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LASER INTERFEROMETER FOR HALL PROBE ALIGNMENT AND MEASUREMENT OF UNDULATOR*

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Abstract

In the Hall probe Magnetic measurement method the field mapping is done along the length of the undulator. The field integral and phase error computed from the field mapping works as the figure of merit of the undulator. In this paper, we discuss the working of a laser interferometer for precise Hall probe alignment. A new user friendly software based on MATLAB has been developed. The phase error and magnetic field integrals are calculated for both taper and untaper U50 undulator of the Laser and Insertion Device Application (LIDA) Laboratory.

INTRODUCTION

The Hall probe method is widely used measurement system for field integral and phase error calculations of undulators. In this method a Hall probe is moved on a moving sledge and the field is mapped along the undulator length. The measurement accuracy of the filed mapping gives precision in the field integral computation. For this purpose a position sensitive detection system is often used to calibrate the z-position of the Hall probe on the translation sledge [1, 2]. In this paper, we introduce additional laser interferometer system and compare the two methods.

LASER INTERFEROMETER ALIGNMENT AND MEASUREMENT

The experimental setup consists of a Hall probe sledge mounted on a motorized z-linear translation stage with a length of 2000 mm. The z-linear translation stage is driven by a stepper motor controlled by a single-axis motion controller. The controller operates using specialized software that enables the recording of multiple Teslameter channels at once. It is programmable to control the speed and direction of the sledge's movement, as well as the delay time and step length for measurements, which can be defined by the user. The control software allows the linear translation stage to move in both forward and reverse directions within a distance range of 2 µm to 2000 mm. The permissible speed of movement can reach up to 20 mm/s, and the system can be set to capture data with a delay time between 0 ms and 9999 ms for each measurement. To ensure accurate measurements of the magnetic field, it is crucial to maintain precise alignment of the Hall probe with the undulator axis. Any deviation from the desired position can introduce errors in the recorded data.

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To verify the results of PSD, The Wollaston prism based laser interferometer is also implemented on the linear translation stage. The setup employs a laser as the primary light source. The light emitted by laser is directed towards a beam splitter. The transmitted light from the beam splitter is then passed through a polarizer. The polarized light emerging from the polarizer enters a Wollaston prism, a birefringent optical element. The Wollaston prism divides the incident light into two distinct rays based on their polarization characteristics: the ordinary ray (o-ray) and the extraordinary ray (e-ray). The retro reflector consists of two mirrors, both equipped with mounts on rotational stages featuring angular adjustment capabilities. These adjustments allow precise control over the tilt angles of the mirrors. By carefully adjusting the tilt angles of the mirrors in the retro reflector setup, the two reflected light rays combine at the Wollaston prism, resulting in constructive or destructive interference. The recombined light rays at the Wollaston prism pass through the polarizer and beam splitter once again facilitating the observation of the interference fringe pattern. The movement of the Wollaston Prism in vertical direction leads to shift in the interference pattern which is used to measure the misalignment of the Hall probe sledge on the linear translation stage. Laser interferometer assembly with Hall probe system shown in Fig. 1.

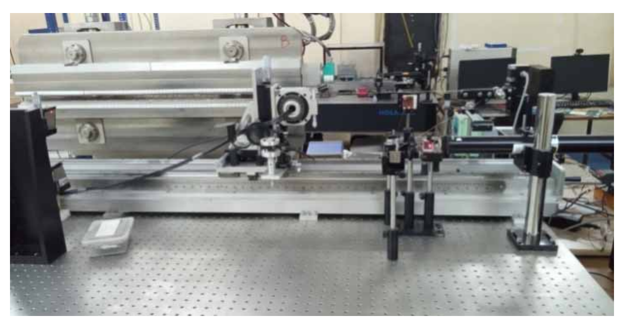

Figure 1: Laser Interferometer system on Hall probe bench.

RESULTS AND DISCUSSION

Throughout the entire length of the undulator, we carefully monitored the motion of the Hall probe with help of PSD. Our observations revealed that the Hall probe remained consistently positioned along the axis of the undulator, with a tolerance within the range of ±30 µm along the vertical direction presented in Fig. 2. The calibration curve of the laser interferometer was constructed as shown in Fig. 3 to facilitate the determination of transverse offset.

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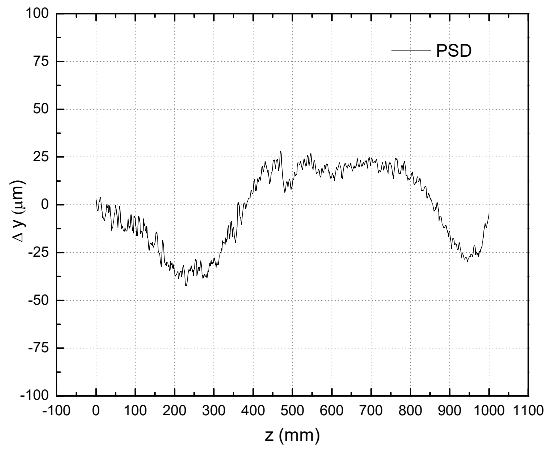

Figure 2: Misalignment captured by PSD.

