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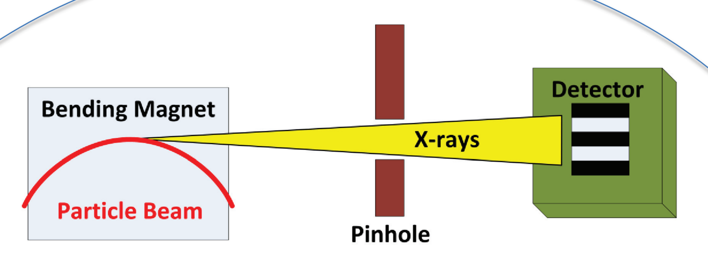
# DEVELOPMENT AND COMMISSIONING OF THE NEXT GENERATION X-RAY BEAM SIZE MONITOR IN CESR *

*N.T. Rider, S.T. Barrett, M.G. Billing, J.V.Conway, B. Heltsley, A. Mikhailichenko, D.P. Peterson, D. Rubin, J.P. Shanks, S. Wang,*
*CLASSE, Cornell University, Ithaca, NY 14853, U.S.A*

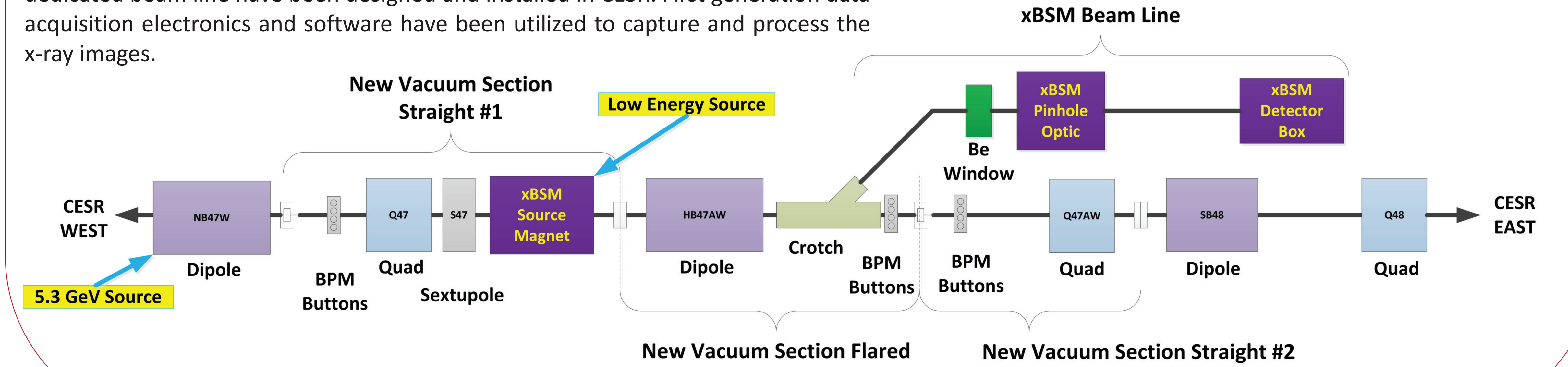
## Overview

The Cornell Electron Storage Ring (CESR) provides electron and positron beams which are used for accelerator research and as a synchrotron light source. Both of these applications require diagnostic equipment and instrumentation to maintain particle beam and x-ray quality. The Next Generation x-ray Beam Size Monitor (NGXBSM) is part of a suite of instrumentation developed for this purpose. The NGXBSM is a natural evolution of the instrument which was developed during the early stages of the CESRTA program. This instrument images x-rays from a bending magnet through a pinhole optical element on to a 32x1 pixel linear array detector.

The normal bend magnet which is used as a source at 5.3 GeV has a field strength of 0.972 kG when CESR is operated at 2.085 GeV. This is not sufficient to provide usable x-rays. Therefore an electro-magnet pair has been designed and constructed to support operation at low energy. This pair, in conjunction with an additional CESR magnet, provides the horizontal beam trajectory necessary to generate x-rays which are of useful energy and direction. In order to transfer the x-rays from CESR to the detector, a flared vacuum chamber, beam line crotch, beryllium window and dedicated beam line have been designed and installed in CESR. First generation data acquisition electronics and software have been utilized to capture and process the x-ray images.




