A BEAMLOSS DIAGNOSTIC SYSTEM FOR CESR

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Abstract

A diagnostic system utilizing commercially available fast analog digitizers has been developed at the Cornell Electron Storage Ring (CESR) for capturing and analyzing transient beam behaviour preceding rapid beamloss. The diagnostic system is based on a turn-by-turn data acquisition system which records beam position information from individual bunches in CESR, as well as RF system diagnostic signals. An accompanying display and analysis package has been developed to aid in diagnosing the causes of beamloss events. Examples of beamloss mechanisms are described.

1 INTRODUCTION

Loss of all or a portion of the stored beam current at a collider facility represents a substantial penalty in operational efficiency. The cost in time to refill the storage ring and collide the beams can become significant if beamlosses are frequent. Furthermore, as the stored beam current in CESR is increased, high-current phenomena may manifest themselves most noticeably as the causes of rapid beamloss. Therefore, understanding the causes of beamloss is central to identifying current limiting phenomena, and constitutes an important aspect of the ongoing program of addressing beam current limits in CESR.

By continuously recording beam position information for a selection of bunches in CESR, it is possible to observe the behaviour of the beam prior to beamloss. In addition to the beam position information, we have found it particularly useful to record fast diagnostic signals from the RF system as well, in order to better understand the interaction between the beam and RF system. The turn-by-turn diagnostic system described in this paper is part of a set of diagnostic tools in use at CESR for evaluating beamlosses.

2 INSTRUMENTATION

2.1 COMET^{TM} Digitizers

The turn-by-turn data acquisition system is shown in figure 1. The heart of the system is a set of COMET^{TM} VME multichannel analog digitizer boards manufactured by Omnibyte, Inc.[1] Four input channels per board are digitized with individual 12-bit ADCs at rates up to 5 MHz. Digitized data from each channel is sequentially stored in its own 128 kbyte buffer (for a total of 512 kbyte of on-board memory). Since each data word is 16 bits, each channel has a buffer depth of 64k samples.

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[1]Omnibyte, 245 West Roosevelt Road, West Chicago, Illinois, 60185

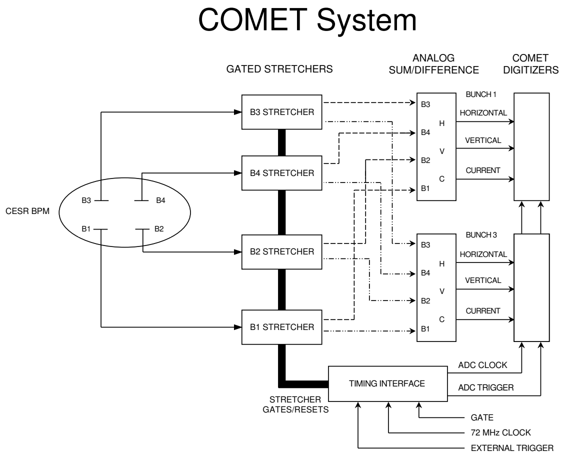

Figure 1: The turn-by-turn data acquisition system. Four beam position monitor signals are gated, stretched, and combined to provide bunch-by-bunch horizontal, vertical, and current signals. The system shown provides signals for one beam species. Another identical system provides signals for the other species.

The digitizer boards support several operating modes. In the "one-shot" mode, a specified number of samples is recorded and sequentially written in local memory *following* a trigger. In the "circular buffer mode," the inputs are continuously sampled and written to on-board RAM, "wrapping-around" to the beginning of the buffer when the end of buffer is reached. In this mode, data-taking is initiated via a software enable, and stopped with a hardware trigger. The number of samples acquired after the "stop" trigger is programmable in software. The turn-by-turn data acquisition system operates in the "circular-buffer-mode" for beamloss monitoring.

The COMET^{TM} on-board RAM is a dual port data buffer that is accessible from the host CPU (a CESR control system VAX) as VME address space through a TurboChannel to VME adapter. The address space is mapped to VAX/VMS global sections so that access to the on-board RAM is accomplished with a read or write operation to an address within the global section.

2.2 CESR BPM Processing

CESR presently collides trains of closely spaced bunches. Each beam consists of 9 trains with 2 bunches per train, spaced by 42 nsec. The CESR Phase II design calls for 3 bunches per train, and an upgrade (CESR Phase III) will allow operation with 5 bunches per train. The minimum bunch spacing within a train is 14 nsec, and the spacing between trains is ∼280 nsec. Due to the closely spaced bunches, narrow gating of beam position monitor signals is necessary to retreive information from a single bunch.

