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# INITIAL PERFORMANCE OF THE WIRE IMAGING SYNCHROTRON RADIATION DETECTOR*

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## *Abstract*

This paper describes the initial performance of a novel detector that measures the positions of intense synchrotron-radiation beams with high precision. Two detectors of this kind are used for the precision energy spectrometers of the Stanford Linear Collider (SLC). The detectors accurately determine the distance between pairs of intense synchrotron beams of typically 1 MeV photons, which are emitted by the primary electron and positron beams of the SLC. The detectors intercept the synchrotron beams with arrays of fine wires. The ejection of Compton-recoil electrons leaves positive charges on the wires, enabling a determination of beam positions.

## INTRODUCTION

The Wire Imaging Synchrotron Radiation Detector (WISRD) [1] is a novel detector for the position measurement of intense high-energy synchrotron radiation beams. Two WISRDs are installed for the two precision energy spectrometers [2] of the SLC. The spectrometers are used to determine center-of-mass energies of the colliding electron and positron beams.

Figure 1 shows schematically the energy spectrometer for the electron beam. Two horizontally bending dipole magnets, one upstream and one downstream the vertically bending spectrometer magnet, generate two horizontal swaths of intense synchrotron radiation. The photons of the synchrotron radiation stripes have an energy typically of 1 MeV [3]. The full width of the stripe at the detector is of the order of 1000 $\mu$m. Given the strength of the analyzing magnet and its distance upstream from the detectors, the vertical separation between the two synchrotron stripes determines the SLC beam energy. The vertical separation is about 0.27 m. The goal for the WISRD is to measure this distance within a few parts in ten-thousand. This measurement will be independent from the measurement performed by the Phosphor Screen Monitor (PSM) [4], which has been used until now for the determination of the SLC center-of-mass energies.

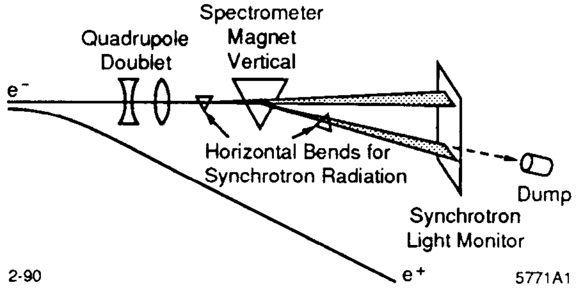

Fig. 1: Conceptual design of the extraction line spectrometer.

This paper briefly reviews the WISRD system and reports on its initial performance. More details about the detector design and read-out electronics can be found elsewhere [1, 5, 6].

## DESCRIPTION OF THE WISRD SYSTEM

The WISRD for the SLC electron spectrometer is shown in Fig. 2. The detector for the positron spectrometer is virtually identical and not explicitly discussed here. At the heart of the detector are two arrays of very fine copper wires, which serve as targets for the two collimated horizontal synchrotron radiation stripes. Both arrays consist of 96 horizontal wires. The wires are 75 $\mu$m in diameter and have a 100 $\mu$m center-to-center spacing.

The wires intercepting the synchrotron radiation photons eject electrons due to predominately Compton scattering. The synchrotron radiation is sufficiently intense to result in positive charges on the wires that can be measured directly. The observed charge as a function of the wire number allows the reconstruction of the profiles and hence the centroids of the two synchrotron stripes. Since the wire positions relative to each other are known to high precision, the vertical distance between the two stripes can be determined.

Numerical calculations and Monte Carlo simulations predict a total charge of 180 $fC$ per stripe distributed over all wires for an electron bunch of $1 \cdot 10^{10}$ electrons and for

