PULSED-WIRE METHOD OF FIELD MEASUREMENT ON SHORT ELLIPTICALLY POLARLIZED UNDULATOR

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Abstract

With two sets of photo couplers, scientists already have applied pulsed-wire method (PWM) to measure the magnetic field along two mutually perpendicular directions. The authors believe that two-dimensional pulsed-wire method is useful for the test of elliptically polarizing undulator (EPU). We tried to use this method to observe the first integral and second integral fields of a short EPU in real time during the polarization tuning. More care is needed than the application of PWM on the planner undulators. The phase difference, the relative field strength along two directions as well as the precise center-line can be achieved.

INTRODUCTION

Since R. Warren developed the PWM [1], many accelerator laboratories have tested or applied this method to measure undulators, especially in the system of free electron laser (FEL). To fulfil the spectrum and accelerator physics requirement, the undulators need a tedious iteration of tuning or shimming. PWM can save the time than Hall probe method. The stretched wire and long loop method can measure the integral field directly as PWM does but can not get the point-by-point information. However, the acoustic noise coming from the vibration and airflow, and intrinsic properties of wire material limit the accuracy of the PWM. Moreover, the PWM suffers from the fluctuation of optical devices. The authors proposed to use thick wire (250 μm) to replace the thin one so as to reduce the effect due to wire defects [2]. The dispersion accompanying the stiffness of thick wire needs additional mathematical manipulation [3].

Helical magnetic fields have been adopted to generate helically polarized radiation. After the test of prototype magnets, National Synchrotron Radiation Research Center (NSRRC) fabricated an EPU of 4 m long and 5.6 cm period; this EPU is in intensive operation [4]. As the increasing demand of helically polarized radiation, NSRRC plans to design two more EPU with high quality.

With two sets of photo illuminator and detector, scientists already have applied the PWM to measure the magnetic field along two mutually perpendicular directions of planer undulators [5]. We believe that two-dimensional PWM is useful for the test of the EPU's. The shimming of the EPU is time-consuming [6]. We are preparing to use this method to observe the first integral and second integral fields in real time during the polarization tuning. An old short prototype EPU serves as the test object.

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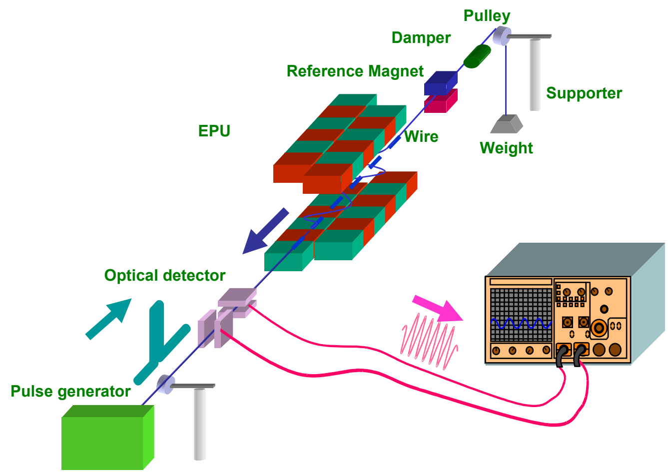

Figure 1: A cartoon showing the set-up of the pulsed wire system to measure the elliptically polarizing undulator.

APARATUS

As shown in Fig. 1, the PWM system is set up to measure an EPU. The main parts are described as follows.

EPU

The old short prototype EPU used as the test magnet is of an Apple II design [7]. It consists of 16 periods of pure NdFeB magnet. The total length is 1 m (named after this, 1m EPU); the period is 5.6 cm. The magnetic gap is fixed at 28 mm. The vertical and horizontal peak field strength is 0.42 T and 0.21T separately.

Wire

We choose beryllium copper for the wire. The diameter of the wire is 250 μm, which is twice of the usual usage 125 μm. The length is 5 m. For the 0.25 mm Be-Cu wire, one can look at it as a thin rod. Due to the stiffness of wire, the bending force is:

$$-EI\frac{\partial^4 x}{\partial z^4},$$

in which E is modulus of elasticity, I is moment of inertia of the cross-sectional area with respect to the neutral axis. For a cylinder rod, I can be expressed by

$$I=\frac{\pi d^4}{64}.$$

When diameter d is doubled, the bending force would be multiplied by 16 times. To get the same sensitivity of optical detector, the current passing the wire should be increased proportionally. Considering the resistance is reduced to one quarter, the power is increased to 64 times. A weight of 1 kg offers the tension of the wire.

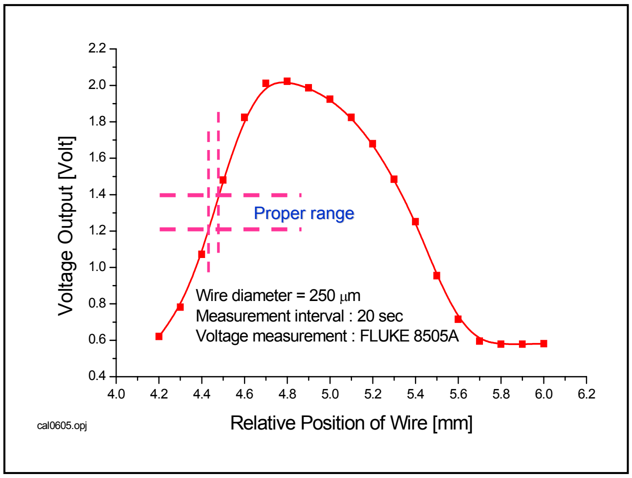

Figure 2: A calibration curve of the output of photo couplers H21A1 with the movement of wire.

