A BEAM TRACKING SYSTEM FOR USE IN ORBITAL DYNAMICS STUDIES

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The extremely small emittance ($< 0.05\ \pi\mu$m) and momentum spread ($< 1 \times 10^{-4}$) of the electron-cooled proton beams makes the IUCF Cooler Ring an ideal laboratory for the study of nonlinear beam dynamics with very high resolution. Various beam diagnostic methods are being developed for use in an upcoming series of nonlinear beam dynamics experiments using the Cooler Ring. The measurement of the evolution of the beam in phase space is the one with the highest priority.

A data acquisition system is being developed to track the position of a single beam bunch in transverse phase space on a turn-by-turn basis in the Cooler. This system consists of four major subsystems: (1) the front-end electronics, (2) the level control with signal conditioning, (3) the sample and hold (S/H) module and (4) the digitizer.

The front-end electronics consists of two existing beam position monitor (BPM) electrodes. For each electrode, amplifiers produce signals proportional to the beam intensity and the product of the beam position and intensity. The signal peak voltage is used in a feedback loop to adjust programmable 10 dB step attenuators with 10 increments to increase the dynamic range. After the attenuators, the short pulses (5–10 ns in length) are peak-detected by a passive RC circuit having a switch-selectable decay time to minimize errors due to timing jitter as they are sampled. The S/H modules use high speed S/H amplifiers having a 12 ns track-to-hold settling time. The output of two S/H modules are fed into a 2:1 analog multiplexer enabling a single digitizer to record both the position and intensity signals; the S/H electronics also reduce the required digitizer speed. The trigger clock for the S/H modules operates off the beam intensity signal and runs at the pulse repetition frequency divided by the rf harmonic number, which may be as large as 2.2 MHz. Transient recorders (TRs) with 12 bit resolution and 8192 channel sample buffers are used as the digitizers.

The TR is a CAMAC module which interfaces to the VAX network, allowing the use of IUCF data aquisition software to control the data aquisition and record the data. This has reduced the amount of software development necessary and produces some flexibility when making additions. It also allows various online analysis functions to be performed, such as calculating a fast Fourier transform (FFT) of the normalized beam position, or producing two dimensional histograms of the horizontal beam position at the two different BPM electrodes (x_1 vs. x_2).

This system has been tested using a 45 MeV proton beam. When the beam is kicked using a a horizontal kicker magnet, a coherent betatron oscillation of a beam bunch is induced. An FFT of the beam position from either BPM after the kick yields the fractional tune, as shown in Fig. 1. A Poincaré map, or phase space map, can also be generated from the data acquired by this system. Online, a simple plot of x_1 vs. x_2 on a turn-by-turn basis is representative of a phase space plot, an example of which is shown in Fig. 2.

The system signal to noise is determined by the input noise in the first amplifier ($0.5\ nV/\sqrt{Hz}$) and the electrode sensitivity ($V/I_{peak}x$), about $0.2/\beta\ \Omega/mm$. Consequently,

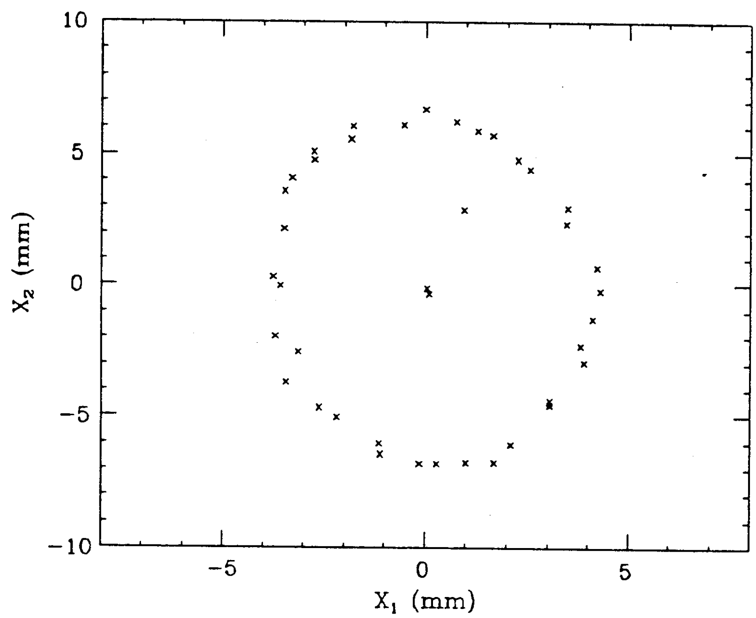

Figure 1. Position and FFT spectra for a kicked beam. The bottom portion of the figure shows the beam position of a single beam bunch for 1024 turns. At turn 512 the injection kicker is fired producing a coherent betatron oscillation. The top portion is an FFT of the recorded beam position; the peak corresponds to a betatron fractional tune of 0.189.