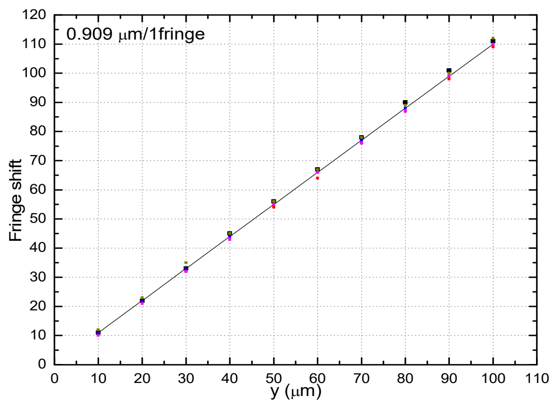

Figure 3: Calibration curve for laser interferometer.

We plotted the fringe shift against various transverse offsets while vertically displacing the interferometer. The slope of the curve represents the magnitude of fringe shift per unit transverse offset. Our analysis yielded a precise measurement of 0.909 microns per fringe shift as the transverse offset. The laser interferometer was systematically manoeuvred along the length of the undulator, utilizing the Hall probe sledge mounted on a linear translation stage. During the measurements, a comparison was made between the readings obtained from the laser interferometer and the PSD. It was observed that there existed a disagreement between the two measurements, with a range of ±0.5µm. Figure 4 shows the result obtained with laser interferometer.

Figure 5 presents the magnetic field measurement of untaper and taper gap undulator. The measurements by Hall probe were recorded at a step length of 1 mm for precise sampling of the magnetic field along the length of undulator, with a delay of 3000 ms between each reading ensured sufficient time for stabilization and minimized any potential interference between consecutive measurements. To calculate the magnetic field integrals, a newly developed user-friendly MATLAB code was utilized. Figures 6 and 7 show the first field integral and second field integral of magnetic field, respectively.

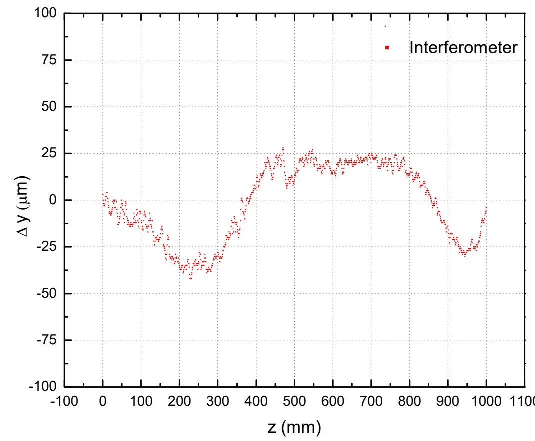

Figure 4: Misalignment captured by Laser interferometer.

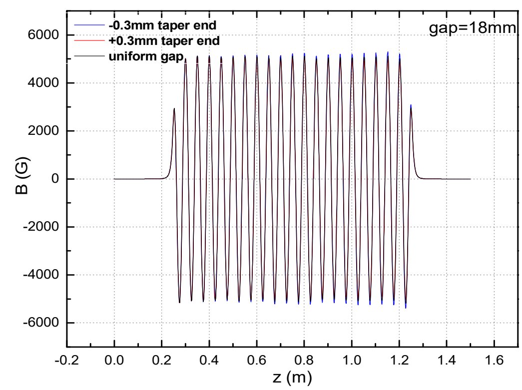

Figure 5: Magnetic field.

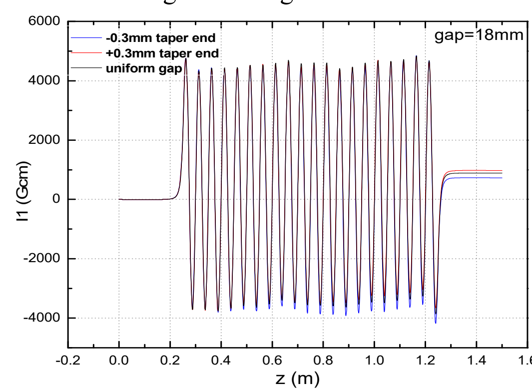

Figure 6: First field integral.

