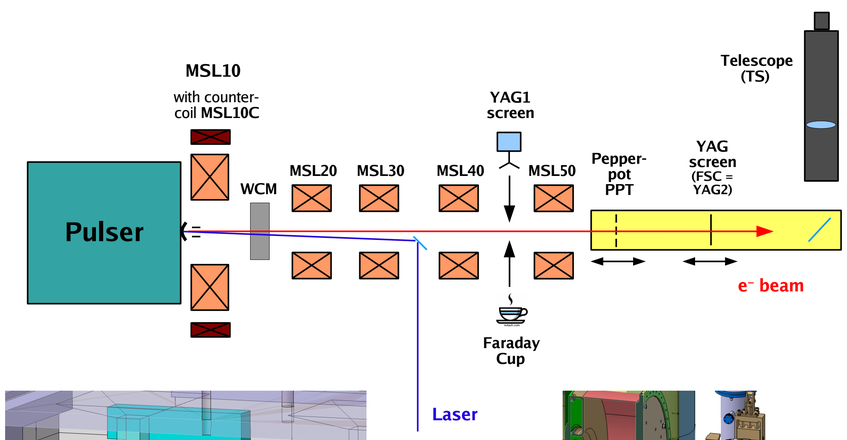
Measurements and Modeling at the PSI-XFEL 500 kV Low-Emittance Electron Source

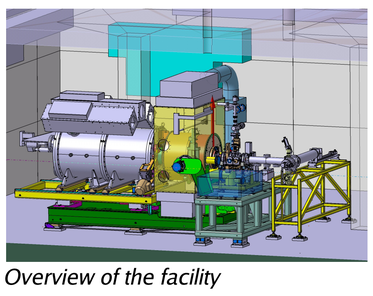
T. Schietinger, A. Adelmann, Å. Andersson, M. Dietl, R. Ganter, C. Gough, C.P. Hauri, R. Ischebeck, S. Ivkovic, Y. Kim, S.C. Leemann, F. Le Pimpec, K. Li, P. Ming, A. Oppelt, M. Paraliev, M. Pedrozzi, V. Schlott, B. Steffen, A.F. Wrulich

Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland

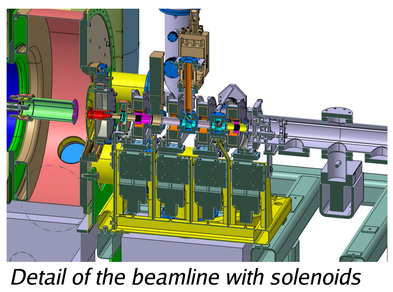
Abstract

Paul Scherrer Institute (PSI) is presently developing a low-emittance electron source for the PSI-XFEL project. The electron gun consists of an adjustable diode configuration subject to pulses of 250 ns (FWHM) with amplitude up to 500 kV from an air-core transformer-based high-voltage pulser. The facility allows high gradient tests with different cathode configurations and emission processes (pulsed field emission and photo emission). In the first stage, the beamline consists of focusing solenoids followed by an emittance monitor. Selected beam characterization measurements from photo cathode operation driven by a 266 nm UV laser system delivering 4 µJ energy during 6.5 ps (RMS) are presented and compared to the results of 3D particle tracking simulations.