Optical detectors

Two photo couplers H21A1 are to measure the magnetic field along two mutually perpendicular directions. To isolate the power line noise, we use 9 V batteries to power the photo illuminator and photo diodes (detectors). The sensitivity is normally 0.25 mV/μm. In the measurement of 1st integral, only 15 mV is obtained.

Due to the limited precision during production and misalignment of the photo couplers, the calibration curve is often asymmetry as shown in Fig. 2.

Because the stock room of the 1m EPU only use traditional fluorescent lamps (non-electronic type), the light induced optical noise of 120 Hz. We need to turn off all the lights during measurement test.

Pulse Generator

The source of pulse signal is provided by a Tektronix AFG320 function generator. To create an acceptable pulse current, this signal is fed into a Darlington transistor with two 2N3771 inside. The power is excited by a Kikusui DC power supply PAD110-10L operating at constant voltage of 80 V. For 1st integral field measurement 10 μs is used; for 2nd integral field 1 ms is used.

RESULTS

After careful alignment of pulsed-wire with the centerline of EPU, we tested the measurement of the first and second integral fields. We define that the EPU under planer condition is in phase zero. With the magnet beams at 1st quarter and 3rd shifted relative to the main structure of the EPU, as depicted in Fig. 1, we called this condition is phase $\pi/2$. Fig. 3 shows the 1st integral of the 1m EPU magnetic field and Fig. 4 does the 2nd field. The measuring time axis corresponds to the position along the EPU centerline and photodiode output can be calibrated to 1st integral value. All of the data are averaged by 25 times of measurement. Though the 1m EPU was carefully shimmed to reduce the integral field six years ago, we don't expect the same good performance at present time.

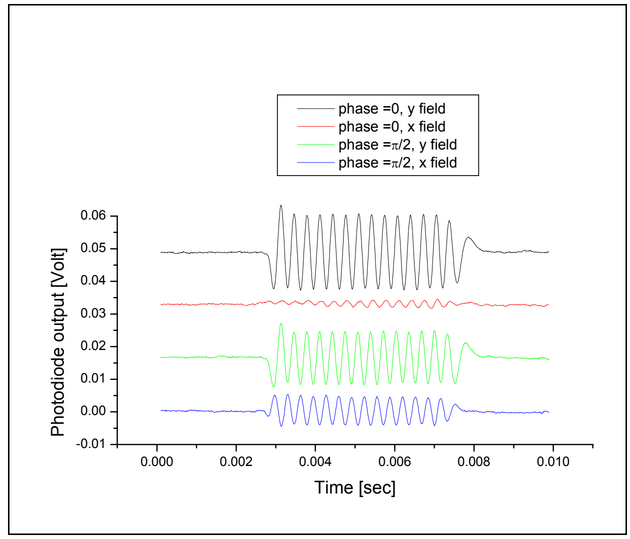

Figure 3: First integral field measurement.

At phase zero, the periodic variation of horizontal field implies the misalignment or manufacture imperfection of optical detectors. The total first integral field is still fine. At phase $\pi/2$, the horizontal periodic integral field comes out with correct ratio to the vertical field. At this stage we have not adopt Fourier transform analysis to trace back the original wave form [3].

In Fig. 4, we see obvious 2nd integrals of both vertical and horizontal field. When changing phase, the total 2nd integral field doesn't change too much.

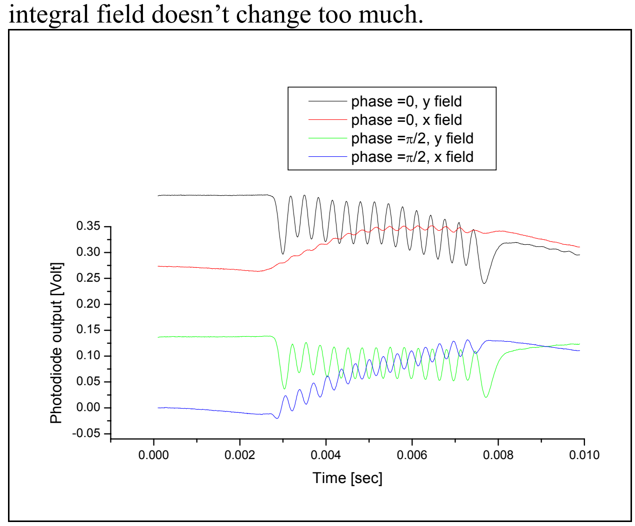

Figure 4: Second integral field measurement.

DISCUSSION

From the measurement of the 1st integral of horizontal field at phase zero, we need to refine the optical detector system in terms of precise alignment.

In the application of PWM so far, the precise quantity is not concerned. To fulfil the requirement of the beam dynamics, it is useful to tune the EPU by PWM.

ACKNOWLEDGEMENT

The authors thank K.T. Hsu, J.G. Chang and H.H. Chen for recovery of the 1 m EPU.

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