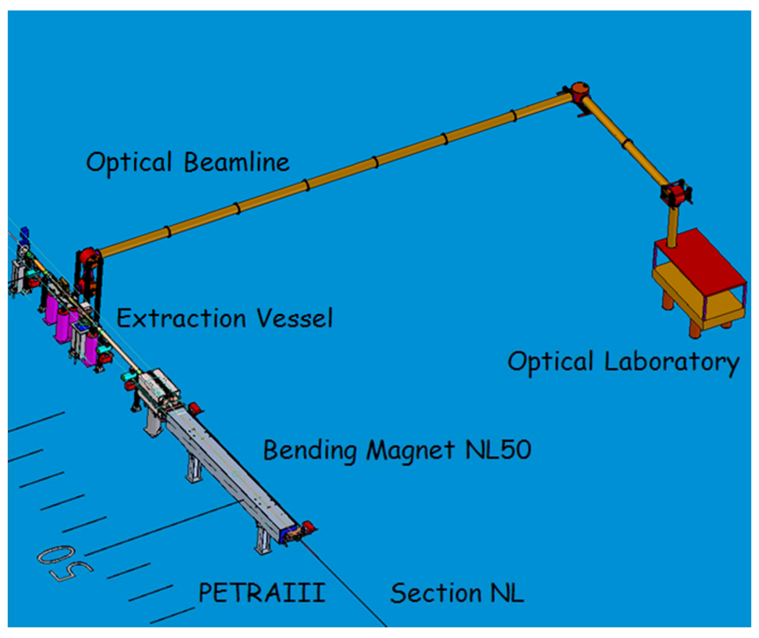
BUNCH LENGTH MEASUREMENT FOR PETRA III LIGHT SOURCE STORAGE RING.

H.-Ch. Schröder, A. Affeldt, H.-P. Gausepohl, G. Kube, G. Priebe,
DESY, Hamburg, Germany

Overview over the Bunch Measurement Setup

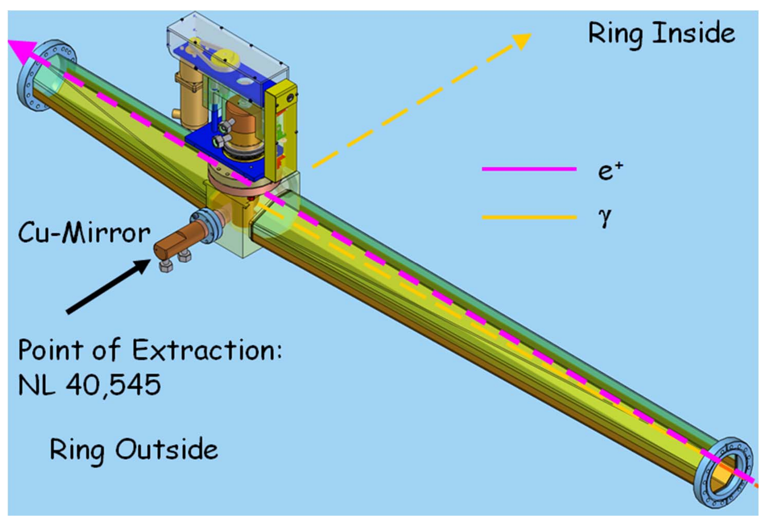


The measurement of the bunch length of the PETRAIII storage ring is based on the analysis of visible synchrotron radiation from a bending magnet [1]. The main parameters, characterising the storage ring and the bending magnet light source are given below:

- Operating Energy E / GeV 6.0
- Revolution Frequency f / MHz 500.0
- Beam Current I / mA 100.0
- Magnetic Radius ρ / m 191.7
- Critical Energy E / eV 2499.2

The measurement is performed with a Streak Camera (SC) system, using a vendor supplied software package [2]. Work for additional analysis systems, such as wave front sensors and dedicated analysis software is underway.

