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DEVELOPMENT OF HALL PROBE SYSTEM FOR ACCURATE FIELD MAPPING AT NSRRC

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Abstract

After 20 years of use, the Hall-probe system at the National Synchrotron Radiation Research Center (NSRRC) has poor measurement reproducibility. The granite bench is 6m long and is robust but the Hall-probe stage with air bearings has deteriorated. To create a reasonable operating space for field correction for an insertion device (ID), the distance between the ID and the measurement system must be increased so a more stable and accurate stage is required. The developed system has a new structure to isolate the imbalance in the forces that act on it when the Hall probe stage is moving and the cable drags. An optical position sensitive detector (PSD) is also fitted to measure the change in the position of the hall probe in space. The positional error in space for the Hall probe is now less than 15um. This is achieved by measuring and correcting the position in real time.

INTRODUCTION

The NSRRC has two third-generation light sources: the Taiwan light source (TLS) with 1.5 GeV and the Taiwan photon source (TPS) with 3GeV [1]. To improve brightness of synchrotron radiation, various types of IDs have been manufactured, measured and the field has been corrected in ID lab at NSRRC [2]. Nine in-vacuum undulators (IU), 2 cryogenic permanent magnet undulators (CPMU), 5 elliptically polarized undulators (EPU) and 1 wiggler have been installed and operated at TPS. Currently, phase-III of the development involves constructing 5 EPUs.

The magnetic field quality of an ID is typically measured and verified using a measurement system such as moving wire and a Hall probe system. The Hall probe system is used to measure the local magnetic field of an ID. This measurement is used to optimize the field and increase the ID quality so light source facilities globally must create a reliable and highly accurate Hall probe system [3-5].

A Hall probe system consists of accurate Hall sensors that are precisely positioned in space to measure the magnetic field. A long stroke along the electron beam direction is required for measurement using an ID. The Hall probe system at NSRRC is supported on air bearings and moves upon a 6-meter-long granite bench. The previous mechanical design loaded the air bearings with large and uneven weights and 20 years of use has resulted in damage to the system. These air bearings are replaced and the system is redesigned to balance the load and meet other measurement requirements.

PREVIOUS VERSION OF HALL PROBE SYSTEM

The previous Hall probe system at NSRRC was designed and built by STI Optronics. In the version of design, the centre of gravity of the carriage is outside the area that is supported by air bearings so the air bearings are abraded on one side. The cable tray supporter assembly is poorly designed so the air-bearing stage is abraded and vibrates, so magnetic field measurements are interrupted.

A short Hall probe holder inhibits sorting the magnet unit, adjustment and measurement. The length from the Hall probe position to the 6-meter-long granite is defined by the centre of gravity of the hole stages, the adapters and devices.