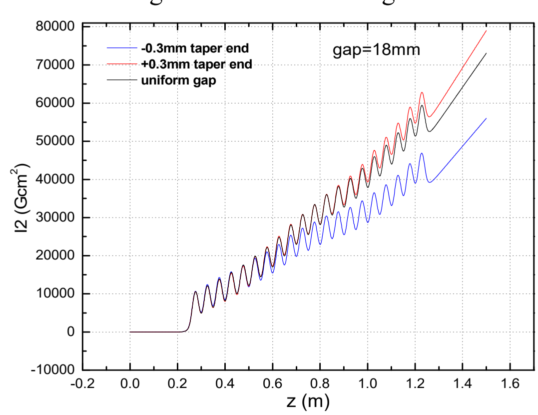

Figure 7: Second field integral.

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In the stretched wire experiment, the measurement of the magnetic field integrals is conducted using a stretched copper litz wire consisting of 100 strands [3]. The wire undergoes multiple movements, and the measurements are averaged to obtain reliable results. Figures 8 and 9 shows the comparison between the measurement with Hall probe and stretched wire system for untaper gap undulator.

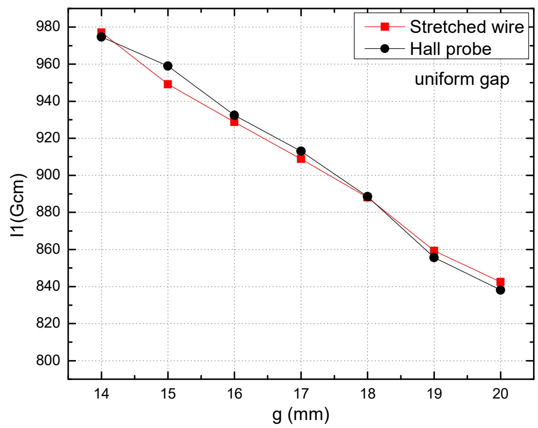

Figure 8: First field integral in uniform gap stretched wire measurement.

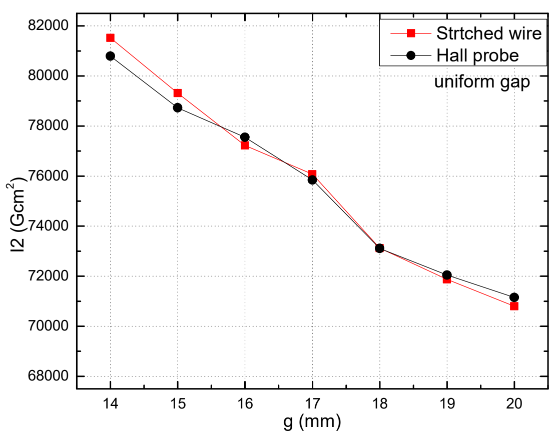

Figure 9: Second field integral in uniform gap stretched wire measurement.

Interestingly, both measurement methods yield closely matching outcomes in case of tapered gap [4]. The measurement is performed to tapered gap from -0.3mm to +0.3mm as shown in Figs. 10 and 11, respectively. Specifically, the first integral measured using the stretched wire exhibits a maximum difference of approximately2 Gcm, while the second integral shows a maximum discrepancy of approximately 100 Gcm^2.

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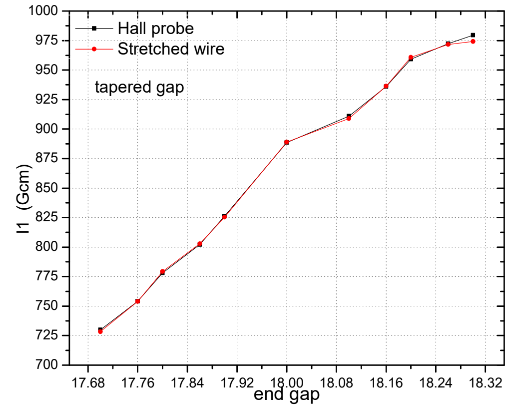

Figure 10: First field integral in taper gap stretched wire measurement.

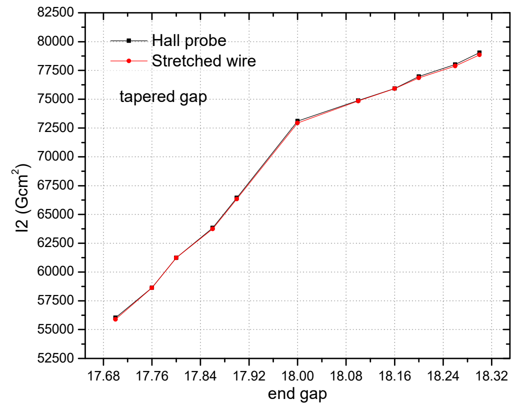

Figure 11: Second field integral in taper gap stretched wire measurement.

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