A two-dimensional Laser-wire Beam Profile Measurement System at PETRA

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The transverse beam profile at the PETRA positron storage ring will be measured using a two-dimensional laser-based beam profile monitor. Such a device, newly installed, uses a finely focused laser beam to scan across the charged particle beam. The flux of the compton scattered photon varies with the position of the laser beam, thus establishing the transverse beam profile. In this paper, aspects related to the laserwire setup, such as the focusing optics, both pre- and post-interaction point diagnostics optics, scanning optics, and ghost analysis are described in detail.

1 Introduction

Precision beam diagnostics for position and beam profile are vital to achieve high performance at a TeV energy lepton collider, such as the International Linear Collider [1]. The high brightness of the lepton beams is well beyond the threshold density for single pulse melting of any material used for conventional wire scanners, thus making their use ineffective. A laser-based profile monitor, in contrast, uses a finely focused laser beam to scan across the lepton beam. The evaluation of the Compton scattered photon flux as a function of the laser beam position yields the transverse lepton beam profile. A two-dimensional laserwire device is being built and is planned to be installed at the PETRA positron storage ring. This paper describes different aspects related to the development of such a laser-wire profile monitor.

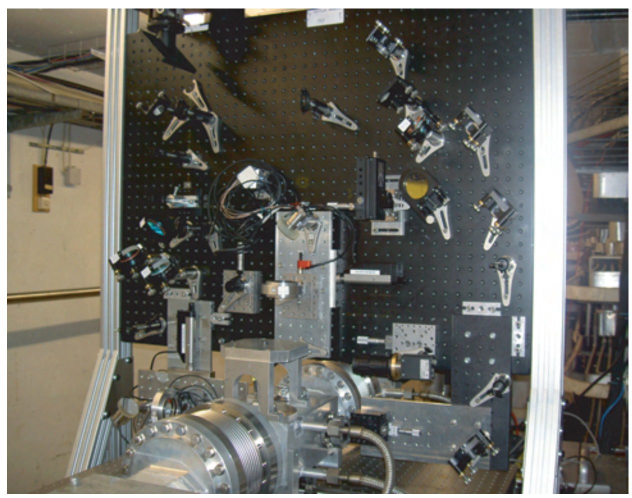

Figure 1. Picture of the laserwire breadboard installed at the PETRA positron storage ring.

2 Experimental Setup

The experimental setup is mainly divided into two areas, the laser hut where both the laser system and the DAQ hardware are installed, and the PETRA accelerator tunnel where the laserwire breadboard setup is installed. Figure 1 shows a picture of the laserwire setup installed at the PETRA positron storage ring. The laser beam, after being expanded by a variable beam expander (1:8), is transported using a matched Gaussian relay made of two $f = 5$ m lenses over a distance of 20 m from the laser via an access pipe into the tunnel housing the accelerator [2]. The beam is then picked up at the entrance of the laserwire breadboard by a 50 mm mirror. Height adjustment and correction for lateral shifts are corrected by combining two other mirrors. The beam is then deflected selectively by a piezo-driven scanner for either a vertical (SV) or horizontal (SH) scan of the electron beam.

3 Focusing lens

The laser beam is focused using a plano-convex lens with a focal lens of 250 mm. Figure 2 shows a ZEMAX [3] simulation of the waist of a high quality mode laser beam at the focus as a function of different input waists at the en-

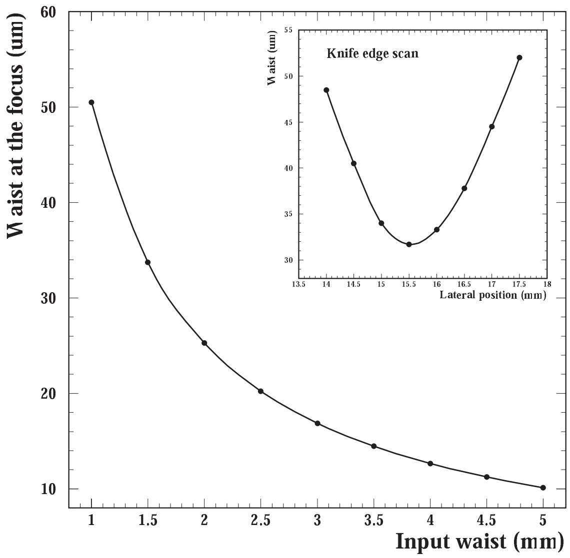

Figure 2. ZEMAX simulation of the variation of the beam waist at the focus as a function of the beam radius at the entrance of the focusing lens. The knife edge scan measurement is shown on the top right.

trance of the focusing lens. For a fixed input laser beam waist of 3 mm, the waist at the focus is $\omega_f \simeq 17\ \mu$m and the rayleigh range $z_f = 1350\ \mu$m. Such a choice is a compromise between having a fine focus at the interaction point to scan across the charged particle beam and a long enough rayleigh range.

The characterization of the focusing lens in real life was done by expanding the output beam of a He-Ne laser to have a waist of 3 mm. The waist at the focus was determined using a knife edge scan (Fig. 1, top right) and was around 17 μm, in complete agreement with the ZEMAX simulation. This measurement was also cross checked using a WinCAM and beam profiler and all results agreed.

