Technical Seminar

The Streak Camera at PITZ and its Optical System

18th of October 2005

Hamburg University
Juliane Rönsch

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What is a streak camera ?

Operating principle

Subcomponents of the streak camera

Use at PITZ

Optical transmission line

Streak Camera

What is a streak camera ?

- high-speed light detector
- in the picosecond (ps) range (1 ps = 0,000 000 000 001 s)
- direct measurement of light phenomena
- temporal resolution up to 200 fs (2 ps for the camera at PITZ)
- it measures simultaneously time, position and light intensity
- it process the data in real-time using a dedicated readout system.
- no other instruments which directly detect ultra fast light phenomena with a better temporal resolution than the streak camera.

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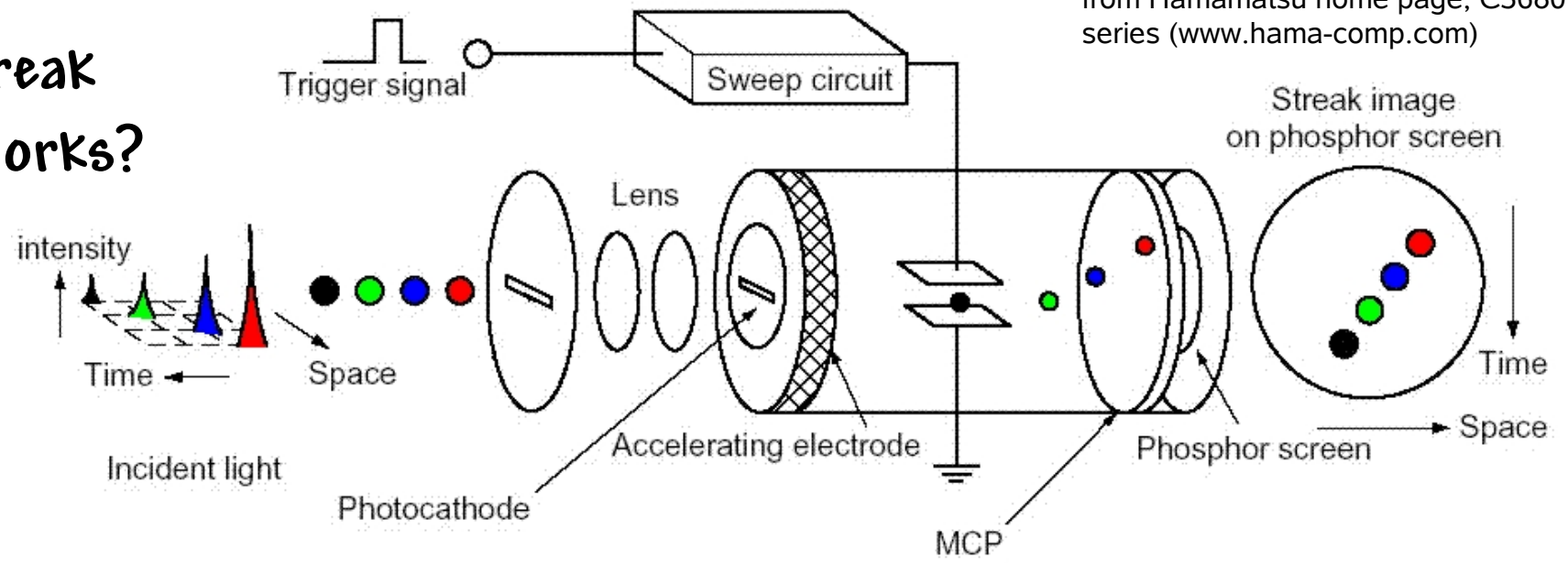
Operating Principle

How a streak camera works?

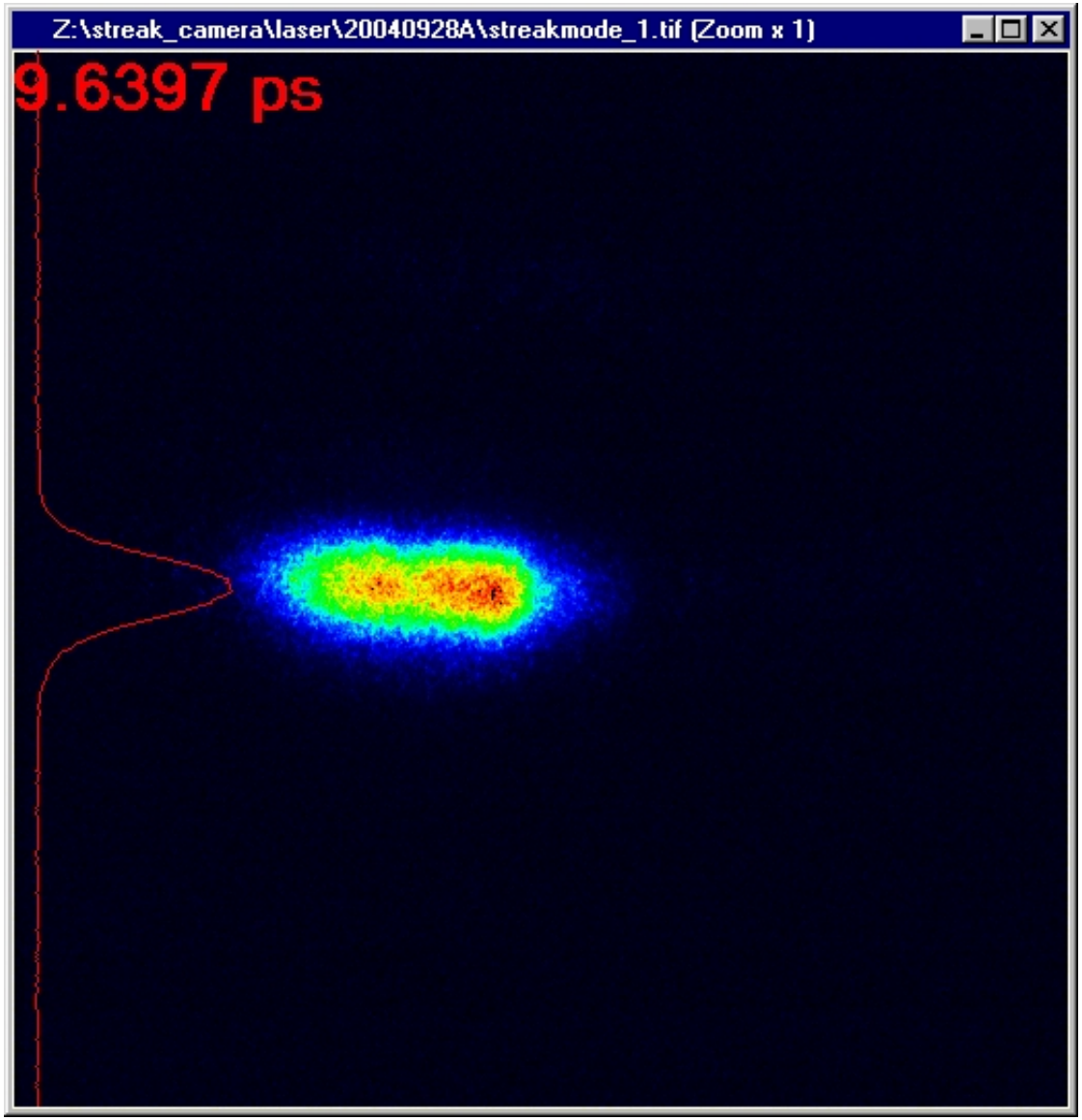
from Hamamatsu home page, C5680 series (www.hama-comp.com)



- light is imaged onto a photochathode
- electrons are produced by the photoelectric effect
- number of electrons is proportional to the light intensity and the time structure is equal to the initial light pulse
- electrons are accelerated towards a phosphor screen
- electrons pass through a fast varying electric field, which deflects them vertically
- first electrons will be deflected different than the latter electrons and will hit the MCP at a different vertical position
- temporal distribution is transformed into a spatial
- the MCP multiplies the electrons
- phosphor screen convertes electrons into light
- CCD camera observes the phosphor screen

Streak Camera at PITZ

How a streak image
Looks like?



