

## STATUS OF THE FERMI@ELETTRA PHOTOINJECTOR\*

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### Abstract

The new FERMI@Elettra photoinjector is presently undergoing high-power testing and characterization at MAX-lab in Lund, Sweden. This effort is a collaboration between Sincrotrone Trieste, MAX-lab and UCLA. The 1.6-cell RF gun cavity and the focusing solenoid were successfully designed and built by the Particle Beam Physics Laboratory at UCLA, delivered to Sincrotrone Trieste at the beginning of 2008, and installed in the linac tunnel at MAX-lab. Use of the MAX-lab facility will allow the FERMI project to progress significantly with the photoinjector while waiting for the completion of the new linac building extension at Sincrotrone Trieste. We report here on the high-power conditioning of the RF cavity and the first beam tests.

### INTRODUCTION

The FERMI@Elettra Project, the single-pass FEL user facility in Trieste, has moved from the design to the construction stage [1]. The performance of the electron source plays a crucial role in obtaining the high brightness e-beam required by the FEL process [2]. In order to guarantee such performance the RF gun cavity has to be carefully designed and realized [3] and undergo an extended commissioning. The 1.6-cell RF gun cavity and the focusing solenoid were completed at the beginning of this year by the Particle Beam Physics Laboratory at UCLA; the low level power performance of the cavity is presented in the next section. The FERMI Gun was delivered to Sincrotrone Trieste in middle of March. Since the new building extension is under completion, the photoinjector system has been installed in the MAX-lab injector tunnel, where a complete characterization at high power is ongoing. This collaboration effort allows the FERMI project to progress significantly with the photoinjector commissioning. The results of the RF gun cavity conditioning and of the preliminary electron-beam extraction are presented in this paper.

### RF 1.6 CAVITY

The mechanical components of the FERMI RF cavity were machined in the UCLA workshop and then braised at

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SLAC. Since no tuners are present, special attention was paid on the machining of the full cell in order to control the resonant frequency. The final tuning can be performed by the cathode deformation and the temperature control. The final measured properties of the FERMI RF gun cavity are listed on Table 1.

Table 1: Cavity Parameters at 22.9 °C in air

Parameter	Measured Value
$\pi$ mode $f$	2997.92 MHz
0 mode $f$	2983.30 MHz
Mode separation	14.61 MHz
$Q_0$	11.900
Field balance ( $E_h/E_f$ )	0.99
$S_{11}$	-15.9 dB
Coupling	1.38

Parameter	Estimated Value
Filling time	530 ns
Input power for 120 MV/m	10.3 MW

The field along the axis was measured at UCLA by the bead drop method and the results are presented in Figure 1 showing a very good balance of the half/full cell field.

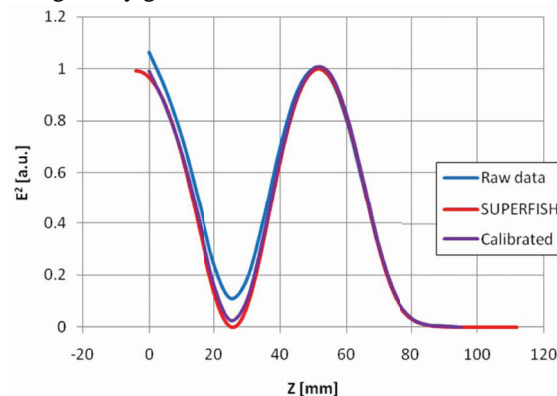


Figure 1: Normalized electric field along the beam axis measured by the bead drop method.

### INSTALLATION

The MAX-lab radiation area is well suited for testing the FERMI gun for many reasons. First of all, the room availability: Figure 2 shows the layout of the area where the FERMI gun is comfortably placed.

