THE BEAM DIAGNOSTICS SYSTEM FOR THE FERMI@ELETTRA PHOTOINJECTOR

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Abstract

The quality of the photoinjector high brightness electron beam plays a crucial role for the performance of the seeded FERMI@elettra FEL. Optimization of the gun is possible with an extensive characterization of the 5 MeV electron beam longitudinal and transverse phase space. The photoinjector diagnostics system includes interceptive instrumentation as YAG:Ce screens for transverse position and profile measurements and Faraday cups for the absolute beam charge measurements. A Cherenkov radiator coupled to a streak camera provides an accurate reconstruction of the longitudinal profile and a slit/pepper pot followed by a screen is foreseen for the transverse emittance measurement. Information on beam transverse position and charge is obtained non-disruptively with respectively stripline BPMs and a current transformer. A dispersive beamline is also foreseen for the beam energy, energy spread and longitudinal phase space measurements. The diagnostics system performances and design principles are presented.

INTRODUCTION

Beam instrumentation has been designed to extensively characterize the low energy, high brilliance photoinjector beam in both transverse and longitudinal planes [1]. The nominal beam parameters in the FERMI photoinjector are summarized in Table 1.

Table 1: Photoinjector main beam parameters

Beam energy	5 MeV
Beam correlated energy spread	100 keV
Bunch charge	0.3 - 1 nC
Bunch length (FWHM)	10 ps
Bunch repetition rate	10 - 50 Hz
Min bunch transverse size @1 nC ($\pm 2\sigma$)	2.7 mm

During commissioning the bunch charge will be lowered down to 50 pC for thermal emittance measurements. The scintillation screens position versus horizontal beam envelope and projected emittance is represented in Fig. 1.

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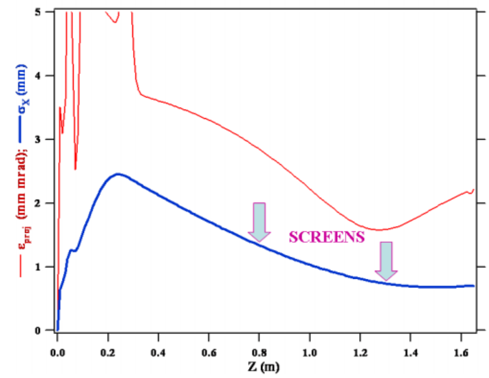

Figure 1: Screen position versus horizontal beam envelope and projected emittance behaviour as a function of the distance from the photocathode.

FERMI PHOTOINJECTOR BEAM DIAGNOSTICS SYSTEM

Beam charge measurement

Beam charge measurements provide information on possible drifts of the photocathode quantum efficiency and help to adjust the laser settings, in particular the correct phase between the laser and RF gun.

The beam charge will be measured non-destructively with a commercial, in-flange, high resolution current transformer [2]; a 60.4 mm internal diameter model is foreseen for the passage of the photocathode laser beam. An interceptive absolute beam charge measurement will be performed with a Faraday cup. Faraday cups including secondary electrons suppression allows 1 pC resolution, while the ICT performs a 1 pC shot-to-shot rms noise.

Transverse plane measurements

The photoinjector BPMs are matched stripline BPMs; electrodes are 150 mm long and signal detection is based on commercial, 500 MHz electronics. The strips are fixed to and aligned with respect to flanges which are, in turn, fixed to the BPM body. For locations where longitudinal space is an issue, resonant striplines [3, 4] less bulky than matched ones, are being considered; their dedicated electronics needs further developing.

Scintillation screens are the preferred solution to measure the electron beam transverse profile at low energy because of their higher photon yield compared to OTR screens. 100 μm thick Yttrium-Aluminium Garnet Cerium doped (YAG:Ce) screens ensure a spatial resolution better than 10 μm, compatible with the limit of the CCD pixel/sensor size and of the optical setup.

At low energies, where the beam dynamics is strongly dominated by space charge effects, accurate emittance measurements are performed using either a 2D pepper-pot device or a 1D slit array. Tungsten single or multi-slit convert the space charge dominated incoming beam into several emittance dominated beamlets which then drift to a detection scintillation screen. Evaluation of the rms emittance only depends on the slit mask geometry, the beamlets size and the intensity distribution on the screen [5], the resolution being mainly limited by jitters of the beam transverse position or profile.

Longitudinal plane measurements

The electron beam longitudinal current distribution and the bunch length are measured using an Cherenkov emitter (Silica aerogel with refractive index of about 1.008) coupled to a streak camera that performs a 200 ps resolution [6].