Overview of the facility



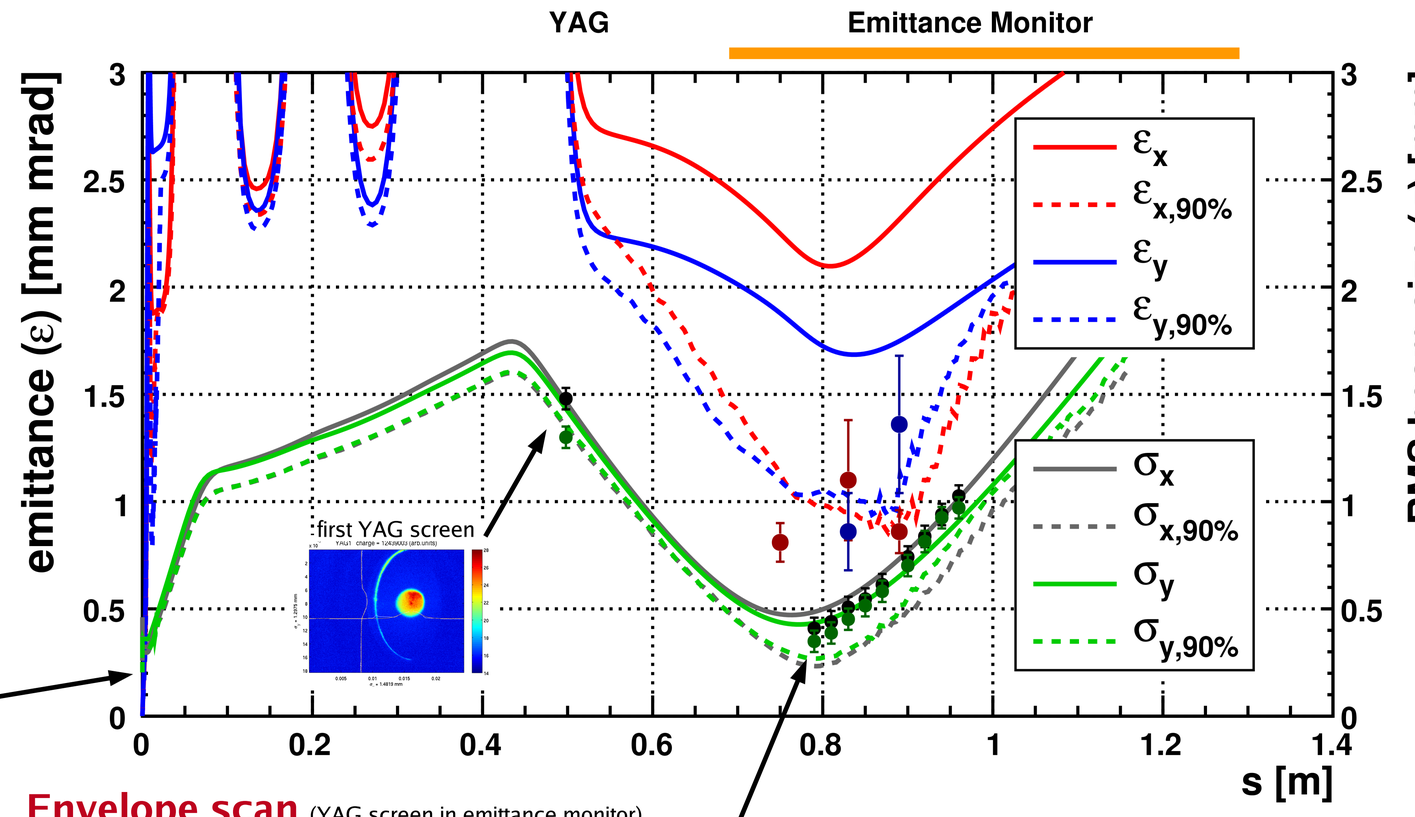
Detail of the beamline with solenoids

Experimental Setup

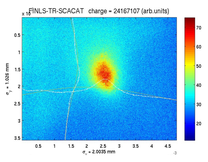
- **High-voltage pulser** delivering 250 ns pulses of up to 500 kV amplitude to an adjustable diode (stainless steel or other material)
- 266 nm UV **laser** (Nd:VAN) illuminating the cathode during pulse (~4 µJ)
- **Diagnostic beamline** consisting of 5 solenoids, wall current monitor, Faraday cup, emittance monitor (pepper-pot) and additional YAG screen.
- **Pepper-pot:** 200 µm thick tungsten disk, 20 µm diameter holes separated by 250 µm. Beamlets are portrayed onto a YAG screen typically 30 mm downstream of the pepperpot.

Simulation: OPAL

- **OPAL = Object-oriented parallel accelerator library**
- C++ framework developed at PSI (A. Adelmann), see http://amas.web.psi.ch/tools/OPAL
- **OPAL-T:** (one of several flavors of OPAL)
  - Time-dependent parallel particle-in-cell code
  - Space-charge solver based on integrated Green function (similar to IMPACT-T)
  - We track 10^6 macro-particles on 32×32×64 mesh.
  - Currently run on 4–8 processors.

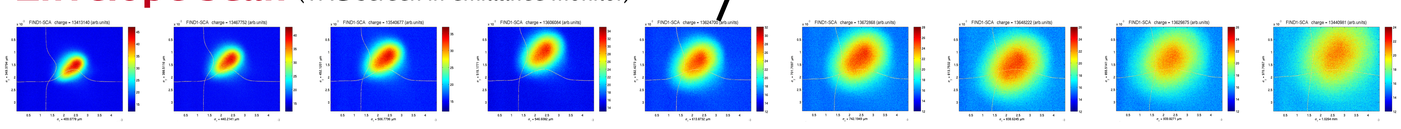


Laser spot

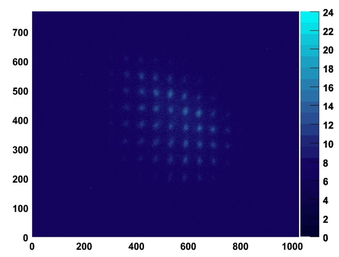


measured with "virtual" cathode (equivalent optical plane)
σ_x = 330 µm, σ_y = 370 µm