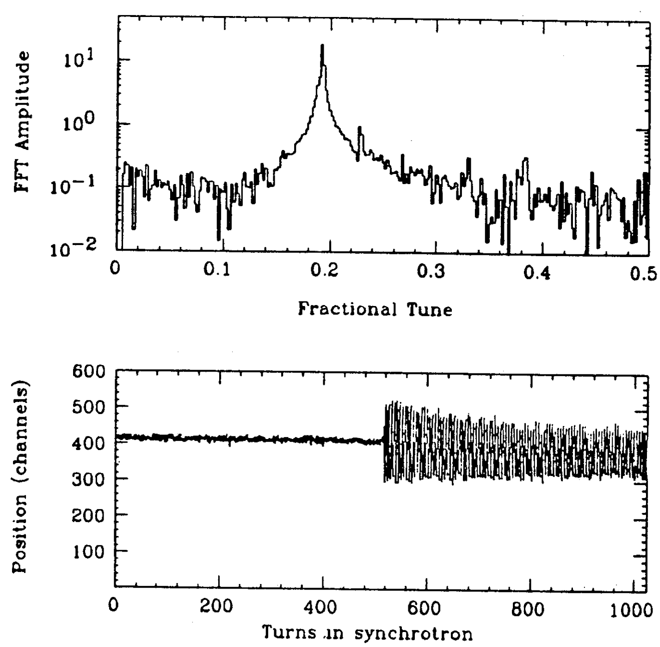

Figure 2. Position BPM2 vs. position BPM1 for the first 30 turns after the kick. Because the two BPMs used in the test are situated approximately 90° apart in betatron phase, the figure traced is nearly circular (if normalized).

operating with peak currents (the product of current and bunching factor) of about 100 μA, a bandwidth of about 100 MHz, and a value for $\beta = v/c$ of 0.3, we expect rms noise of less than 0.1 mm. Although normalized beam position resolutions of 0.13 mm have been observed, more systematic testing is needed. The system has demonstrated a 1% amplitude linearity over the 10 dB step attenuator range. Since the trigger circuitry operates directly off of the beam signals, no adjustments are required with varying beam velocity, harmonic number, bunching factor, or intensity.

COMPLETION OF T-SITE CONSTRUCTION FOR EXPERIMENT CE03

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The 6° bending magnet and vacuum chamber for the CE03 experiment ($p+p \rightarrow p+n+\pi^+$) was assembled, carefully field mapped over a large volume, integrated to the gas jet target box, installed and aligned at the T-site, and tested. Experiment CE03 has completed several runs with this facility, which are described elsewhere in this report. There are several approved experiments which plan to use this facility for recoil experiments. Experiment CE06 is the first of these. For this experiment, a detector vacuum chamber to enclose a special array of detectors is being built to attach to the thin window exit of the 6° vacuum box on the inside of the ring. The details of this experiments are discussed elsewhere in this report.

The 6° magnet is essentially a small-angle spectrograph which permits ejectile exit angles up to 54° towards the inside of the ring and up to 30° towards the outside for particles of high rigidity, or for negative ejectiles. The fully usable area of the gap is 33 cm wide by 12.7 cm high, over the entire length of 34.3 cm. An extensive map of the magnetic field has been made, with and without an upstream field clamp, which will be necessary for planned use with a polarized ^{3}He target. The field differs in the fringe field areas from a TOSCA calculation. The maximum rampable magnet field is 0.38 T·m, suitable for bending 500 MeV protons. The maximum field in the center of the gap is 0.75 T.

As a result of the larger acceptance requirements in this region of the new ring tune, the exit pipe of the vacuum box was enlarged to 29 mm square at the exit of the box tapering to 36 mm square at a distance of 22.37 in downstream at the exit junction of the pipe. This pipe limits how close to the beam detectors may be placed. For further details of the features of this facility see the description in the May 1988-April 1989 Scientific and Technical Report of the Indiana University Cyclotron Facility.