A magnetic spectrometer is a crucial diagnostics element for establishing the proper RF gun tune and overall performance. The dispersive beamline provides information on the beam energy, energy spread and longitudinal phase space [7]. The expected rms energy spread varies in the range 100 - 300 keV depending on the phase between the laser pulse and the gun peak field. The spectrometer design goal is to measure it with 1 % resolution.

FERMI PHOTOINJECTOR DIAGNOSTICS LINES LAYOUT

One of the crucial aspect in the design of the beam diagnostics system for the FERMI photoinjector is the very tight longitudinal space (less than 1 m from the solenoid exit to the entrance of the first accelerating session). In Fig. 2 the foreseen layout is schematically shown as a function of the distance from the photocathode.

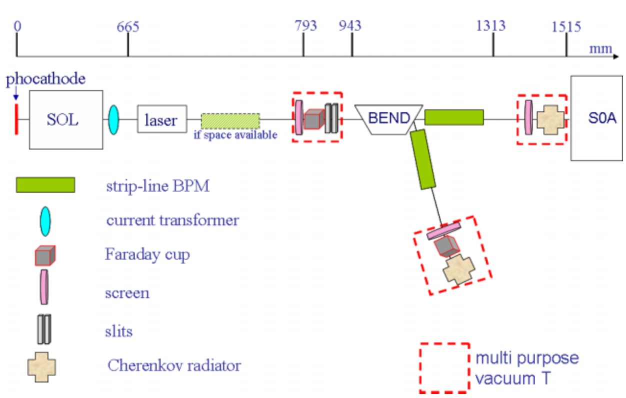

Figure 2: Schematic layout of the beam diagnostics system as a function of the distance from the photocathode.

In Fig. 3 the beam diagnostics system is integrated with the other photoinjector components. Just after the solenoid is a vacuum van followed by the current transformer for the non-destructive beam charge measurement.

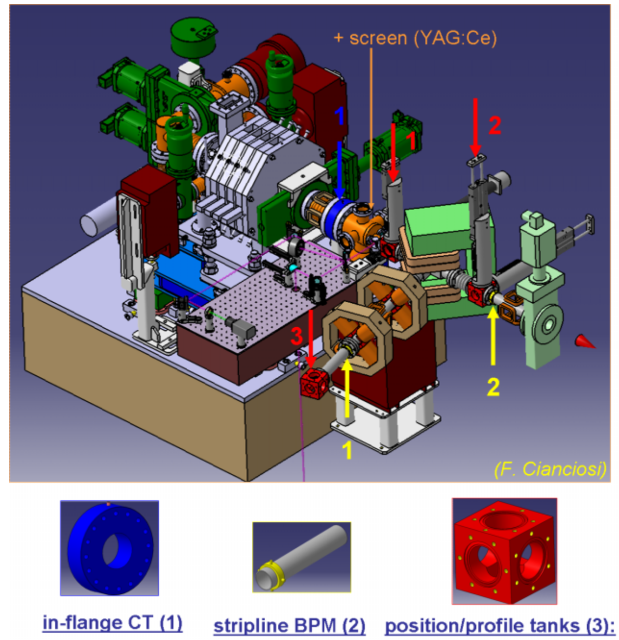

Figure 3: Photoinjector lines layout with instrumentation mechanical details.

The path of the photocathode laser beam inside the photoinjector vacuum chamber is represented in Fig. 4.

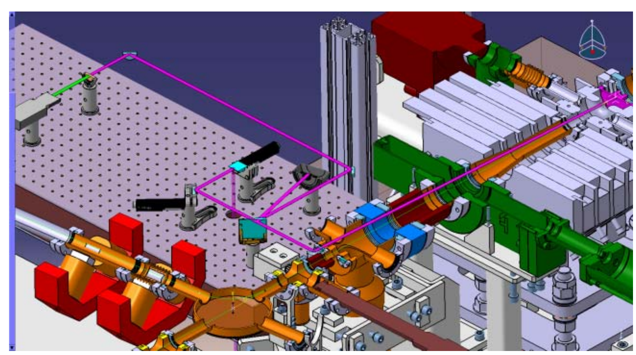

Figure 4: Photoinjector lines layout - cut view with laser beam path.

