THE FERMI@ELETTRA COMMISSIONING

Giuseppe Penco* on behalf of the FERMI Commissioning Team (ELETTRA, Basovizza)

Abstract

The FERMI@Elettra injector, comprised of a high-gradient s-band photo-cathode RF gun, the Photocathode gun driven laser, the first two accelerating sections, the controls and the suite of diagnostics has been commissioned in 2009. In early 2010 linac commissioning up to 250MeV continued. The electron beam has been characterized in terms of charge, energy, energy spread and transverse emittance. In this paper we give an overview of the obtained results.

INTRODUCTION

FERMI@Elettra is a seeded FEL source, designed to supply photons in a spectral range from 100 to 4 nm. The Linac layout scheme is reported in Fig. 1 and the main beam parameters are listed in Table 1.

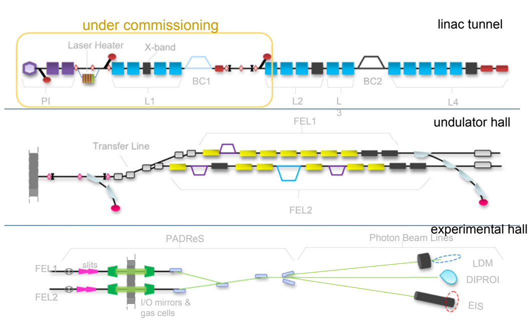

Figure 1: FERMI@Elettra project machine layout, including the linac, the undulator hall and the experimental hall.

Table 1: FERMI linac specifications

Repetition Rate	50 Hz
Beam Energy range	0.9 - 1.5 GeV
Bunch Charge	$\leq$ 800pC
I_{peak}	800A
Bunch Length (Full Width)	$\sim$1ps
ϵ_{slice}	$\leq 1.0\mu m$
σ_E (uncorr.)	$\leq$150keV

The beam tracking optimization studies performed in the past years [1] called for a 800pC-10ps bunch at the gun exit, with a ramped longitudinal profile, necessary to linearize the strong wakefield effects in the linac section [2]. After testing the feasibilty to shape the laser pulse profile in a proper way to extract the desired ramped current bunch, we have decided to simplify the machine configuration for this commissioning phase. In fact, since the actual linac layout does not include the X-band section and the second bunch compressor (BC2), we set as main target for the 2010 beam commissioning the optimization of a 250pC-flat top electron bunch ("low charge option"), at an energy of 1.2GeV and its longitudinal compression from $\sim$5 ps to $\sim$0.5-1ps (full width). ELEGANT simulations of this configuration (see Fig. 2) reveal that the bunch current profile could present a strong peak current in the head, which provides a SASE contribution negligible with respect to the FEL power radiation coming from the seeded portion, due to its very short length ($\sim$ 10 fs). The strategy and FEL

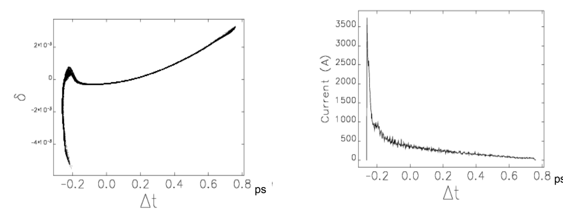

Figure 2: Longitudinal phase space (left) and current profile (right) obtained tracking with ELEGANT the FERMI linac without X-band section and BC2.

commissioning requirements are described in [3].

The beam commissioning has been divided in four phases, separated by shut-down periods dedicated to installation of new equipments. A 5 meter-thick wall has been placed after the bunch compressor in order to allow operating the beam for the injector commissioning in parallel with the installation of the rest of the linac downstream. From the end of August to the mid of November 2009 the photo-injector was commissioned. In February and in March 2010 the beam was transported at the bunch compressor (BC1) spectrometer at about 300MeV, optimizing the electron bunch in terms of charge, optics parameters, projected emittance, charge and energy spread. The experimental results and the electron bunch characterization from the gun to the BC1 spectrometer are presented in the following sections.

