CESRTA X-RAY BEAM SIZE MONITOR DESIGN

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Abstract

We report on the performance goals and design of the CESRTA x-ray beam size monitor (xBSM). The xBSM resolution must be sufficient to measure vertical beam sizes down to 10$\sim$20μm. The xBSM images 2$\sim$4keV synchrotron radiation photons onto a one-dimensional InGaAs photodiode array. Instrumentation in the dedicated x-ray beam line includes upstream interchangeable optical elements (slits, Coded Aperture, and Fresnel Zone Plate), a monochromator, and the photodiode detector. To provide sufficient x-ray flux in 2 GeV operation, the beam line is evacuated, with only a thin diamond window isolating the detector vacuum from the damping ring. The readout is a beam-synchronized FADC that is sufficient to measure consecutive bunches independently in a 4ns bunch spacing configuration.

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 the design and performance goals of 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.

OPTICS

The optical element is located 4.3m from the CESR dipole source, and 10.5m from the photodiode array; the image magnification is 2.44. The primary optical assembly holds three optical elements that can be selected remotely to focus the x-ray beam: a vertically limiting adjustable slit, a Fresnel zone plate (FZP), and a coded aperture (CA)[1].

The Fresnel Zone Plate and the Coded Aperture are both fabricated on the same silicon substrate[1] and can be selected remotely by moving the substrate to center the desired device on the beam. The patterning on the FZP and CA is done in 0.7μm gold, with the active areas supported by a thin 2.5μm silicon membrane.

In addition to these elements, an adjustable vertically limiting slit for pinhole operation is available and can be similarly selected remotely. At any given time only one of the three optical elements is in use, and all can be fully retracted from the beam when not needed. The pinhole has an adjustable vertical aperture size that ranges from 30 to 120μm and is rugged enough to be used in high energy, high flux beams if needed. At normal CesrTA beam energy (2 GeV) the typical power load on the optical element is of order 1 mW/mA; the optical elements are in contact with actively cooled copper supports.

THE DETECTOR ENCLOSURE

The detector enclosure is held at a milliTorr level vacuum and contains a multilayer monochromator, a mask used for single diode illumination, a fluorescent screen for initial setup and beam location, and a 32 diode-array detector. All these components can be moved remotely in the plane perpendicular to the beam axis.

The Monochromator

The monochromator is a silicon-tungsten multilayer mirror ($\sim$100 layers) that selects x-ray energies with a bandwidth (FWHM=1.5%) well matched to the chromatic sensitivity of the 239-ring FZP. Imperfections in layer structure introduce angular smearing which could lead to degraded resolution; by placing the monochromator close (20cm) to the detector, the position smearing of photon arrivals at the detector is small compared to the diode pitch.

The Detector

The detector has a vertical array of 32 InGaAs diodes[2]. The diodes have a pitch of 50μm, a height of 25μm and a horizontal length of 500μm. The InGaAs layer is 3.5μm thick, enough to absorb 73% of photons at 2.5keV; there is a 160nm Si3N4 passivation layer. The time response of the detector is subnanosecond.

VACUUM CONTROL SYSTEM

A vacuum control system gaurantees a low pressure differential across the delicate diamond window. In the event of a catastrophic window burst, a fast gate valve located 4m upstream closes to protect CESR vacuum.

[1] Manufactured by Applied Nanotechnology, Edmonton, Alberta

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

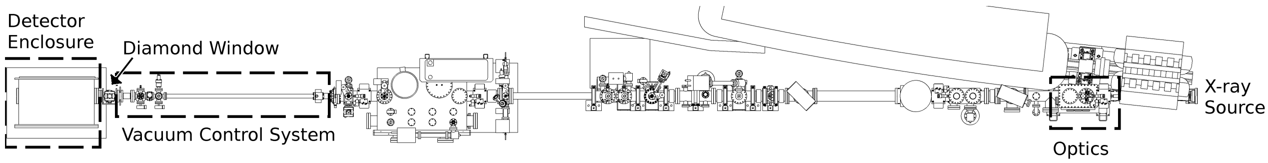

Figure 1: Overhead view of our beam line

A thin ($4\mu m$) diamond window[3] separates high quality CESR vacuum from the relatively dirty vacuum of the detector enclosure. The window transmits 76% of the x-rays at 2.5keV, and is supported by a thick silicon frame; the $4\mu m$ membrane region is 2mm (horizontal) x 6mm (vertical).

SUMMARY AND PROSPECTS

We successfully commissioned beamline upgrades such as the vacuum control system and the diamond window, which resulted in higher photon flux than our previous set up. This increase of flux led to our first beam size measurements with the CA and FZP [2]. Future plans include the addition of a second beamline to allow for beam size measurements for both electrons and positrons.

REFERENCES

[1] J.W. Flanagan *et al*, TH5RFP048

[2] J.P. Alexander *et al*, TH5RFP027

[3]Fabricated by Diamond Materials GmbH, Freiburg