Vacuum Vessel for Light Extraction



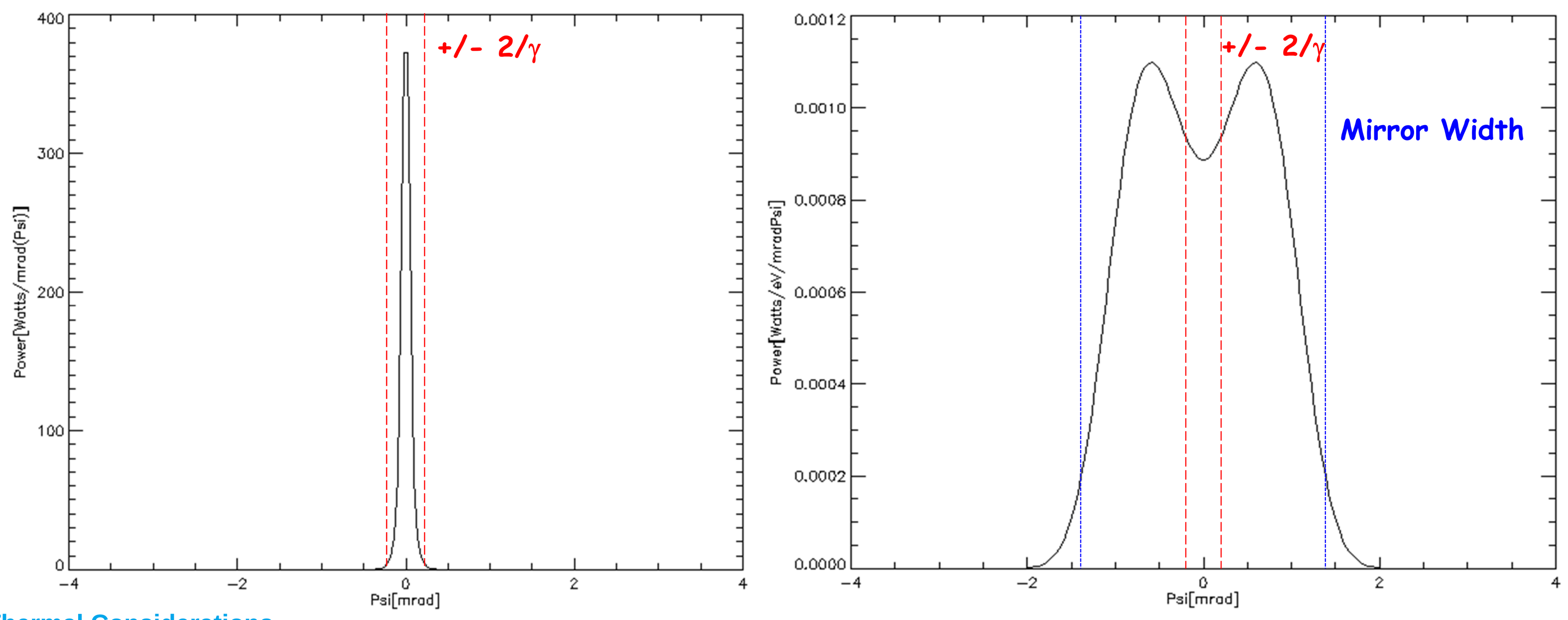
UHV Section Light Path

The Synchrotron light from the last bending magnet of the PETRA NL section at 50 m, is extracted using a specially designed extraction vessel. This vessel deviates from the circular shape of the PETRAIII straight section vacuum pipes in order to avoid vignetting of the tangentially emitted synchrotron light by the pipe walls.

The source point for the light extraction is located about 1.5 m beam upstream from the flange inside the magnet and the light is reflected by a water-cooled Cu-mirror of 22 x 22 mm^2 (ϕ=2.8 mrad, ψ=2.8 mrad) projected area.

The light exits the vacuum pipe through a quartz window into a separate optical beam line. This beam line is not part of the machine vacuum and is designed to be operated either under its own vacuum or, as now, at normal air pressure.

