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LASER INSTRUMENTATION AND INSERTION DEVICE MEASUREMENT SYSTEM

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Abstract

In this paper, we discuss the Hall probe, pulsed wire and stretched wire magnetic measurement systems indigenously developed and installed at the university laboratory at Devi Ahilya VishwaVidyalaya, Indore, India. The laser instrumentation such as position measuring detector, laser scanning micrometer, Wollaston interferometer and Michelson interferometer improves the Hall probe sledge alignment and magnet alignment in the undulator thus improves magnet measurement accuracy. The salient features with design specifics of the laser instrumentation along with magnetic measurement system parameters are described with context to some prototype undulators designed and developed in the laboratory.

INTRODUCTION

In recent years there exits interest in undulator design and development techniques. The undulator field strength B_0 scales with the undulator gap as $B(T) = 1.72 B_r \exp(-\pi g / \lambda_u)$ where g is the magnet-to-magnet gap and λ_u is the period. Therefore, a uniform gap undulator, the precise measurement of gap is crucial as a variation of the magnet-to-magnet gap introduces errors in undulator parameters along the length of the undulator. An error in the undulator parameter is the cause of the beam wander and line broaden. Hall Probe method is a point-to-point measurement. Pulsed wire and stretched wire are integral field measurement methods for characterization of the undulator field.

THE PULSED WIRE BENCH

The schematic of the pulsed wire and Hall probe magnetic measurement system is shown in Fig.1. A motorized linear translation stage with a Hall probe measures the magnetic field profile. The Hall probe is aligned by a position sensitive detector system. The undulator length is 500 mm with 20 mm period length. The accuracy of the Hall probe position during the motion along the undulator length is measured by a position sensitive measuring detector system. The vertical and horizontal offset of the Hall probe measured during the motion is less than 60 micron and 10 micron respectively as shown in Fig. 2. The pulsar in the pulsed wire bench is a 50V-12A High Current Voltage Source (HCVS). The V-I characteristics of the HCVS is shown in Fig. 3. Two wire diameters are used for the experiment. The 250µmwire is used with a current of 5A in the wire. The 125µmwire is used with 1.32A for the experiment.

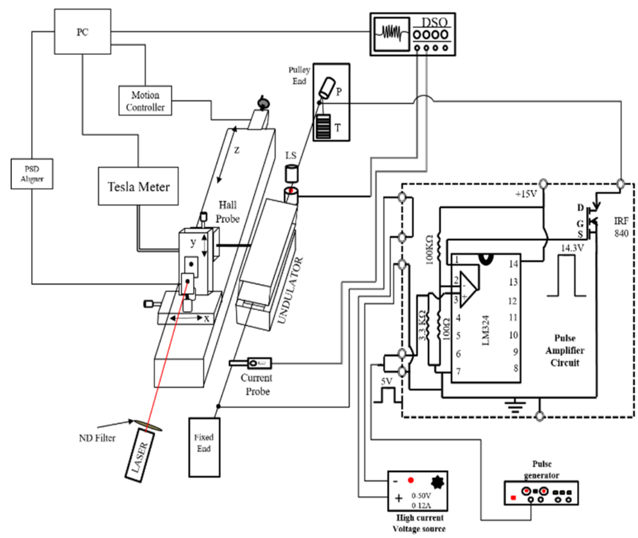

Figure 1: Schematic of the pulsed wire bench and Hall probe bench.