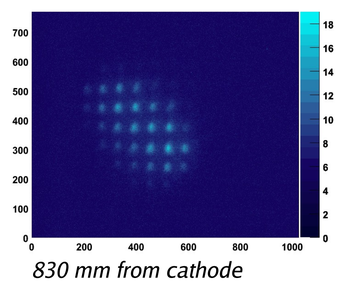
Envelope scan (YAG screen in emittance monitor)



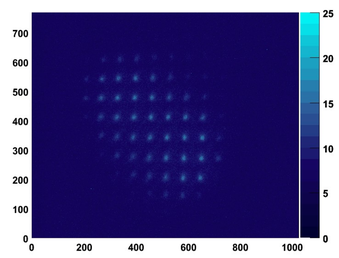
Pepper-pot images



750 mm from cathode

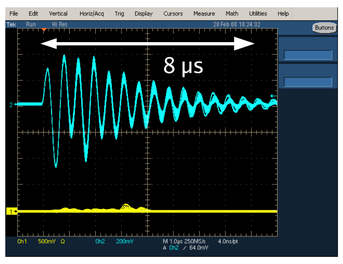


830 mm from cathode

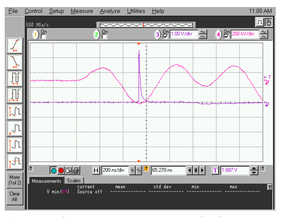


890 mm from cathode

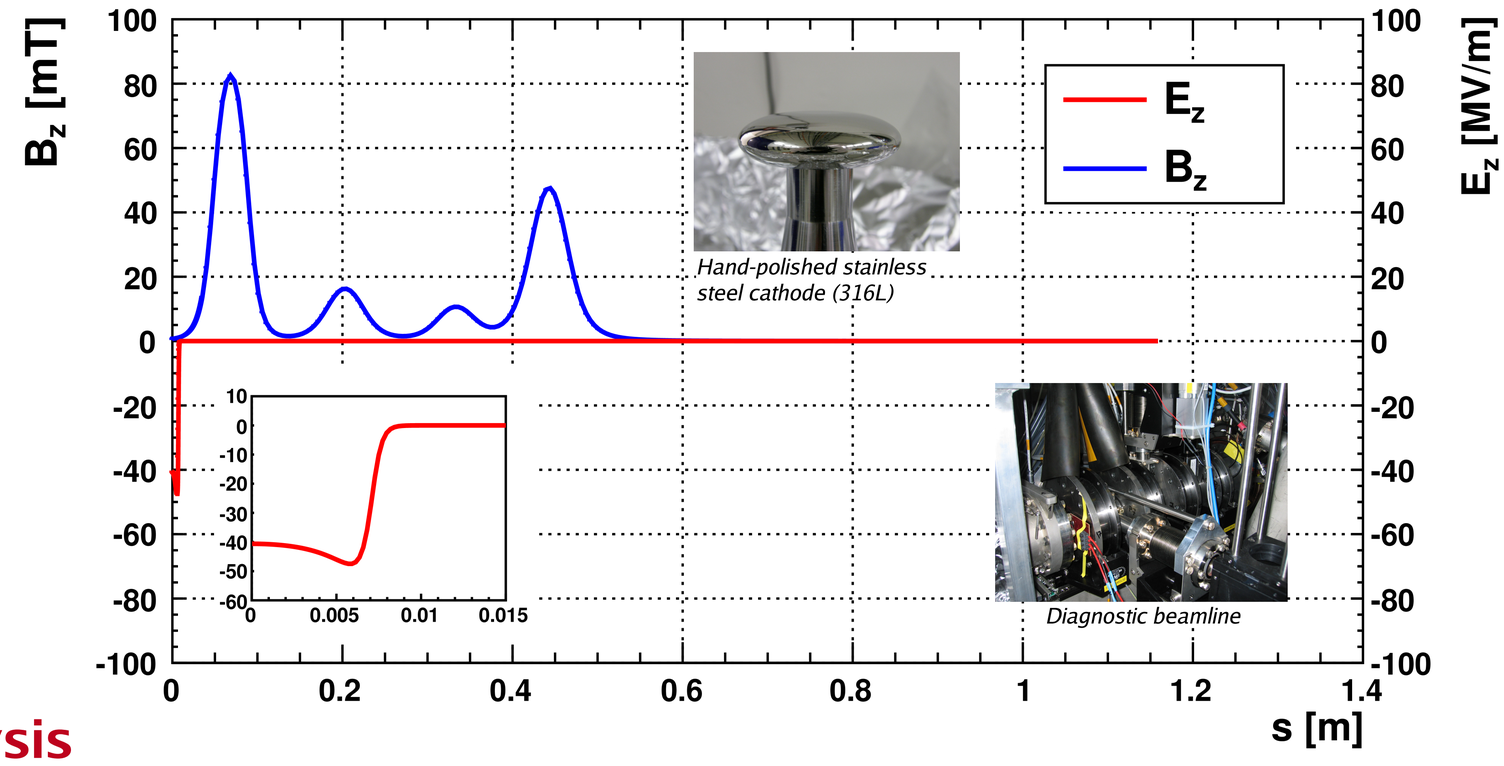
Pulse shape



250 ns FWHM pulse (first peak)



Synchronisation with laser



Hand-polished stainless steel cathode (316L)

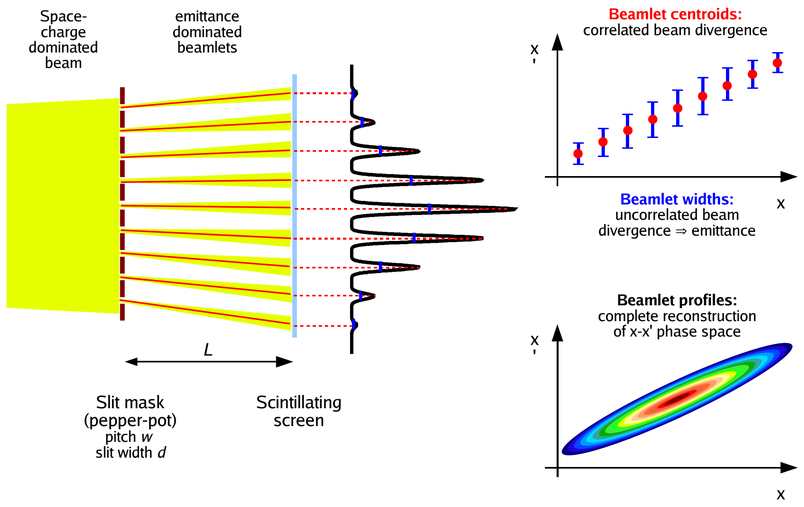
