FIRST RESULTS FROM THE CESRTA X-RAY BEAM SIZE MONITOR

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Abstract

Engineering data sets were collected with the CESRTA x-ray beam size monitor (xBSM) during November 2008 and January 2009 runs. We report on the performance of the InGaAs photodiode array detector, including time response and signal-to-noise performance. We report on measurements of vertical beam size using the interchangeable optical elements: slits, Coded Aperture, and Fresnel Zone Plate.

INTRODUCTION

The International Linear Collider (ILC) will depend on low-emittance beams to achieve the luminosity targets set by the physical goals of the machine. The emittance in the ILC damping rings must be measured and monitored to ensure that the desired emittance is achieved. Because of the folding of long beam trains into the relatively small circumference rings, warm (undamped) and cool (damped) bunches may be in adjacent buckets and the monitoring must separate neighboring bunches cleanly. CESRTA is an experiment to explore the effects and means of ameliorating electron cloud build up in a damping ring, a potential source of emittance degradation. We use synchrotron radiation to measure the vertical bunch size and thereby vertical emittance. In this paper we discuss early results from the x-ray beam size monitor (xBSM). This device accepts x-rays of 2-4keV emitted in a dipole magnet and focuses the photon flux with various (selectable) optical elements onto a fast photodiode array.

BEAMLINE

X-rays from 2GeV positrons are imaged onto a fast photodiode array. The imaging element is located 4.3m from the source and 10.5m from the photodiode array, resulting in a magnification of 2.44 [1]. The optical element may be selected from a vertically limiting adjustable slit, a Fresnel zone plate (FZP), and a coded aperture (CA).

DETECTOR TIME RESPONSE

The photodiode array[1] exhibits a time response shown in Figure 1. The 1.5ns risetime seen in the figure is due to bandwidth limitation in the preamplifier; the overshoot is an artifact of additional RC shaping originally deployed for a slower sensor.

[1]Manufactured by Fermionics, Inc., Simi Valley, CA

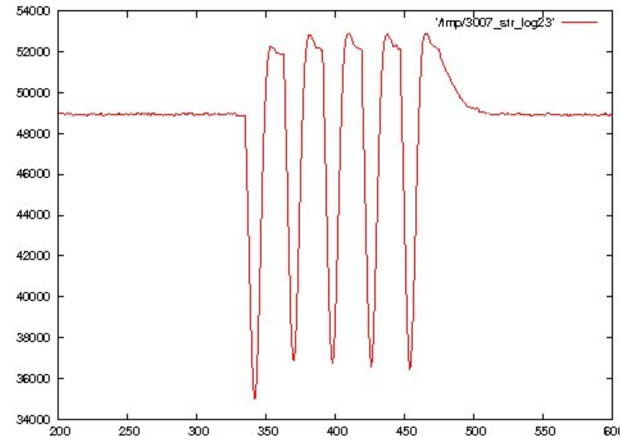

Figure 1: Signal response of our photodiode array. The peak-to-peak temporal spacing is 14 ns corresponding to standard CESR positron bunch spacing. Five CESR bunches are seen in this figure. The 1.5ns rise time seen in the plot is consistent with the preamplifier bandwidth and the S/N evident in these data is characteristic of 100-turn averages.

FOCAL POINT OF FRESNEL ZONE PLATE

To find the focal point of the FZP intensity profiles were taken (Figure 2). There are 13 peaks that correspond to 13 different x-ray energies selected in successive images by tilting the monochromator; the overall envelope reflects the energy spectrum of x-rays reaching the photodiode array. Since the focal length of the FZP is proportional to wavelength, a scan through x-ray energies determines which wavelength is best in focus given the fixed geometry of the system. The narrowest peak in the scan corresponds to 2.4 keV x-rays and occurs when the monochromator angle is set to -11.5 degrees (Figure 3).

INTEGRATED BEAM SIZE MEASUREMENT WITH FZP UNDER DIFFERENT BEAM CONDITIONS

Beam size measurements were made with the Fresnel Zone Plate optics under different settings of CESR optics (Figure 4). During these measurements a closed dispersion bump was generated to increase the beam emittance. The beam size measurements reflect the changes in CESR optics as expected. Measurements were also made with the Coded Aperture [2] under similar but somewhat degraded beam conditions, yielding consistent results (Figure 5).