Fundamentally, the xBSM is a pinhole camera which images the synchrotron radiation fan onto a pixel detector. Based on the calculated point response function and the optical characteristics of the pinhole and beamline, a vertical beam size is calculated.

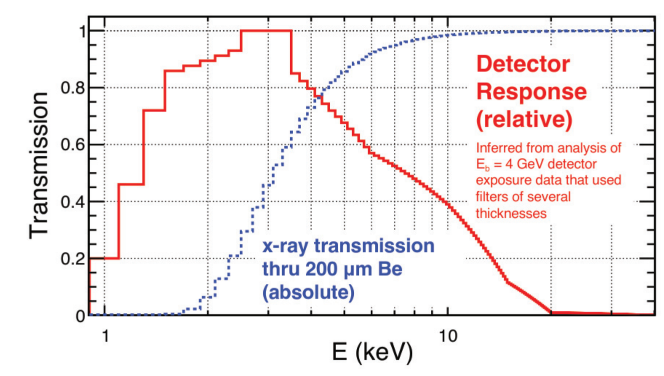


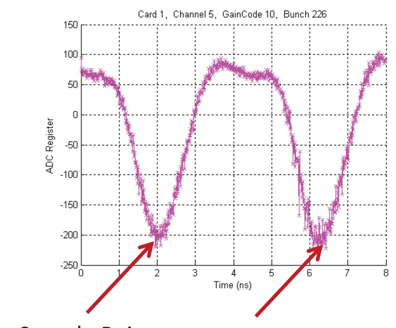

## Abstract

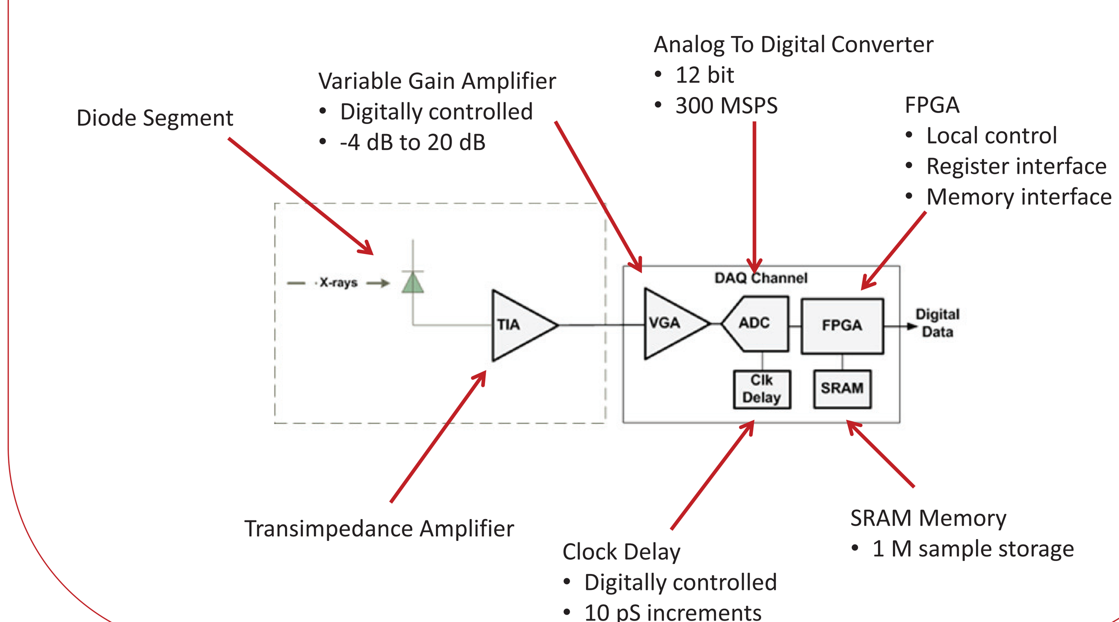
The CESR Test Accelerator (CESRTA) program targets the study of beam physics issues relevant to linear collider damping rings and other low emittance storage rings. This endeavour requires new instrumentation to study the beam dynamics along trains of ultra-low emittance bunches. A key element of the program has been the design, commissioning and operation of an x-ray beam size monitor capable, on a turn by turn basis, of collecting single pass measurements of each individual bunch in a train over many thousands of turns. The x-ray beam size monitor development has matured to include the design of a new instrument which has been permanently integrated into the storage ring. A new beam line has been designed and constructed which allows for the extraction of x-rays from the positron beam using a newly developed electro magnet pair. This new instrument utilizes custom, high bandwidth amplifiers and digitization hardware and firmware to collect signals from a linear InGaAs diode array. This paper reports on the development of this new instrument and its integration into storage ring operation including vacuum component design, electromagnet design, electronics and capabilities.