Laser
Gausian distribution
20 μm slit width

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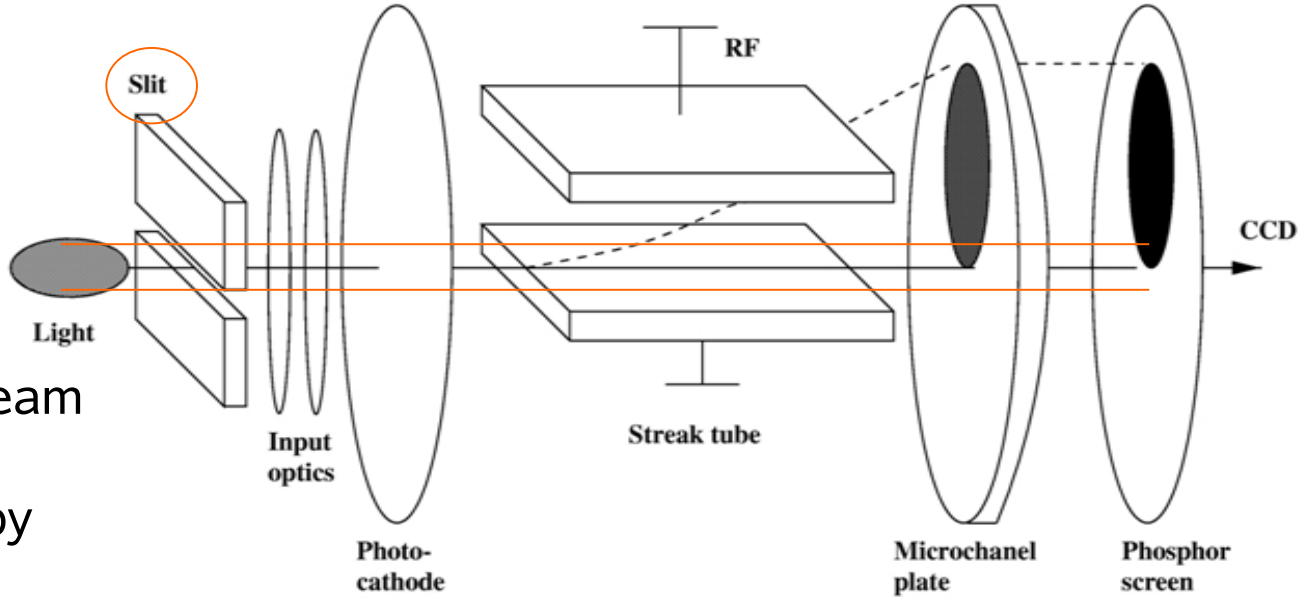
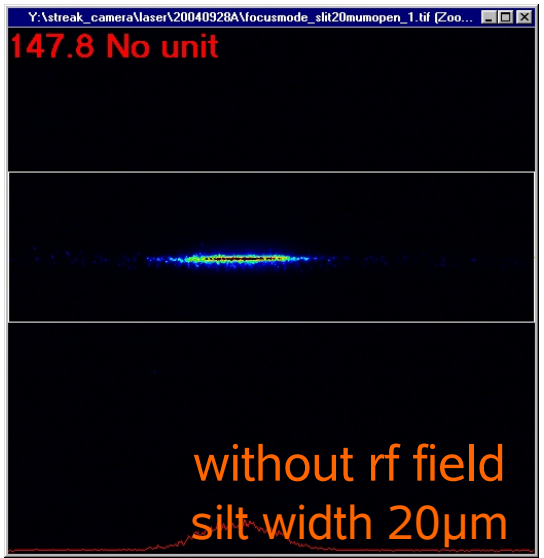
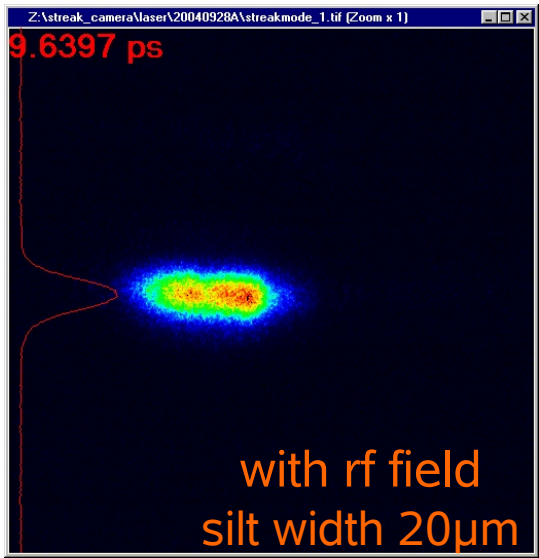
Subcomponents

Entrance of the streak camera

- the vertical size of the light distribution influences the temporal resolution
- the slit reduces the vertical beam size
- the slit width can be chosen by the user
- as smaller the beam size as better the temporal resolution, but also the number of incident photons is reduced
- a compromise between numbers of photons an temporal resolution has to be found
- typical slit widths: 5 – 100 µm



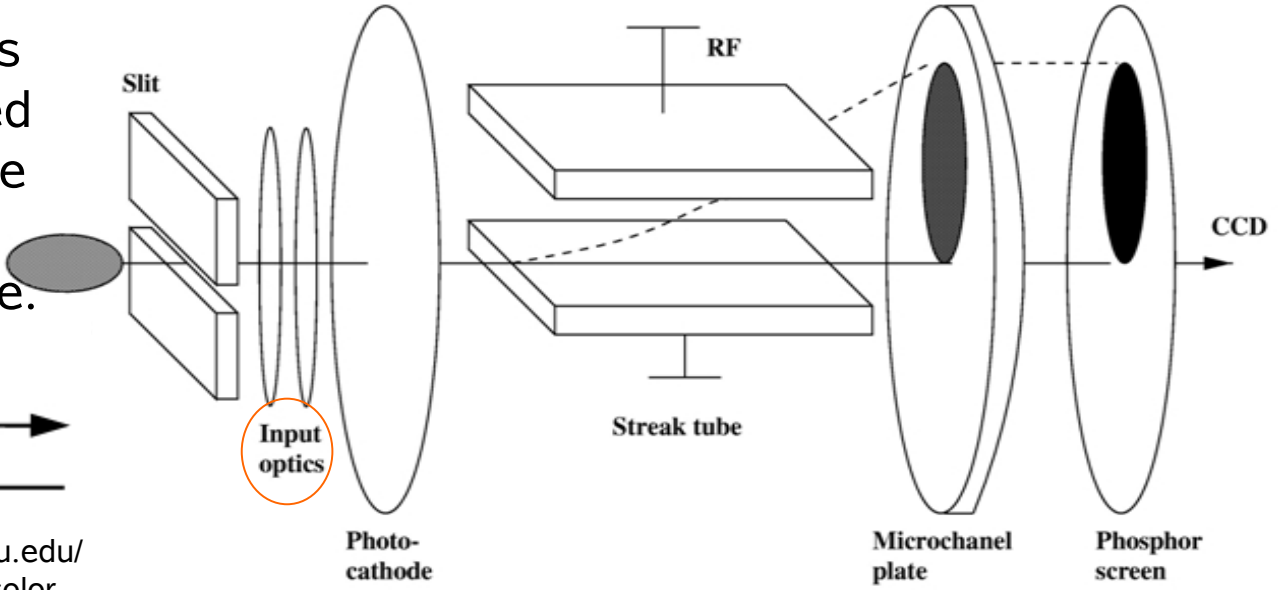


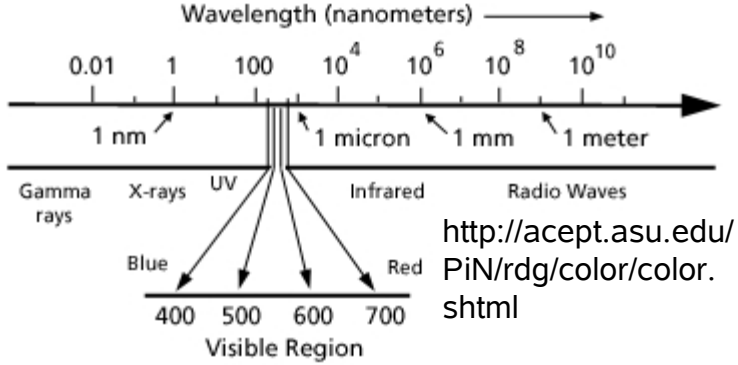


Subcomponents

Internal input optics

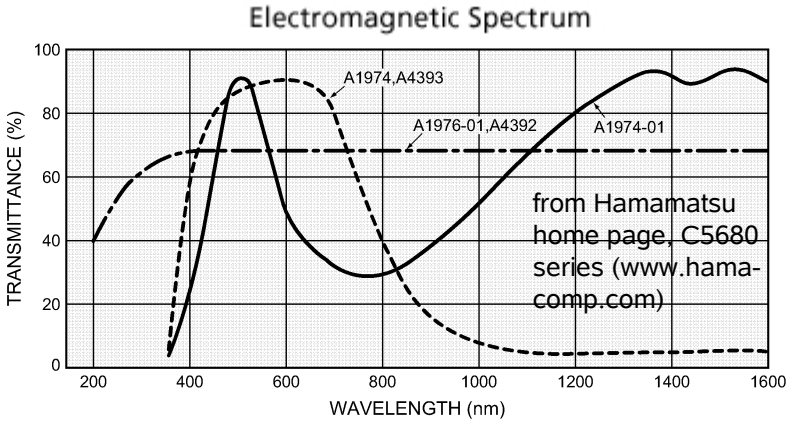
The function of the input optics is to image the light to be measured in the entrance slit plane onto the photochathode.
Several input optics are available.





http://acept.asu.edu/PiN/rdg/color/color.shtml

wavelength of the laser light: 262 nm,
wavelength of the Cherenkov light: 400 – 750 nm

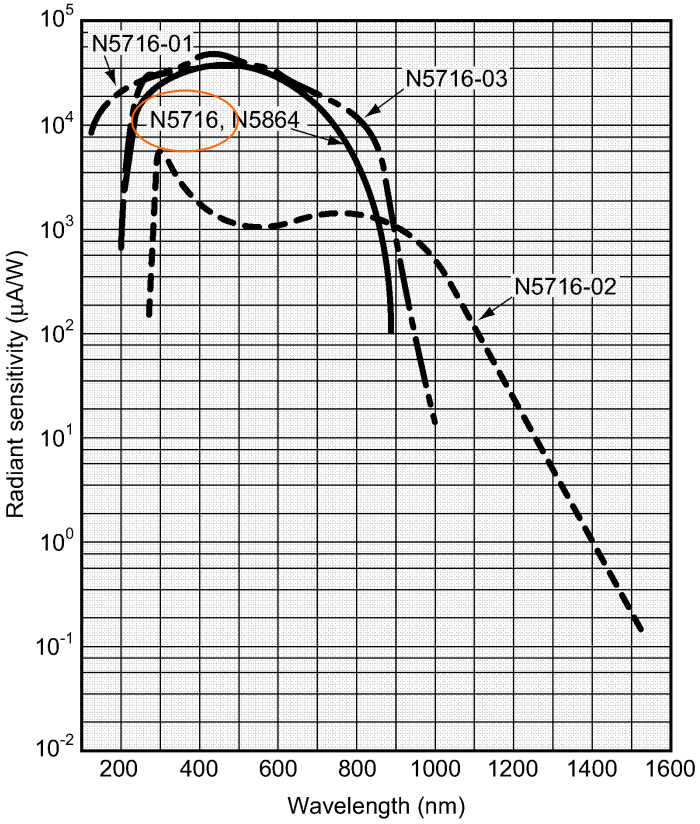


optics	Spectral transmission (nm)	F-number
A1974	400 - 900	1.2
A1976-01	200 - 1600	5.0
A 6856 (Mirror optics)	200 - 1600	4