Spectral Angular Distribution of PETRA III Synchrotron Radiation



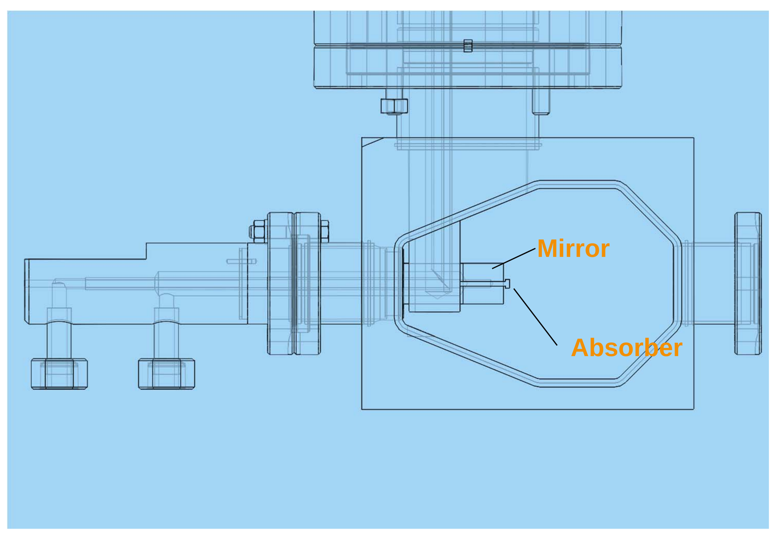
Thermal Considerations

Since the optical part of the synchrotron radiation spectrum is very small in terms of power, most of the radiation power impinging on the mirror is dissipated as heat, rather than reflected. In order to minimize a thermal deterioration of the optical surface of the Cu-mirror, advantage is taken of the spectral angular distribution of the synchrotron radiation.

While the major part of synchrotron radiation is emitted nearly in the orbit plane with an opening angle of $1/\gamma$ (about 85 µrad for PETRAIII), as shown in the left picture, the optical part with $\hbar\omega << \hbar\omega_{crit}$ has a much broader distribution with a typical out-off-plane angle much larger than $1/\gamma$, right picture.

Therefore, placing an absorber with a width of $+/-2/\gamma$ in front of the mirror will obstruct the high energy fraction from the mirror [3]. The loss of visible light, also obstructed by the absorber, is about 15%.