## Detector

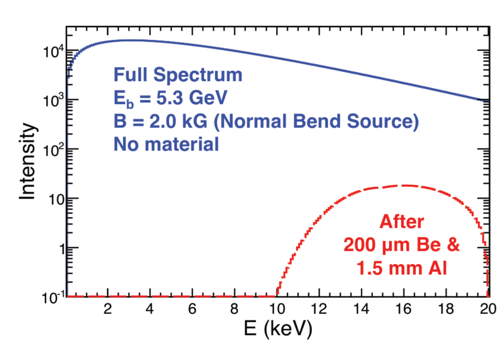
The standard detector is a vertical array of 32x1 InGaAs diodes with a 50µm pitch and horizontal width of 400µm. The diode array is mounted to a printed circuit board and the diode connections made with wire bonds. The InGaAs layer is 3.5 µm thick, which absorbs 73% of photons at 2.5keV; there is a 160nm Si3N4 passivation layer. The time response of the detector is sub-nanosecond.



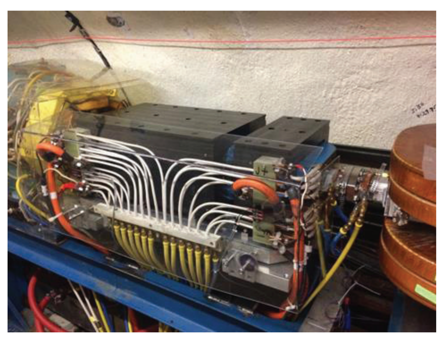

## High Energy x-ray Source

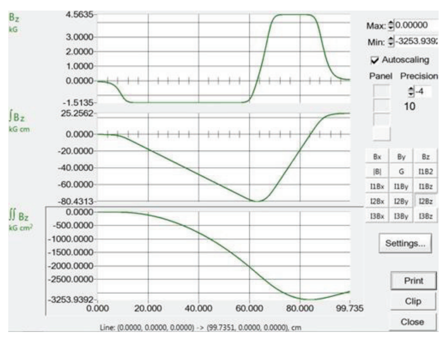


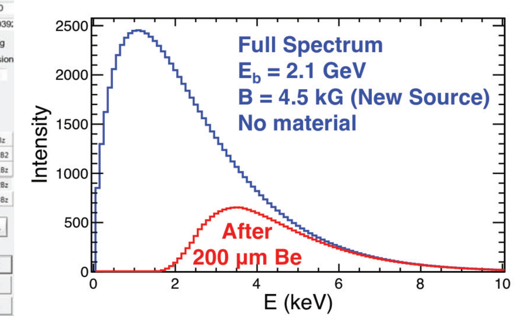

For CESR operations at 5.3 GeV an existing normal bend magnet is used as the x-ray source. This magnet has a field strength of 2 kG. A 1.5 mm aluminum filter is required at 5.3 GeV to lower the intensity so as to not saturate the detector. This filter is removable for operation at lower CESR beam energies.