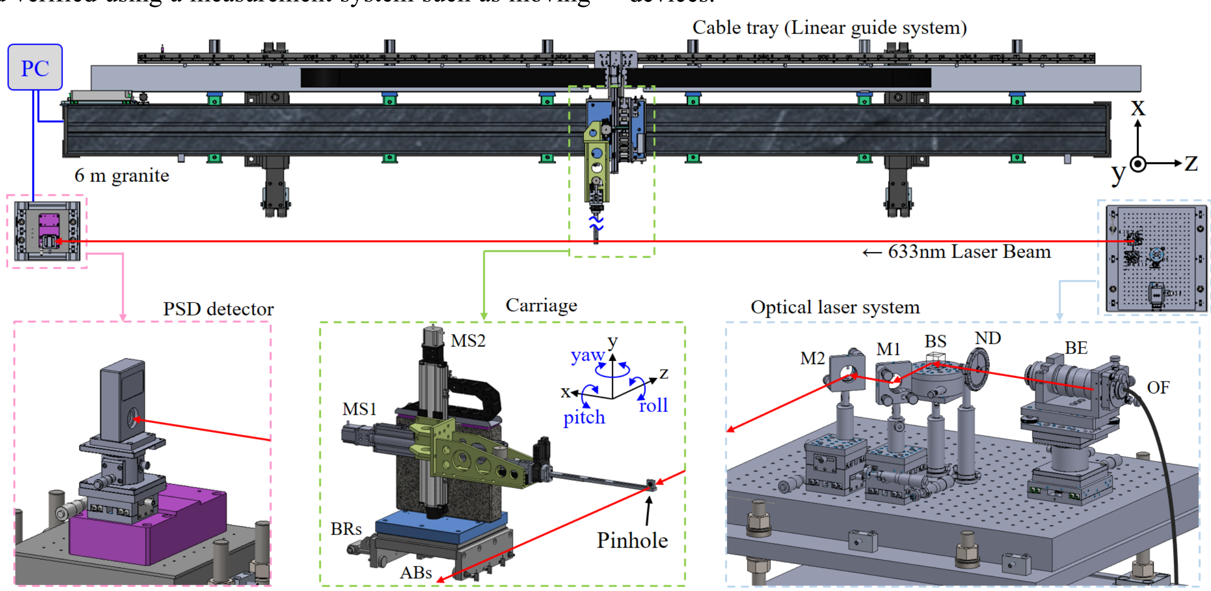

Figure 1: Carriage and optical PSD measurement system.

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DEVELOPMENT OF THE EXPERIMENTAL SETUP

This study optimizes the stability of the air- bearing stage and increases the distance from the Hall sensors to the granite bench to allow easier manipulation.

To increase the stability of the air-bearing stage, the center of gravity is simulated in different motorized positions using Solid Works 2016 to ensure that the center of gravity remains within the area of the air-bearings. The center of gravity shift depends on the position of the MS1 (motorized stage, x-axis). If the weight of components is correctly defined, the center of gravity is easily measured in any position. The air-bearing set supports an area of about 240 mm x 260 mm on the granite bench. Movement of the center of gravity remains within the area that is supported by the air-bearings by limiting the travel for each motor.

The center of gravity is defined and all ABs (air bearings) are renewed and the cable tray is connected using a different mechanism, which induced vibration in the previous version. The development of the cable tray mechanism uses a linear guide system beside the granite bench to support the cable tray, so the load of the cable tray is supported out-side the area of the air-bearing stage (see Fig. 1) to eliminate any moment due to drag from the connection of cable tray holder.

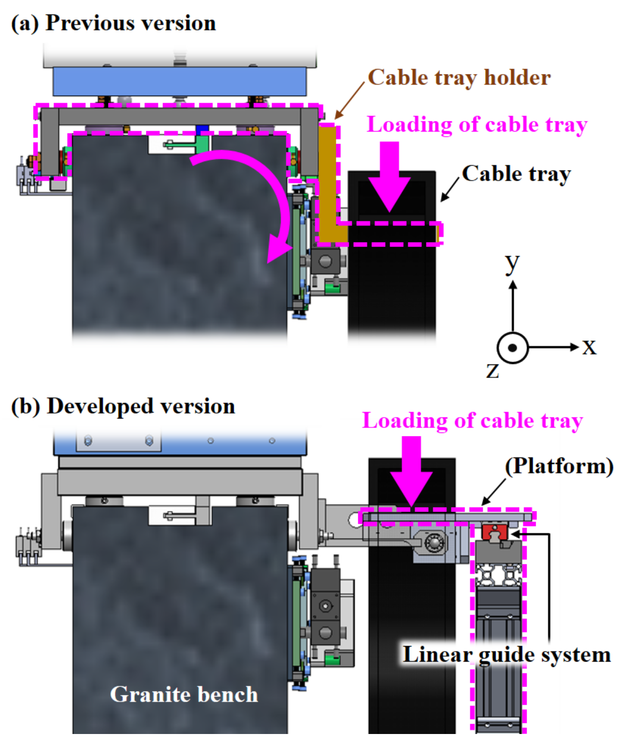

Figure 2. (a) the previous cable tray mechanism and (b) the developed mechanism. The previous version of the cable tray contact mechanism creates a moment so the air-bearing stage experiences drag due to the position of cable tray load. The developed mechanism uses a linear guide system to support the load of the cable tray. The moment due to the cable tray load affect only the linear guide system, which is acceptable.