Design of Cu-Mirror and Absorber



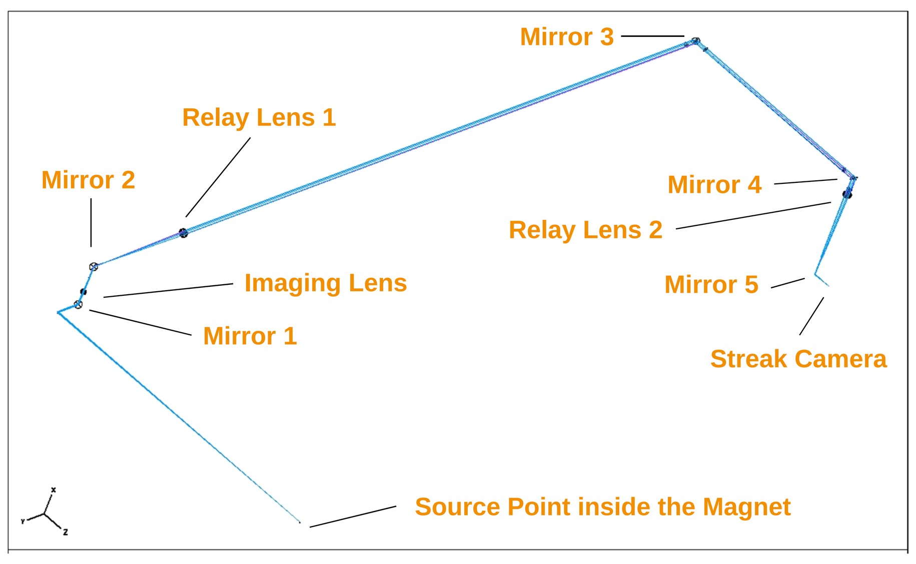
Design Decision

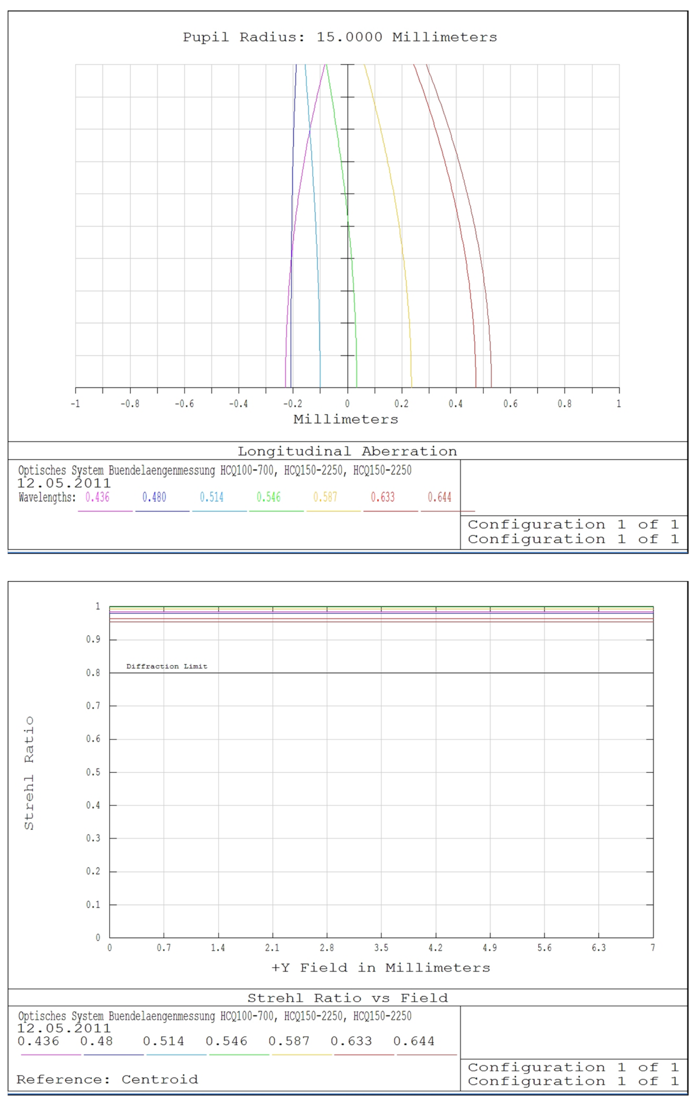
Based on the previous considerations, the final design of the UHV vacuum vessel for synchrotron light extraction includes a Cu-mirror and an absorber, both water-cooled.

Temperature Monitoring

The temperatures of the mirror and the absorber as well as selected vessel areas are measured using PT100 thermometers and the corresponding data are processed by the PETRAIII temperature monitoring system.

Properties of Light Propagation in the Optical Beam Line





Light Transport

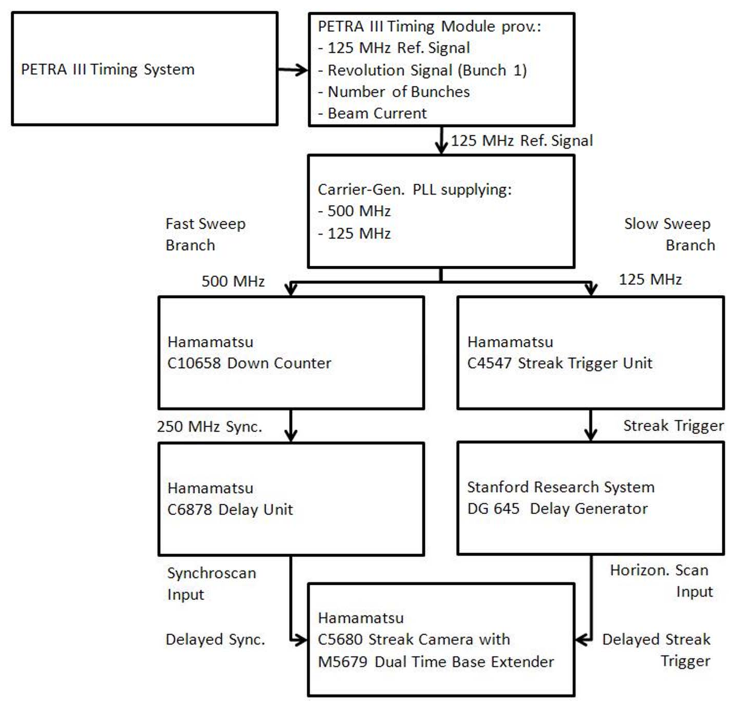
The optical beam line is used to transport the visible synchrotron light into the laboratory. It consists of one imaging lens (D=100mm, f'=700 mm), five high quality flat mirrors (D=150mm, λ /20 p.t.v. at 632 nm) and two relay lenses (D=150 mm, f'=2250mm. The relay system provides full colour and full geometrical correction in order to allow for further wave front analysis based diagnostics. The figure shows a scaled view of the light path.