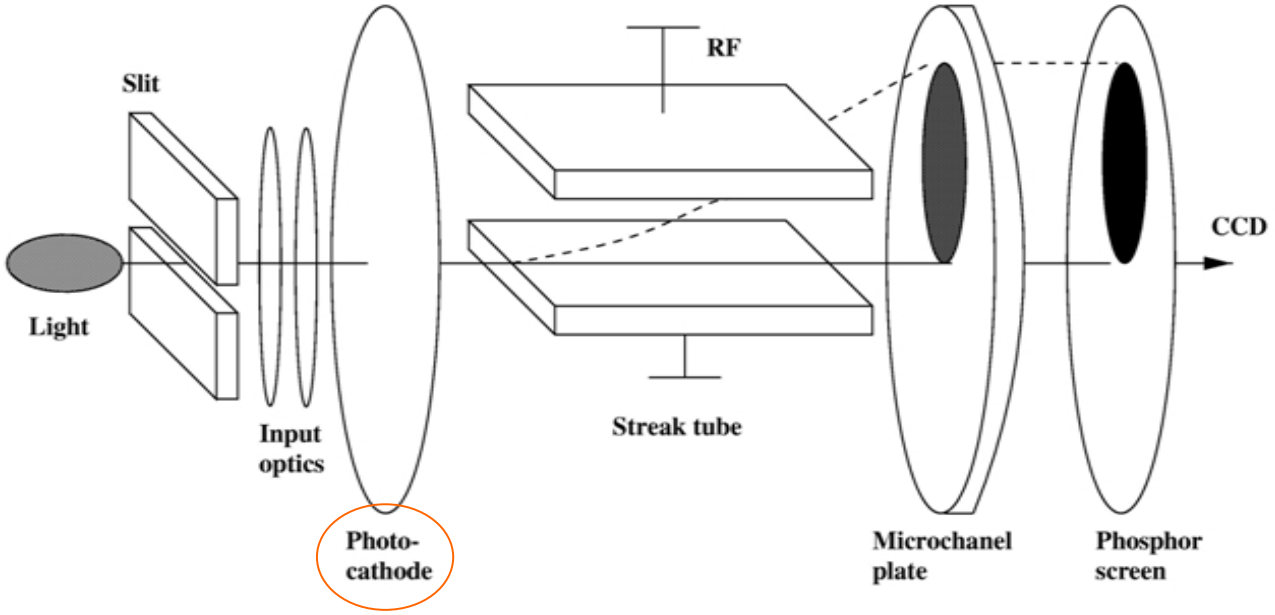
Subcomponents

Photocathode

spectral sensitivity



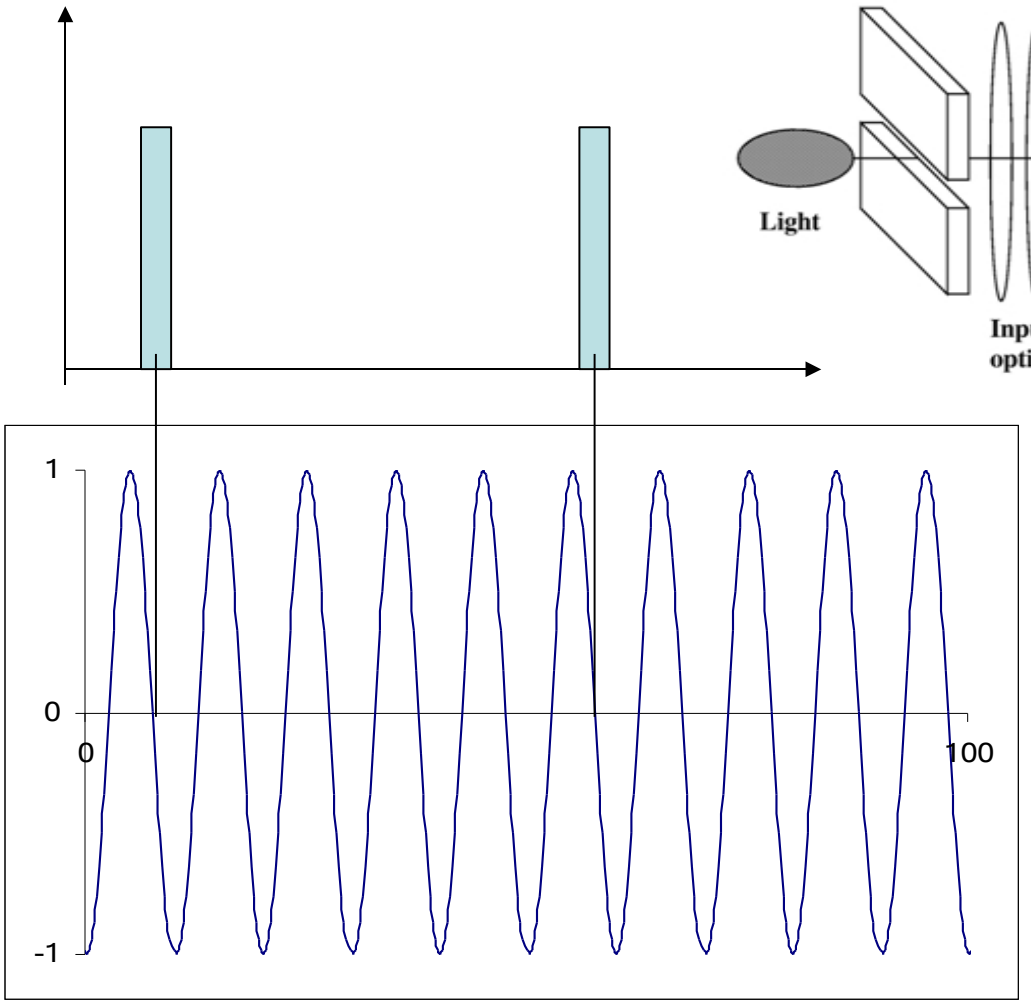
from Hamamatsu home page, C5680 series (www.hama-comp.com)

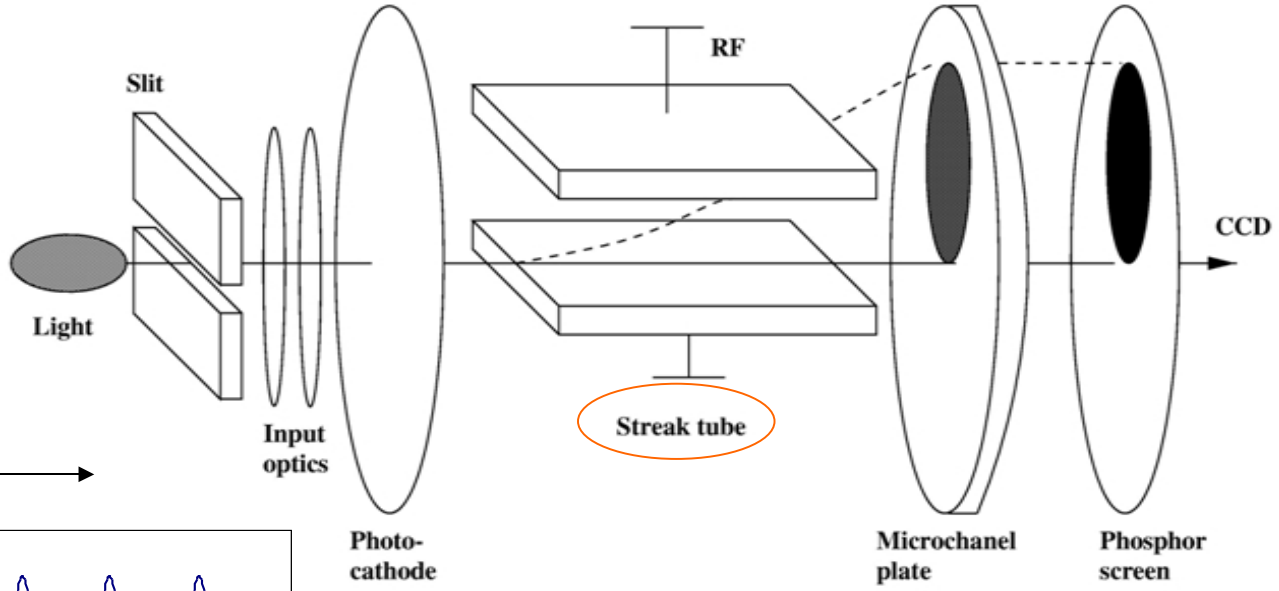


Depending on the wavelength of the incident light the material of the photocathode is chosen.
The dependence of the number of electrons of the wavelength of the incident light is called spectral response characteristics.

