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Analysis of Pulsed wire measurements on bi-harmonic undulator

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ABSTRACT

In this paper we report measurement of bi-harmonic undulator in a Pulsed wire bench. The pulsed wire data for field integral is compared with Hall probe data. It is observed that the wire rigidity and stiffness of the thick wire do not affect the bi harmonic undulator field measurement and gives comparable results with Hall probe data.

1. Introduction

The measurement of undulator is an important issue in design of uniform, precise and quality undulators for synchrotron radiation and free electron laser applications. Such measurements are usually made point to point to by a Hall probe. The pulsed wire method was suggested as an alternate method for field integral measurements [1]. In this method, a thin wire is stretched along the undulator axis. When a current flows through the wire, a force proportional to the local transverse field component is exerted on the wire. This force evolves into a wave on the wire that propagates from the vicinity of the wire to a sensor located at the undulator ends. The sensor output versus time is the field integral versus position along the wire. The pulsed wire method has been used successfully over the years for magnetic measurement studies of undulators in close agreement with the Hall probe results. The wire sag, non uniformities of the wire and dispersion are some of the limitations of the method. Some other limitations and errors include attenuation, scattering on in homogeneities, reflection from the wire end supports, electronic and optical noise, ground and thermal vibrations that affect the accuracy and precision pulsed wire measurements of the undulator.

Pulsed wire magnetic field measurements [2] were made on a 4.3 m long undulator. The permanent undulator has 3.56 m period length with 120 periods. The detector was H21A1 optical interrupter switch. The CuBe wire length was 12 m and wave velocity is 340 m/s. The CuBe wire with 76 μm diameter was used in the experiment. CuBe wire with 56 μm diameter was used with the optical switch in the pulsed wire measurement of 75 cm long Hallbach undulator [3]. The wave velocity up to 270 m/s versus wire tension was measured. The Pulsed wire system [4] used wire diameter 400 μm with a H21A3 optical switch as a detector. The wave velocity was 100 m/s and the tapered undulator was 1 m long with 40 number of periods. The first and second field integrals were measured and the field was determined by differentiating the first integral [5]. A laser–photodiode detection system was used on a 2.7 cm tapered period wiggler. The method was applied successfully to field measurements in pulsed

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microwigglers [6,7]. The pulsed wire method was used for undulator magnetic field measurements [8,9]. A CuBe wire with 100 μm diameter, 2.7 m long was used for the measurement system. The undulator was 60 mm period length and there were 10 periods. An infrared 100 mW laser diode and a fast infrared 100 MHz photodiode was used for detection. The first and second field integrals of the undulator was measured with an accuracy close to that of Hall probe results. The Pulsed wire method was improved [9] by use of special thin dielectric hangers to decrease wire sag. Oil bubble dampers for damping the wave signals reflected from the wire supports were used in the experiment. The Pulsed wire method [10] was used for field integral measurements with CuBe wire of 100 μm diameter wire, 2 m long with an optical detector. The undulator was a hybrid undulator with 9 periods with 6 cm period length each. Further developments of the Pulsed wire method for magnetic measurements and focusing strength measurements in long undulators was reported [11,12]. The effects of wire imperfections and dispersion of the acoustic wave was analyzed for a thick wire [13–15]. The Pulsed wire method was improved with improved sensitivity of the optical switch, H21A1 by varying the aperture of the switch [16]. The undulator used for the experiment was 15 periods and each period was 10 cm long. The pulsed wire method used CuBe wire of 100 μm diameter of 4.86 m long. The effect of the wire dispersion was discussed. Most recently the pulsed wire technique was applied for field measurement studies of table top planar undulator of 30 cm long with six periods [17,18]. The CuBe wire diameter was 250 μm diameter. The detector was a Motorola optical switch. The pulse length requirements were discussed. The detailed theory of wave dispersion was theoretically analyzed [19]. An algorithms is derived to correct the dispersion and finite pulse width errors in the measurements of first integrals and dispersion errors in the second field integral measurements [20]. All these developments have made PWM as an attractive option for magnetic measurements in narrow gap undulator or in cryogenic environments such as superconducting undulators that stimulated researchers to apply PWM in other measurement applications. The PWM was applied for measurement of millimeter wave travelling wave tube [21] which is the new application area of pulsed wire technique. Another application, the PWM has been effectively used for magnetic axis alignment of pulsed solenoids with a resolution better than 25 μm [22].

In this paper we apply PWM for measurement of new novel exotic type undulators. The PWM so far has been applied for magnetic measurements of planar/elliptical PPM, hybrid type and tapered undulators. However due to its increased applications, the undulator technology has been improved for new, unique applications of undulators in the areas of synchrotron radiation and free electron laser applications. For example, there are multi frequency undulators, Optical – klystron Undulators, crossed Undulators, crossed overlapped undulators and step tapered undulators. In this paper as possible extension applications of PWM, we use PWM for magnetic measurements of recently reported bi-harmonic undulators [23]. The biharmonic undulators are modified planar sinusoidal undulator fields proposed to enhance free electron lasing at a desired higher harmonic. The standard planar undulator is a one peak per half period undulator field. The third bi-harmonic field is two peak per half period undulator field. As the harmonic number increases, the number of peaks per half period of the undulator is increased. The fifth, seventh and ninth harmonic undulator have three, four, five peaks in each half period of the undulator. As a consequence it requires fast detection systems to pick up multi peak oscillations of the wire in each half undulator field. In Section 2, we describe the new pulsed wire bench. It is equipped with both the detection systems. An optical switch is located at one end of the undulator while the laser-photodiode sensor is used the other end of the undulator. Two wires with different diameters are used in the set up to verify the effects of dispersion on the accuracy of the PWM over hall probe data. Two different sensors are used for measurements with same sensitivity for a given wire diameter. The studied verifies the usefulness of the PWM for bi-harmonic undulator field measurements. It is observed that both the sensors give results in close agreement with the Hall probe results. The stiffness and dispersion of the thick wire and the multi peak wire oscillations of the wire do not affect the accuracy of the PWM but limits the range of tension in the pulley end in comparison to a planar sinusoidal field. The measurement results are discussed in Section 3.

2. Pulsed wire bench

The pulsed wire bench is set on the same vibration isolation support. Two wire diameter of 250 μm CuBe wire having $\mu = 4.1 \times 10^{-4}$ kg/m and 125 μm CuBe wire having $\mu = 1.01 \times 10^{-4}$ kg/m is installed for magnetic measurements. The wire length is 1.39 m, which is more than four times the length of the undulator. Two sensors are employed for wire deflection measurements. An opto coupler is used as the sensor at the location of 148 mm away from the one end of the undulator. The optocoupler switch used for the experiment is a Motorola make Model No is MOC7811. The optocoupler switch consists of a infrared LED and a phototransistor which are molded in a plastic housing. The Optocopler switch is mounted on a assembly mount shown in Fig. 1a. The mount assembly consists of two circular rings. The outer diameter of the outer ring is 85 mm and the outer diameter of the inner ring is of 60 mm. The outer ring is marked. The inner ring can be rotated inside the outer ring. The optical switch is fixed on the inner ring. The rotation of the inner ring allows the optical switch to measure both the horizontal and vertical field integral data. So it is useful for field integral measurement of the helical type undulator also. There is a slot of 12 mm width for removing and inserting the wire. So one not need to remove the wire from fixed and pulley end at each time. The drawing and schematic of the system is as shown in Fig. 1b. The mount assembly is attached to a post of 12 mm diameter and 58 mm in length and is mounted on a rail through *xyz* translation stages. The rail