A current probe measures the current in the wire. We use Tektronix make, Model No A622 AC/DC current probe for the measurement. It is capable of measuring up to both 100A peak AC and DC current. We use Cu-Be wire for the experiment. The wire material parameter is $\mu = 4.1 \times 10^{-4} Kg/m$ for 250µmwire diameter and $\mu = 1.01 \times 10^{-4} Kg/m$ for 125µmwire diameter. The total wire length is 1660 mm and passes through the 500 mm length undulator on axis. The pulley end is 660 mm away from the undulator end. The fixed end is 500 mm away from the other undulator end. The wire length in the arrangement is kept at 3.32 times the length of the undulator i.e. $L \geq 3.32 L_u$, L_u is the length of the undulator. The issue of influence of end reflections on measurements is not observed. A laser-photodiode is used as the sensor. It is located near the undulator end at pulley side of the wire. Figure 4 shows the calibration curve of the sensor with no current in the wire. The experiment is conducted in the linear portion of the curve. The sensitivity is 6.5mV/µm and 6.0mV/µm for the two wires respectively. The transverse wire displacement propagates along the wire as a wave longitudinally along both the directions and is detected by a sensor located at the ends of the undulator. The shape of the pulse used for the study is close to rectangular. Both the long pulse and short pulse is shown in Figs. 5-8. The current falling is about 1.6% when the pulse length is 4ms. The current falling is 0.39% at 19.7µs.

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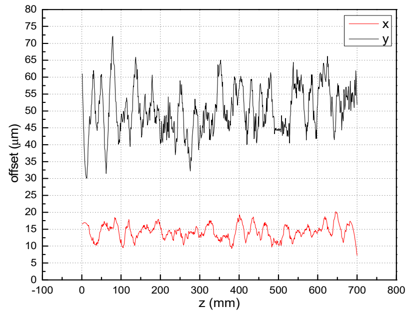

Figure 2: Horizontal and vertical offset.

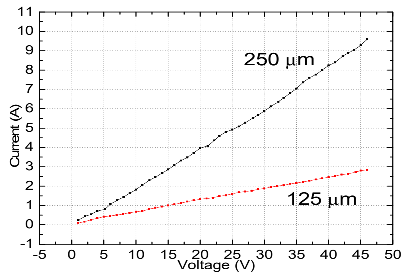

Figure 3: V-I characteristic of high current voltage source.

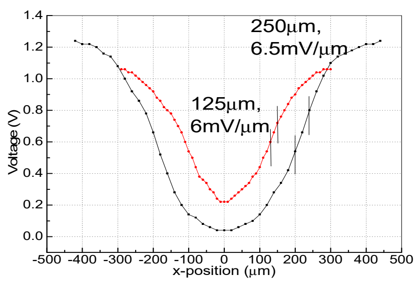

Figure 4: Calibration curve.

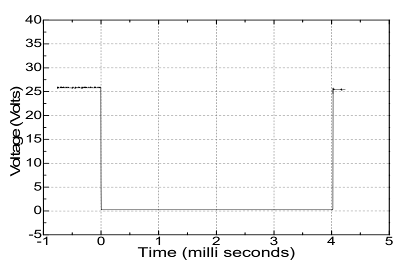

Figure 5: long pulse, 4ms at 5A.

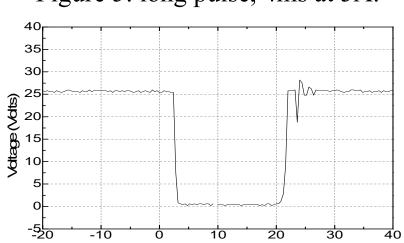

Figure6: 19.7μs pulse at 5A.

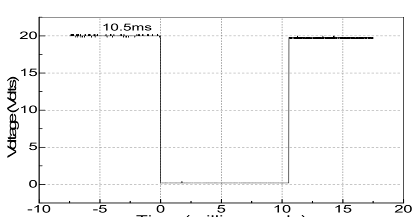

Figure 7: 10.5ms pulse width.

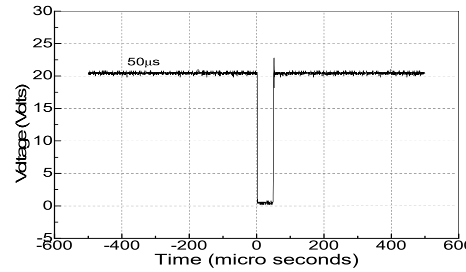

Figure 8: 50μs pulse width.

