A 2-D Laser-Wire Scanner at PETRA-III

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1 Abstract

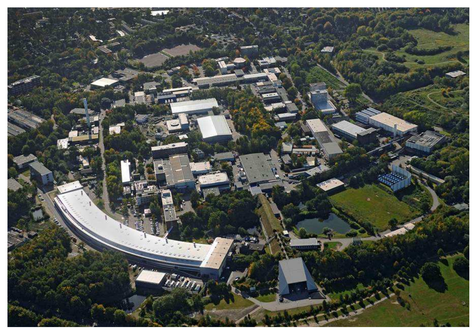
The PETRA-III Laser-wire (LW), a Compton scattering beam size measurement system at DESY, uses an automated mirror to scan a Q-switched laser across the electron beam and is developed from the system previously operated at PETRA-II. Here, recent upgrades of the optics, vacuum vessel and data acquisition are reported. First beam profile measurements are also presented.

2 Introduction

The LW system is an upgrade of the 2-D LW tested previously at the PETRA-II accelerator [1]. New features, such as real-time correction for laser pulse-to-pulse power fluctuation and time or position jitter, make measurements more reliable. Also, knife-edge scans to measure the laser spot size as it is at the interaction point can be performed on-demand, so the contribution of the laser width can be extracted from the total signal distribution.

Nominal PETRA-III parameters [4], [5].

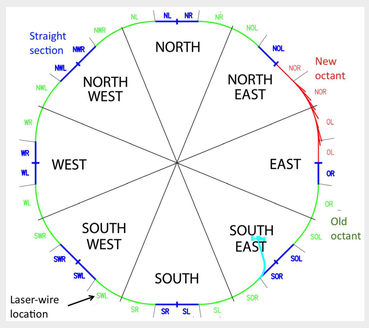
Parameter	Value	Unit
Energy E	6	[GeV]
Circumference C	2304	[m]
Horizontal emittance ϵ_x	$\sim$1	[nmrad]
Vertical emittance ϵ_y	$\sim$0.01	[nmrad]
Revolution frequency f	130.2	[kHz]
Bunches per fill N_{fill}	960 (40)	
Interbunch spacing	8 (192)	[ns]
Bunch length RMS L_b	$\sim$12	[mm]
Electrons per bunch N_e	0.25 (12)	$\cdot 10^{10}$
Exp. hor. beam size σ_x	$\sim$175	[μm]
Exp. vert. beam size σ_y	$\sim$15	[μm]



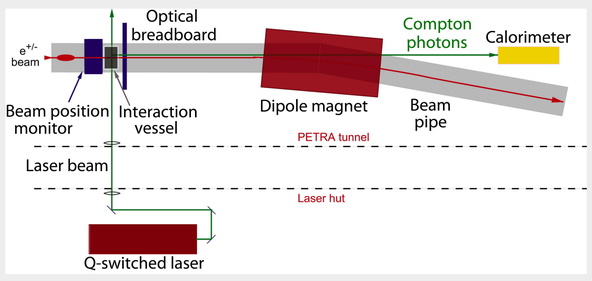
Aerial view of the PETRA-III facility.

3 Experimental Setup

The laser pulse collides with the positron bunch within a custom built vacuum vessel. The Compton photons are separated downstream by a dipole magnet and detected by a calorimeter. Button pick-up BPMs on either side measure the positron beam position.

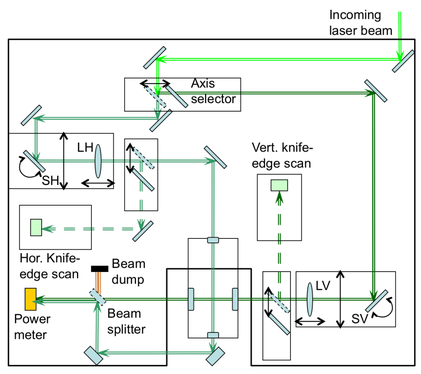


Location of LW.



Overview of the LW setup.

4 Vertical breadboard



Schematic layout.

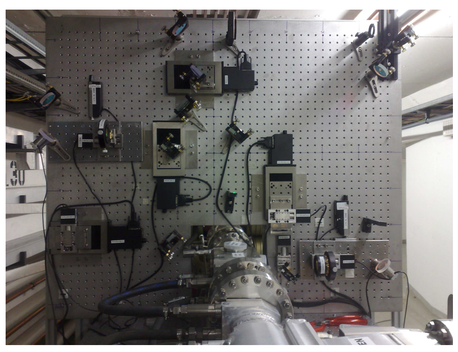
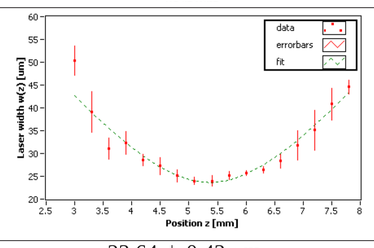
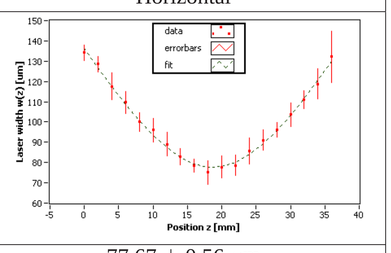


Photo of the optical breadboard.

