Design of the bunch length measurement for the Photo Injector Test Facility at DESY Zeuthen, PITZ

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

A photo injector test facility for free electron lasers (FEL) and the TESLA linear collider is under construction at DESY Zeuthen and will be commissioned in autumn 2001. The project is a common effort of a collaboration originated by the following institutions: BESSY Berlin, DESY (Hamburg and Zeuthen), Max-Born-Institut Berlin, Technical University Darmstadt. It is funded partially by the HGF-Vernetzungsfonds.

Goals:

- Operate a test facility for laser driven RF guns and photo injectors to optimize injectors for different applications: free electron lasers and future linear colliders.
- 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 (TTF-FEL)
- Test of new developed components (laser, cathodes[1], 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

1) INFN Milano

Schedule and status:

Ongoing

- Mounting the laser (Max-Born-Institut Berlin)
- Setting up interlock systems
- Setting up the control system
- The vacuum system including cathode section, cavity section and diagnostics section is under vacuum
- Preparation of diagnostics subsystems

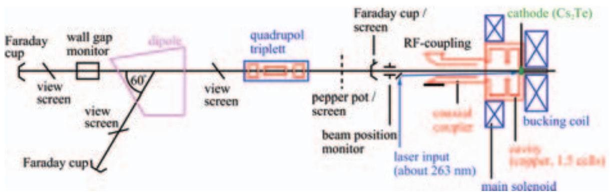
Next steps

- Commissioning of RF-system
- Conditioning of Cavity
- First photo electrons in autumn 2001
- Commissioning the full setup

Future

- Upgrade with booster cavity

Description of PITZ



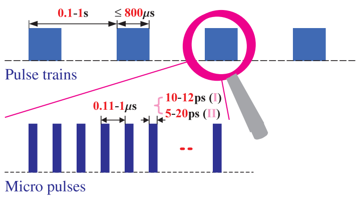
Main components of PITZ

- Photocathode: Cs_2Te
- Cavity: 1.5 cell geometry
- Laser: 263 nm
- RF-system: Klystron 5 MW...10 MW, 1.3 GHz
- Control system based on DOOCS (Distributed Object-Oriented Control System)
- Diagnostics section

Parameters of PITZ

- Charge per bunch: 1 nC
- Laser beam diameter on cathode: 1...10 mm diameter
- Electron beam energy: ~5 MeV (without booster) ~30 MeV (with booster)

Schematic time structures of the laser beam



I) Phase 1: gaussian shape ~6 ps

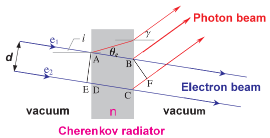
II) Phase 2: rectangular shape with rise and fall time < 1ps

Diagnostics for longitudinal phase space

Measurement of bunch length

Goal: Convert the electron beam into a photon beam using Cherenkov radiators and measure the photon pulse length with a streak camera. The Cherenkov radiators (quartz, fused silica aerogel) are optimized to create a relativ small time spread.

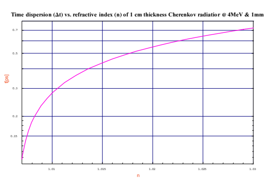
- **Time dispersion**



Schematic of the light production by two electrons in a bunch passing through a Cherenkov radiator (n). => Time dispersion ~ n, d

Time dispersion

$$\Delta t = \frac{d\cdot n\cdot \sin\theta_c}{c} = \frac{d}{c}\cdot\sqrt{n^2-\frac{1}{\beta^2}}$$



Time dispersion from Cherenkov radiator as a function of refractive index (electron energy: 4MeV, diameter of beam: 1mm). => To achieve high time resolution, one should choose a Cherenkov radiator with very low refractive index. => aerogel

- **Theory and numerical results of Cherenkov radiation**

The angular and spectral distribution of the Cherenkov radiation intensity is described by the Tamm formula [1,2].

[1] I. E. Tamm, J. Phys. USSR 1(1939)439

[2] V. P. Zrelov, M. Klimanova, V. P. Lupiltsev, J. Ruzicka, Nucl. Instr. Meth. 215(1983)141

$$\frac{d^2N}{d\ \ d} \quad \frac{n\ l^2}{3}\sin^2 \quad \left(\frac{\sin(k\ )}{k}\right)^2$$

Where:

$$\frac{e^2}{2\ _0hc}\quad\frac{1}{137}$$ is the fine structure constant;

n is the refractive index of the medium;

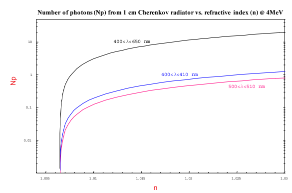
l is the trajectory length of the electron in the medium;

is the wavelength of the produced Cherenkov radiation;

is the angle of observation of radiation with respect to the direction of electron movement;

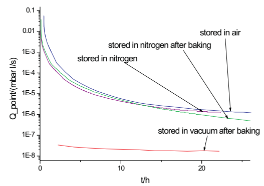
$k\quad\frac{l}{\ }(1\quad n\ \cos\ )$, is the relative velocity of the electron;

d = 2 sin d

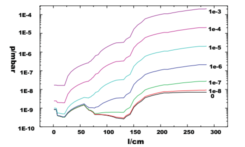


Number of photons from a 1 cm thick Cherenkov radiator with refractive index (n) produced by a 4 MeV electron.

- **Vacuum properties of Aerogel**



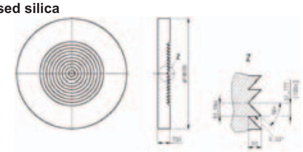
- **Influence of the gas load coming from the aerogel on the pressure distribution**



Assumption: pumping speed of the titanium sublimation pumps: 500 l/s

The tube to connect the pump with the electron beam tube was taken into consideration.

- **Fused silica**



A specially machined quartz could dramatically reduce the time dispersion

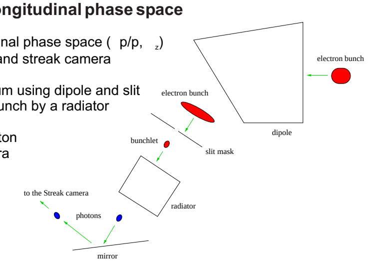
Measurement of longitudinal phase space

Goal: measure the longitudinal phase space (p/p, $_z$)

Setup: dipole, slit, radiator and streak camera

Function:

- separation of momentum using dipole and slit
- transmit the electron bunch by a radiator in photons
- measure length of photon bunch by Streak camera
- measure complete longitudinal phase space by repeating the first three steps with different slit positions



Streak camera and optical beam line for time resolved measurements

Two types of streak cameras both from Hamamatsu are available

FESCA-200: time resolution 200fs, single shot

C5680: time resolution 2ps, synchroscan and single shot.

For analysing electron bunches the electron beam hits radiators based on the Cherenkov effect. The light emitted by the radiators has to be transmitted through a 25m long optical system up to the streak camera lab. This beam-line is optimized to have a high light collection and transmission efficiency and a high degree of optical correction. The dispersion within the optical wave bunch should be small (<<1ps). Finally, the output aperture matches to the slit of the streak camera and its input optical system.