* Intensity is defined to be electromagnetic energy per unit time per unit area per unit current perpendicular to the x-ray beam in arbitrary units

## Low Energy x-ray Source

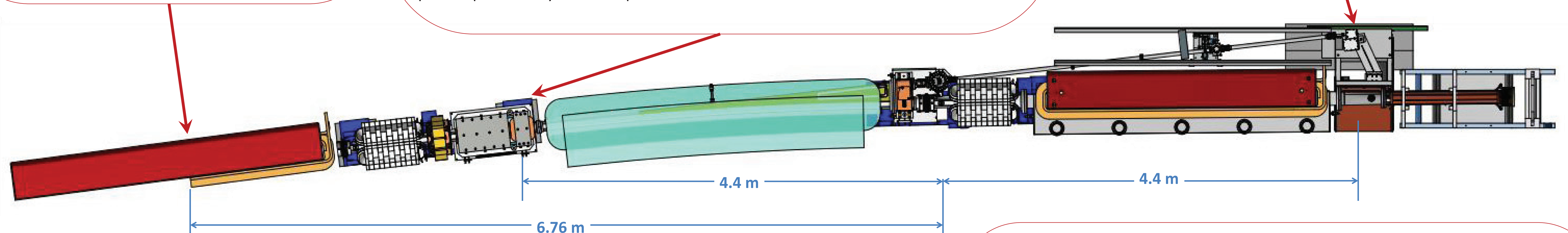




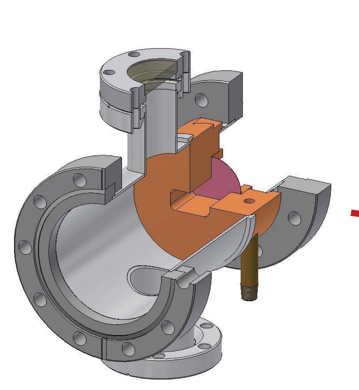



The new magnet was limited to two poles due to spatial constraints. An additional trim winding, which is part of a normal CESR bending magnet, is used to close the beam orbit disturbance created by the NGXBSM source magnet. Maximum horizontal beam orbit displacement within the source magnet is calculated to be 5.2 mm radially outward.

The two magnet poles are powered by a common 60 Volt, 300 Amp switched power supply. The current provided by the supply is controlled via the CESR control system. This allows for a design field of 4.5 kG in the shorter pole and 1.5 kG in the longer pole. The ratio between these two magnet poles provides the proper CESR beam trajectory for x-ray transmission. A 25 Amp active shunt is connected around the long pole and allows for precision adjustment of this ratio. The x-ray source point is provided by the short pole.



