Latest results from the upgraded PITZ facility

Chase Boulware, DESY, Zeuthen, Germany, for the PITZ collaboration
The PhotoInjector Test facility in Zeuthen (PITZ) characterizes high-brightness electron sources for FELs like FLASH and the planned European XFEL.

<table>
<thead>
<tr>
<th></th>
<th>FLASH</th>
<th>XFEL</th>
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<tbody>
<tr>
<td>normalized rms transverse emittance</td>
<td>2 mm mrad</td>
<td>0.9 mm mrad (injector)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.4 mm mrad (undulator)</td>
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<tr>
<td>bunch charge</td>
<td>1 nC</td>
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</table>

The best measured rms transverse emittance for 1 nC so far at PITZ: 1.26 ± 0.13 mm mrad (100% of detected charge, geometric mean of the transverse planes ± measurement standard deviation).

Improving from the FLASH requirements to the XFEL and measuring this emittance is a real challenge.
Overview of upgrades to the PITZ facility

- new 1-1/2 cell L-band gun
- new photocathode drive laser
- new dipole magnet in low-energy dispersive section
- new high-energy spectrometer based on 180-degree dipole magnet
- conditioning test stand (separate from main linac)

Virtually every component of the beamline has been replaced or relocated in the last 8 months.
Panorama of the PITZ tunnel

- new dipole spectrograph
- gun prototype 4.2
The new gun prototype has a more sophisticated water cooling design than previous guns.

greater surface area for water channels and more temperature sensors

cross-section of the gun cavity at the iris plane

cathode

electron beam

Water flow rates in the 14 input channels of the new gun are independently measured and adjusted.
The new gun cavity has been conditioned up to 50 kW average RF power.

- 7.2 MW peak RF power in the gun
- 700 μs flat-top pulse length
- 10 Hz repetition rate

This conditioning was performed at a dedicated conditioning test stand.
The new cavity, prepared with a dry-ice cleaning procedure, shows markedly reduced dark current and reflected RF power.

Dark current in the mA range has an adverse effect on cathode lifetime, and creates high radiation levels in the accelerator tunnel.

Reflected RF power from gun cavity 4.2 is also reduced by about an order of magnitude, down to \( \sim 0.3\% \) of the input power.
Cathode uniformity can be routinely monitored with quantum efficiency (QE) maps.

modulations smaller than 10% (+/-)

Raster scan with a small UV spot (diameter ~ 200 μm)

The largest spot size used for beam operation has a diameter of 3.0 mm.

Cs₂Te cathode lifetimes*

2007 run:

~100 hours at high peak field

Present run:

>180 hours and still running with QE = 5 – 10% at high field

*requirement to reach 1 nC is around 0.5% QE
The new photocathode laser will produce flat-top pulses with much shorter rise and fall times.

**Old** laser profile (streak camera measurement)

**Temporal profile of the new laser system, measured by optical sampling at MBI**
Simulation results predict that the shorter rise and fall times of the laser bring a reduction of 20% in the rms projected emittance.

The head and tail of the bunch have around twice the emittance of the central slices, and sharp rise/fall times reduce their influence.
Measurements of beam momentum before the booster (1.1 m downstream the gun) have been performed with the redesigned dipole magnet.

- Increased inner chamber width (27 mm) for transmission over a broader range of focusing conditions
- Dispersion coefficient at the observation screen = 425 mm

Simulations of the momentum vs. RF power measurements confirm gun gradients ~ 60 MV/m (XFEL design parameter).

See J. Rönsch, poster TUPPH038
The longitudinal phase space is measured by combining the dipole dispersion with streak camera measurements.

<table>
<thead>
<tr>
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<th>pulse length (FWHM)</th>
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<tr>
<td>photocathode laser</td>
<td>2.1 ps, Gaussian</td>
</tr>
<tr>
<td>electron bunch</td>
<td>13 ps</td>
</tr>
</tbody>
</table>

1-nC bunches

see J. Rönsch, *poster TUPPH038*
A multipurpose dispersive section has been installed after the booster cavity.

**Diagram:**
- Reference screens
- Quadrupole magnets
- Booster cavity
- Electron gun
- 180-degree dipole
- Slit
- Measurement screens

**Specifications:**
- Bending radius: 300 mm
- Maximum field: 0.46 T
- Dispersion coefficient: 600 mm

This section is designed for beam momentum, longitudinal phase space, and slice emittance measurements.
Two programs for slice emittance measurements are being pursued.

**Quadrupole scan with streak camera:**
Errors are very large for the single quadrupole scan (optical resolution, lost signal at streak camera slit, space-charge effects), so multiple-quadrupole techniques are being considered. **Poster TUPPH037** (R. Spesyvtsev)

**Off-crest acceleration in the booster cavity:**
Difficulties include the proper solenoid optimization and errors caused by any steering after the booster, but estimations of error are reasonable (5-10%). **Poster TUPPH079** (Y. Ivanisenko)
The PITZ facility has been substantially upgraded and the measurement program is underway.

- **new 1-1/2 cell L-band gun**
  - improved cooling, dry-ice cleaned
  - **60 MV/m peak field at cathode**, lower dark current and lower reflected RF power (factor of 10)

- **new photocathode drive laser**
  - rise and fall times of laser pulse shortened from 7 to **2 ps** → simulation predicts lower transverse emittance

- **new dipole magnet in low-energy section**
  - momentum and longitudinal phase space measurements already performed

- **new high-energy spectrometer**
  - designed for beam momentum, longitudinal phase space, and slice emittance measurements

* European XFEL specifications

**The further beam characterization program is in progress, including thermal emittance and emittance at 1 nC.**
Acknowledgments


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This work has partly been supported by the European Community, contracts RII3-CT-2004-506008 and 011935, and by the 'Impuls- und Vernetzungsfonds' of the Helmholtz Association, contract VH-FZ-005.

2 postdoc positions and 1 PhD student position are currently open! See http://pitz.desy.de

C. Boulware – FEL 2008 – August 29th, 2008