Time Resolution

Using apochromatic lenses [4], the dispersion in the region from 400 nm to 700 nm and thus the chromatic focal shift was minimized. Their chromatic focal shift is 0.2 mm each, corresponding to a time blur of the complete OBL of $\Delta t_{OBL} = 0.4 / c = 1.34$ ps compared to typically 2 mm or 6.67 ps of a single achromatic lens [5]. This value remains constant throughout the whole field of view.

The light yield is typically two times more, than an achromatic system can deliver, if it could operate on such a broad spectral range. Thus, the loss of 15% of intensity due to the absorber in the extraction system is more than compensated using apochromatic lenses.

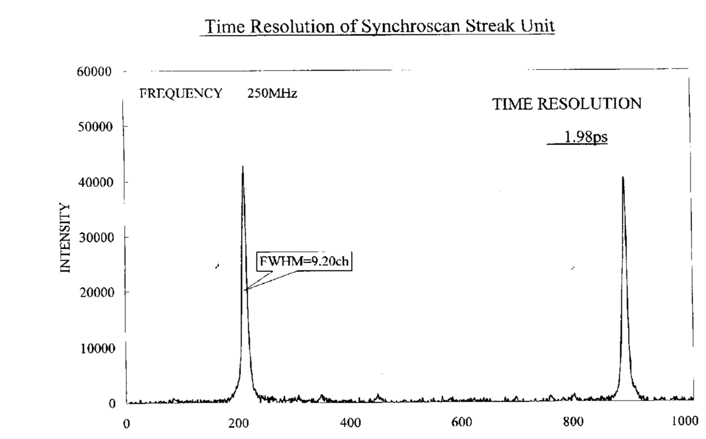
Streak Camera



General Description

Finally, the light is fed into a Hamamatsu C5680 Streak Camera (SC) with dual time base extender, operated at 250 MHz, thus allowing the observation of single bunches in a 500 MHz bunch train in the synchroscan mode.

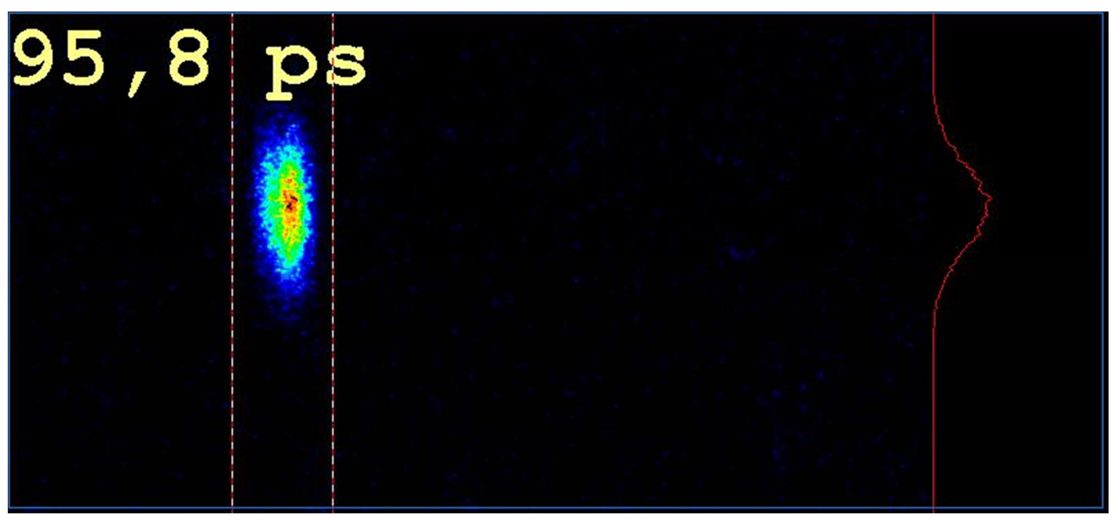
The input optics of the SC is matched to the apochromatic transport beam line, allowing a spectral range from 400 to 700 nm to be imaged on the photo cathode with low intensity loss and with a flat spectral intensity distribution [6]. It is connected to the PETRAIII timing and feedback system using the standard timing module and a low noise RF amplifier system [7].