A metal platform on a linear guide passively follows the air-bearing stage launches. The mechanism for the platform connects the air-bearing stage and the cable tray by fixing the driven end of cable tray and the contacting BRs (ball rollers) on the air-bearing stage. The BRs allow a point-contact between the air-bearing stage and the platform so the linear guide and the granite bench are slightly less than parallel (see Fig. 3). Figure 4 shows the connecting mechanism for the BR's.

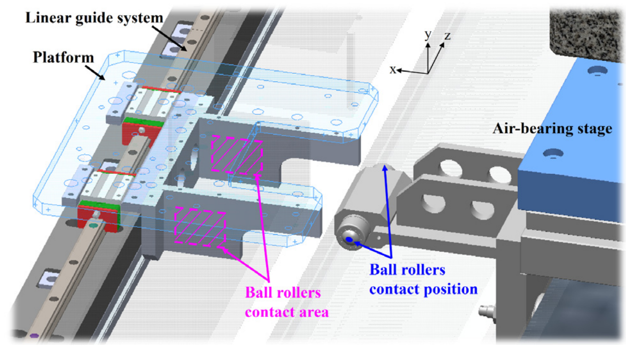

Figure 3. A sketch of the platform mechanism: the driven end of the cable tray is fixed on the platform. Two aluminum ribs (plates) are fixed above the platform and these contact the spherical ends of each BR. This connection mechanism allows the platform to carry the cable tray and passively follow the air-bearing stage along the linear guide system.

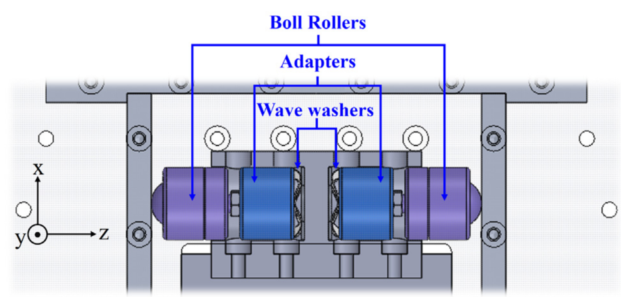

Figure 4. Top view of the platform: the depth of the adapter and the compression of the wave washers compression is adjusted to reduce backlash so the platform mechanism allows a better connection and less impulse when the air-bearing stage moves.

The distance from the Hall probe to granite bench is increased to 750 mm: the previous version used a distance of 300 mm. This increases the distance between the EPU (elliptically polarized undulator) and the granite bench to allow steady measurements. There is also more space for sub-module sorting or if hardware requires repair or adjustment (see Fig. 5). The length of the Hall probe holder is increased so the center of gravity changes. The vertical variation (opposite leg) in the Hall probe position also increases because the holder is longer (adjacent leg) (the ratio of tangent is assumed to be equal). The vertical variation is decreased if detection uses the PSD system.

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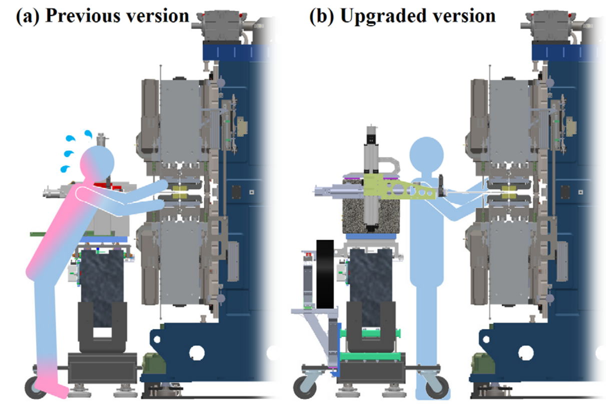

Figure 5. (a) before and (b) longer Hall probe holder, which allows easier manipulation/sorting of EPU's.

The electronic control device has x-axis (MS1) and y-axis (MS2) motorized stages (300 mm, 404300 XRMP, Parker) and a linear motor (IL12-31, Kollmorgen) on a 6-meter-long granite bench, which is the z-axis. The guidance mechanism in the longitudinal direction (z-axis) is supported by air bearings (flat round air bearing, New Way). Six Ø 50 mm air bearings support the granite and two Ø 40mm air bearings are mounted on each side of the granite. All air bearings use a 55~60 psi dried air source for launching. The material must be stiff to support the load on the air bearings so aluminum alloy is used.

