Design and Calibration of an Emittance Monitor for the PSI X-FEL Project

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Abstract
The Paul Scherrer Institute (PSI) intends to realize a compact X-ray Free Electron Laser (XFEL) based on the development of a high brightness, high current electron source. Field emission arrays (FEA) in combination with high gradient acceleration promise a substantial reduction of transverse emittances by up to one order of magnitude compared to existing electron sources for XFELs. The acceleration concept and the main beam parameters will be demonstrated in a 250 MeV injector LINAC project. A flexible, high resolution emittance meter based on the pepperpot measurement technique has thus been designed to characterize this low emittance beam. The realization of this monitor and the calibration procedure will be presented.

PSI X-FEL Project (2012 – 2015)


Main Accelerator Parameters
- Beam Energy: 5.8 GeV
- Peak Current: 1.5 kA
- Peak Power: 1.4 GW
- Photon Energy: 12.5 keV
- Undulator Period: 15 mm
- Undulator Type: planar
- Undulator Strength: K = 1.19
- Undulator Length: ≤ 50 m

Main FEL and Facility Parameters
- FEL Facility Length: ≤ 800 m
- Radiation Wavelength: 1 Å


Main Accelerator Parameters – Project Goals
- Beam Energy: 250 MeV
- Peak Current: 3.0 kA
- Peak Power: 10.8 GW
- Photon Energy: 30 keV

Pepperpot Emittance Measurement Principle

- B-scan profiles on the screen provide information of angular beam distribution at the position of the PP holes
- B-scan position with respect to center of gravity is a measure for the correlated divergence
- B-scan position of particle paths with respect to optical axis is given by: \( x' = \frac{x - x_c}{L} \)
- RMS emittance can be determined considering the second moments of \( x' \) and \( y' \):
  \[ \epsilon_{\text{RMS}} = \sqrt{\langle x'^2 \rangle} = \sqrt{\langle y'^2 \rangle} \]

Images of Pinholes

- PSF has been measured in optical lab using a He-Ne laser source
- Gaussian fit with \( \sigma = 0.95 \) (95% of intensity distribution) has been taken into account and leads to upper limit of \( \epsilon_{\text{RMS}} \)
- Port’s area with respect to optical axis is given by: \( x' = \frac{x - x_c}{L} \)
- Images 5 μm, 10 μm, 35 μm, 100 μm, 500 μm

Point Spread Function

- PSF for 5 μm, 10 μm, 35 μm, 100 μm, 500 μm