Subcomponents

Streak tube

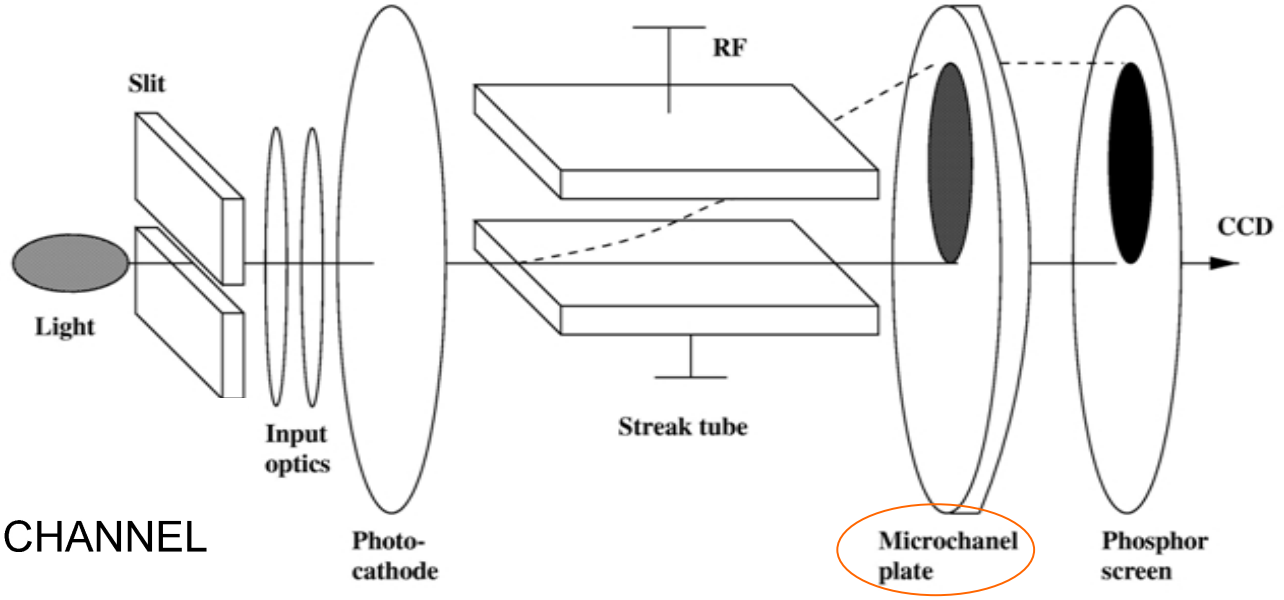


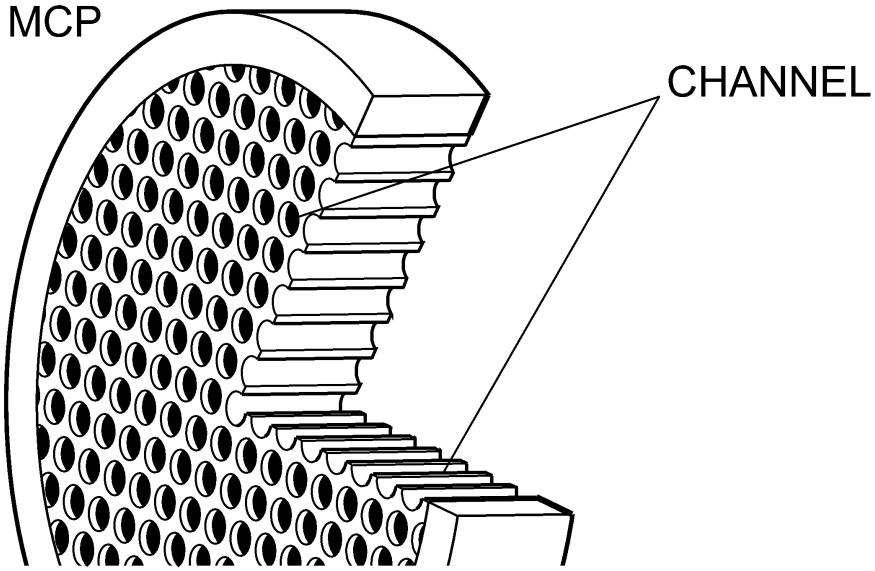


A high-frequency sinewave voltage is applied to the deflection electrodes. By synchronizing the repeated sweep frequencies, streak images can be accumulated at a fixed position on the screen.

Subcomponents

Microchannel plate



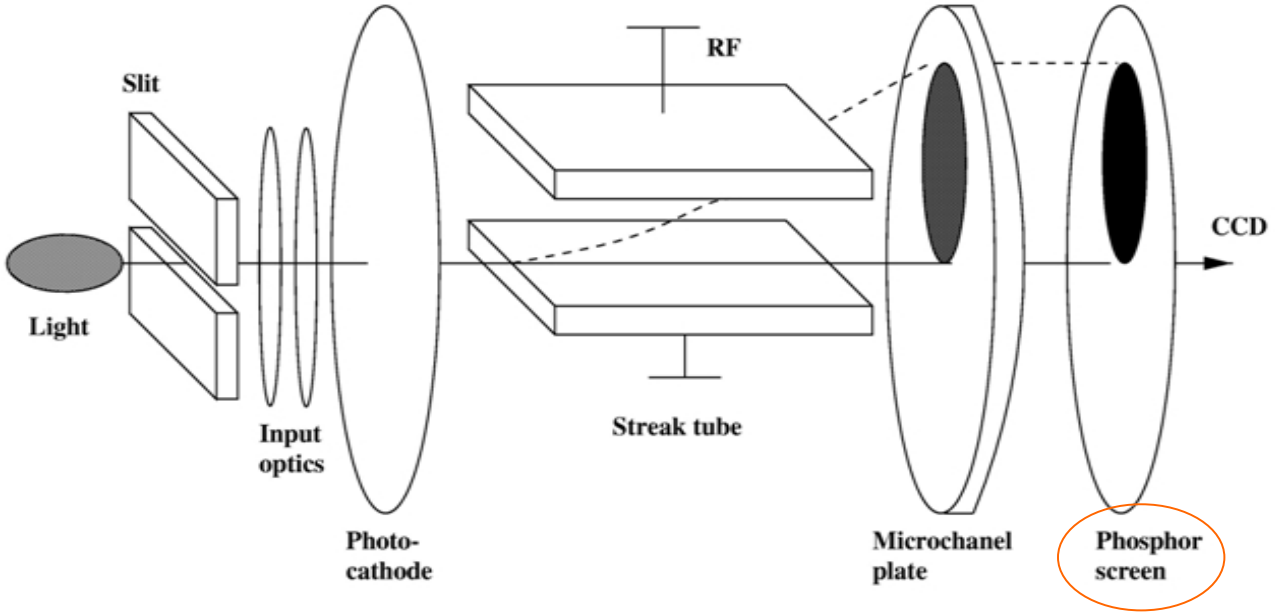


from Hamamatsu home page, C5680 series (www.hama-comp.com)

- MCP: electron multiplier
- consisting of many thin glass capillaries
- internal diameters: 10 – 20 µm
- thickness: 0.5 – 1.0 mm
- internal walls are coated with secondary electron emitting material
- amplification: upto 10000

Subcomponents

Phosphor screen



- produces light when electrons hit it
- consists of glass plate and layers of fluorescent material
- the amount of light is proportional to the kinetic energy of the electrons
- fiber-optic output

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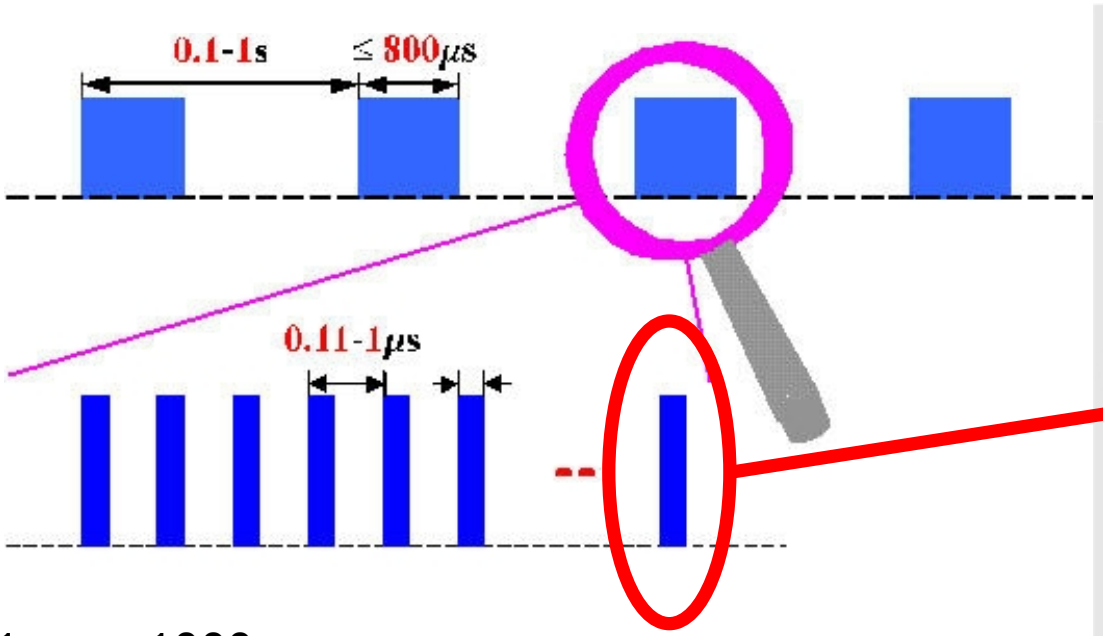
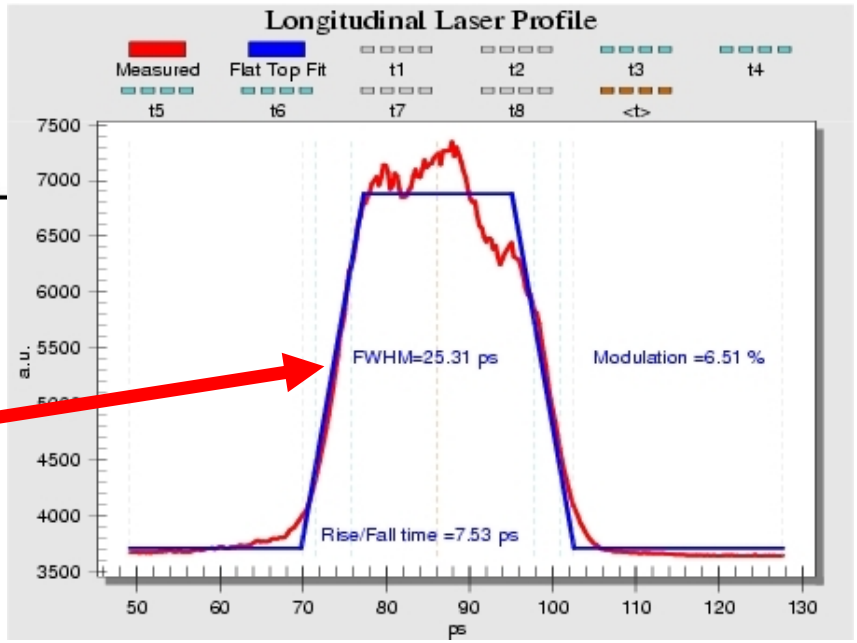
Streak Camera at PITZ

How is the streak camera used at PITZ?

Measurement of:

- the longitudinal laser pulse distribution (laser pulse length)





1 ms = 1000 s
1 μs = 1000 000 s
1 ns = 1000 000 000 s
1 ps = 1000 000 000 000 s

Streak Camera at PITZ

How is the streak camera used at PITZ?

