# STATUS OF THE SPARC PROJECT

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*Abstract*

The SPARC Project has started commissioning 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 are installed and working inside the SPARC bunker. The photocathode drive laser has been characterized in terms of pulse shape and quality. We conducted initial beam measurements at RF gun exit using the emittance meter and a spectrometer. Preliminary indications of emittance oscillations driven by space charge in the drift downstream ther RF gun are observed, in agreement to what expected from our theoretical model and numerical simulations. The design of the 12 m undulator for the FEL experiment has been completed and the first undulator section out of 6 is under test: we expect to fully characterize it at Frascati ENEA laboratory within the next months. Recent results of R&D activities on new photocathode materials are also reported.

## 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. 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 elsewhere in these proceedings[3].

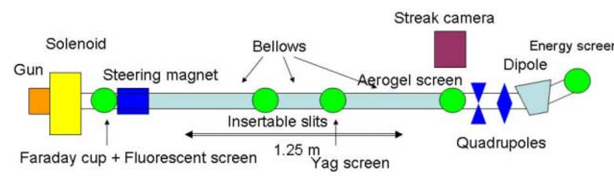


Figure 1. Block diagram for first phase of SPARC photoinjector commissioning.

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 i) creates the uniform transverse profile by truncating the tails of the beam distribution with an iris and ii) 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).

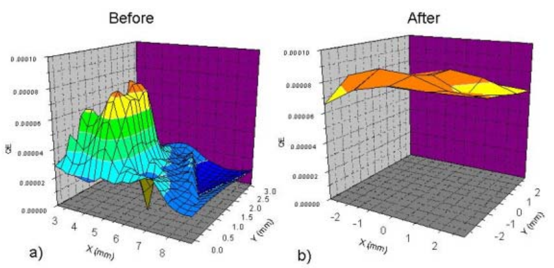


Figure 2. Quantum efficiency map before (a) and after (b) the laser cleaning procedure.

In Fig. 3 we show 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.

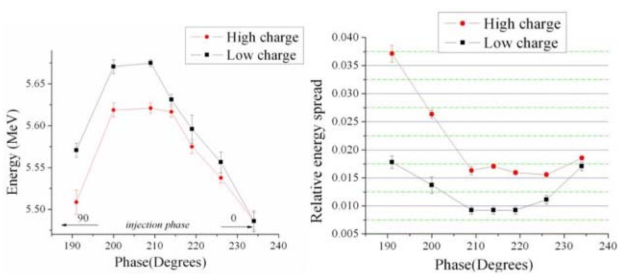


Figure 3. Beam energy and energy spread as functions of the launching phase.

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 2ps 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 experimental 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)

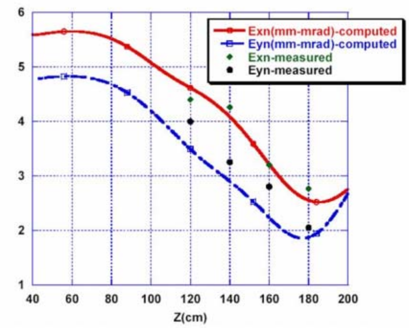


Figure 4. Measured emittance along z compared with Parmela simulations

## UNDULATOR AND FEL

The undulator system is made by six sections designed by ACCEL Gmbh, under our specifications. In Figure 5 the drawing of the first undulator section is shown. The first prototype section is currently under magnetic test at ACCEL. The delivery to Frascati is expected at the end of July 2006. Field characterization is planned before the final installation in the SPARC-Hall.

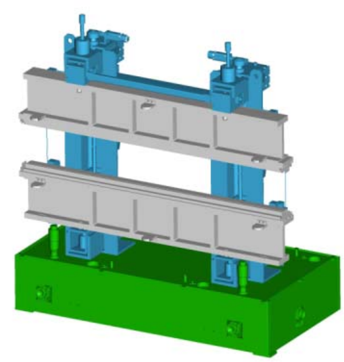

Figure 5: Technical drawing of the first undulator section

In SASE mode at 500 nm, the expected saturation length is about 10-12 m. A plot of FEL power behaviour vs. the e-beam parameters, as estimated by GENESIS 1.3, is shown in Fig. 6. Several experiments exploiting schemes of non-linear harmonic generation and seeding from external sources are also foreseen [7].