PHOTOCATHODE GUN

The FERMI 1.6-cell RF gun has been installed for one year at MAX-lab in Lund in order to perform a complete characterization at high power, together with some preliminary beam tests [4]. In April 2009, the RF gun with its solenoid was installed in the FERMI tunnel. Figure 3 shows the schematic layout of the 1.5 meter-long gun-to-linac section. The drive laser for the photo-injector is the

* giuseppe.penco@elettra.trieste.it

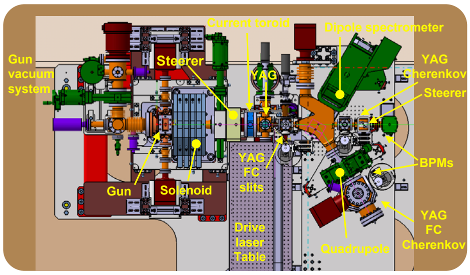

Figure 3: Gun-to-linac area, including the spectrometer beam line.

third harmonic (∼260nm) of a Ti:Sa amplifier, with a maximum energy per pulse of about 0.5mJ. Fig. 4 shows the typical flat-top transverse distribution.

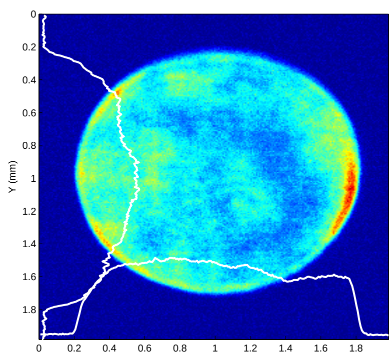

Figure 4: Laser distribution at the virtual cathode.

The first electron beam was extracted in August 2009, and a quantum efficiency (Q.E.) of about $3 \cdot 10^{-5}$ has been observed. With use, this value rapidly decreased, losing more than one order of magnitude after 3 months of operation, probably due to the deposition of the residual gas on the Cu surface induced by the interaction with the UV driven laser. In fact, the Q.E. drop is localized in the cathode center where the UV laser is more often driven (see fig.5). During the shut-down between November '09 and February '10 a cleaning procedure has been performed, consisting in venting the RF gun with Ozone gas for few hours and baking out for 2 days. When the beam commissioning started again in February 2010 the Q.E. came back to more than $3{\cdot}10^{-5}$. Fig. 5 shows the comparison between the Q.E. map of October '09 and that one of February '10.

Several tests on the laser pulse shaping were carried out to reproduce the desired longitudinal profile, Fig. 6 shows an output laser profile obtained with a cross-correlator. First measurements of the corresponding longitudinal profile of the electron bunch have been carried out using a Cerenkov

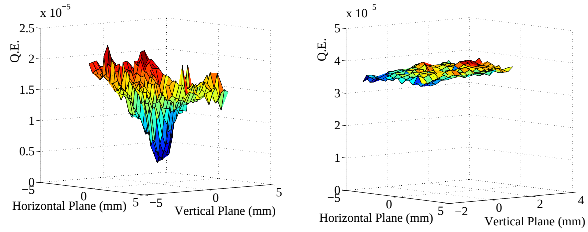

Figure 5: Q.E. map before (on the left) and after (on the right) the Ozone gas treatment.

radiator installed at a distance of 80cm from the cathode in combination with a streak camera; evaluation of the data is still ongoing. Moreover by setting the RF gun phase in

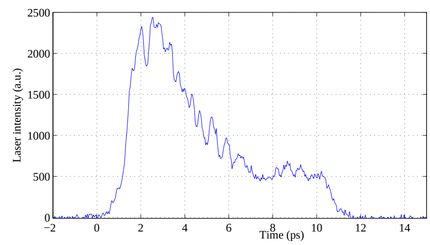

Figure 6: First laser longitudinal ramp profile as measured with cross-correlator (head on the right)

order to have a linear correlation between energy and position, the gun spectrometer was also used to have a qualitative descriptions of the bunch longitudinal structures. As already mentioned, these studies were interrupted and the effort was mainly focused on the low charge option configuration.

INJECTOR, L0 AND L1 COMMISSIONING

The injector parameters optimization was performed by measuring the Twiss function of the beam after the first two accelerating sections (Linac 0), at about 100MeV. Readers are referred to [5] for a detailed description of the 100-MeV beam diagnostic station, that includes four quadrupoles followed by three screens for the measurement of the transverse emittances and for the optics matching between the injector and the linac. For this purpose, two additional quadrupoles are installed between the two sections. We adopt this optimization procedure:

1. Center the laser spot on the Gun solenoid axes by minimizing the beam drift downstream, when scanning the Gun solenoid;
2. Schottky scan to find the nominal RF gun phase (about -30deg with respect to the zero cross);
3. Finding the "crest" phase of the Linac 0;
4. Emittance and Optics measurements by the quadrupole scan technique in the 100-MeV beam diagnostic station;
5. Find the minimum of the projected emittance by tuning

the gun and the Linac 0 parameters;
6. Back track the measured optics to the Linac 0 intra-section and forward track to find the quadrupoles setting needed to obtain the desired optics.
7. Check the emittance and optics by repeating the quadrupole scan in the beam diagnostic station.