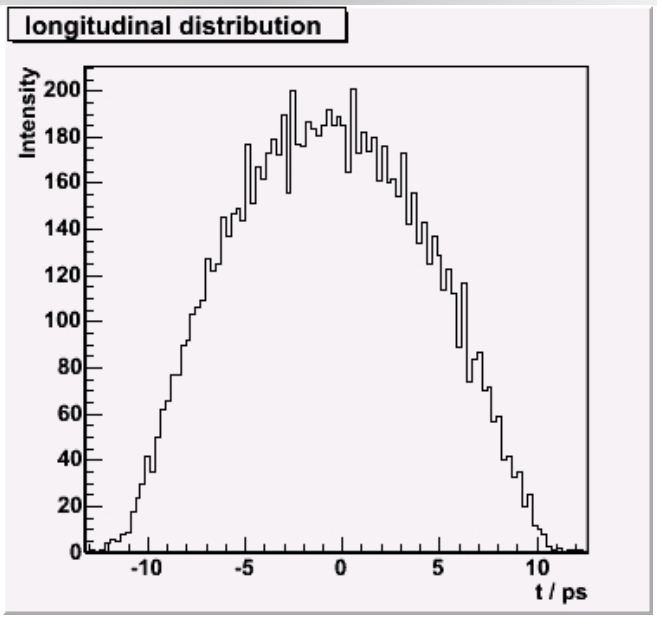
Measurement of:

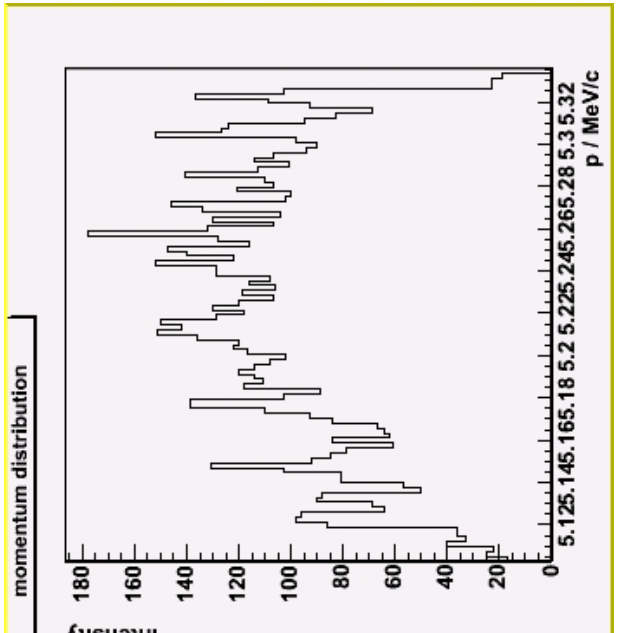
- the longitudinal laser pulse distribution (laser pulse length)
- the longitudinal distribution of the electron bunch (bunch length)
- the longitudinal phase space of the electron bunch (correlation between the momentum and the position of the electron in the bunch)

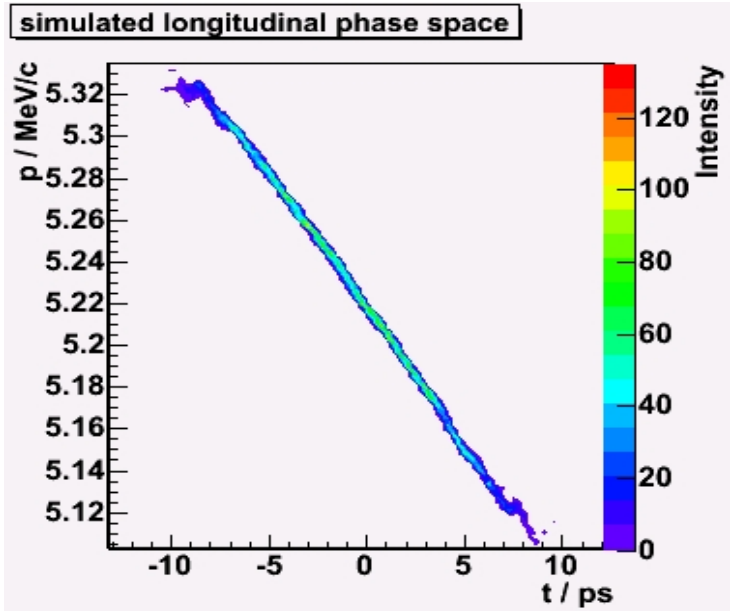
Streak Camera at PITZ

PITZ
Photo Injector Test
Facility Zeuthen

Longitudinal phase space







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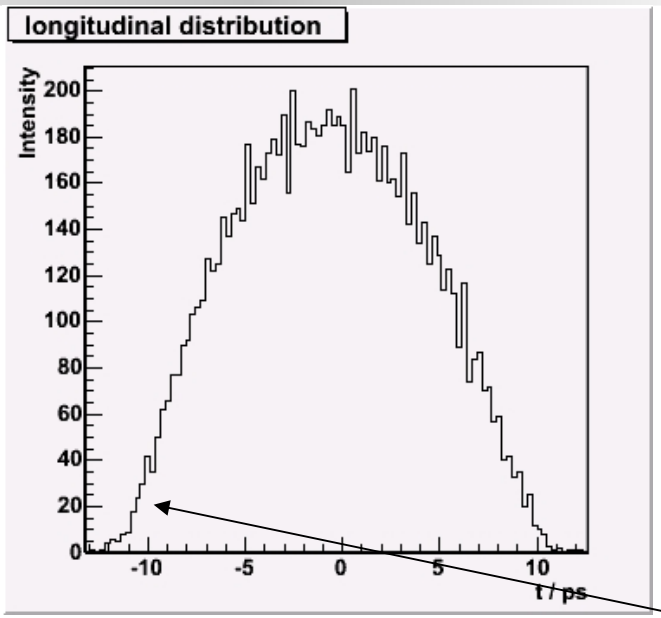
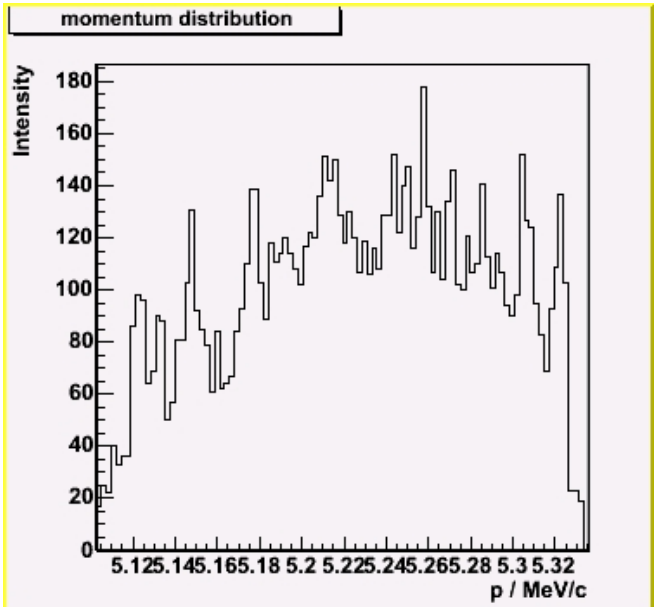
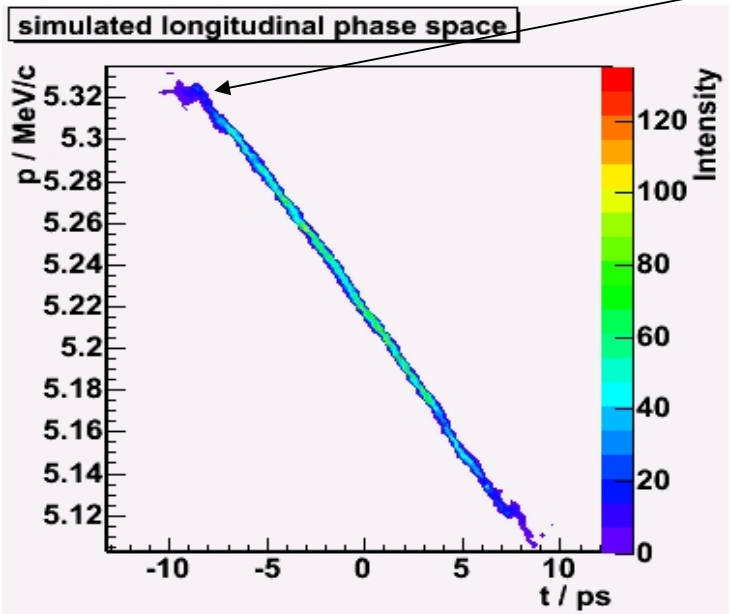


beginning of the bunch





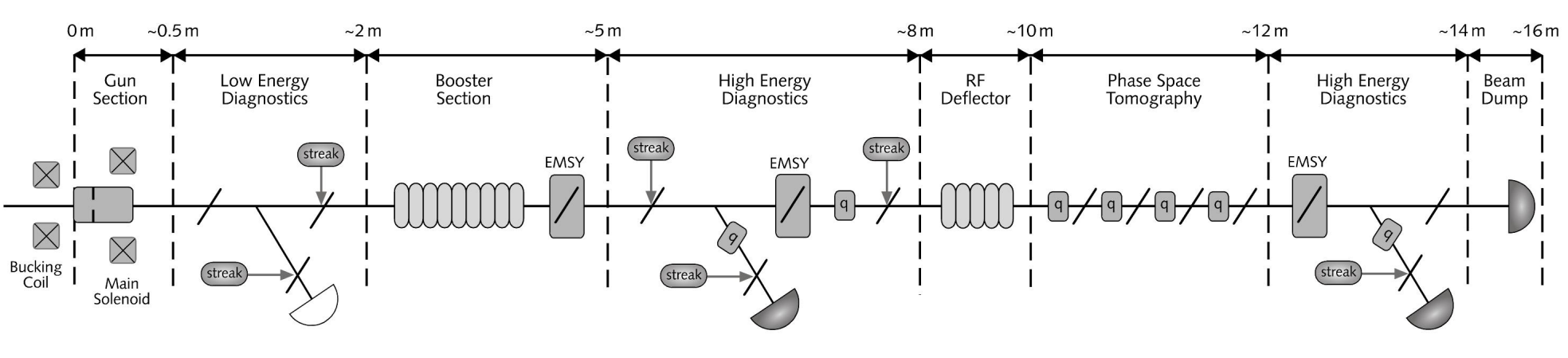
Streak Camera at PITZ

How is the streak camera used at PITZ?