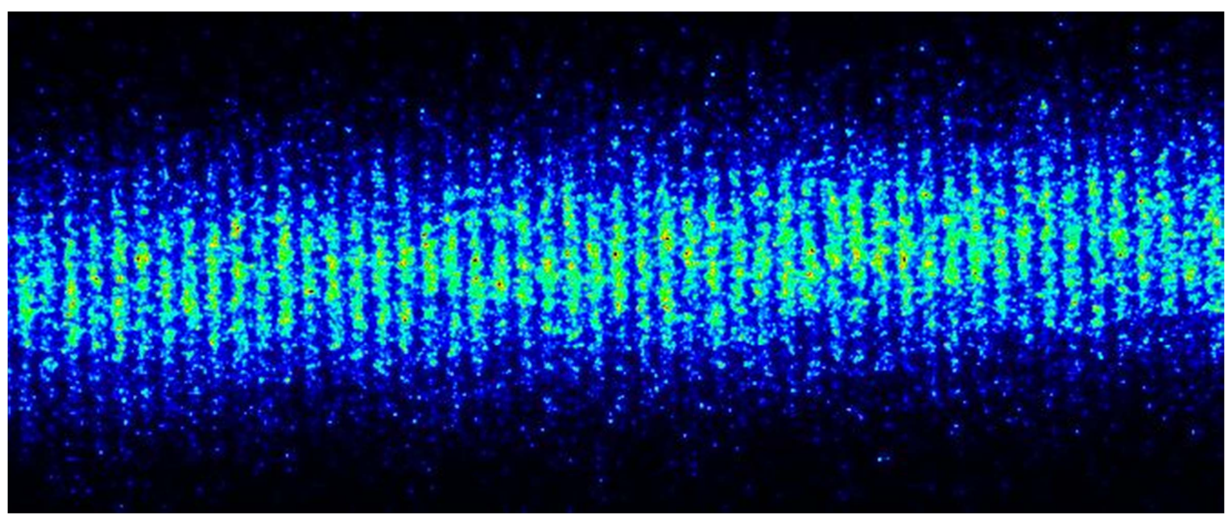


Time Resolution

The SC time resolution, including the input optics, measured with a pulsed Ti:Sa LASER, is about $\Delta t_{SC}=2$ ps [8]. Adding the time resolutions of the SC and the OBL quadratically, a total resolution of $\Delta t_T=\sqrt{\Delta t_{SC}^2 + \Delta t_{OBL}^2}=2.4$ ps is achieved

Bunch Length Measurement





General

To fulfill the demand for a very high brilliance synchrotron light source, it is required, that the transversal beam size does not exceed certain limits in linear dimension and divergence during the storage time.

To control the energy spread, which might couple in the transverse plane due to dispersion, the length of the particle bunches must be measured.

Typical measurements with the described setup include single bunch as well as bunch train measurements.

Single Bunch Measurement

In a single bunch measurement the bunch spot, the corresponding intensity profile and its half widths is given.

The half widths of Γ_b = 95.8 ps corresponds to a sigma of the bunch length of $\sigma_b=\Gamma_b/2.3458$=40.8 ps, in accordance with the PETRAIII design parameters.

Bunch Train Measurement

Analyzing the bunch train allows the determination of several beam parameters not presented here. Work on dedicated software is currently underway [8]. In the Figure a 5 µs wide and 430 ps high window shows a part of the bunch train of a 50 mA, 72 bunch filling of PETRAIII.

Conclusions

The presented PETRAIII bunch length measurement system is sufficient to measure the bunch lengths of single bunches and parameters of complete bunch trains. The time resolution is shown to be less than 3 ps, the typical measured bunch length of 40 ps is in accordance to the PETRAIII design parameters. Investigations to improve the time resolution and the measuring process are underway.

References

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