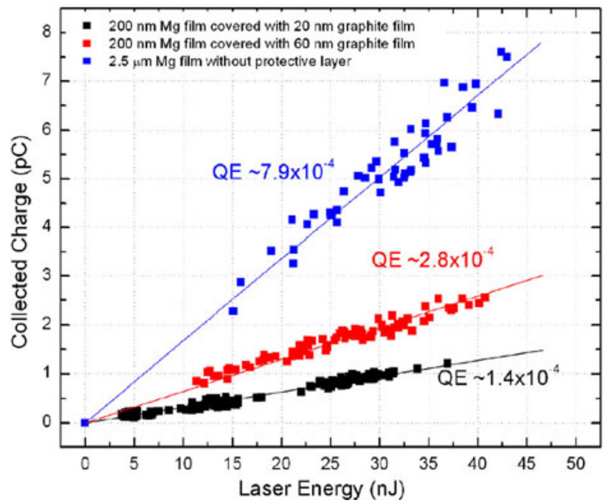

Figure 6: Emission curves of different Mg samples deposited by PLD on Cu substrates, after the laser cleaning of the protective or contaminated layers.

3 X-BAND STRUCTURE

A Bi-Periodic X-Band accelerating section for linearizing the longitudinal phase space in SPARC project has been proposed and the copper prototype, shown in Fig. 7, has been realised.

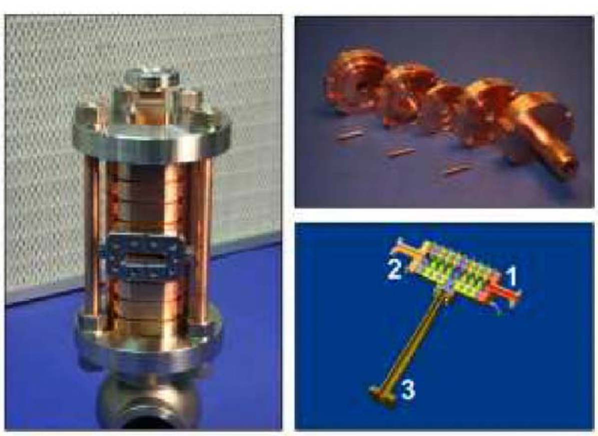

Figure 7: Copper prototype of the structure.

Resonant frequency, quality factors and electric field have been measured on the copper prototype in the open and close stop-band cases. Even if the prototype is not brazed the measurement results are very close to the expectation.

Thermal analysis has been carried out using ANSYS code.

Brazing tests are now in progress in the LNF for the construction of the final device.

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