Signals from four individual beam buttons of a standard CESR BPM are brought from the tunnel to the control room for processing. The receiver is a gated stretcher module developed for CESR's digital transverse feedback system [1]. The receiver uses GaAs fast gates to shunt the beam signal into one of five parallel stretcher channels, one for each 14 nsec "bucket" in a train providing individual stretched output for each bunch in a train. The stretcher diode is reset before the next train passage. Two sets of gated stretchers are required to provide positron and electron signals.

The set of four stretched outputs (one for each beam button) for each bunch in a train is then combined in an analog sum/difference board to provide a horizontal position error signal, a vertical position error signal and a bunch current signal. Sets of these signals are available for all bunches in CESR.

Local timing signals are generated by a timing interface card, one for positron timing and another for electron timing. These cards generate gates and reset signals for operation of the stretcher modules, and ADC clock signals used by the COMET cards. In addition, the timing interface card synchronizes an external trigger to local timing.

In order to obtain a beamloss trigger, a single beam button signal is stretched and then differentiated. A threshold is set on the differentiated output to provide a beamloss trigger. During normal CESR operation with ∼300 mA of stored beam current, the threshold corresponds to loss of approximately ∼150 mA.

In addition to beam position and intensity signals, we have found it valuable to record a set of diagnostic signals obtained from the four CESR RF cavities on a turn-by-turn basis. These include RF-enable signals, forward power, reflected power, tuning angle, and cavity phase.

At present, the beamloss diagnostic system uses 5 COMET^{TM} ADC boards to digitize a total of 20 beam position and RF system signals. We plan to increase the capacity of the system to 40 channels.

3 SOFTWARE

The beamloss diagnostic system runs continuously during CESR operation. When a beamloss is detected, a subset of the total information available (the total RAM is ∼2.5 Mbytes) is written out in three data files. One data file contains 2048 turns (a CESR turn is 2.56 μsec) of BPM data for one bunch in all 9 trains of electrons and positrons. A second data file contains 2048 turns of BPM data for a single e^+ bunch and a single e^- bunch and 2048 samples of RF system data. A third data file contains RF system data sampled at the train spacing frequency (∼280 nsec). When a beamloss is detected, data is made available on a control-room screen for diagnosis.

The beamloss data is stored on disk and is available for viewing and analysis. An X-windows based data viewer and analysis package has been developed for studying and analyzing beamloss data.

4 BEAMLOSS ANALYSIS

Although we have seen a wide variety of beamloss mechanisms at work in CESR, most beamlosses in the past year may be placed into one of three categories: i) RF system trips, ii) beam instabilities, and iii) electrostatic separator action.

4.1 RF System Trips

The CESR RF system protection circuits may trip for a variety of reasons. Common occurances are unacceptably high vacuum conditions or high reflected power (VSWR trips).

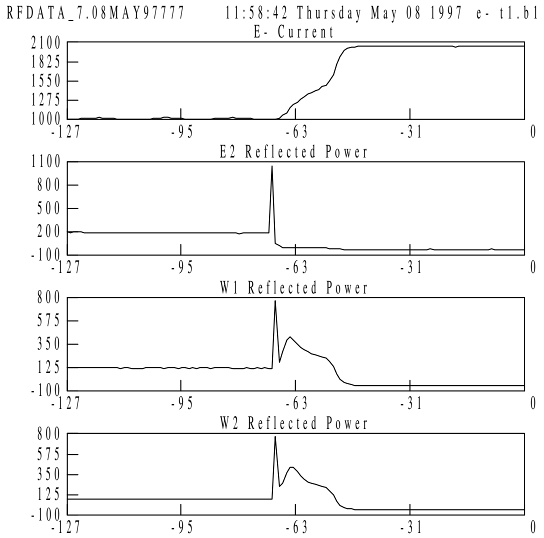

Figure 2: Beamloss due to an E2 RF cavity reflected power trip. The e^- current (decreasing upward) and RF cavity reflected power signals are shown for 128 turns bracketing the beamloss.

One such particularly interesting high reflected power event is shown in figure 2. The figure shows the reflected power of three CESR RF cavities together with the stored e^- beam current for the final 128 turns bracketing the beamloss. The e^- current begins to decrease near turn -65 (less current *increases* in the raw units) and has completely disappeared ∼20 turns later. The cause of the beamloss is the E2 cavity VSWR occuring near turn -70 which initiates removal of the forward power. The striking feature shown in this data is the lack of a beam signal in the E2 cavity. After the forward power is removed, the W1 and W2 cavities extract power from the beam, as seen by the increasing reflected power near turn -63. The E2 cavity, however, is incapable of being driven by the beam, as if the cavity were "shorted" for a period of time. It has the behaviour of an arc which takes some time to recover.

