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Design of a local bump feedback system for a variably polarizing undulator

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A local bump feedback system is under construction to correct the orbit distortion caused by the magnetic field errors of a double-array undulator used to generate linear and circular polarization of light for a soft X-ray beamline. The local bump orbit is created by steering coils several turns long and four sets of steering magnets. The kick angle of the long steering coils and the steering magnets is determined according to the motion of the undulator and by detecting the beam position.

Keywords: undulators; local bump orbit; beam position monitors; steering magnets; magnetic field error.

1. Introduction

A local bump feedback system is under construction at a double-array undulator section of a soft X-ray beamline. The design of the undulator, based on the APPLE type (Sasaki *et al.*, 1992), has been reported previously (Kobayashi *et al.*, 1996). It generates linear and circular polarization of light in the horizontal and vertical directions by moving the relative position of pairs of magnet rows (phase shift). The magnetic field strength is varied by changing the gap between the upper and lower jaws, thus changing the photon energy in the soft X-ray range. Fig. 1 shows the undulator and its permanent magnet array.

Magnetic field errors from an undulator are caused by differences in the magnetic properties of the magnet blocks, and the errors vary depending on the gap distance and the phase shift. The phase-shift frequency of this undulator is 0.5 Hz, so the field errors vary at 0.5 Hz in the phase-shift mode. The feedback system corrects the orbit distortion caused by the field errors of the undulator. It comprises a monitoring system and a magnet system. The monitoring system measures the position of the electron beam using beam position monitors (BPMs) and calculates the local bump orbit needed to avoid increasing the closed orbit distortion and to stabilize the photon beam from the undulator. The magnet system, composed of long steering coils and four steering magnets, cancels the magnetic field errors and creates the local bump orbit.

2. The design of the local bump feedback system

The local bump feedback system is shown in Fig. 2. The steering magnets are located at both ends of the undulator section and the beam position monitors are placed next to the steering magnets. The long steering coils are attached to the stainless-steel vacuum chamber inserted in the gap of the undulator.

2.1. *The BPM system*

Four button pickups for the BPM are mounted on the BPM block of the vacuum chamber. These button pickups are arranged to give the same sensitivity for both the horizontal and vertical positions. The BPM is made from non-magnetic materials to minimize the disturbance of the magnetic fields of the adjacent magnet. A cross-sectional view of the BPM is shown in Fig. 3.

A schematic diagram of the BPM system is shown in Fig. 4. It comprises beam position monitors, a BPM signal processor and a VME (Versa Module Europa bus) system. The passage of the electron beam induces pulsed signals at the button pickups. These button signals are transmitted to the BPM signal processor board (BPM board) through 30 m long coaxial cables and Chebyshev-type band-pass filters. The signals from the four buttons of a BPM are processed in a single set of BPM boards, where they are time-multiplexed into a single signal and supplied to a superheterodyne receiver. The detection frequency was chosen to be 508.58 MHz, which is the same as the r.f. acceleration frequency. The demodulated signal is demultiplexed into four signals, A, B, C and D. To obtain information on the beam position, these signals are analog-processed as the sum of four signals, Σ, which is kept constant. The horizontal position x is obtained by $A-B-C+D$ and the vertical position y by $A+B-C-D$ (Hinkson & Unser, 1995). These positions are obtained as sequential analog output. The output range is ± 10 V and the resolution was chosen to be 1 V mm^{-1}. The same sampling frequency is supplied to four sets of BPM boards from an external clock. The frequency is tuned to eliminate the aliasing of certain types of beam motion. Four button signals can be sampled up to a frequency of 10 kHz by GaAs switches. The beam-position output signals from the four sets of BPM boards are converted into a 16 bit digital signal by an eight-channel analog-to-digital converter in the VME system. The minimum through-put rate of each channel is 10 µs, so the horizontal and vertical beam-position signals from the four sets of BPM boards are sampled at up to 5 kHz frequency. A VME-bus CPU (HP9000-743rt/64) calculates the bending angles caused by the magnetic field errors of the undulator and the kick angles of the steering magnets to create the local bump orbit from the relative beam position.