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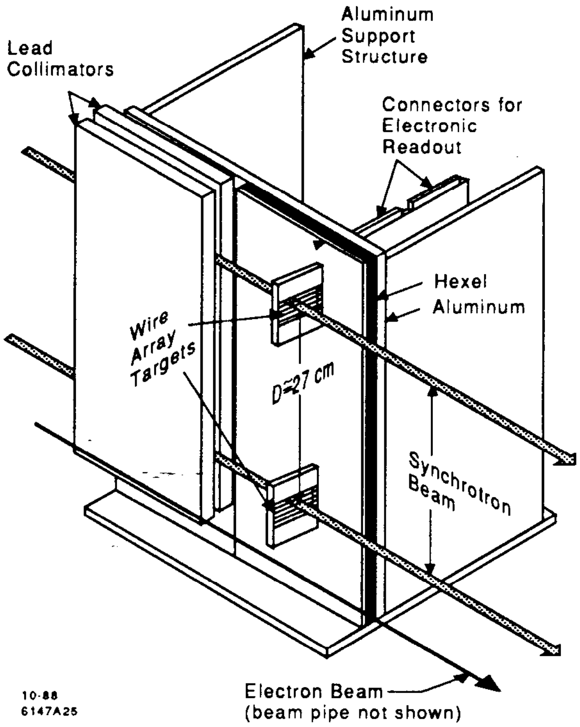

Fig. 2: An isometric view of the wire imaging synchrotron radiation detector (WISRD).

a stripe length collimated to 1 cm. This signal is detected with the data acquisition system shown in Fig. 3. Each detector wire is connected to one channel of a LeCroy HQV-820 charge sensitive amplifier followed by a pulse-shaping circuit. Twenty-four shaped pulses are sampled twice by a parallel-in, serial-out analog memory circuit (CDU [7]). The timing of the samples is controlled by software [6]. The serial output of the analog memory circuit is digitized by a 12-bit ADC, then encoded and transmitted through a 300-m-long cable to a CAMAC data acquisition system. A VAX 8600 reads the CAMAC crate and writes the data to tape.

The proximity of the WISRD is a harsh environment for electronics. To suppress electromagnetic interference, the electronics shown in Fig. 3 is housed in a RF shielding box. The RF box is located about 4 m away from the detector to avoid radiation damage to the electronics from the synchrotron radiation beam halo.

## INITIAL WISRD DATA

Initial data have verified the basic components of the WISRD system and provided pointers for further improvements.

The WISRD electronics has been designed to allow extensive testing and calibration of the system with test pulses [5]. Out of the nearly 400 channels of electronics, 4 were found to be dead. A major challenge in the fabrication of the detector target arrays was to avoid accidental electrical contacts between pairs of detector wires; only four detector wire pairs were found to be shorted. The cross talk between channels due to coupling in the detector and the electronics is 5% on average.

The readout electronics permits the measurement of the shape of an electronic pulse after the shaping stage. Figure 4 shows such a measurement for a typical