- Laser: 20 Hz Nd:YAG laser (1064 nm, frequency doubled)
- 2” high reflective static mirrors, 2 piezo-driven scanning mirrors
- Horizontal (H) scan: 750 mm lens, vertical (V) scan: 250 mm lens

5 Laser beam size

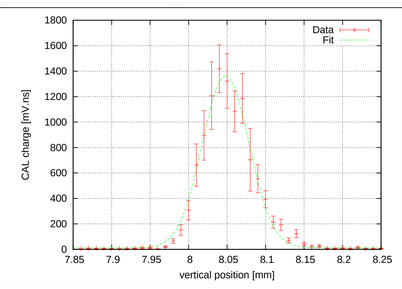
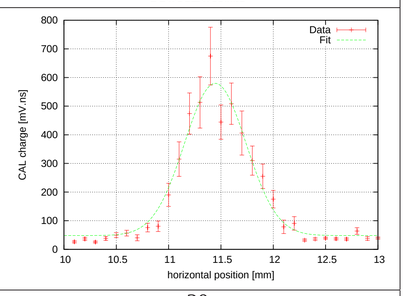
The spot size at the laser waist (w_0) was measured using a digital CCD/CMOS camera. The laser was passed through an optics setup designed to replicate the IP focussing outside the vacuum vessel with the camera mounted on a translation stage in the focus.

Laser profile	Vertical	Horizontal
		
Waist, w_0	23.64 $\pm$ 0.43 μm	77.67 $\pm$ 0.56 μm
M^2	2.09 $\pm$ 0.07	2.75 $\pm$ 0.02
Rayleigh range, z_R	1.58 $\pm$ 0.08 mm	12.94 $\pm$ 0.21 mm

6 LW operation

- Two types of transverse scans possible:
  - *Ramp scan* – Using the piezo-mirror with the translation stages fixed: step resolution $<$ 1 μm, scanning range 1.25 mm V and 3.75 mm H. Scan rate is only determined by the laser frequency: 20 steps and 10 shots per step only take 10 s.
  - *Stage scan* – Using only the motorised beam-finding stage with the piezo-mirror fixed: step resolution $<$ 1 μm, scanning range $\sim$ 25 mm. 500 ms overhead for stepping the stages: scan with 20 steps and 10 shots per step takes about 20 s.
- Laser focus position relative to the beam can be moved by another translation stage.
- LW system self-correction features:
  - Knife-edge scan to check waist size and Rayleigh range of the laser.
  - Photodiode to measure laser pulse-to-pulse power fluctuation and time jitter.
  - CCD camera to determine the laser pulse-to-pulse position jitter.

7 Profile measurements

Stage scan	Vertical	Horizontal
		
Laser positions	40	30
Laser shots	20	100
Scan time	60 s	165 s
Bunch current	260 μA	690 μA
Dimension	30.38 $\pm$ 1.43 μm	293.6 $\pm$ 18.1 μm

Profiles are a convolution of the transverse size of the positron bunch with the laser beam profile and the laser pointing jitter.

8 Conclusions & Outlook

- Successful performance of horizontal and vertical scans.
- Beam profile resolution is currently about 5%.
- Scan times of 60 s and 165 s for the V and H axis respectively were achieved.
- Full integration of the LW system into the PETRA-III control system.
- Benchmarking beam studies compared with other beam size diagnostic instruments [6], e.g. to measure the lattice characteristics (dispersion, compaction factor, beta functions, etc.).

[1] A. Bosco et al. A two-dimensional laser-wire scanner for electron accelerators. In *Nuclear Instruments and Methods in Physics Research Section A*, volume 592, issue 3, pages 162–170, July 2008.
[2] I. Agapov et al. Beam emittance measurement with laser wire scanners in the International Linear Collider beam delivery system. In *Physical Review Special Topics – Accelerators and Beams*, volume 10, issue 11, 112801, 2007.
[3] Y. Liu et al. Laser Wire Beam Profile Monitor at SNS. Presented at *EPAC’08*, TUPC061, Genoa, Italy. June 2008.
[4] I. Ascone et al. PETRA-III: A Low Emittance Synchrotron Radiation Source. In *K. Balewski et al., editors, Technical Design Report*. February 2004.
[5] K. Balewski and R. Wanzenberg. Beam current limitations in the synchrotron light source PETRA III. Presented at *EPAC’04*, THPKF021, Lucerne, Switzerland. July 2004.
[6] G. Kube et al. PETRA III Diagnostics Beamline for Emittance Measurements. Presented at *IPAC’10*, MOPD089, Kyoto, Japan. May 2010.

Third DITANET School on Beam Diagnostics (Advanced Level), Stockholm, Sweden, 7-11 March 2011. Produced using LaTeX.