The second advantage is the possibility to use the S-band

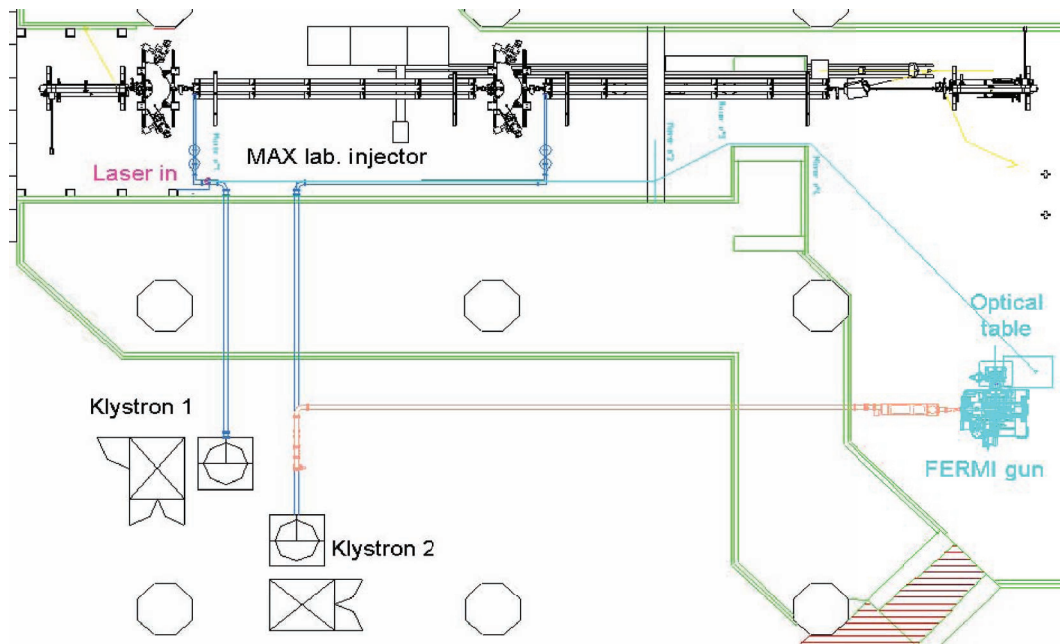


Figure 2: MAX-lab injector tunnel layout. Legend: *black* - present linac injector, *green* - radiation area perimeter, *orange* - new wave guide line, *cyan* - FERMI gun system, *red* - entrance.

25 MW klystron (that normally fills the second section of the MAX-lab injector) during the free time in between injections and whenever operation of the MAX-lab injector is not required by physics experiments.

Another reason is the availability of the existing photoinjector UV laser (262 nm, 10 ps duration and 500  $\mu\text{J}$  pulse energy available) [4].

At the beginning of this year the existing RF power distribution waveguide system has been modified to suit the needs of the FERMI gun, including the installation of new waveguide switch, circulator and new waveguide sections up to the PC-gun ceramic window. An optical transport system has been installed in the MAX-lab tunnel to bring the photon beam to the FERMI gun photocathode.

The main elements of the FERMI photoinjector (RF cavity, magnets, laser diagnostics and transport and electron beam diagnostics) have been installed in the injector tunnel of MAX-lab, as shown in Figure 3, during Easter shutdown. The system was completely set up in situ by assembling the different components (supports, vacuum wave guides, pumping system and diagnostics). The pumping system has proved its capability by achieving a base pressure of about  $5 \cdot 10^{-10}$  mbar in just two days after the activation.

The photoinjector has also been equipped with its own control system that interfaces all pump high voltage power supplies, vacuum gauges and magnet power supplies and acquires the data from the diagnostic devices. The computers run the GNU/Linux operating system and the Tango control system software is adopted. This configuration allows to interface in an effective manner all the devices and to easy develop of high-level software making also use of the 02 Synchrotron Light Sources and FELs

Matlab tools.

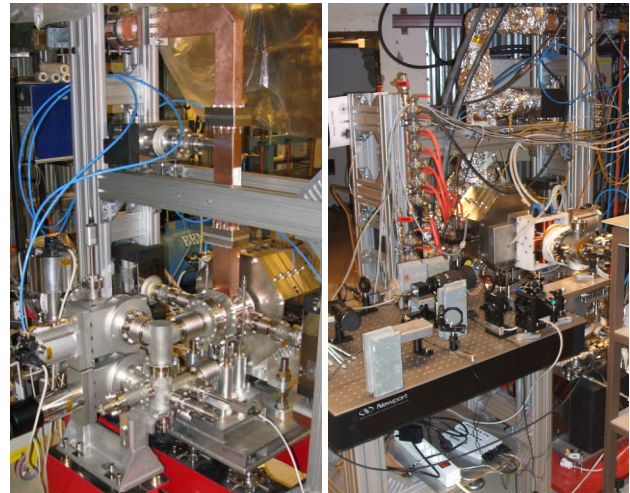


Figure 3: Photo-cathode Gun at MAX-lab: *on left* - the back view of the cavity and the pumping system; *on right* - the front view with the corrector, the laser port, the laser and e-beam diagnostics and optical transport.