4 Diagnostics:

The diagnostics section is divided into a pre- and post-interaction point diagnostics. The pre-IP diagnostics consists of imaging the interaction point (IP) for both horizontal and vertical dimensions into individual CCD cameras. For each dimension, an appropriate cubic beam sampler reflects a small fraction of the beam towards a ten time beam expander in front of a CCD camera. Figure 3 shows a schematic drawing of the diagnostics section. The post-IP diagnostics consists of imaging the waist at the focus using a plano-convex lens with a focal length f of 125 mm into a CCD camera. The distance p between the imaging lens and the interaction point and the distance q between the

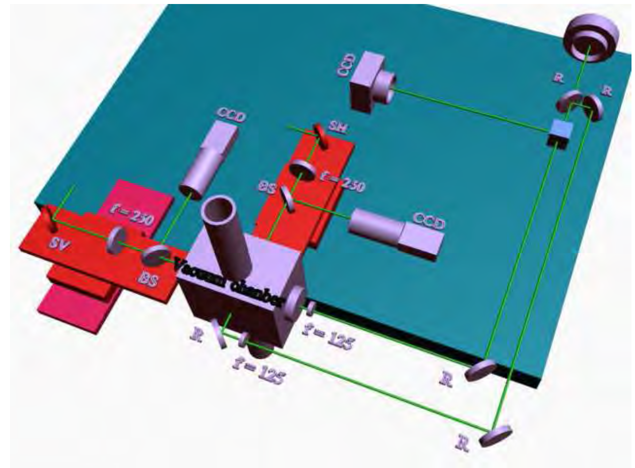

Figure 3. Schematic of the imaging section of the laserwire setup for both vertical and horizontal dimensions. SR and SH are the piezo scanners for horizontal and vertical dimensions, R is for high reflective mirrors

imaging lens and the CCD camera are set precisely to have almost the same magnification used for the pre-IP imaging system.
Table 1 shows measurements of the beam waist at the interaction point, at the pre-IP and post-IP. The input laser beam at the entrance of the focusing lens was set to 3 mm. Once the magnification of the beam waist at the post-IP is measured, it is enough to rely on the post-IP diagnostics system. The pre-IP section can be disposed of, thus reducing the cost of the laserwire setup.

	IP	pre-IP	post-IP
Vertical	17.37	17.5	16.5
Horizontal	16.78	17.23	16.44

Table 1. Measurements of the beam waist at the IP. pre-IP and post-IP.

5 Scanner

A piezo-driven platform with an attached 50 mm high reflective mirror has been used to scan the laser beam across the charged particle beam. The platform is driven by two pairs of piezo actuators, each controlled as a unit in push/pull mode when supplied by a voltage. The tilt range is 2 mrad. The load frequency depends on the load on the piezo platform. Simulation showed that with a load equivalent to a 50 mm mirror on the platform, the maximum loaded frequency necessary to have a scan range of 2 mrad is around 400 Hz. Figure 4 shows the achieved laser beam deflection as a function of the voltage supplied to the piezo scanner.

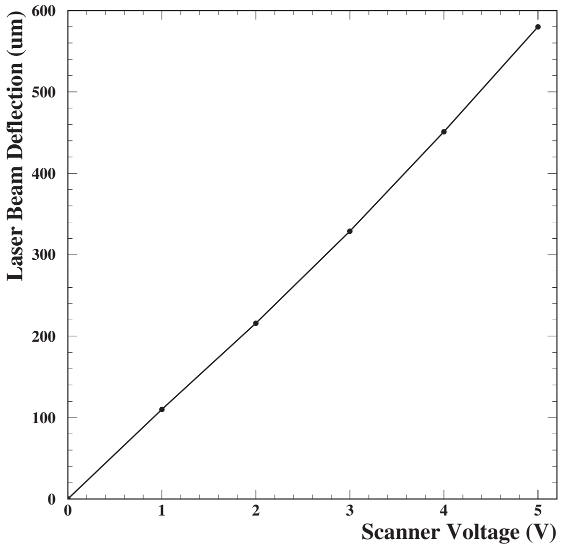

Figure 4. Dependence of the travel range as a function of the voltage supplied to the piezo scanner.

A scan range of 580 μm, corresponding to a voltage supply of 5V to the piezo scanner, was measured on the CCD camera. This limit is set by the aperture of the chip on the CCD camera.

6 Ghost analysis

A ghost analysis using the ZEMAX program revealed the existence of several ghosts, of which the most critical are those hitting the viewport of the vacuum chamber. These ghosts originate from the imaging lenses for the port-IP diagnostics situated just behind the viewports. Figure 5 indicates, in arrows pointing from right to left, the location of such ghosts. These were confirmed by looking at the back reflection of imaging lenses. Placing a 1 to 1000 neutral filter in front the imaging lenses reduces the ghosts encircled energy to a safe level.

7 Conclusion and outlook

A two-dimensional laserwire profile monitor is been built and installed at the PETRA positron storage ring in December 2005 and is ready for operation. Both horizontal (x) and vertical (y) electron beam sizes will be determined by scanning a finely focused across the charged particle beam using a piezo-driven mirror. A new injection seeded laser with a good mode quality will allow the determination of the transverse beam profile with a high accuracy.

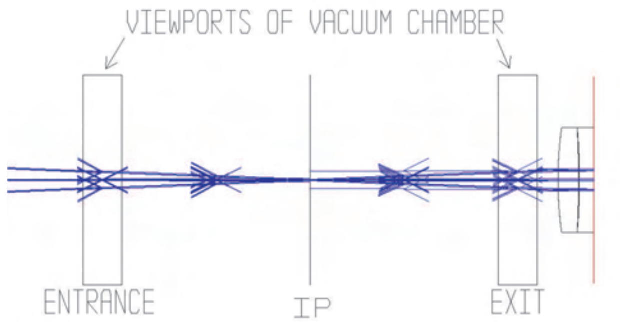

Figure 5. ZEMAX simulation of the location of the ghosts (arrows from right to left) hitting the viewports of the vacuum chamber.

8 Acknowledgements

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