DESIGN OF THE BEAM ORBIT FEEDBACK SYSTEM FOR THE TRISTAN LIGHT SOURCE STUDY

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ABSTRACT

A beam orbit feedback system was designed and built for the TRISTAN Light-Source Study. Some of the experiments which use TRISTAN Main Ring as a synchrotron-light source require very high beam position and slope stability. The beam orbit feedback system eliminates oscillations of the beam in time at the center of an undulator. The feedback system is composed of 2 single-path beam monitors and 4 each of horizontal and vertical steering magnets. The control system was built with EPICS.

INTRODUCTION

TRISTAN, the electron-positron colliding ring for high energy physics, has been in operation since 1986. The experiments with this facility were completed in June 1995 and the TRISTAN Main Ring was altered to be utilized as an extremely intense and highly advanced light source facility. An undulator was installed for purposes of study, with experiments planned from September to December 1995 [1][2]. In order to provide high quality light to the experiments the accelerator must satisfy tight tolerances and have low emittance and high current. The beam orbit feedback system was designed to satisfy one of these requirements, the stability of the beam position and slope at the light source point.

THE REQUIREMENTS FOR THE FEEDBACK SYSTEM

Since our beam line is long (about 100 m), the requirements for stability of beam position and slope are relatively tight. Figure 1 shows them for several experiments.

	Experiments	Position Stability	Slope Stability
Horizontal Direction	All	± 1500 (μm)	± 15 (μrad)
Vertical Direction	Muscle fibers	± 500 (μm)	±10 (μrad)
	The microbeam	± 50 (μm)	± 10 (μrad)
	Solid wave	± 100 (μm)	± 5 (μrad)
	X-ray parametric scattering	± 50 (μm)	±10 (μrad)
	Nuclear resonance scattering	± 500 (μm)	± 5 (μrad)

Fig. 1 Requirements from each experiment

In order to design the feedback system, we first measured relatively slow closed orbit distortions (timescale from 10 minutes to 8 hours) and fast beam vibrations (from 3 to 100 Hz). From the closed orbit distortion measurement, assuming that the orbit distortion was caused by the change of a quadruple magnet position, we can estimate that magnets move 1.7/2.6 μm (at the one sigma level) in the horizontal/vertical direction over 8 hours. This corresponds to the light source position moving 48/94 μm (r.m.s.) in the horizontal/vertical direction and the slope moving 14/21 μrad (r.m.s.). The fast beam vibration (3 to 100 Hz) was also measured. The beam position vibrates 0.22/0.40 μm in the horizontal/vertical direction at 5 Hz and the corresponding slope changes 0.05/0.08 μrad. From these measurements we thus conclude that we can ignore the fast beam vibration.

FEEDBACK DESIGN

Figure 2 shows a schematic of the feedback system. For H, to approximate both the response of the steering magnets and an eddy current effect of the vacuum chamber, we write the transfer function as:

$$\frac{1}{\frac{1}{85}s+1} = \frac{85}{s+85}$$

where 1/85 comes from the measured field of the steering magnets and s is the usual imaginary angular frequency (s=iω). The Z-transform, appropriate for discrete time sampling, is:

$$H(z) = \frac{1-e^{-aT}}{z}(z-e^{-aT})$$

where a=85 and T is the sample time. Similarly the Z-transform of the control function becomes:

$$G(z) = \frac{K}{z}\left(1+\frac{T}{T_I\left(1-\frac{1}{z}\right)}+\frac{T_D\left(1-\frac{1}{z}\right)}{T}\right)$$

where K, T_I and T_D are constants. The three terms inside the large parentheses are the familiar proportional, integral and differential contributions. Finally the closed loop gain as a function of disturbance frequency (f) can be written as:

$$g(f) = \frac{\text{error(e)}}{\text{disturbance (d)}} = \left|\frac{1}{1+H(z)+G(z)}\right| .$$

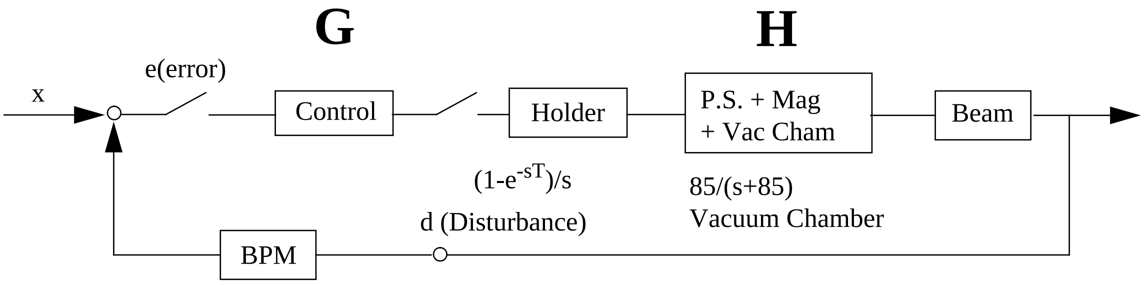

Fig. 2 Schematic view of the feedback loop

HARDWARE IMPLEMENTATION

Figure 3 shows a rough sketch of the beam line around the undulator. The STFH and STFV are the horizontal and vertical steering magnets of the feedback system and the STH and STV are normal horizontal and vertical steering magnets. The beam position and slope at the center of the undulator are calculated from the two recently implemented beam position monitors that are installed on both sides of the undulator and are adjusted with 4 each of vertical and horizontal steering magnets.