## CAVITY CONDITIONING

During the allocated beam time of week 21, the RF gun was conditioned to full specifications, achieving, in five nights, 10 MW input peak power (corresponding to a maximum gradient at the photocathode of about 120 MV/m), 3  $\mu\text{s}$  pulse duration at 10 Hz repetition rate.

Electrons due to field emission from the copper cathode

T02 Lepton Sources

(the so called 'dark current') were observed on both the integrating current transformer (ICT) and on the YAG:Ce scintillation screen starting from gradient values of about 90 MV/m. The corresponding 'dark charge' was measured on the ICT in the range of a few nC.

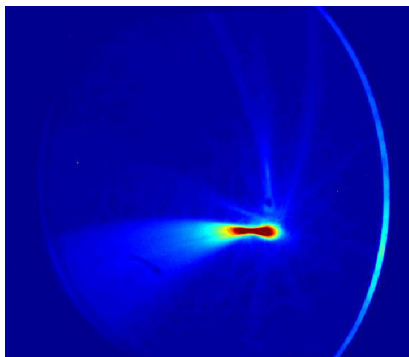


Figure 4: Dark current image on the YAG screen with 120 MV/m maximum gradient and  $I_{solenoid} = 190$  A.

Figure 4 shows a typical image of the dark current on the YAG screen focused by the solenoid. Screen acquisitions were performed at different gradients and as a function of the focusing solenoid strength and of the corrector current with the aim to evaluate the beam energy.

The bunch energy has been extrapolated from the analysis of spot displacement as function of the calibrated corrector strength: at 120 MV/m the energy results about 5 MeV; due to the large dark current energy spread the measurement depends on the solenoid strength.

## FIRST EXTRACTED ELECTRON BEAM

The RF gun's copper cathode was illuminated by the UV laser delivering  $50 \mu\text{J}$  per pulse. Figure 5 shows the time behaviour of the RF power at the gun input measured by means of a directional coupler, the laser time arrival with a photodiode signal and the electron beam current signal with the ICT. The photo-electron peak, superimposed on the dark current background, is clearly visible on the ICT trace in coincidence with the laser shot.

The photo-electron beam charge was measured to be 180 pC, corresponding to a quantum efficiency of  $QE = 1.7 \cdot 10^{-5}$ .

## CONCLUSIONS

The FERMI 1.6-cell RF gun cavity and the focusing solenoid were successfully built within the specifications. The FERMI photo-cathode gun has been successfully installed in the MAX-lab tunnel. The system commissioning has started with encouraging results: the cavity conditioning went on smoothly and the first quantum efficiency measurement indicates a good cathode surface cleanliness.

Further activities are planned at MAX-lab to continue the characterization of the FERMI gun e-beam. The system

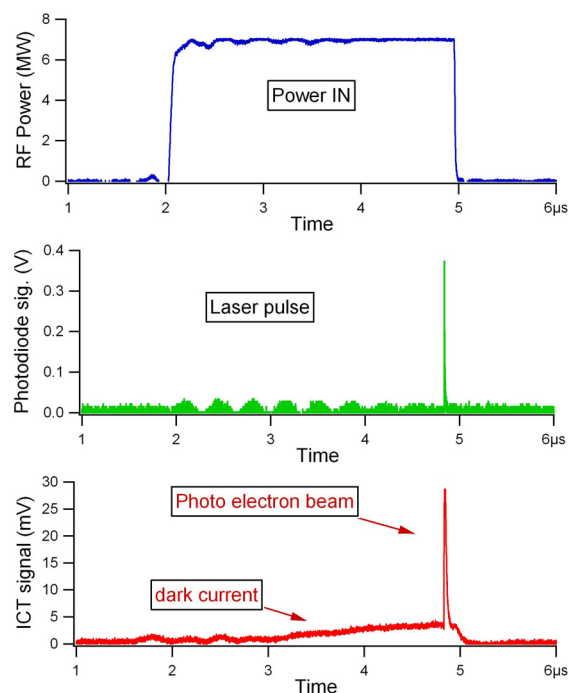


Figure 5: Time behaviour of the RF power at the input of the gun (*top*), of the photodiode signal of the laser (*middle*) and of the ICT signal (*bottom*)

will be moved back to Trieste as soon as the FERMI site is ready.

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