BUNCH-BY-BUNCH INSTRUMENTATION UPGRADES FOR CESR, BASED ON REQUIREMENTS FOR THE CESR TEST ACCELERATOR RESEARCH PROGRAM*

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Abstract

The research focus of the CESR Test Accelerator program requires new instrumentation hardware, software and techniques in order to accurately investigate beam dynamics in the presence of electron cloud effects. These new instruments are also required to develop low emittance beam conditions which are key to the success of the damping ring design for the International Linear Collider. This paper will detail some of the architecture and tools which have been developed to support these efforts. Emphasis will be placed on the 4 ns bunch-by-bunch Beam Position Monitoring system as well as the 4 ns capable x-ray Beam Size Monitor.

CESR INSTRUMENTATION SUPPORT

A structure of supporting hardware and software has been developed to support the instrumentation required for the CESR Test Accelerator (CesrTA) program.. Some of the components of this structure are listed below:

- Matlab based control and analysis software
- Custom C based control and analysis software
- Standardized data formats with shared file input/output routines
- Common low level communication interfaces
- Common timing synchronization and triggering

BPM DEVELOPMENT

A new turn-by-turn beam position monitoring system has been developed. This system allows for turn-by-turn multi-bunch measurements of 4 nS spaced bunches. Some of the key design goals of the new system are as follows:

- Front-end bandwidth of 500 MHz
- Absolute position accuracy of 100 um
- Single-shot position resolution of 10 um
- Differential position accuracy of 10 um
- Channel to channel sampling accuracy of 10 pS
- BPM tilt errors of 10 mrad or less

Performance of the bpm system has been shown to be in line with these goals. Fig.1 shows vertical orbit differences between pairs of detectors located close together on a single vacuum chamber. The histogram contains 256k turns of data. The single unit sigma is shown on each plot and is substantially consistent with our design goals.

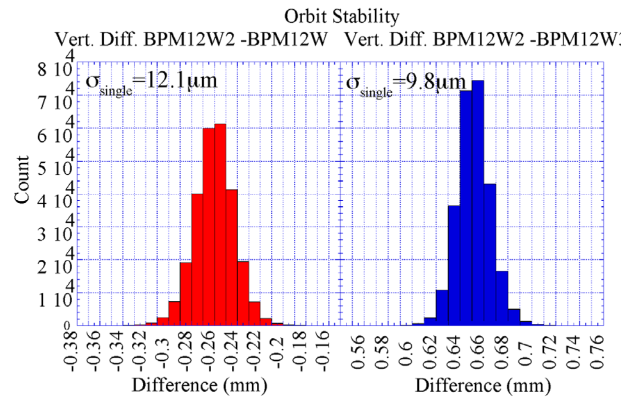

Fig 1: BPM Stability Measurement Results

XBSM HARDWARE

The x-ray Beam Size Monitor (xBSM) [1,2,3,4] has been developed in conjunction with the Cornell High Energy Synchrotron Source. Existing beam lines have been utilized while optics and detectors were designed specifically for the monitor. The x-ray source is a dipole magnet which is part of CESR. X-rays pass through the evacuated beam line and a set of optics elements. There are three optics elements that can be used: a vertically limiting slit, a Fresnel zone plate and a coded aperture. The layout of the XBSM experimental set up is shown in figure 2.

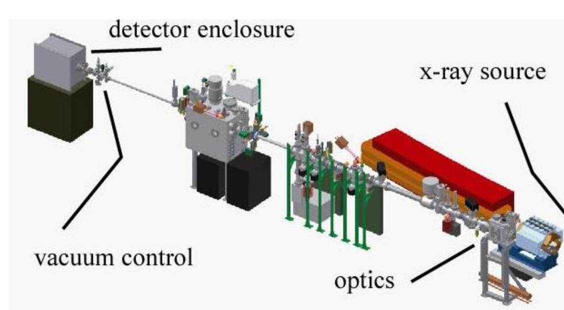

Fig 2: XBSM Layout

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The **vertically limiting slit** operates as a pin-hole lens. The slit has been adjusted to be about 50µm in height, which gives the minimum image height. This slit size creates an image with width about (20 um x magnification). A smaller slit height would cause the image to broaden due to diffraction while a larger slit height would cause the image to broaden due to transmission.

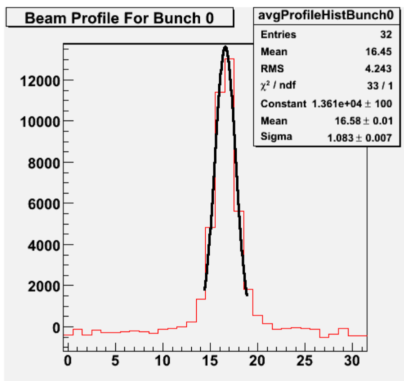

Fig 3: Vertically limiting Slit Image

Advantage:
The pin-hole image is largely insensitive to the x-ray wavelength within the synchrotron radiation spectrum.

Disadvantage:
While the pin-hole provides a simple peak, as shown in figure 3, the image is a convolution of the beam height and the slit height resulting in large uncertainties for beam size measurements below about 16µm.

The image of the **Fresnel Zone Plate** (FZP) is a diffraction pattern and sensitive to the x-ray wavelength. There is a central peak due to designing the x-ray beam and FZP to focus near the maximum of the x-ray wavelength distribution.