Steering magnets

In order to get fast response, laminated iron-core magnets were used for steering. They were designed to control the beam position to 1500 µm in the horizontal direction and 5 µm in the vertical, which correspond to kick angle accuracies of 150 µrad horizontal and 5 µrad vertical. In order to get these slope accuracies at the center of undulator, the steering magnet kick angles must be good to 7.5 µrad/2.5 µrad.

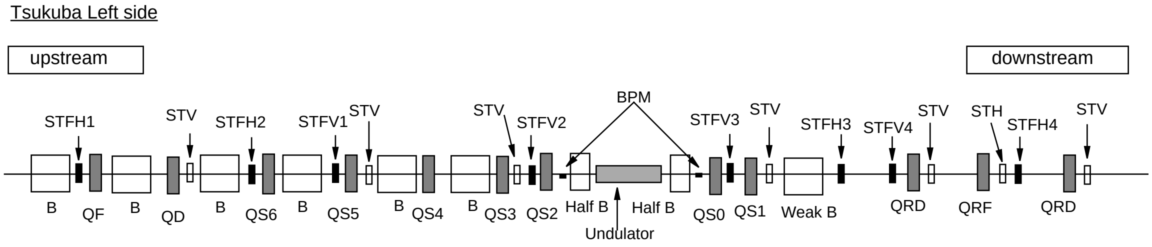

Fig. 3 Schematic view of the beam line around the undulator

Beam position monitors

Two new monitors can measure turn by turn beam positions. Figure 4 shows a block diagram of the read-out system, based on the AM/PM method [4], with 10-bit digitizations. In order to measure the beam position with an accuracy of 50 µm, 100 turn data are accumulated in the memory and used to calculate the beam position.

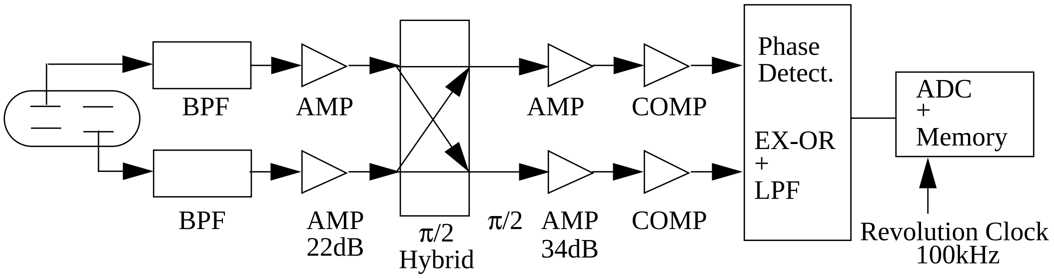

Fig. 4 Block Diagram of the AM/PM method beam monitor readout system

CONTROL SYSTEM

The control system was built based on EPICS; Figure 5 is a block diagram. One VME board (Force 25MHz clock CPU40) and an HP9000/755 were used as control computers. To build the control system some EPICS tools were used. The graphic user interface was written in MEDM, and beam position/slope data were collected by EPICS archive tools. Although EPICS sequencer supports data update of up to 60 Hz, we extended this to 200 Hz by using the auxiliary clock of the VME CPU board.