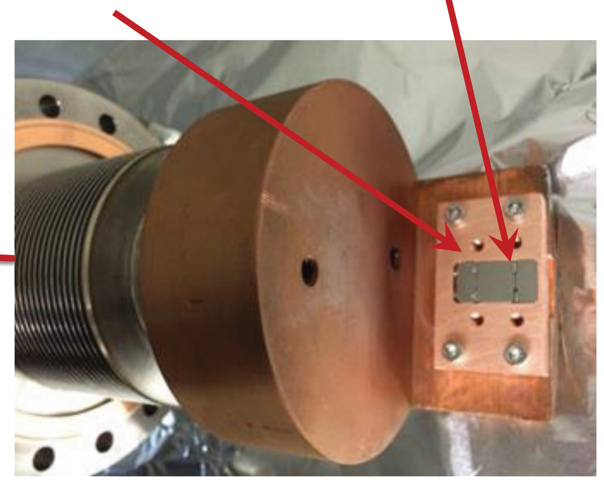

## Beam Line Components



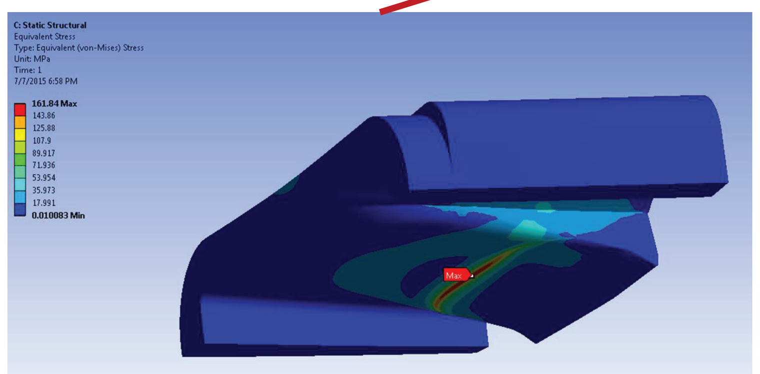
200 micron Beryllium Window provides vacuum isolation and x-ray filtering

35 micron Pinhole

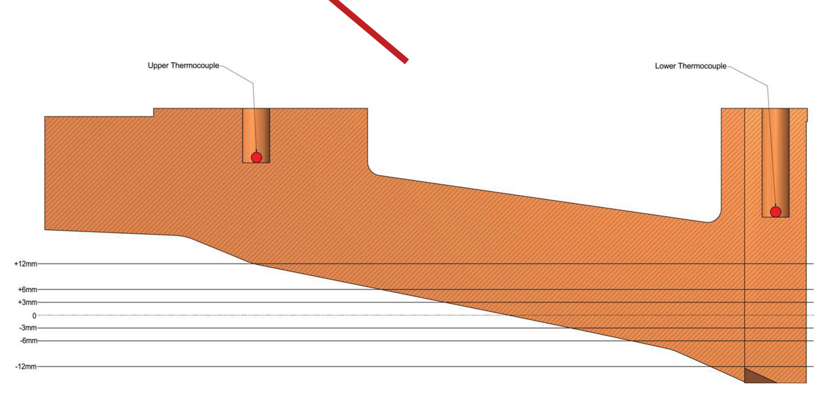
200 micron Pinhole



xBSM Pinhole Optics



Beam Line Crotch Thermal Analysis



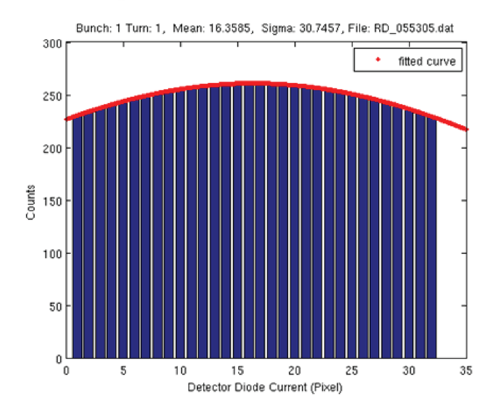
Beam Line Crotch Profile

A copper beam line crotch was designed to provide separation between the CESR and x-ray beam pipes. This crotch is water cooled and has a variable slope face which is designed to absorb synchrotron radiation across the operating conditions of CESR

## Commissioning

X-ray Fluorescence

5.3 GeV x-ray Fluorescence



2.085 GeV Detector Readout

At this point in the project, x-rays have been delivered to the detector at both 2.085 GeV and 5.3 GeV. During alignment, a digital camera was used to capture the x-ray beam position on the aluminum flag at 5.3 GeV. Once basic alignment was achieved, the detector and accompanying electronics were used to capture an x-ray profile of the straight through beam at 2.085 GeV.

## Future Efforts

The motorized pinhole stage has been completed and will be installed prior to the CESR accelerator start up in October 2016. It is expected that alignment will be completed and measurements at 5.3 GeV will be made using the 35 and 200 micron pinhole optics. The instrument will then be used for experimental measurements as part of normal CHESS operations. 2.085 GeV alignment and measurements will be made during the December 2016 CESRTA run. Additional efforts to improve the quality of the detector itself are being planned.

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