Diagnostic beamline

Issues

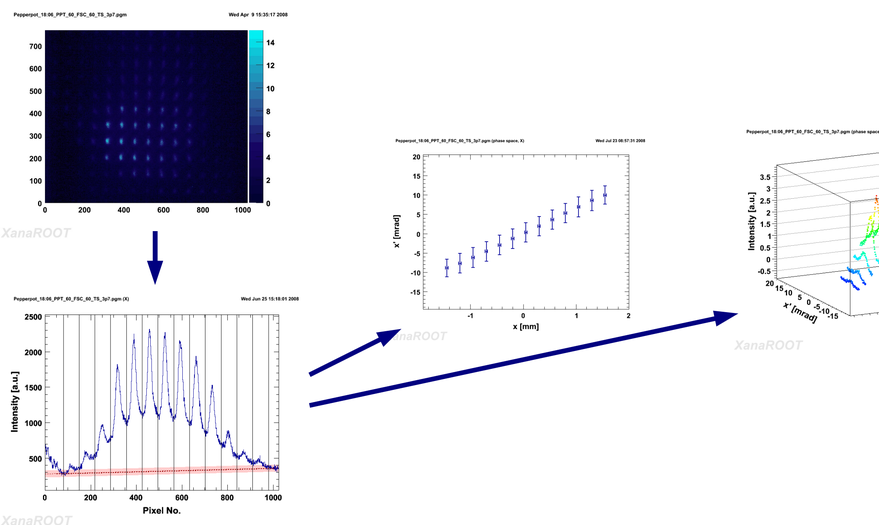
- (Too?) Large emittance in simulation.
- Can be traced back to a large but faint halo (in the simulated beam) – not observed in measurement.
- Strategies (under study):
  - Only consider central 90% of particles in simulation (left)
  - Modify initial distribution on cathode (tails are not very well known)
  - Aperture from anode iris?

Pepper-pot analysis

Principle:



Reality:



XXIV Linear Accelerator Conference 2008
Victoria, BC, 30 September 2008