THE STRETCHED WIRE BENCH

The DAVV stretched wire magnetic measurement system is shown in Fig. 9. The components of the system are assembled on a pneumatic vibration isolation table (Holmarc, India make, model no. TTNM 240-120) with honeycomb table-top of width 200 mm. The table is 2400 mm in length and 1200 mm wide. Two units of X-Y translation stages are placed at two ends of the table. The distance between these two units is kept at 1860 mm. The translation stages (Holmarc, India make, model no. LMS-100-100) have a travel range of 50 mm, load capacity 15 Kg. 1 mm pitch and resolution 0.0025 mm each. The physical size of the translation stages measure 100 mm×100 mm.The translation stages are driven by stepper motor of Holmarc, India make, model no. 57SH51-4ASM. Motion controller of Holmarc, India makes, model no. Ho-HPC-2H and used to interface the stages with the desktop computer system.

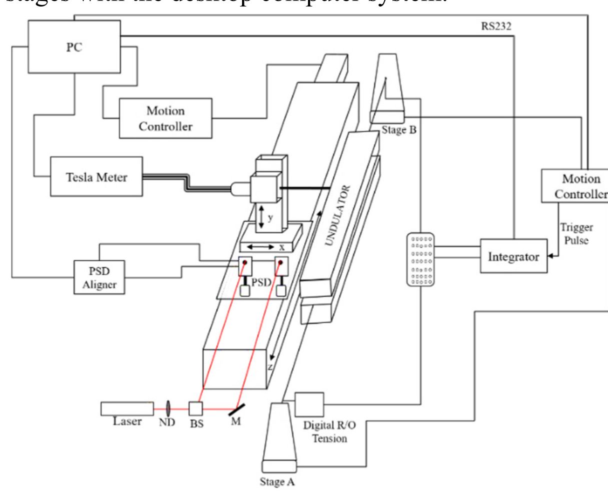

Figure 9: Schematic of stretched wire setup.

Both the units of translation stages given a height 355 mm from the table top through which the wire hangs at a height of 275 mm from the table top. Both the units of translation stages sit on a lab jack to provide another height adjustment of 60 mm to 115 mm. Litz wire of 100 strands with overall size 1400 μm including enamel coating of the single wires is used for the measurements. The Litz copper wire is stretched with the help of tension at one end of the straight length of the wire. The total length of the wire is 5meter. The wire tension plays an important role in controlling sag and thereby the accuracy of the measurement. A digital display unit at the load end

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reads the tension up to 50 Kg in three digits. Series connections of the 100 strands are made in a PCB located in a terminating box from where the output goes to the integrator through a low pass filter circuit. A Labview code is written to control the synchronous motion of the positioning stages and the integrator to record the voltage signal induced by the wire movement [1].

THE LASER MICROMETER

The laser micrometer [2,3] is a non-contact magnet size measurement method where a laser light is focused onto the facets of a rotating polygon mirror. The parallel light emerging from the polygon facets falls on the object through an F-theta lens. The object obstructs the light. A lens on the opposite side of the object focuses the un-interrupted light onto a detector. This causes an output voltage to be recorded by a Digital Storage Oscilloscope (DSO) that is connected to a detector through a BNC. The voltage versus time curve shape is proportional to the object size. Figure 10 illustrates the basic principle of laser micrometer arrangement.

The polygon mirror is eight facets of Lincoln laser USA with microcontroller PWB 1-2-3060-610-00 P1BB. The microcontroller provides an RPM in the range from 1000 to 10000.

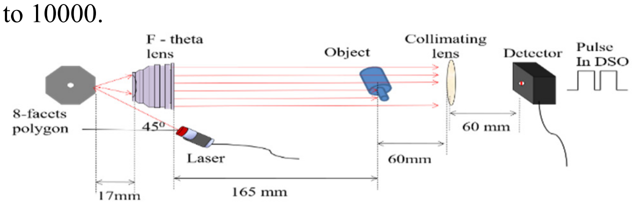

Figure 10: Principle of laser micrometer with an object.