Measurement of:

- the longitudinal laser pulse distribution (laser pulse length)
- the longitudinal distribution of the electron bunch (bunch length)
- the longitudinal phase space of the electron bunch (correlation between the momentum and the position of the electron in the bunch)

In order to measure the longitudinal distribution of the electron bunch with the streak camera, the bunch has to be transformed into a light pulse with a similar longitudinal distribution.



http://www-zeuthen.desy.de/~apohl/pitz2/

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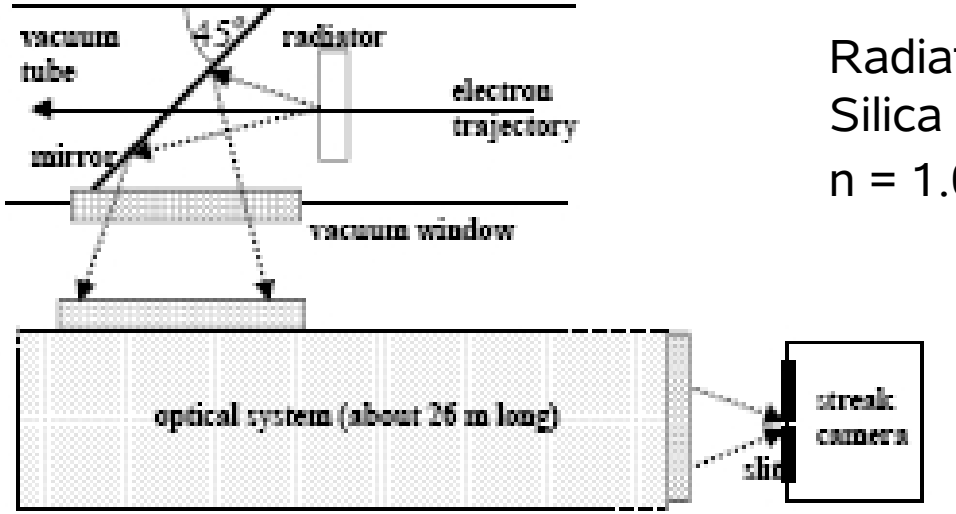
Cherenkov Effekt:

- a particle moves in medium faster than light ($v_{particle} > v_{light} = c/n$)
- ➢ Cherenkov light is emitted under a certain angle, depending on the energy



Radiator:
Silica aerogel (SiO_2)
n = 1.03 / 1.05

Measurement of the longitudinal phase space at the Photo Injector Test Facility at DESY Zeuthen, PITZ

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Optical transmission line

Optical transmission line

Design of the optical transmission line

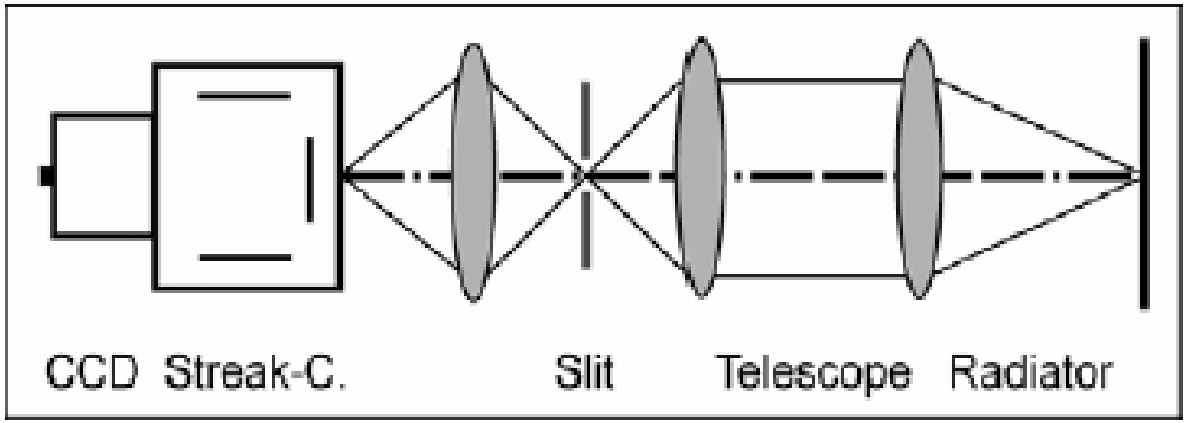
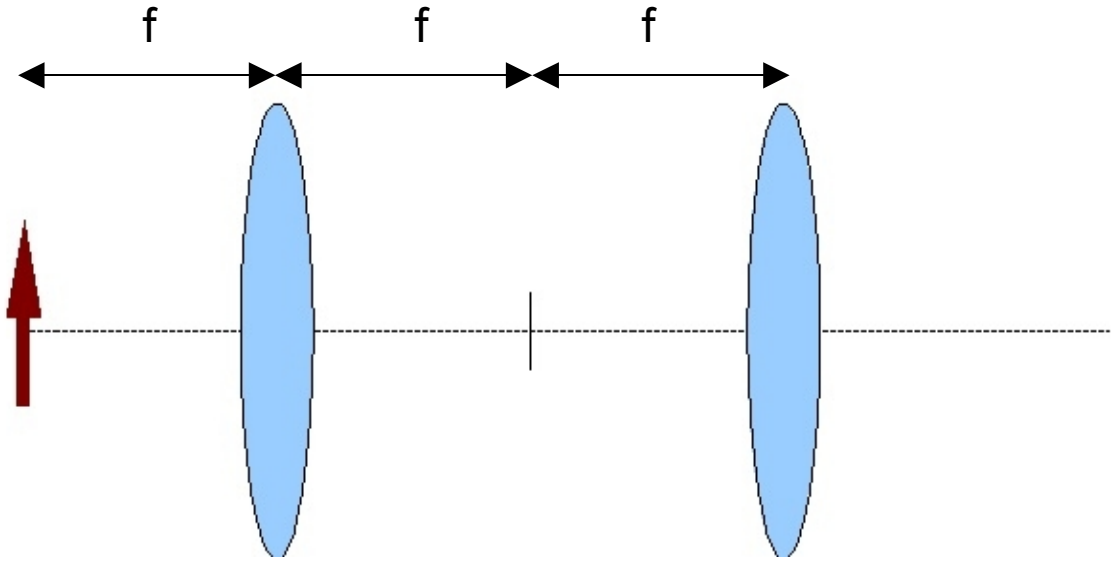


Figure 4: Schematic of an optical transmission line

- light is emitted by the radiator has to be transported to the streak camera over a distance of 27 m
- the light is collected by the first lens of the optical chain
- image is transported with telescopes
- imageing onto the entrance slit of the streak camera