Labview™ is used to acquire measurement data from the PSD system and for analysis. The correction mode for real-time measurement requires information about the traveling distance, the correction speed and the variation in the correction.

RESULT AND ANALYSIS

The straightness of the 6-meter-long granite bench was determined using an auto-collimator. A respective variation of twenty and ten micrometers in the pitch and yaw domains. Rotation of the roll domain has a variation of 0.10 mrad (maximum). Using the PSD measurement system, the spatial variation in the position of the Hall probe is about 50 µm (about ±0.025 mm) along the y-axis. The traveling position, correction speed and variation in the correction are added to the operating program to minimize the vertical variation in the path of the Hall probe. In terms of the PSD measurement, the corrected variation is approximately 15 µm (maximum) at full stroke.

A laser point displacement system is used to measure the horizontal and vertical displacement of the Hall probe station as it moves along the Z-axis on the granite platform. The laser point displacement system includes a 633nm solid-state laser, a beam expander, a thin aperture (SM05D5D, Thorlabs) with a diameter of 1.5 mm and a PSD (2L10SP, On-Trak) system. The laser beam diameter is increased to 2 mm using the beam expander. The Laser beam passes through the thin aperture and measures the displacement using the PSD system. The laser beam is larger than the aperture so when the laser beam passes through the aperture, a concentric diffraction pattern is generated. The PSD system is used to measure the offset in the horizontal and vertical direction of the 0^{th}-order beam in the diffraction pattern.

The vertical displacement of the Hall probe station is measured using the PSD (line in Fig. 6). The variation in the air-bearing stage (scatter in Fig. 6) is measured using an inclinometer (Clinotronic plus, Wyler), translated by L·tanθ, where L is the distance from the Hall probe to the center of the granite bench and θ is the angular variation.

The angular variation data is measured every 340 mm, which is approximately the length of air-bearing stage along the z-axis. The data is similarly scattered so the PSD device collects the signal correctly, which is consistent with the angular variation.

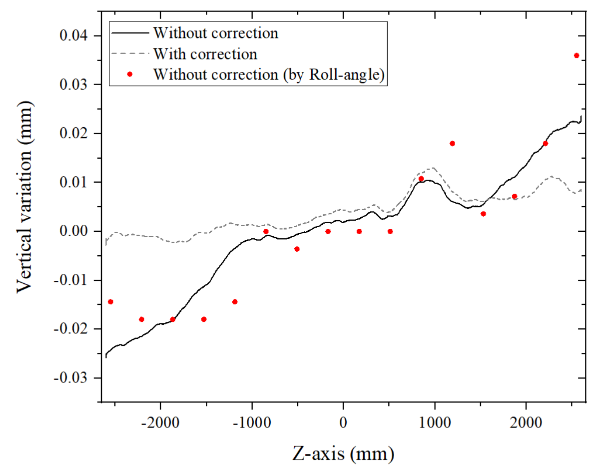

Figure 6. PSD measurement with (dash line) and without (solid line) correction mode

The measurement without correction (solid line, Fig. 6) has two gradients at the beginning and end of the full stroke, which is approximately at section -2600 to -1100 mm and section 1400 to 2600 mm. The variations in these two sections is used to optimize the spatial variation. The original total variation in the pinhole is about 50 µm. After correction of the original path, the variation in the beginning and end sections is reduced. A path that is corrected by 15 µm gives 70% better spatial variation.

CONCLUSIONS

This study develops the Hall probe system at the NSRRC. The air bearings are replaced and the uneven forces to which the carriage was subjected during measurement are eliminated by supporting the weight of the cable using an additional linear guide system. The carriage is smoother and more stable when moving and there is good spatial accuracy in the position of the Hall sensor for the length of the Hall probe. The results are verified using PSD measurements and the working space that is required to correct the ID magnetic is increased.

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