We have found that by processing the RF at high pulsed power we have been able to reduce the RF system trips substantially, and to increase the stored beam current in CESR.

4.2 Beam Instabilities

The total beam current in CESR is presently limited by a longitudinal dipole coupled bunch instability [2]. Figure 3 shows the horizontal position of a positron bunch for 2048 turns prior to beamloss. The lower figure is the corresponding frequency spectrum (shown as a function of fractional tune), showing a peak at the synchrotron tune $Q_s = 0.05$ and higher harmonics. The longitudinal oscillation frequency is readily seen in the horizontal signal because of dispersion at the BPM. The longitudinal oscillation grows without bound, eventually causing loss of beam near turn -100. A longitudinal feedback system is under development.

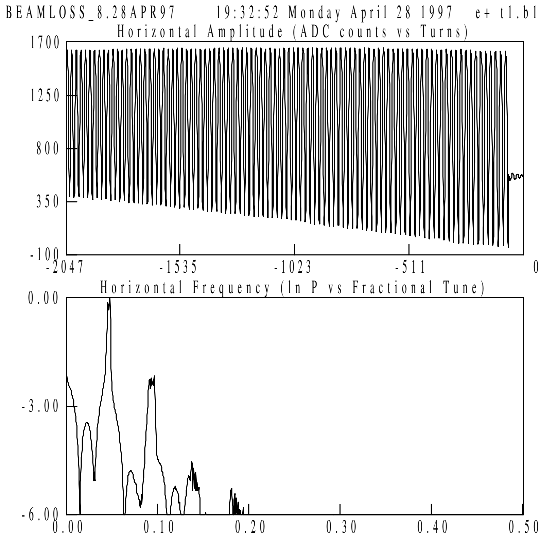

Figure 3: Beamloss due to a longitudinal coupled bunch instability. The horizontal position and frequency spectrum of a single bunch for 2048 turns prior to beamloss are shown.

4.3 Electrostatic Separator Action

CESR has four horizontal and two vertical electrostatic separators. As beam currents in CESR have increased, we have observed increased photocurrents on the separator plates. In the case of the vertical separators, this increased current has led to instabilities, sparks, trips, and loss of beam. Figure 4 shows the vertical position signal of a positron bunch for 1024 turns prior to beamloss. the vertical separator sparks near turn -255, and the beam is lost near turn -80. The lower curve is the corresponding frequency spectrum, showing a peak at the vertical tune $q_v = 0.41$. The photocurrents in the vertical separators have been reduced by installing permanent magnets to act as electron traps, and by biasing the separator plate voltages [3]

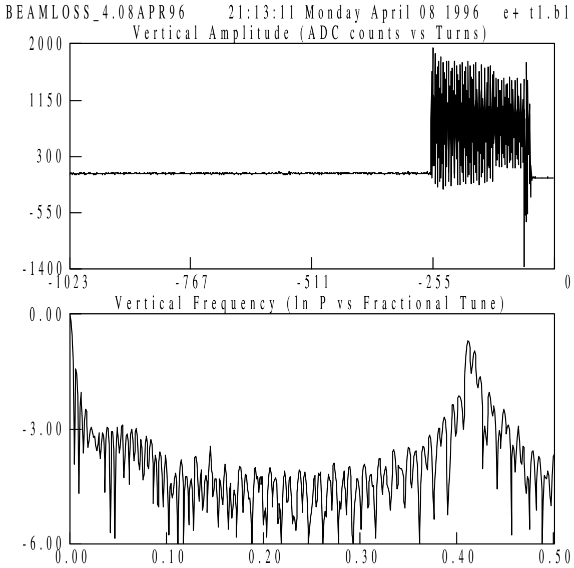

Figure 4: Beamloss due to a vertical electrostatic separator spark. The vertical position and frequency spectrum for 1024 turns prior to beamloss are shown.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

[1] J.T. Rogers et. al., "Operation of a Fast Digital Transverse Feedback System in CESR," Proc. 1995 Part. Acc. Conf, 2426 (1995).

[2] M. Billing, "Observation of a Longitudinal Coupled Bunch Instability with Trains of Bunches in CESR", these proceedings.

[3] S. Greenwald, "Photocurrents in Electrostatic Separators at CESR", these proceedings.