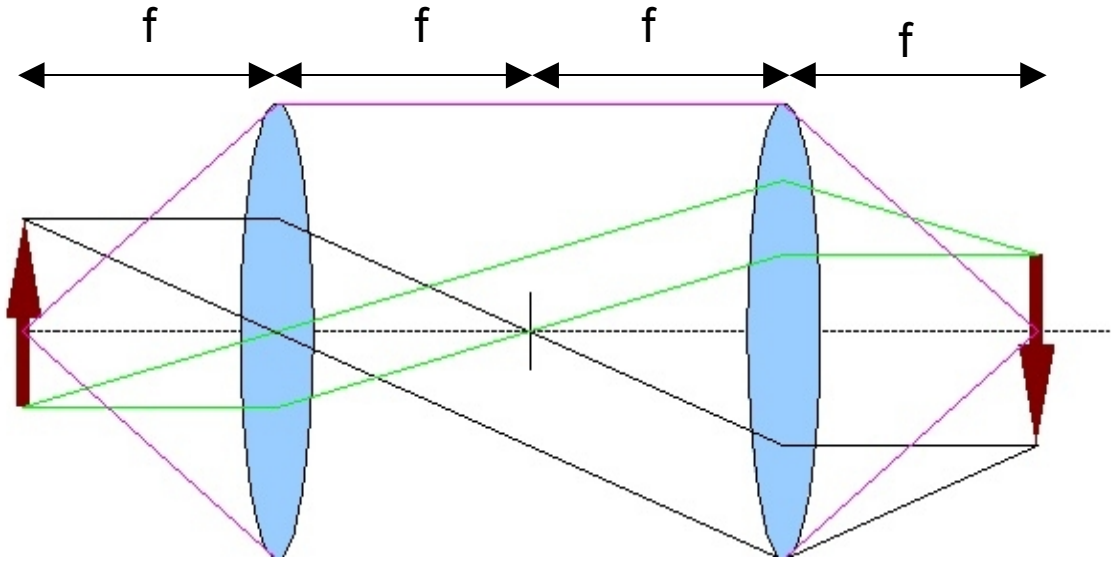
Optical transmission line

Telescope



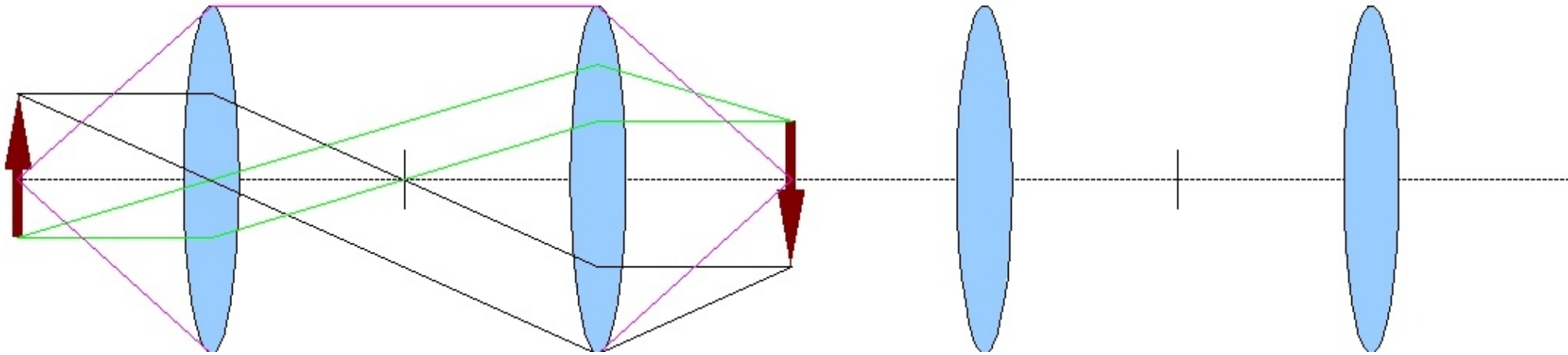
Optical transmission line

Telescope



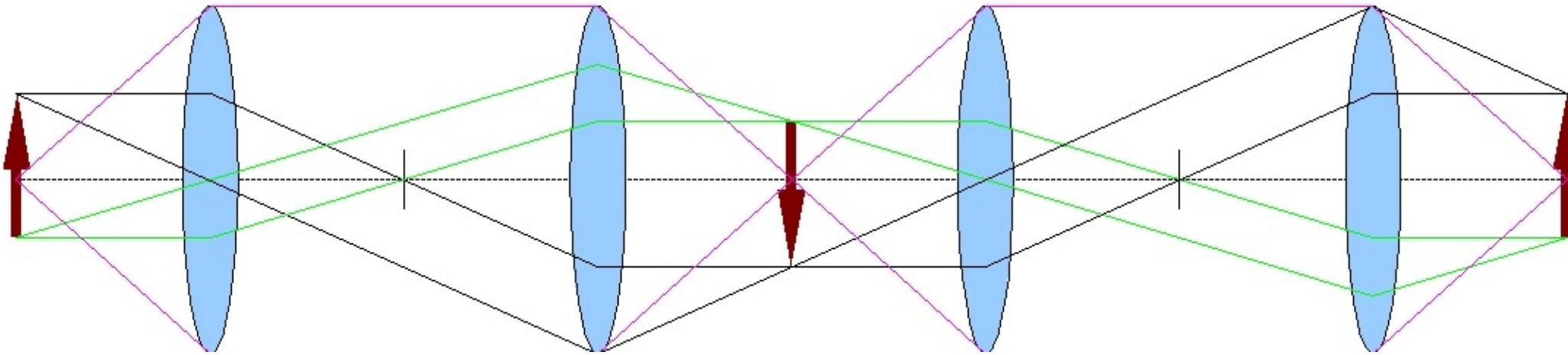
Optical transmission line

Telescope

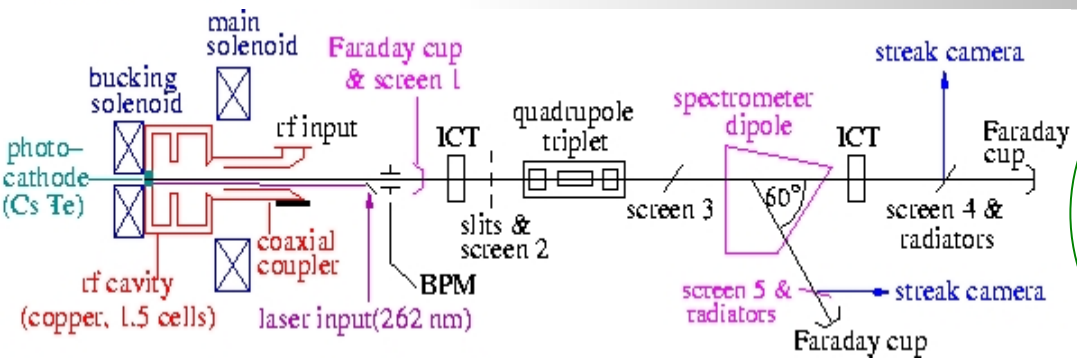


Optical transmission line

Telescope

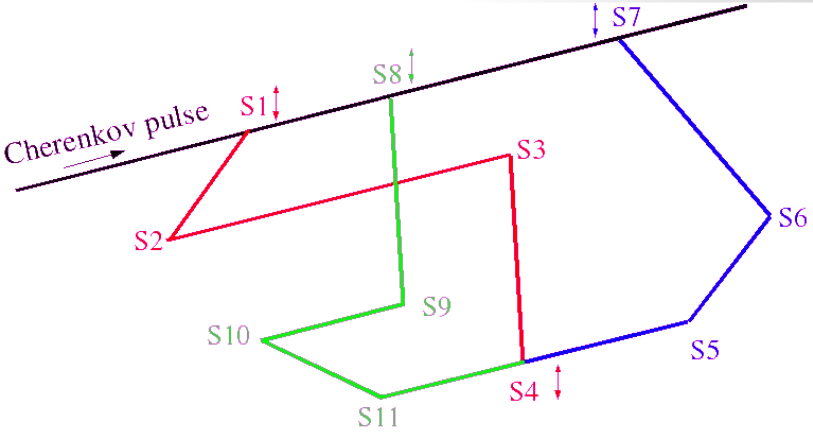


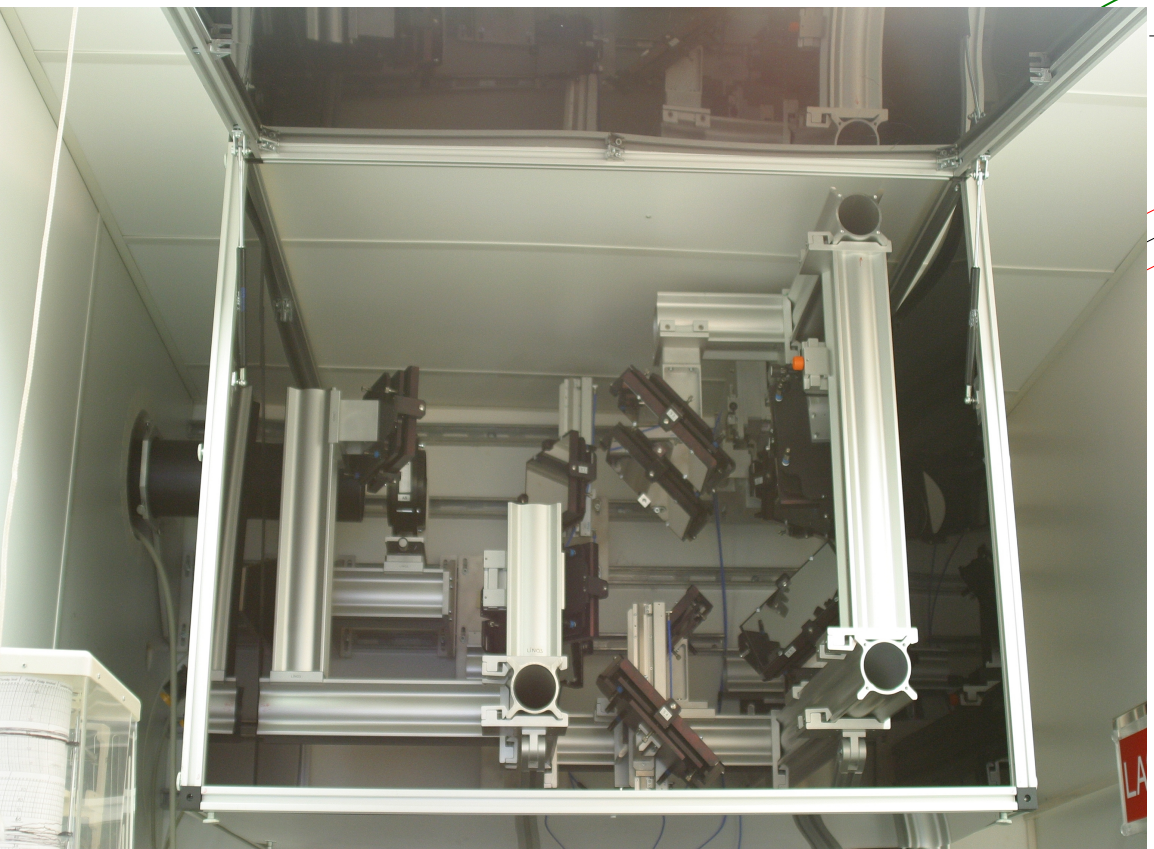
Optical transmission line

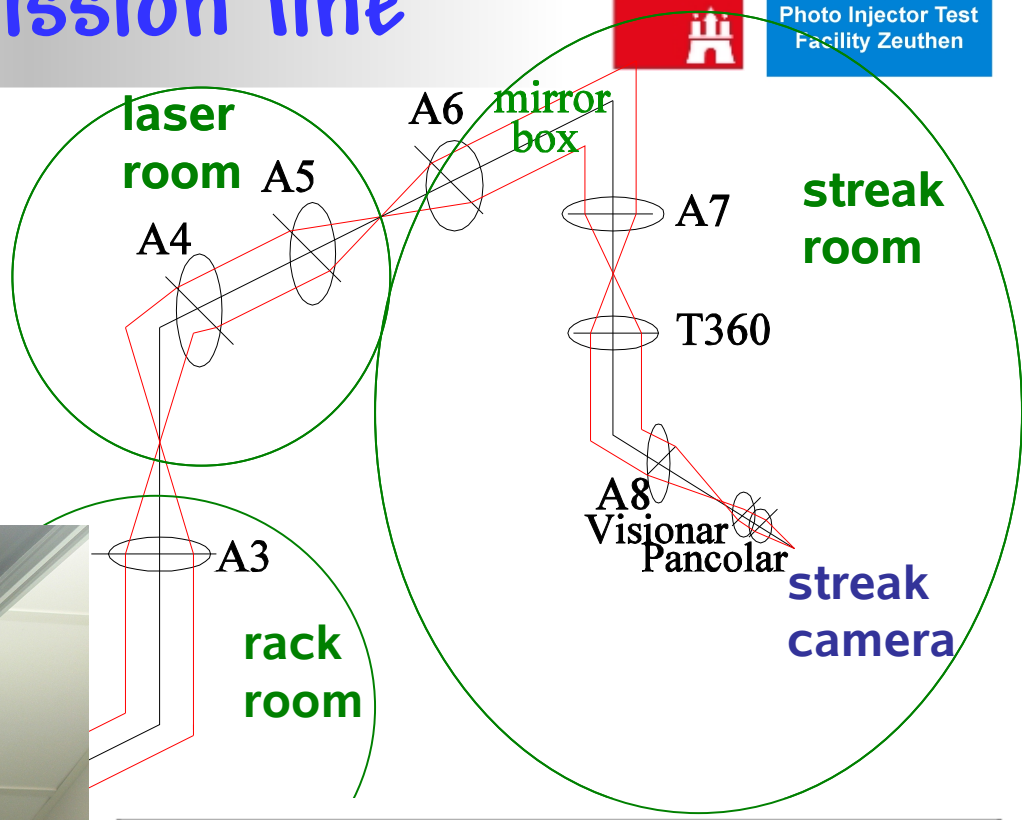


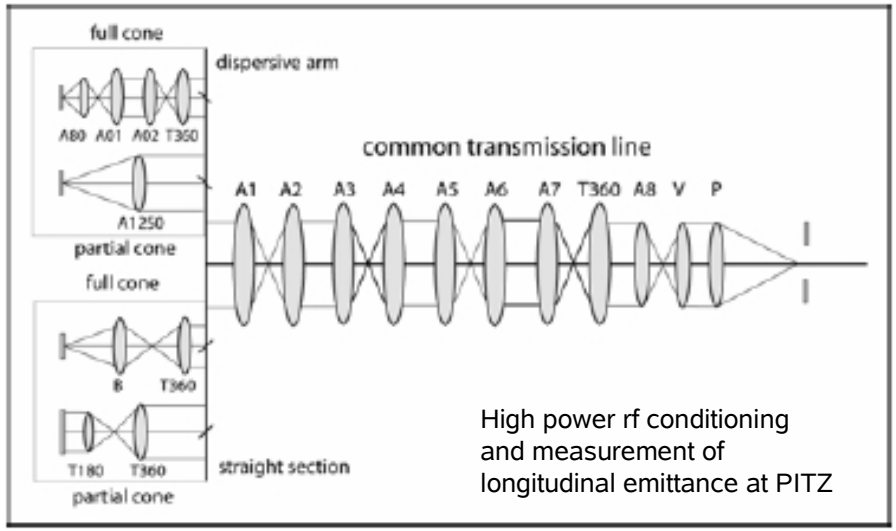
High power rf conditioning and measurement of longitudinal emittance at PITZ

Optical transmission line







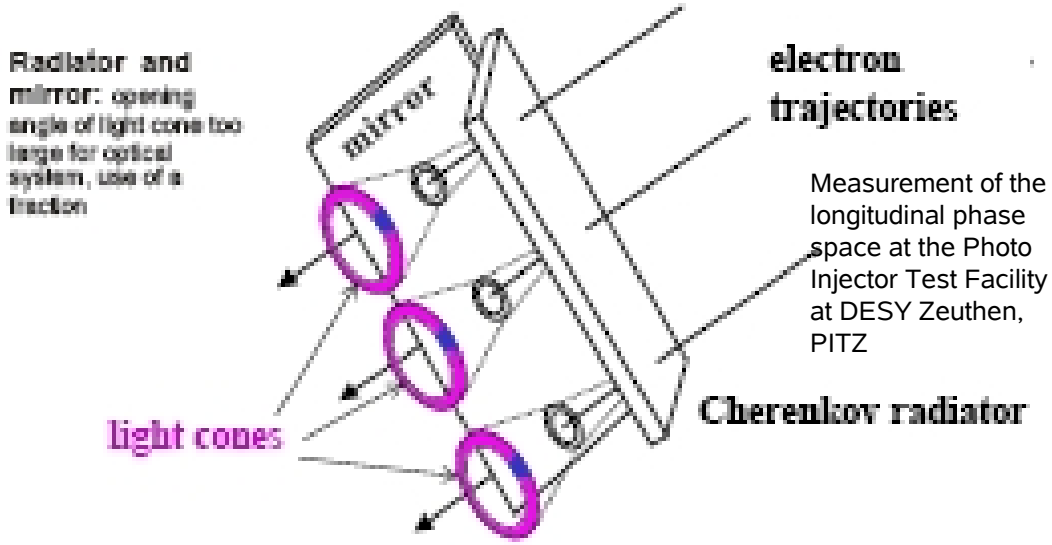


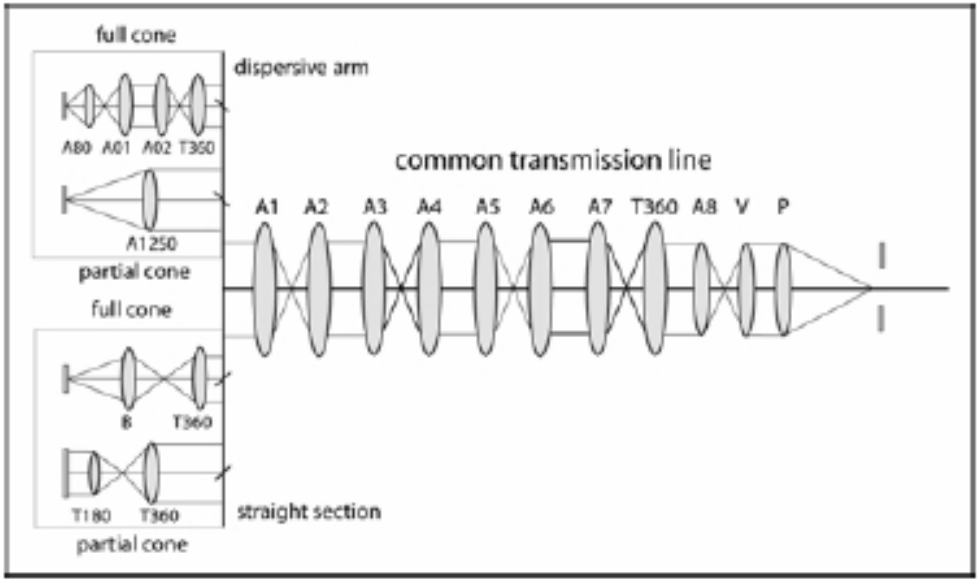
High power rf conditioning and measurement of longitudinal emittance at PITZ

Optical transmission line

input optics	transmission	demagnifying optics
•full cone: collect maximum of light -> high aperture •partial cone: project quasiparallel bundel into focal plane of the first lens	•transmitting light over 27m using telescopes •closed by tubes avoid background illumination and straylight	•demagnification •aperture match

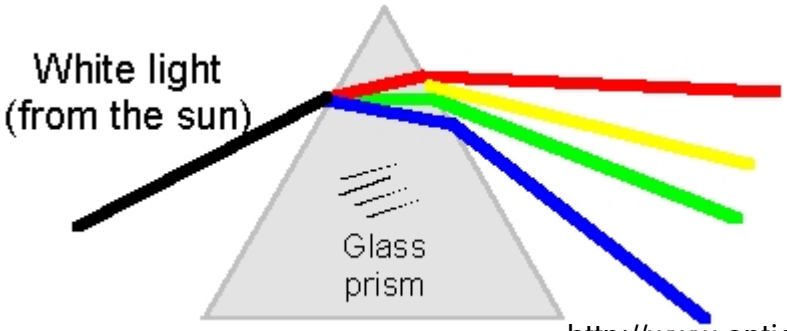
