

## BETATRON PHASE ADVANCE MEASUREMENT AT SPEAR\*

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### Abstract

There are many reasons to determine the betatron phase advance between two azimuthal positions in a circular accelerator or storage ring. We have measured the betatron phase advance between various pairs of azimuthal points in the SPEAR Storage Ring by two different methods. The first method is to excite a steady state coherent betatron oscillation with a network analyzer. The second method is to excite a free coherent betatron oscillation with an impulse kick, and to digitally sample the transverse position of the beam at the pickup stations. The results of these digital samples are Fourier analyzed with a computer to obtain the phase advance. The second method is discussed, and the experimental results compared to theory.

### 1. Introduction

It is desirable to check the optics of colliding beam storage rings by measuring the lattice functions at various points around the ring. A magnet error at one point in the ring can produce a change in the betatron and dispersion functions at all other points around the ring. This makes it somewhat difficult to use the measurement of these lattice functions to precisely locate the magnet errors in the ring. The additional measurement of the betatron phase between two position monitor pickups can be utilized, along with the measurements of these lattice functions, to help locate magnet errors in large storage rings.

There are two different methods that can be used for these measurements. The first method is to excite a steady state coherent betatron oscillation with a CW oscillator and to measure the phase of the oscillation at two pickup stations with a network analyzer<sup>1</sup>. A second method, which we have used at SPEAR, is to excite a free coherent betatron oscillation with an impulse kick, and to digitally sample the transverse position of the beam at the pickup stations. The results of these digital samples are Fourier analyzed with a computer to obtain the phase advance between the monitors.

### 2. Signal Processing

The signals from two pairs of pick-up buttons, Figure 1, are brought to the control room via dispersive coaxial lines. Two identical wideband processing circuits consist of passive filters, linear amplifiers and a zero-crossing detector. Each pair of pulses is stretched, amplified and a trigger is derived and made to occur on the first peak of the signals. For each monitor a difference signal is obtained from hybrid junctions and is applied to a pair of Lecroy TR 8837F Transient Recorders.

### 3. Measurements

A single bunch of electrons is excited horizontally by pulsing one of the injection kickers. The coherent betatron oscillation amplitude is a linear function of the kicker voltage, while the damping rate is linearly related to both the current in the bunch and the chromaticity of the ring. In practice the coherent amplitude of the beam oscillation is displayed on an oscilloscope and the horizontal chromaticity adjusted to obtain damping times from less than 1000 turns to damping times greater than 10,000 turns. Presently the maximum number of turns that can be sampled is 32,768. After the kicker is fired, two trains of clock pulses at the SPEAR revolution frequency are used to sample the processed output signals from the two beam pickup stations

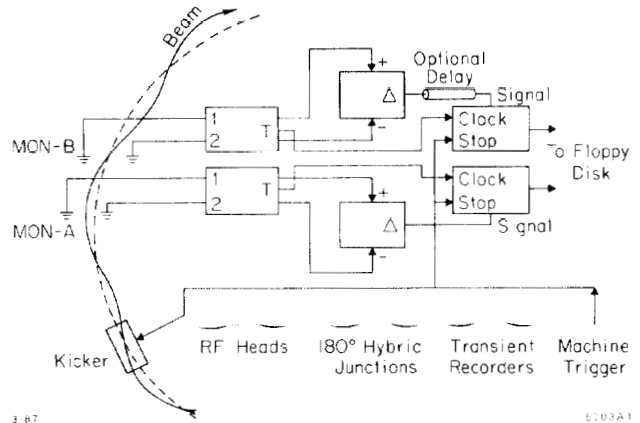


Fig. 1. Block Diagram of the Betatron Phase Advance Measurement experiment.

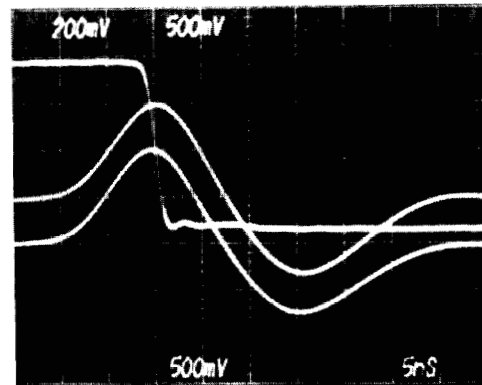


Fig. 2. Processed signals from a pair of electrodes, and the Beam-derived trigger.

once per revolution. These sampled signals are digitized and read by an IBM PC; the results are stored on disk and analyzed later. It is important that the negative slope of the clock pulses occur during the flat portion of both of the stretched signals from the two position monitors. Figure 2 shows a display of the actual output from one of the processors and the clock pulse train. Figure 3 displays the sampled signal as a function of revolution number and clearly shows the excitation of the coherent signal by the kicker and the subsequent decay.

A pseudo-phase plot can be obtained by plotting the coherent signal at position monitor *B* against the coherent signal at position monitor *A* on a turn by turn basis (on the same turn the electron arrives at Monitor *A* before Monitor *B*). Two examples of such plots are shown in Figure 4. In Figure 4(a) the phase shift between Monitor *A* and Monitor *B* is 12 degrees and we obtain an ellipse tilted at approximately 45 degrees while in Figure 4(b) the phase shift is nearly 90 degrees so the ellipse is approximately upright.