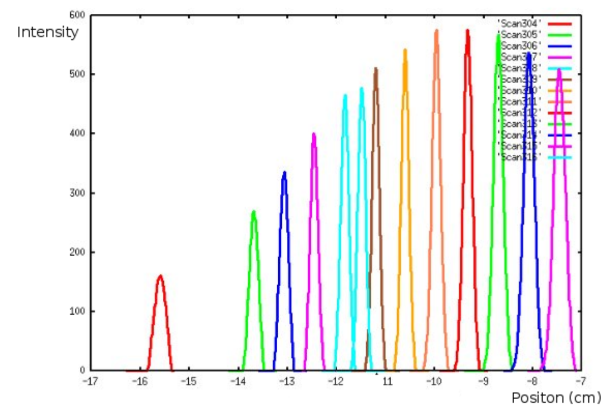

Figure 2: Intensity profiles taken with the FZP at different x-ray energies.

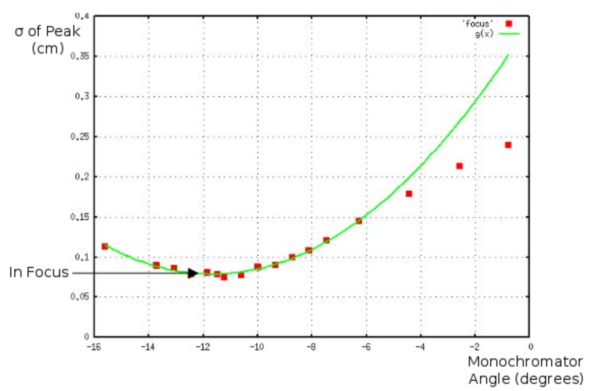

Figure 3: Extracted widths of the 13 image peaks, plotted versus the monochromator setting.

PHOTON NUMBER CALCULATION

Fluctuations in signal intensity are dominated by photon statistics. We therefore can use the spread of signal amplitude to count average photon yield. The mean of an ensemble of signal intensity is proportional to the average number of photons, while the rms is proportional to the square root of the number of photons, with the same proportionality constant. We extract the following photon counts when CESR circulates one bunch of 1mA:

- Fresnel Zone Plate and monochromator:
  6 photons/mA-bunch
- Coded Aperture (no monochromator):
  290 photons/mA-bunch
- Direct white beam:
  2275 photons/mA-bunchs

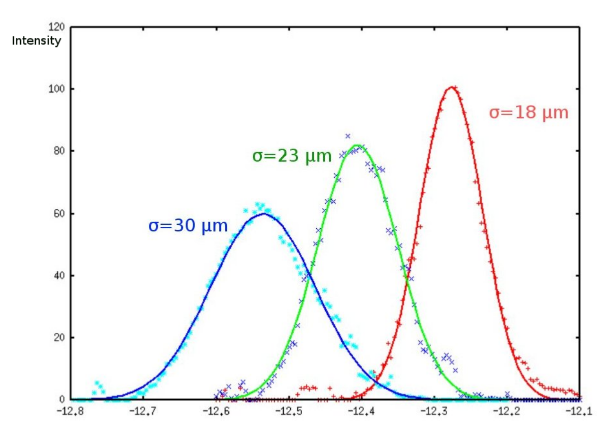

Figure 4: Variation of beam size for betasing 1 settings

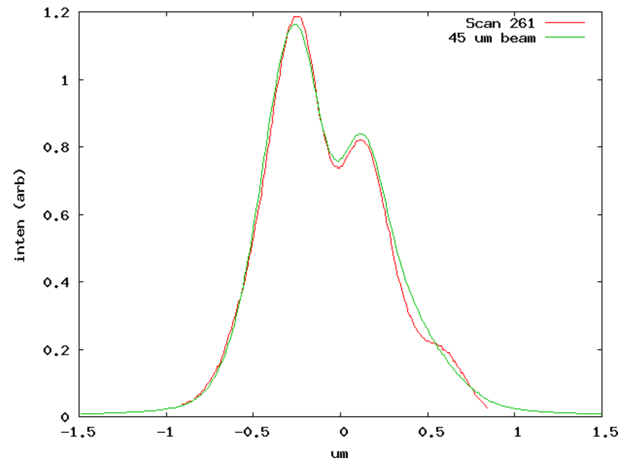

Figure 5: Beam profiles with the Coded Aperture in place under slightly degraded beam conditions

SUMMARY AND PROSPECTS

We successfully made integrated beam size measurements under different beam conditions with both the CA and the FZP which were consistent with expected beam sizes. We also studied the effects of the monochromator with FZP, and CA on photon flux. Measurements of the flux will aid in selecting which optical element to use for different beam conditions.

REFERENCES

[1] J.P. Alexander *et al*, "X-Ray Beam Size Monitor Upgrade for CesrTA", PAC'09, Vancouver, TH5RFP026

[2] J.W. Flanagan *et al*, "Performance of Coded Aperture X-Ray Optics with Low Emittance Beam at CesrTA", PAC'09, Vancouver, TH5RFP048