Conceptual design of electron beam diagnostics for high brightness plasma accelerator

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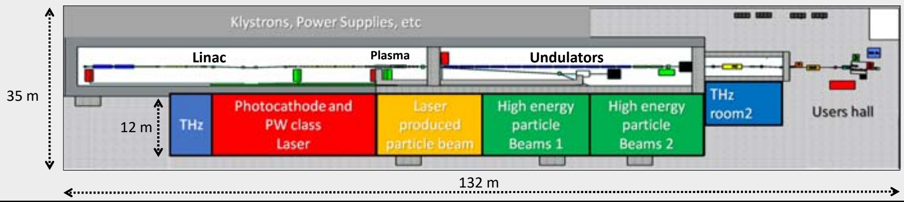
ABSTRACT

A design study of the diagnostics of a high brightness linac, based on X-band structures, and a plasma accelerator stage, has been delivered in the framework of the Eupraxia@SPARC_LAB project. In this paper, we present a conceptual design of the proposed diagnostics, using state of the art systems and new and under development devices.

Eupraxia@SPARC_LAB

- FEL user facility (1 GeV – 3nm)
- Advanced Accelerator Test facility
- 500 MeV by RF Linac + 500 MeV by Plasma
- 1 GeV by RF Linac only



General issues

Diagnostics for conventional accelerators up 1 GeV is not a big challenge, but an X-band accelerator must be very compact, small, and also the diagnostics must be compact as well to avoid the decrease in the effective gradient.

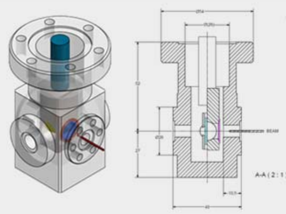
There are several challenges for the diagnostics in the PWFA regime: The bunch length is very small, down to few fs, the bunch size can be also very small in some position, down to few μm.

Another important point is the possibility to have single shot measurement, especially for transverse parameter when the plasma acceleration (multishot instability) is used.

In the beam driven plasma accelerator the driver beam can be a source of background noise after the interaction with the plasma. A collimator/filtering is mandatory in order to clean the beam and to separate the witness before measurement.

	Units	1 GeV Case	5 GeV Case
Bunch charge	pC	30	30
Bunch length rms	fs	10	10
Peak current	kA	3	3
Rep. rate	Hz	10	10
Rms Energy Spread	%	1	1
Slice Energy Spread	%	0.1	0.1
Peak current	kA	3	3
Rms norm. emittance	μm	1	1
Slice norm. emittance	μm	<1	<1
Slice Length	μm	0.75	0.75
Radiation wavelength	nm	4	0.1
ρ	$\times 10^{-3}$	≥ 1	≥1
Undulator period	cm	1.5	1.5
K		0.872	0.872

Conventional View Screens



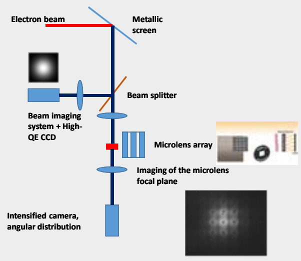
View screens are fundamental to measure the envelope and properly match the beam in the different accelerator sections.
They will be based on scintillators normal to the beam direction and a mirror in the back at 45 degrees.
Compact design is required in order to preserve the compactness of the whole machine.

Longitudinal diagnostics

Longitudinal diagnostics is mandatory to clearly set the correct compression phase in the velocity bunching and to recover the correlated energy spread induced in this way.

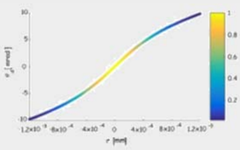
- X-band RF deflector (RFD)
  - For bunch length measurements down to few fs, longitudinal phase space, Comb.like beam quadrupole scan, slice emittance
- EOS (Electro Optical Sampling)
  - Not intercepting diagnostics to monitor bunch length down to 50 fs
  - Monitor to online measure the distance of comb-like beams
  - Time of arrival monitors
- Coherent radiations
  - Compression monitor (relative measurement)
  - Bunch length (hopefully single shot)

Advanced diagnostics



The optical transition radiation is divide in two arms. In one there is a camera to record the image size of the beam. In the other the beam image is reproduced in the plane of a microlens array. Due to the very short focal system of this array is not possible to put the detector directly in the focal plane of this device. We image this focal plane on a intensified camera where the angular distribution of every single microlens is produced, containing information of beam angular divergence in different spatial positions.

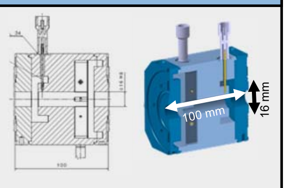
Simultaneous measurement of betatron radiation spectrum and electron spectrum gives the possibility to retrieve in a single shot the emittance also with the correlation term. For more information Curcio, A., et al. *Physical Review Accelerators and Beams* 20.1 (2017): 012801.



Charge and trajectory monitor

For accurate charge measurements we plan to use Bergoz Turbo- ICT (down to 50 fC, up to 300 pC)

For trajectory diagnostics (very important in a X-band machine) we plane to have stripline BPM for S band linac, where the resolution can be in the order of 100 um, and cavity BPM for the rest of the machine. We are studying the possibility to use the dipole mode in the X-band to measure the beam position.



Swiss FEL Cavity BPMs are an example of very compact and precise device

Diagnostics layout