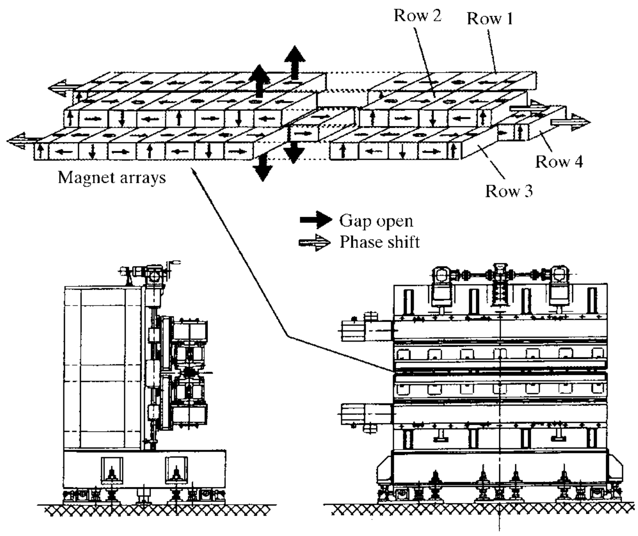

Figure 1
The structure of the double-array undulator and the movement of the magnet array.

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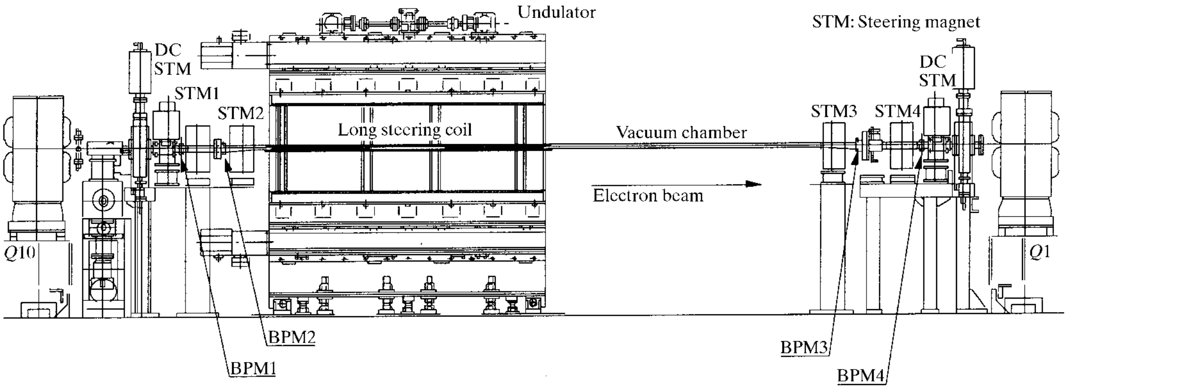

Figure 2
The layout of the undulator section. BPMs and steering magnets are placed at both ends of the section and long steering coils are inserted in the gap of the undulator.

2.2. *The magnet system*

The magnet system comprises the long steering coils and four steering magnets. The long steering coils cancel most of the integrated magnetic errors of the undulator, which are estimated to be lower than 500 μT m, and the steering magnets are excited to make a local bump orbit to eliminate fast and residual orbit distortion which cannot be corrected by the long steering coils. The system of four steering magnets can correct both the position and the angle of the orbit distortion. The long steering coils and the steering magnets are both composed of a horizontal plane coil and a vertical plane coil which can be excited separately. These coils are air-cored, have no residual magnetization and have good linearity between current and magnetic flux density. These properties make it easy to control the magnetic fields.

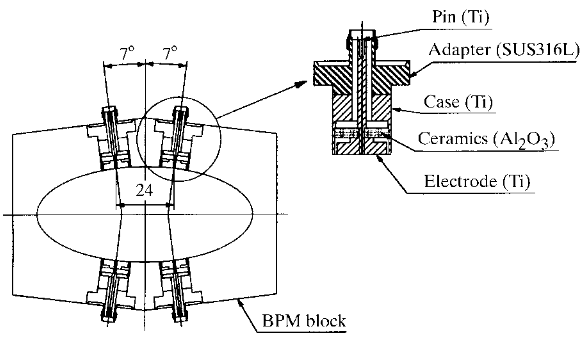

Figure 3
A cross-sectional view of a BPM. The button pickup is made from non-magnetic materials.