Minimize number of optical elements
Optimize optical resolution
Object size restricted to 2 mm diameter to avoid vignetting





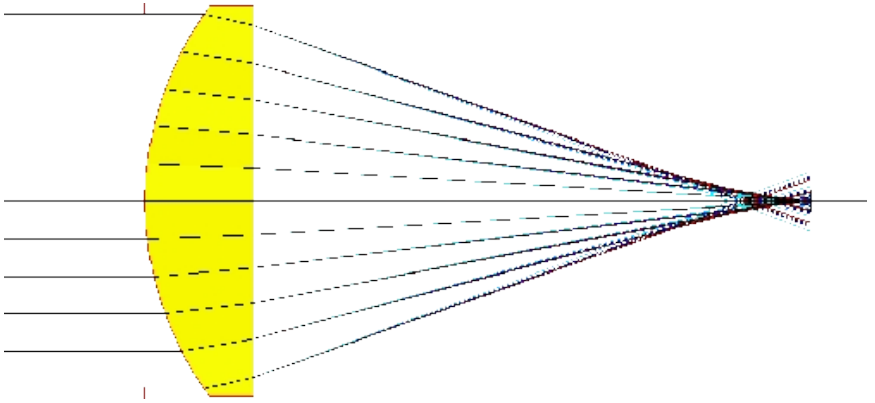
Optical transmission line

dispersion

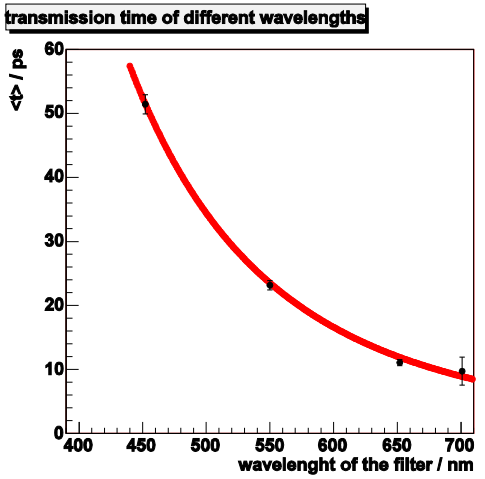


http://www.opticalres.com/kidoptx.html#MainPoints

In optics, dispersion is a phenomenon that causes the separation of a wave into spectral components with different frequencies, due to a dependence to the wave's speed on its frequency.



- Cherenkov radiation has a broad spectrum
- lens optics: dispersion
- it is necessary to suppress the dispersion, since the bunch-broadening due to the dispersion in the lenses is in the femtosecond to picosecond regime
- bandpass filters with 10nm bandwidth have been used
- in future the lenses will be replaced by mirror optics



Streak camera

What´s imporant for the handeling of the streak camera?

- A high photon density can destroy the camera, especially in the focus mode!
- In case of too high photon density space charge forces increase the electron bunch in the streak camera and change the temporal distribution

Streak camera

Thanks!