A first YAG:Ce screen, controlled by a stepper motor, will be placed in the tank for the photocathode laser beam entrance to adjust the beam centering and measure the dark current with the gun on and the laser off. A first beam position monitor (BPM) will provide non-interceptive information on the beam position if the available longitudinal space is sufficient. A second tank will host a YAG:Ce screen, a movable Faraday cup and the horizontal and vertical slits to be used for the emittance measurement with the second screen in the straight line.

A second BPM measures the beam position in the straight line after the spectrometer, followed by the screen for the emittance measurement; the tank will be equipped also with a Cherenkov detector for the beam longitudinal profile measurement.

Finally, the dispersive beam line will be equipped with a BPM and a tank that hosts a screen, a Cherenkov detector and a Faraday cup. These monitors provides the beam intensity, position and profile and allow the reconstruction of the longitudinal phase space.

BEAM DIAGNOSTICS PROTOTYPE TESTS AT THE 1.0 GEV LINAC

Two diagnostics station have been installed on the 1.0 GeV LINAC to test FERMI diagnostics prototypes on the currently available beam. The station at 100 MeV, shown in Fig. 5, consists of an integrating current transformer and a tank equipped with an optical radiation transition screen (OTR) and two different scintillation screens: Chromox, traditionally used at the laboratory and a YAG:Ce screen for a better spatial resolution. The station at 1 GeV consists of a wideband longitudinal pickup (BAM) and a tank with the an OTR and two scintillation screens as above, as shown in Fig. 6.

Aim of the tests is to provide information on the main beam parameters as bunch profile and position, transverse emittance, charge and beam longitudinal structure.

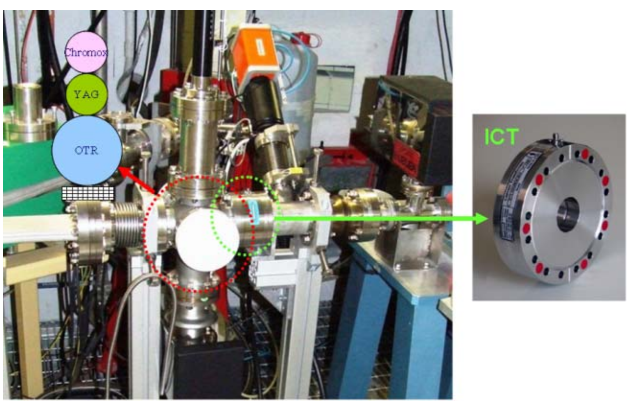

Figure 5: The FERMI beam diagnostics station prototype in the LINAC @ 100 MeV with a schematic representation of the screens/calibration grid geometry and a detailed view of the in-flange ICT.

The integrating current transformer, as shown in Fig. 5, is embedded in conflat flanges for direct mounting on the beam pipe and longitudinal space saving.

Screens are coupled to digital CCD (Basler A321f [8]) with remote controllable gain/shutter time to avoid saturation in a large dynamic range. It is foreseen to establish a remote control for the lens diaphragm and focus and to use telecentric lenses to increase the spatial resolution of the detection system. CCDs are shielded with lead bricks because of their low radiation hardness.

The two screen stations are equipped with an illumination system and a 10 mm long, 1 mm pitch grid in both vertical and horizontal planes for calibration.

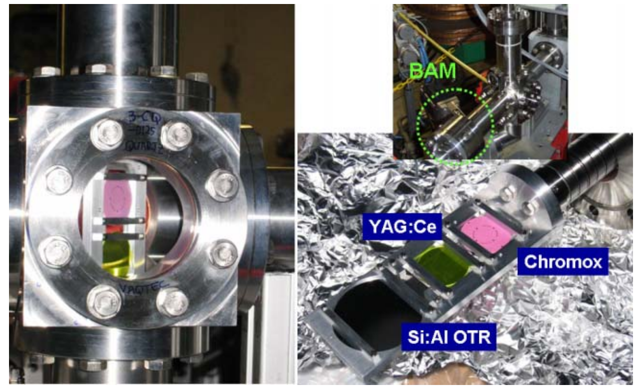

Figure 6: The FERMI beam diagnostics station prototype in the LINAC @ 1 GeV with a detailed view of the screens mounted on the support and of the in-flange BAM.

CONCLUSIONS

An overview of the beam diagnostics and instrumentation system for the complete characterization of the FERMI photoinjector low energy high brilliance beam is presented. Two FERMI diagnostics prototypes ready to be used in the ELETTRA 1 GeV LINAC for beam charge, longitudinal structure and transverse plane measurements are also described.

REFERENCES

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