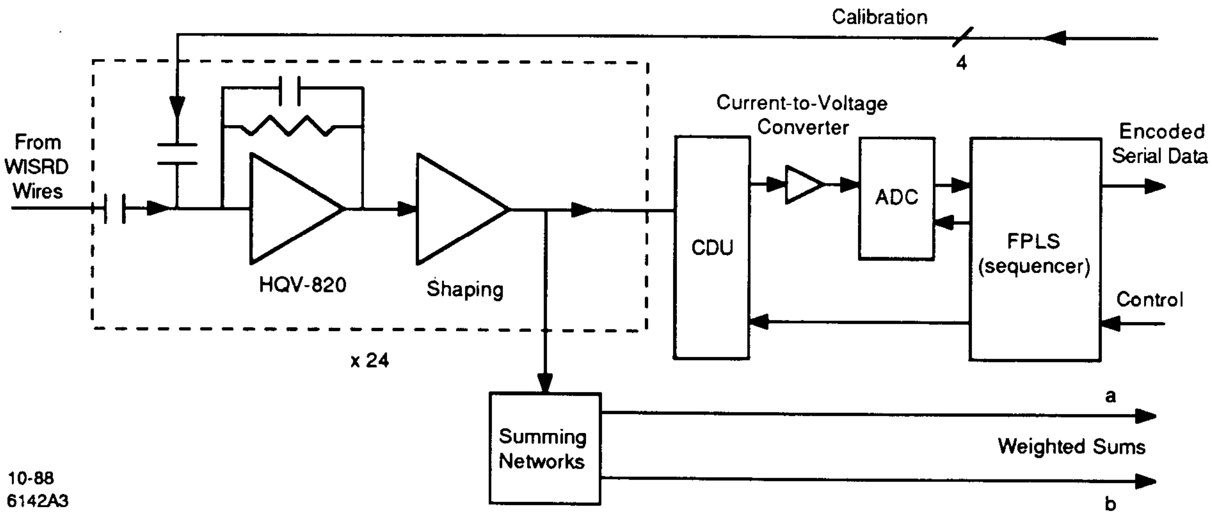

Fig. 3: The Data Acquisition (DAQ) Module receives signals from 24 wires in the WISRD wire array, amplifies and shapes the signals, and stores two samples of each shaped output in a parallel-in, serial-out analog memory (CDU) on every beam crossing. After data acquisition, the analog samples are digitized and encoded for transmission. The DAQ Module also forms two weighted sums of the charge distribution on its wires.

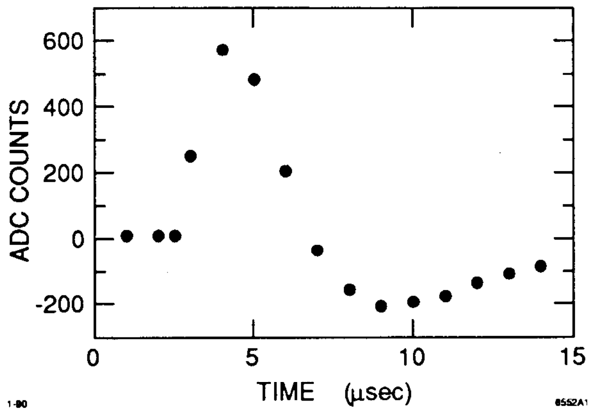

Fig. 4: A calibration pulse responds after shaping as measured by the CDU chip. This shape has been reconstructed by taking the difference of the two CDU samples, where one sampling occurs shortly before the calibration pulse onset and the other sampling is scanned in 1 $\mu$sec steps across the pulse.

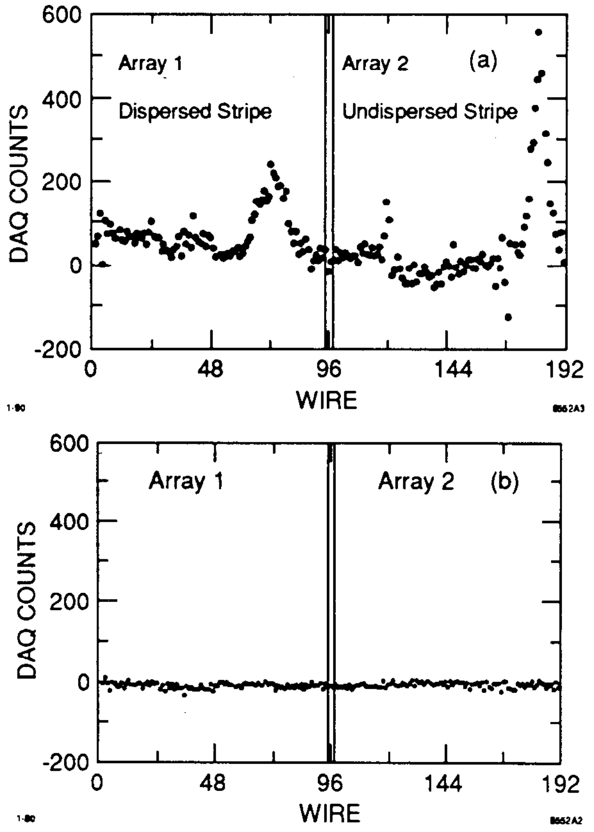

Fig. 5: (a) Typical signal distribution from the two synchrotron radiation stripes hitting the two wire arrays. The right peak is from the stripe emitted by the undispersed electron beam; the left peak, from the stripe emitted by the dispersed electron beam. (b) Same plot as (a); however, the signal for each wire has been sampled immediately before beam by-passing. Unlike (a), no background is seen.

