First Results and Future of the Photo Injector Test Facility at DESY Zeuthen – PITZ

• introduction
• first measurements
• future schedule

Frank Stephan for the PITZ Collaboration,
TTF Meeting Saclay, April 3\textsuperscript{rd} – 5\textsuperscript{th}, 2002
The PITZ project:

- develop and test photo injectors with minimum transverse emittance (measurements, simulations, sub-components)
- project initiated by DESY, started in collaboration with BESSY, MBI, TEMF@TUD (money from the HGF-Vernetzungsfond)
- further collaboration with INFN Milano, INR Troitsk, PI Yerevan, INRNE Sofia, HEPI Tbilisi
- autumn 1999 to spring 2000: planning
- until autumn 2000: civil construction
- since then: installation and commissioning of accelerator components: mechanics (vacuum), radio frequency, controls, diagnostics
Layout of the current setup
• December 2001: first rf in the cavity

• January 13th: first photo electrons

\[ \Delta \text{rf (laser- rf)} = 5 \text{ kHz} \quad \Rightarrow \quad \text{automatic phase scan} \]

• a week later: same master oscillator for rf and laser (Thanks to Saclay !!!)

• first running period with beam until January 31st
First Measurements in January 2002 (ackn. Dirk Lipka)

Laser settings:

UV light at the virtual cathode:

$$RMS_{x,y} = 0.6 \, mm$$

long. profile by streak camera:

used different number of bunches within a train

$$FWHM_z = 14.1 \, ps$$  (expected: \(\approx 7 \, ps\))
RF power:

- forward power from klystron: ~3-4 MW
- accelerating rf power not measured
- 1 Hz operation
- pulse length up to 400 µs

Solenoid settings:

main and bucking coil used at different settings
magnetic field set to zero at cathode
Charge of bunches

\[ Q_{\text{bunch}} \approx (5 - 30) \ pC \] (uncertain meas.)

QE was low (\(< 1\%\)),
possible reason: CsTe cathode was in gun while TSP was fired
Bunch size at screen pepper pot

**settings** for example: \( I_{\text{main}} = 180 \text{ A} \)

\[ \Rightarrow RMS_{x,y} = 1.1 \text{ mm} \]

(this fits to a charge of about 30 pC)
Simulation with ASTRA

ASTRA inputs:

\[ RMS_{x,y}^{\text{laser}} = 0.6 \, mm, \]
\[ \sigma_z^{\text{laser}} = 6 \, ps, \]
\[ I_{\text{solenoid main}} = 180 \, A, \]
\[ E_{\text{max acc}} = 32 \, MV / m, \]
\[ Q_{\text{bunch}} = 1.5 \, pC, \quad 30 \, pC \]
\[ \varepsilon_{\text{th}} = 0.36\pi \, mm \, mrad \]

Beam Size

RMS spot size / mm

\[ 30 \, pC \]
\[ 1.5 \, pC \]

\[ z / m \]
Measurement of momentum

\[ P_{\text{mean}} = (3.740 \pm 0.013 \text{ (stat.)} \pm 0.104 \text{ (syst.)}) \text{ MeV} / c \]

\[ P_{\text{RMS}} = (6.59 \pm 0.85) \text{ keV} / c \]

\[ \Rightarrow \frac{P_{\text{RMS}}}{P_{\text{mean}}} = 0.2\% \]

(expected from simulation: 0.07%)
Commissioning of Emittance Measurement System started

(ackn. Velizar Miltchev)

First results:
**Beamlet profiles acquired after multi-slit mask insertion**
Conclusion of January run

• charge of bunches too low:
  - check laser power,
  - check charge measurement,
  - change cathode

• do further conditioning ⇒ increase electron momentum

• check longitudinal profile of laser pulse

• continue commissioning of EMSY

Second run with beam:
March 15\textsuperscript{th} to March 26\textsuperscript{th}
Measurements in March 2002

RF power / conditioning:

- **forward power measured at the gun**
  (cross check between calorimetric and directional coupler measurement)

- **5 Hz operation only** (higher pulse to pulse stability of HV pulse in klystron)

- **up to 34 MV/m at the cathode**, limit
  with old S-band PS (new PS in May)

- **stable operation up to 400 µs** (at 600 µs major problems with gun water cooling system, needs to be adjusted to high average power)
Dark Current Measurements
(A. Oppelt, M.v. Hartrott)

dark current for $I_{\text{main}} = 0$A

- ○ 400 $\mu$s pulse length
- △ 100 $\mu$s pulse length

Dark Current ($\mu$A)

Gun Gradient (MV/m)
dark current for 400 μs pulse length

- $I_{\text{main}} = 0 \text{A}$
- $I_{\text{main}} = 50 \text{A}$
- $I_{\text{main}} = 100 \text{A}$
- $I_{\text{main}} = 150 \text{A}$
- $I_{\text{main}} = 200 \text{A}$
- $I_{\text{main}} = 250 \text{A}$
- $I_{\text{main}} = 300 \text{A}$