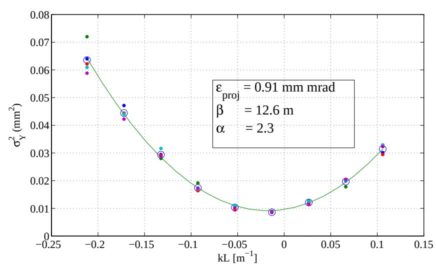

Figure 7: Vertical projected emittance measurement through quadrupole scan. For each quadrupole setting, five images at the YAG screen were acquired (coloured dots) and their RMS value (blue circles) is used for the quadratic fitting.

Figure 7 shows the measured vertical projected emittance (calculated over 100% of the bunch particles) after the optimization and the optics matching. In a similar way, we obtained a horizontal projected emittance of 0.95 μrad. The optics matching procedure between the injector and the linac is described in details in [6].
Some shifts were dedicated to preliminary tests on the laser heater, installed after Linac 0. Figure 8 shows the spontaneous emission (783nm), produced when the bunch passes through the chicane undulator, closed to the nominal gap, reflected by a Optical Transition Radiation (OTR) screen. No degradation of the projected emittance is obsvered when the chicane is switched on at the nominal deflection configuration and the undulator gap is closed to the nominal gap. Refinement of the preliminary longitudinal ($\sim$ 200 ps) and transverse ($\sim$0.5mm) alignment between laser and bunch will be performed in the next commissioning phases.

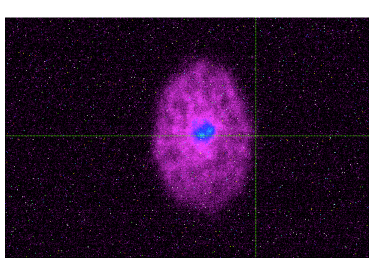

Figure 8: Spontaneous emission from the laser heater undulator (elliptical halo) reflected by the OTR screen superimposed to the OTR image of the beam (central intense spot).

After the optics matching between the injector and the linac, the beam was transported and accelerated to about 300 MeV through the Linac 1 (see figure 9). Trajectory

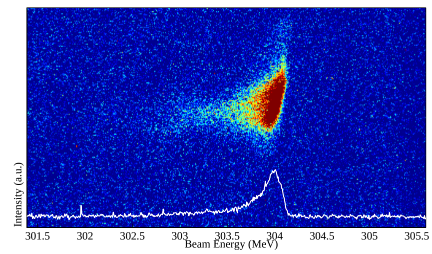

Figure 9: BC1 spectrometer YAG image of the bunch (Top) and the corresponding energy distribution (Bottom)

feedbacks have been fully functional (more details in [7]). When feedbacks are switched off, we measured an RMS charge jitter of $\sim 0.5\%$, an RMS energy jitter of $\sim 0.04\%$ and an RMS trajectory jitter of less than $100\mu m$.

CONCLUSION

The FERMI@Elettra linac has been commissioned up to 300MeV. The optimized beam, at low charge, meets the requirements in terms of beam stability, energy and projected emittance. In the next commissioning phase, starting in June 2010, the bunch will be compressed and transported to the end of the Linac.

ACKNOLEDGEMENT

The FERMI commissioning was carried on by the physicists team, strongly supported by the control, the diagnostic and linac groups. This work was supported in part by the Italian Ministry of University and Research under grants FIRB-RBAP045JF2 and FIRB-RBAP-6AWK3.

REFERENCES

[1] "Conceptual Design Report" for the FERMI@Elettra project (2007).
[2] M.Cornacchia, S. Di Mitri, G. Penco, A.A.Zholents, Phys. Rev. ST Accel. Beams 9, 120701 (2006).
[3] E. Allaria et al. "Requirements for FEL Commissioning at FERMI", Proc. of this conference.
[4] M.Trovó et al., "Status of the FERMI@Elettra photoinjector", Proc. of EPAC 2008 Conf., Italy.
[5] G. Penco et al.," The 100-MeV beam diagnostic station for the FERMI linac", Proc. of EPAC 2008 Conf., Italy.
[6] S. Di Mitri et al., "Integration of Elegant Tracking Code into the Tango Server-based High Level Software of FERMI@elettra for Optics Measurements and Modeling", Proc. of this conference.
[7] M.Lonza et al., "Beam-based Feedbacks for the FERMI@Elettra Free Electron Laser", Proc of this conference.