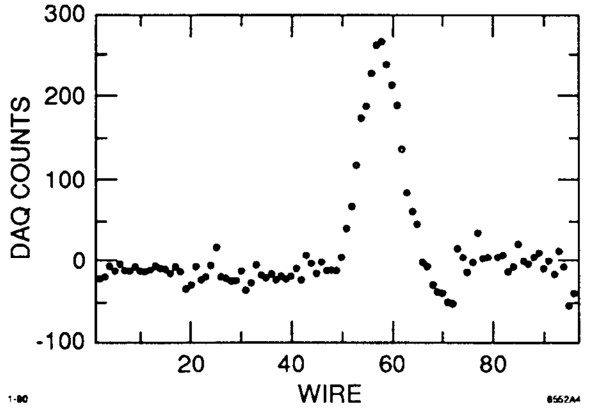

Fig. 6: A synchrotron stripe (integrated over 10 pulses) as seen in an earlier electronics and data acquisition configuration. This plot shows that beam-correlated background as in Fig. 5(a) can be widely suppressed.

channel. Such data are useful for tuning the sampling times for optimization of signal amplitude and background suppression. In normal data analysis, the signal amplitude for a wire is computed by subtracting the two recorded samples of the analog pulse shape. Nominally, the first sampling time is on the positive peak and the second sampling time is on the negative peak.

The data presented in Fig. 5(a) show signals corresponding to one SLC pulse containing roughly $10^{10}$ electrons. The signals are corrected for gain and pedestal variations. Wire numbers from 0 to 95 refer to the lower wire array in Fig. 2, and the remaining wire numbers correspond to the upper array. The peaks centered around wires 75 and 180 are due to the synchrotron beams. In addition to the desired signals, beam-correlated backgrounds are present, as can be verified by shifting the sampling times to times just before the arrival of the beams; see Fig. 5(b).

Work is in progress to reduce the beam-correlated background. Initial data provide guidance for further improvements of the system: sample time adjustments; pulse shape optimization; and electromagnetic shielding improvements. The background has been observed to vary significantly with these parameters; for example see Fig. 6, which shows data from an preliminary test configuration. With improvements in both hardware and software, it is anticipated that beam-correlated backgrounds will be effectively suppressed.

The prominent synchrotron-beam signals seen in Fig. 5 are typical of data that are now routinely collected by the WISRD system. They show the features that were anticipated in the detector design. The right peak seen in Fig. 5(a) is produced by the synchrotron stripe emitted upstream of the spectrometer magnet by the SLC electron beam. Monte Carlo simulations imply that this width is dominated by the $1/\gamma$ production angle characteristic of synchrotron radiation. The left peak is produced by the synchrotron stripe emitted by the SLC electron beam after being dispersed by the spectrometer magnet; hence it is wider. The expectation that the areas under the two peaks be equal is also consistent with the data.

## DISCUSSION OF ERRORS

A design goal for the WISRD is to determine the positions of the centroids to 25 $\mu$m. This corresponds to a contribution in the SLC beam energy error of about 4 MeV. Contributions to the measurement error come from uncertainties in the wire geometry, electronic noise, calibration constants uncertainties, and electromagnetic backgrounds:

- Data bases containing redundant measurements of wire positions [8] are available for the determination of the wire geometry. The vertical distance between any two wires in the detector can be calculated [1] to 10 $\mu$m.
- Electronic noise inherent to the electronic system contributes an uncertainty to the centroid measurement. This centroid uncertainty contribution has been estimated [5] to be 9 $\mu$m for beam currents of $10^{10}$ electrons per pulse. Note that the effect of random noise reduces in significance for analysis involving data from more than one SLC beam pulse.
- Calibration data are used in the calculation of gain and pedestal corrections of the data. Calibration uncertainties contribute [5] typically 10 $\mu$m to the centroid error.

The combined effect of the above three sources of error is about 17 $\mu$m. We are confident that the beam-correlated background can be sufficiently suppressed by hardware and software to meet the design goal of 25 $\mu$m.

## CONCLUSION

The WISRD is a novel detector that monitors with high precision the positions of intense high-energy synchrotron radiation beams. It is going to be a key element of the precision spectrometers that records the center-of-mass energies of the SLC.

The WISRD detector and its electronics are in place and fully operational. The expected signal due to the synchrotron beams has been confirmed. This validates the design of detector and its electronics. Preliminary measurements indicate that it is possible to determine the synchrotron stripe positions to better than 25 $\mu$m.

## ACKNOWLEDGMENTS

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