**Graph Details:**
- **Y-axis:** Dark Current (μA)
- **X-axis:** Gun Gradient (MV/m)

Each marker represents a different current level, showing how dark current changes with varying gun gradients.
Test Quantum Efficiency
(M. Pohl, F. Stephan)

- measurement in cathode transport chamber (800 V, static)
- average laser power measured with joule meter (5 Hz rep. rate of laser, joule meter needs at least ~5 mW)
- electron charge measured with oscilloscope for one pulse train
Conclusion: $\text{QE} \leq 10^{-4}$

- did one Ti:sub pump firing kill the cathode?
- did 10 day operation with wrong laser phase kill the cathode?
- error during production (nr. 47)?
- ???
Summary of March run

- 5 Hz operation
- up to 34 MV/m at the cathode
- stable operation up to 400 μs
- dark current up to ~ 35 μA
- QE of cathode $\leq 10^{-4}$
  $\Rightarrow$ need new cathodes

- The rf vacuum window at the gun was leaking, exchange is prepared and happens now.

- Next run: starting next week
Future plans

- upgrade rf system for better stability and higher output power (urg. need new PS, in summer: 10 MW klystron)
- continue commissioning of whole facility
- commission diagnostics (p&Δp, Q, BPM, EMSY, bunch length, long. phase space)
- continuous program for detailed measurements of electron beam properties
- until end of April 2003: current FEL gun should be fully characterized
- then: upgrade PITZ with a booster cavity [a) FNAL NC cavity, b) Troitsk CDS], beamline has to be designed and built
- 2004: measurements with higher beam energy (~ 40 MeV)
Simulations on booster cavity
(Ph. Piot)

E-field for CDS (10 cells) and TESLA 9-cell structure
Does the CDS-structure breaks the beam axi-symmetry? NO!

- $\beta \gamma e_x$ (mm-mrd)
- $\beta \gamma e_y$ (mm-mrd)

CDS 10 cells

distance from photocathode (m)
TTF2 gun+sol. set-up with a booster

- TESLA 9 $\sigma_X$ (mm)
- TESLA 9 $\beta \gamma X$ (mm-mrd)
- CDS 10 $\sigma_X$ (mm)
- CDS 10 $\beta \gamma X$ (mm-mrd)
- drift $\sigma_X$ (mm)
- drift $\beta \gamma X$ (mm-mrd)

booster
diag.
Acknowledgements

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ZEU-TI, ZEU-MECH, ZEU-DV, ZEU-EL, ZEU-F, ZEU-EXPS, ZEU-V1→4

Cooperation partners: BESSY, MBI, TEMF@TUD, INFN Milano, INR Troitsk, PI Yerevan, INRNE Sofia, HEPI Tbilisi

Colleagues from the Zeuthen PITZ group: J. Bähr, I. Bohnet, Z. Li, D. Lipka, A. Oppelt, T. Thon
Summary

• first measurements with beam have been taken
• commissioning of PITZ is going on
• RF and diagnostics need further upgrade
• characterization of current FEL gun until spring 2003
• then: upgrade facility with booster cavity

• Groups interested to join are very welcome!
The DEUTSCHES ELEKTRONEN-SYNCHROTRON (DESY) in Hamburg and Zeuthen, member of the association of national research centers Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren, is a national center of basic research in physics with app. 1,400 employees and more than 3,000 scientific guests from Germany and foreign countries per year. The accelerators in operation are dedicated to particle physics and research with synchrotron radiation.

In the framework of an international collaboration, DESY is coordinating the development of the superconducting electron-positron linear collider project, TESLA, with integrated free electron laser facility.

The Laboratory in Zeuthen (near Berlin) invites applications for a

**RESEARCH ASSOCIATE (m/f)**

for R&D work associated with the installation, operation and further development of a test facility for RF photo-injectors.

For the operation of free electron lasers and e^+e^- linear colliders, electron sources with very challenging beam properties are required. In order to do research and development in this field, a new photo-injector test facility is at present being commissioned at DESY Zeuthen. The successful candidate should play an important role in this project and should contribute significantly to the development, operation and optimization of the RF photo-injector for using at the TESLA test facility free electron laser as well as at TESLA. The work will include detailed measurements as well as further development of simulation tools.

Applicants should have a PhD in physics. Substantial knowledge in accelerator physics and particle beam dynamics is required as well as several years’ relevant professional experience. Candidates will be expected to take responsibility for sub-projects. The capability to work with physicists and technicians in a motivated team is necessary.

In the framework of the position shift work may be necessary at times.

The position is **permanent**. The salary will be according to the German civil services BAT-O Ib salary scale. The deadline for applications is **April 30th, 2002**.

DESY is an equal opportunity employer and welcomes the application of qualified women. Handicapped applicants will be given preference in case of equal qualification.

Interested scientist should send their complete application as well as the names of three referees and their addresses to:

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