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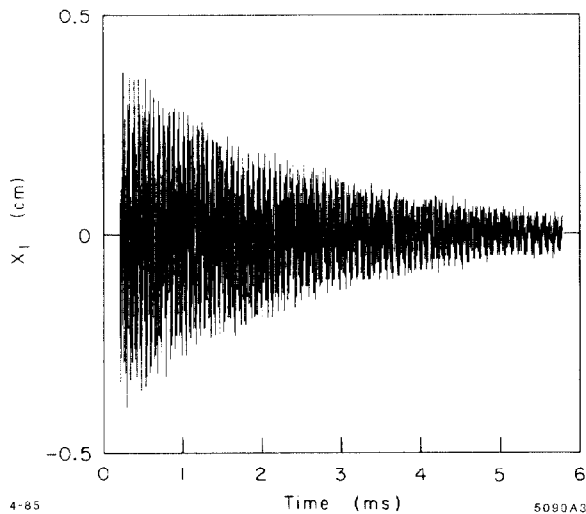


Fig. 3. Envelope of the sampled signal.

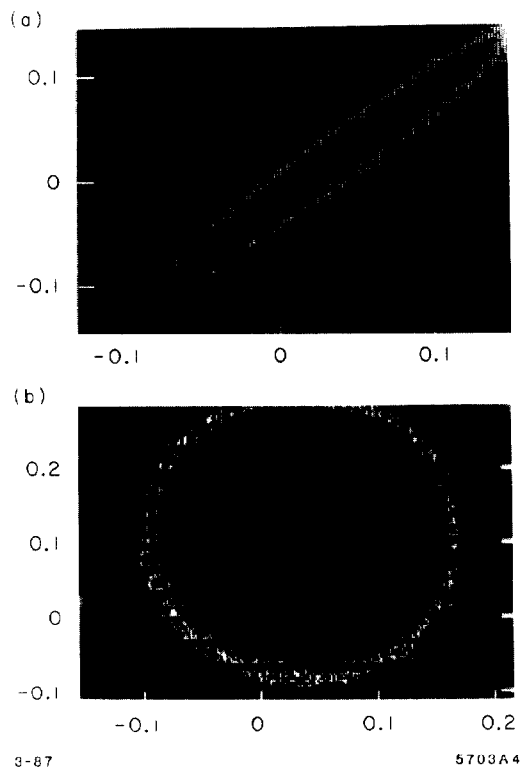


Fig. 4. Pseudo-phase plot of the coherent signal at Monitor B (ordinate) and at Monitor A (abscissa).

- (a) The phase shift between 16S15 and 1S2 is 12 degrees.
- (b) The phase shift between 16S15 and 13S14 is 270 degrees.

We have taken the discrete Fourier transform of both set of digital samples and then calculated the phase advance. In Figure 5 we have displayed the theoretical horizontal betatron phase advance as a function of the distance from position monitor 16S15. The interaction points in the ring are denoted by an \*. In Figure 6 the accumulated error in the horizontal betatron phase advance is displayed; the error in the measurement is approximately  $\pm 0.001 \times 2\pi$ . There does not appear to be any large errors in the phase advance around the SPEAR ring.

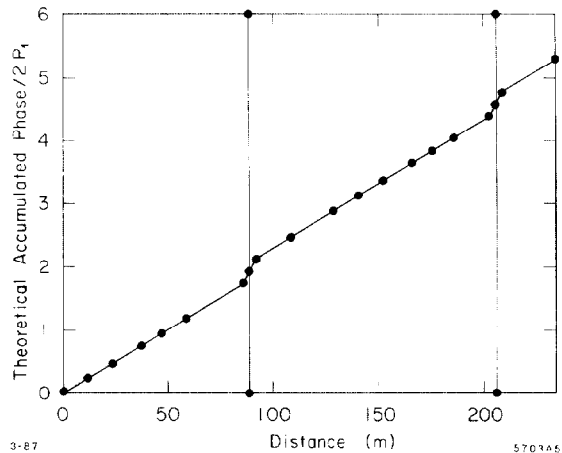


Fig. 5. Theoretical Horizontal Betatron Phase Advance as a function of the distance from Monitor 16S15 around SPEAR.

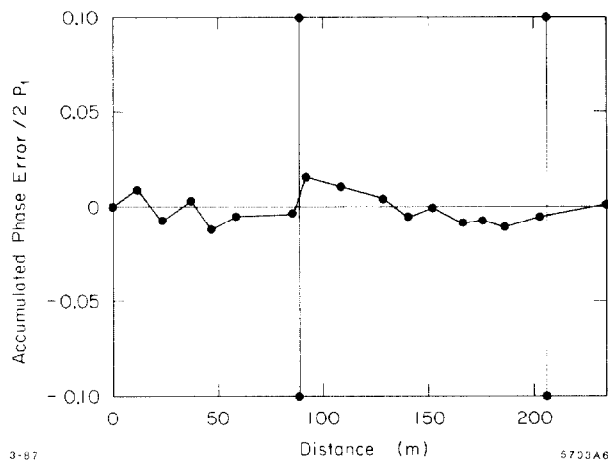


Fig. 6. Accumulate error in the Horizontal Betatron Phase Advance around SPEAR, starting at Monitor 16S15.

#### REFERENCES

1. J. Borer, A. Hofman, J.-P. Koutchouk, T. Risselada, and B. Zotter; IEEE Trans. Nucl. Sci., NS-30, No. 4 p. 2406 (1983).