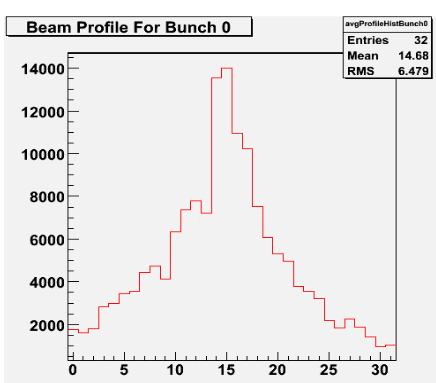

Fig 4: Fresnel Zone Plate Image

Disadvantage:
The image shown in figure 4 is without the use of a monochromator; it has a broad underlying distribution of out-of-focus x-rays. Use of a monochromator eliminates the broad component but does not allow enough x-ray flux for useful turn-by-turn measurements.

Advantage:
The central peak of the image is a focus with natural width less than one pixel width; it provides useful beam size measurements to the smallest beam size. Turn averaging and fitting procedures to extract this information are being developed.

The image of the **Coded Aperture** shown in figure 5 is a combination of transmission and diffraction resulting from the 8 slits ranging in size from 10 to 40µm.

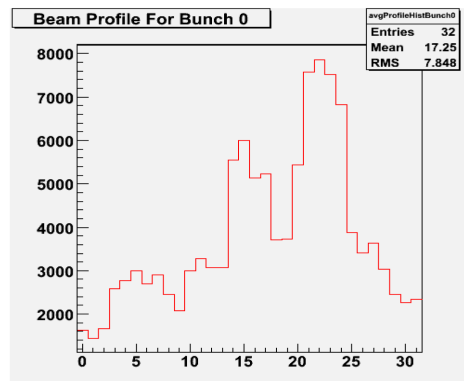

Fig 5: Coded Aperture Image

Advantage:
As in the case of the vertically limiting slit, the imaging is relatively insensitive to variations in the wavelength. The resolving power of the coded aperture has been compared to that of the Fresnel zone plate both without the use of a monochromator. Data was collected in "slow scans" for the two imaging devices, for two beam sizes. For each imaging device, the RMS of the difference between images from different beam sizes is an indication of the resolving power. The RMS difference for the coded aperture was 1.7x greater than that of the Fresnel zone plate (for the same change in beam size and normalized for incident photon flux), indicating that the beam size resolving power of the coded aperture is superior. The coded aperture is discussed in further detail elsewhere [5].

A Challenge:
In the future, we will develop the fitting procedures necessary to exploit the improved information provided by the multiple-peaked image.

HIGH SPEED DIGITIZER DEVELOPMENT

To match the characteristics of the ILC damping ring design, CESR is being upgraded to operate with 4ns bunch spacing. The new readout system for the XBSM provides 32 parallel 250MHz digitizers. Variable gain amplifiers have a range of 24dB. Digitization of the amplifier output, shown in figure 6, demonstrates successful operation of the digitizers and optimization of the amplifiers for 4 ns operation.

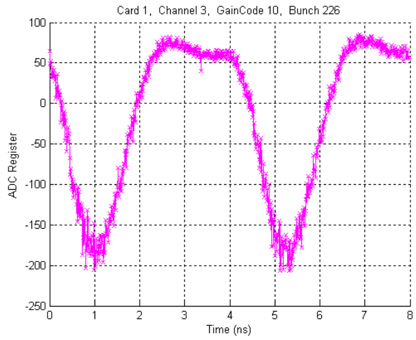

Fig 6: 4 nS Spaced Bunch Digitization

DETECTOR DEVELOPMENT

The detector is a vertical array of 32 InGaAs diodes with pitch 50µm and horizontal width 400µm. The InGaAs layer is 3.5 µm thick, which absorbs 73% of photons at 2.5keV; there is a 160nm Si_3N_4 passivation layer. The time response of the detector is sub-nanosecond. As shown in figure 7, sequential diodes are read out on opposite sides of the array with 100 µm spacing; diodes are connected, via wire bonds, to a conventional 250 µm center-to-center printed circuit board.

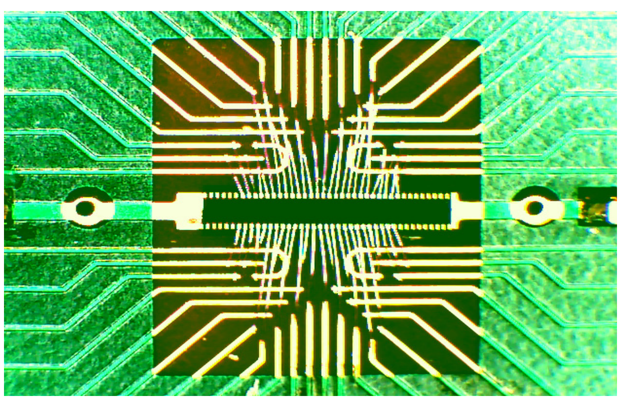

Fig 7: xBSM Detector

SUMMARY

The CesrTA program has necessitated the development of many pieces of instrumentation software and hardware. These pieces have all been integrated into a supporting framework upon which the Beam Position Monitors and X-ray Beam Size Monitors depend.

The upgraded 4 ns x-ray Beam Size Monitor is undergoing commissioning and development while providing useful experimental results for the program. Future developments in analysis techniques will allow the program to achieve the program goals in support of the International Linear Collider design effort.

REFERENCES

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