Photo Injector Test Facility under Construction at DESY Zeuthen, PITZ

F. Stephan (*), D. Krämer (+), I. Will (#), and A. Novokhatski (&) for the PITZ Cooperation consisting of

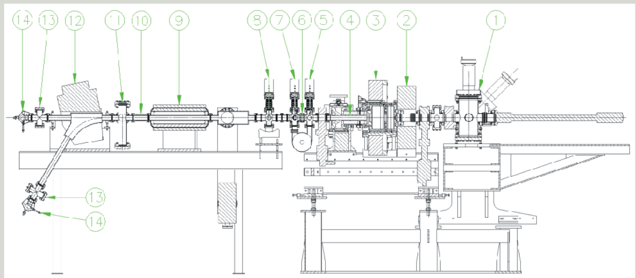
(*) DESY, 22603 Hamburg and 15738 Zeuthen, Germany, (+) BESSY, 12489 Berlin, Germany, (#) Max-Born-Institute, 12489 Berlin, Germany, (&) TU Darmstadt, Department TEMF, 64289 Darmstadt, Germany

Scientific goals, experimental setup, status and schedule of the project

Goals:

- operate a test facility for rf guns and photo injectors to optimize injectors for different applications: free electron lasers, flat beams for linear colliders, polarized electron sources
- comparisons of detailed experimental results with simulations and theoretical predictions
- conditioning and test of optimized cavity resonators for subsequent operation at the TESLA Test Facility - Free Electron Laser
- test of new developed components (laser, cathodes, beam diagnostics) under realistic conditions
- test of new concepts for the design of rf electron sources for the production of flat beams
- on a longer term basis: investigations for the design of polarized electron sources

Setup



The test stand for rf electron sources (length about 5m):
1. cathode system, 2. bucking solenoid, 3. main solenoid, 4. coaxial coupler, 5. laser input port, 6. beam position monitor, 7. Faraday cup + view screen, 8. emittance measurement system (slits + pepper pot), 9. quadrupole triplet, 10. wall gap monitor, 11. + 13. view screen, 12. dipole,14. Faraday cup

Status + Schedule

- raw construction work is mainly finished
- mid September 2000: start installation of modulator, klystron, the test stand shown above and all the other equipment
- November 2000: first rf inside the rf gun
- December 2000: fist stage of the laser system (gaussian pulses, 6 ps sigma) is installed at Zeuthen. A continual upgrade of the laser system up to a flat top temporal profile with rising and trailing edges of about 1 ps is foreseen.
- January 2001: first photo electrons are produced
- mid 2002: test facility is upgraded by the installation of a booster cavity

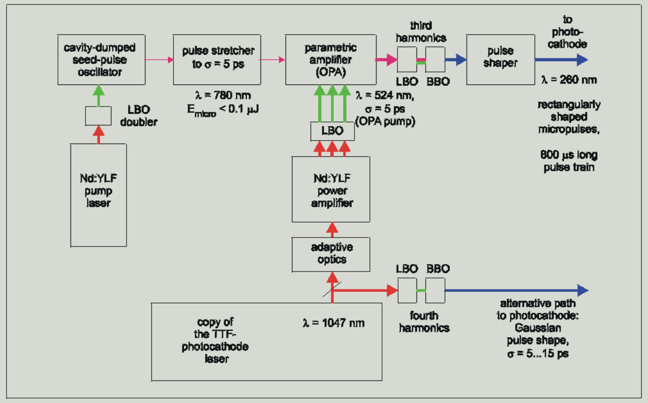
Next generation photocathode laser for generation of micropulses with programmable shape

New requirements to the laser system

- pulsetrains of up to 7200 micropulses with 9 MHz repetition rate
- rectangularly shaped micropulses, rising and trailing edges as short as 1 ps
- tuneable duration of the micropulses between 5 and 20 ps FWHM
- high stability of the laser

New laser concept

- key element: optical-parametric amplifier (OPA)
  OPA provides large amplification bandwidth and therefore allows for amplification of short pulses or pulses with sharp edges, respectively.
- thermal load of the amplifying crystal is strongly reduced in comparison to standard laser crystals
- extended version of the field-tested TTF photocathode laser will serve as the pump laser for the OPA
- grating combination for programming the shape of the micropulses
- correction of wave front deformations by means of computer-controlled optics



Scheme of the next-generation photocathode laser for generation of micropulses with variable shape

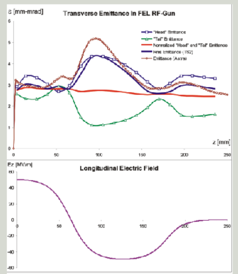
pulse duration	5 - 20 ps FWHM
shape of the micropulses	rectangular, with short rising and trailing edges
rising and trailing edges of the micropulses	<1 ps
wavelength (ultraviolet)	λ = 260 nm
energy per micropulse in the ultraviolet	20 µJ (at 1 MHz)
energy per macropulse train in the ultraviolet	160 mJ
length of the macropulse train	800 µs maximum
repetition rate of the micropulses	1 MHz and 9 MHz
repetition rate of the macropulse trains	1 - 10Hz

Design parameters of the new photocathode laser

Simulations

Complete MAFIA calculation of the electron bunch development in the rf gun

- goal: find the minimum attainable transverse and longitudinal emittance for 1 nC bunch charge depending on gun parameters
- current simulation takes into account space charge and nonlinear rf-forces, thermal emittance will be included in future simulations

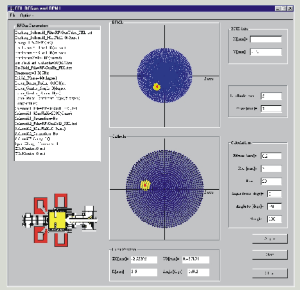


- main part of transverse emittance caused by emission process
- behaviour of projected emittance inside the gun is a result of rf-field effects
- transverse emittance of "head" and "tail" have opposite behaviour, average value ≈ unchanged
- projected emittance: MAFIA and ASTRA in good agreement

Development of transverse emittance and longitudinal E-field (on axis) in the rf gun

On-line simulation program (V-code)

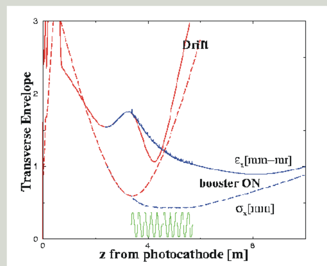
- algorithm is based on the model of ensembles
- important tool for commissioning and operation of the test facility. It will help to obtain an online understanding of the dynamics of the electron beam.



As an example the application of the code for the reconstruction of the laser beam position at the photo cathode using data form the first beam position monitor (BPM1), installed just after the cavity is shown.

ASTRA simulation with booster cavity (DESY)

- study the emittance compensation and damping via acceleration using a booster cavity
- several options, currently use of a room-temperature booster cavity (like for TESLA positron injector). Such a cuted disk structure can provide an average gradient as high as 12.58 MV/m allowing to boost the beam energy up to 30 MeV approximately.
- test numerical simulation predictions according to which, when properly matched into the booster cavity, the beam can reach emittances in the sub-mm-mrd regime



The figure presents the expected emittance and beam spot development along the evolution of the PITZ beamline using a cutted disk structure booster cavity: even with relatively moderate E-field an emittance minimum as low as 0.9 mm-mrad is expected.

The project is partially funded by the HGF Vernetzungsfond