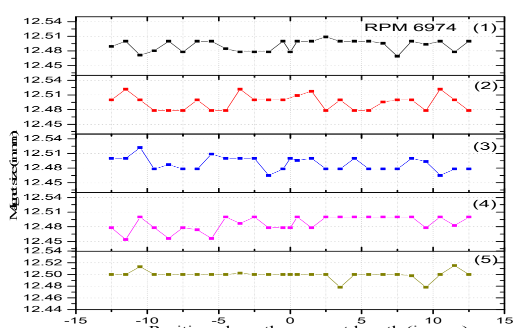

Figure 11: Magnet size measurement of 12.5 mm magnets.

The F- theta lens is of Edmond Optics Model No.63-311 with an effective focal length of 165 mm. The collimating lens size is 27 mm with a focal length of 60 mm. The detector system is an 818-BB detector connected to a digital storage oscilloscope (DSO) through BNC. When an object is placed, the light in the central portion of the pulse is interrupted causing a dip in the pulse width. The different pulse sizes are plotted for a number of solid objects from 3 mm to 13 mm. The curves show linearity.The slope of the curve gives sensitivity in µs/mm. The reciprocal of this when multiplied with the width of the pulse dip of an unknown object gives the object size in mm. To measure the size of the magnets, it is placed at the focal length of the F-theta lens.The inner width of the pulse on DSO is a measure of the magnet size measured in µs. To convert the magnet size from µs to mm, we multiply the data by calibration factor. Figure 11 represents the magnet size measurement for magnets of 12.5 mm. It is observed that the magnet sizes can be measured at an accuracy of 20 µm.

THE INTERFEROMETER

Figure 12 illustrates the working principle of the dual interferometer [4], detection system and Hall sensor attached to it. The dual interferometer consists of Wollaston Prism Interferometer (WPI) and Michelson Interferometer (MI). The light from laser passes through beam splitter (BS) reflect from mirror goes through splits through BS falls on the mirrors of MI.

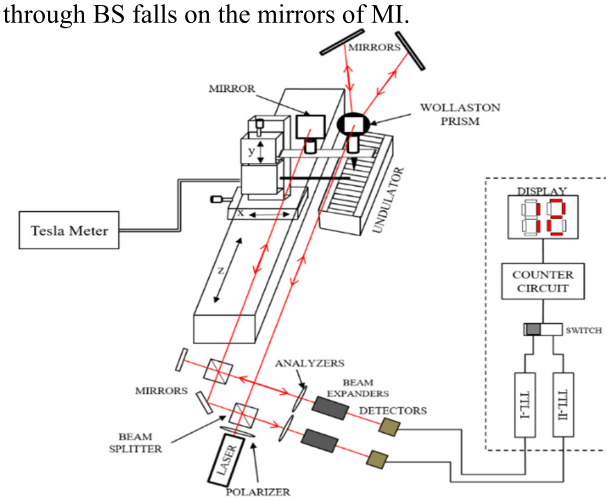

Figure 12: The Interferometer set up.

The lights reflected back from the movable mirror and fixed mirror combines at BS passes through the analyzer and beam expander to form interference pattern. The linear motion of the stage leads to change in longitudinal position of movable mirror causes the change in interferometer pattern. The light through BS continues towards the WPI where it splits into two – the o-ray and the e-ray. These two rays further fall on the combination of mirror forming the retro reflector, which sends back the light rays to the prism where they combine and transmit through analyzer and beam expander hence interference patternis observed. The transverse motion of the prism gives rise to change in the interference pattern, which can be employed, to measure transverse offset good field region of the undulator. A fringe counter reads out the fringe shift corresponding to the motion of the two interferometers. The fringe counter is attached to the two interferometers by a switch.The MI setup reads the longitudinal position of Hall probe which is used to determine the accuracy of the linear scale attached to the translation stage.

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