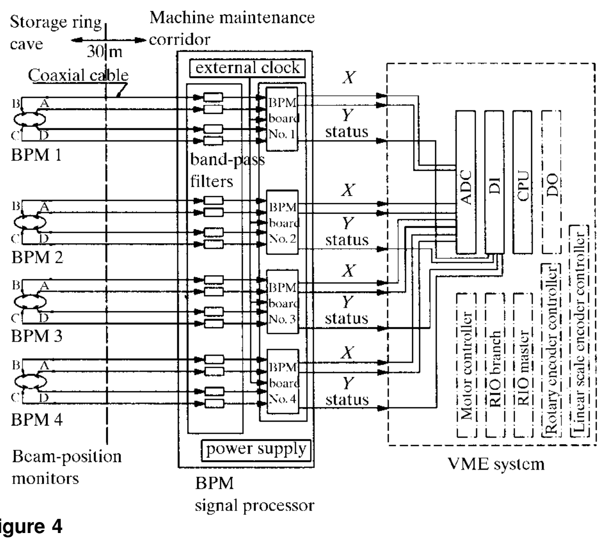

Figure 4
A schematic diagram of the BPM system. Signals from 16 button pickups are processed in this system.

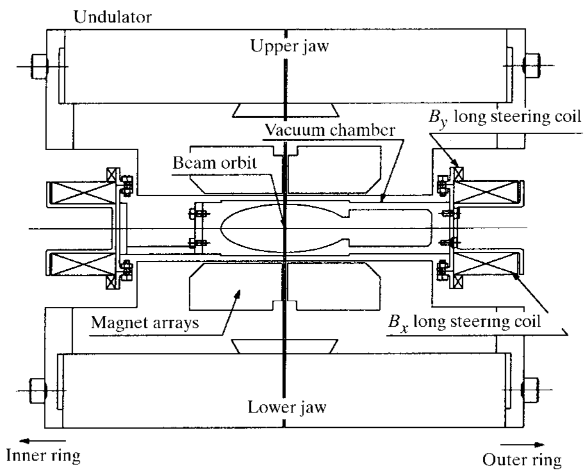

Figure 5
A cross-sectional view of the long steering coils. These coils cancel most of the magnetic field errors of the undulator.

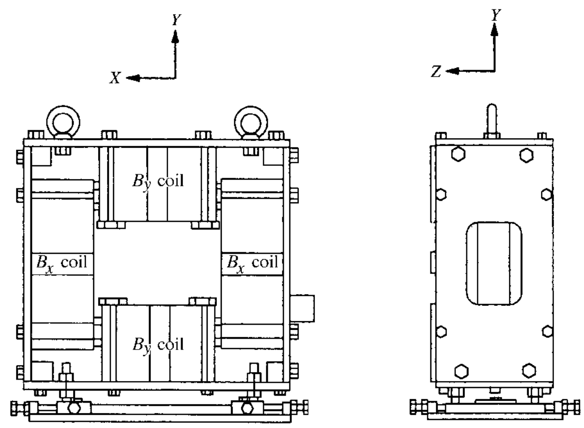

Figure 6
The structure of a steering magnet. Four sets of magnets create a local bump orbit.

A cross-sectional view of the long steering coils is shown in Fig. 5. The coils are attached to the vacuum chamber so that they are not in contact with the magnet arrays of the undulator. The coils for the vertical magnetic field are 2 m long two-turn coils. The horizontal coils are divided into two sets of four coils to avoid interference with the vacuum pump port. The kick angle of the long steering coils is a function of the gap distance and the array phase of the undulator. The function is determined using the magnetic field data measured before installation in the ring. The value of the gap distance and the array phase of the undulator is measured by a linear scale encoder fabricated on the undulator. The CPU in the VME system calculates the kick angle of the long steering coils using this function and controls the magnet power supplies. The fluctuation of the magnetic errors caused by the gap distance and the array phase of the undulator is slow, so the control frequency of the long steering coils is d.c.-like. The calculated maximum field strength of the long steering coil is 500 μT m.

Four steering magnets are excited to make a local bump orbit depending on the readings of the BPMs. The CPU in the VME system controls the eight coils of the steering magnets independently, so local bump orbits in the horizontal and vertical plane are created independently. The maximum variable speed of the current for the steering magnet is 1 A ms^{-1} when the maximum supply current is ± 15 A. The calculated maximum field strength is 200 μT m in the horizontal direction and 240 μT m in the vertical direction. Fig. 6 shows the structure of the steering magnet.

3. Schedule

This system has been built and its performance will be tested before installation in the ring. The frequency of the feedback performance may be 20 Hz at first because of software performance. We are planning to improve the performance to 100 Hz in the final stages. Some improvements in the software and hardware will be needed to achieve this. The system will be installed in the ring during the winter shut-down period of 1997.

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