The vacuum chamber for the electron beam transport has been realised in AISI 316L stainless steel with a thickness of 0.5 mm and external dimensions of 13x8 mm. The vacuum has been both simulated and after that, experimentally tested. Results report a pressure of $2 \cdot 10^{-7}$ mbar close to the pumping system and $10^{-5}$ mbar at the central point of the vacuum chamber section, corresponding to the centre of the undulator. The technical design of the diagnostic chambers has been completed: a drawing is shown in Figure 7.

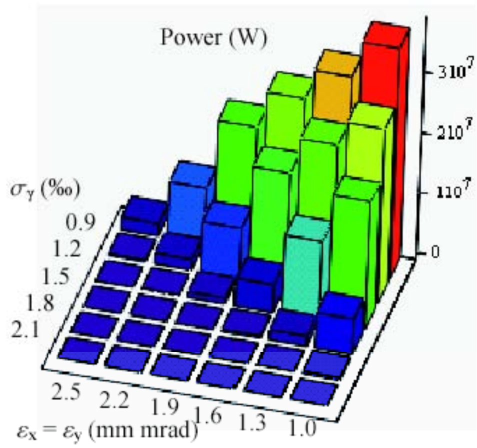


Figure 6: FEL power vs. beam energy spread and emittances from GENESIS 1.3 simulations.

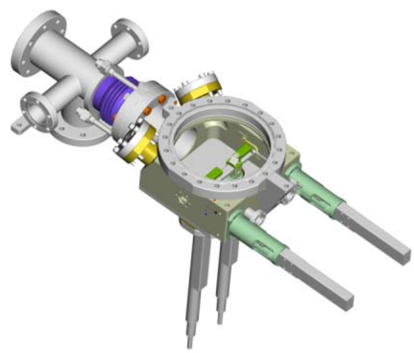

Figure 7: Diagnostic chamber drawing.

Two different, three steps, vertical actuators are hosted inside the chamber, capable of hosting different optical systems. The vertical movement is performed by precise motorised linear stages, with linear encoders in closed-loop control. The aim is to minimize detrimental effects of electron beam misalignments on the FEL amplification process. In order to minimize the impedance mismatch experienced by the electrons and to suppress the wake-field effects, we introduced a screening pipe.

## 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 $1.4\text{x}10^{-4}$ up to $7.9\text{x}10^{-4}$ at low dc electric field (1 MV/m).

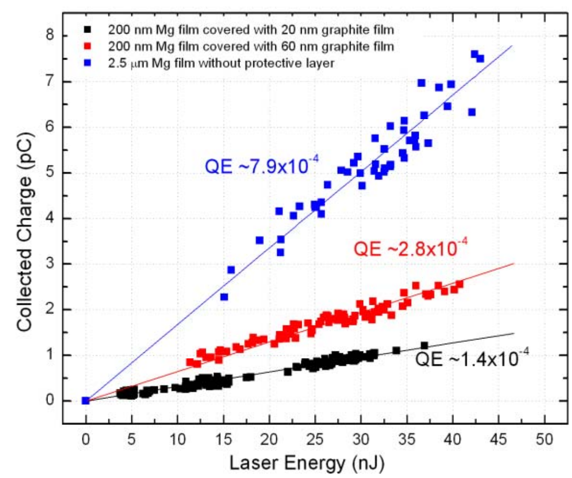


Figure 8: Emission curves of different Mg samples deposited by PLD on Cu substrates, after the laser cleaning of the protective or contaminated layers.

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## ACKNOWLEDGEMENTS


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