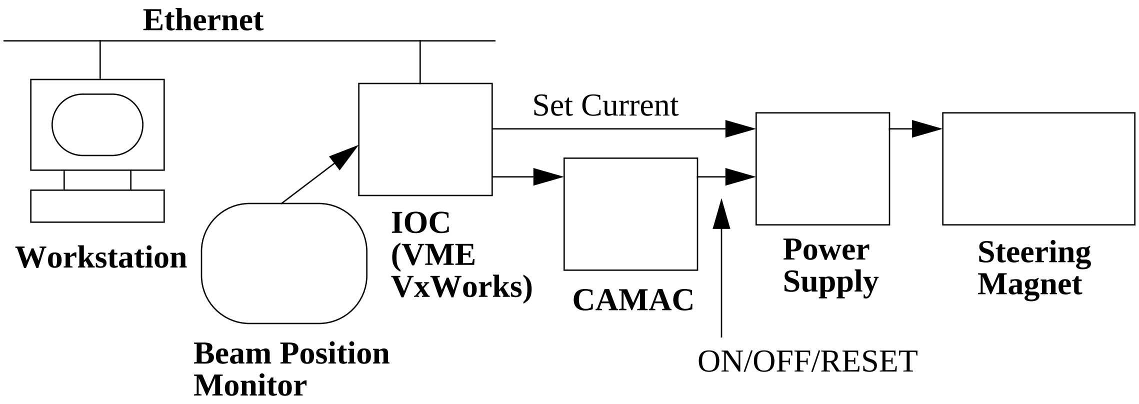

Fig. 5 Block diagram of the control system

FEEDBACK SYSTEM PERFORMANCE

Figure 6 shows a preliminary result of the beam orbit feedback system performance. The feedback frequency was set to 100 Hz and the beam position and slope were calculated with 100 turn data. Figures 6 (a) and (b) show vertical beam positions when the feedback was off/on. Figures 6 (c) and (d) show the corresponding slopes. When the feedback was turned on the beam positions could be made stable within ± 30 μm in both directions, and similarly the slope within 5 μrad.

CONCLUSION

The beam orbit feedback system was built to make the position and slope of the beam stable at the center of an undulator. The control system was designed based on EPICS. When feedback was turned on the requirements for beam stability were satisfied.

REFERENCES

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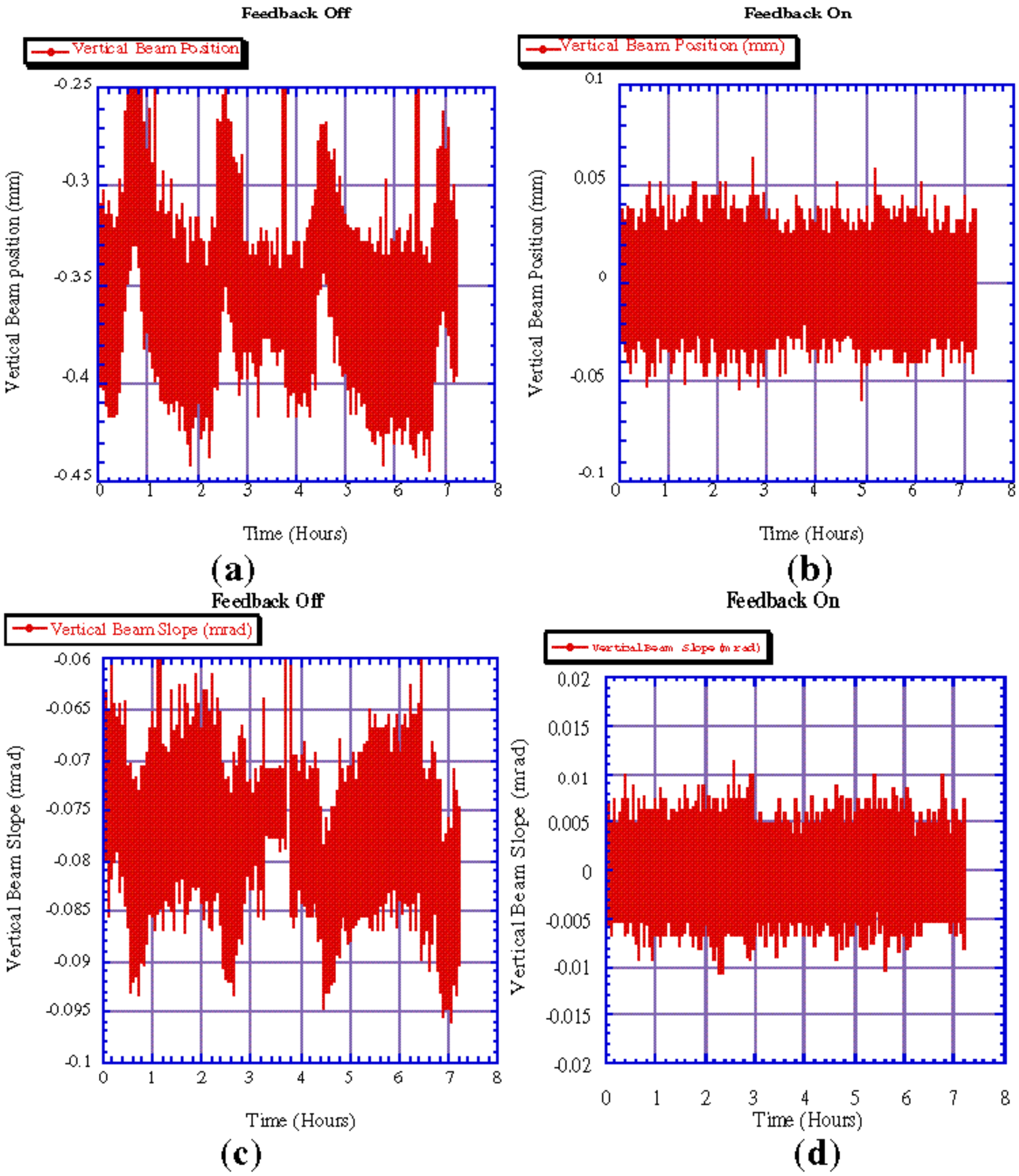

(a) **(b)** **(c)** **(d)**

Fig. 6 Vertical beam position and slope at the center of undulator