Application Note: Motion & Sensing 14

Piezo-Based Positioning for Magnetic Field Detection

Achieving Ultra-High Position Accuracy with attocube's EC* and AN* Series

Ida Simson and Danilo Schmidt
attocube systems AG, Eglfinger Weg 2, 85540 Haar, Germany

Carsten Kuhn
Helmholtz-Zentrum Berlin Research at Large-Scale Facilities
Undulator Working Group

Introduction

X-rays, also referred to as synchrotron radiation, serve as an important tool to observe the structure and dynamics of matter. Modern light sources like free-electron lasers or third and fourth generation storage rings provide X-rays for a vast range of scientific areas, such as nanotechnology, health and medicine, engineering, forensics, archaeology, and agriculture. The synchrotron radiation is generated by bending magnets, wigglers or undulators. While the radiation from bending magnets or wigglers has a broader spectrum of photon energies, an undulator generates radiation with narrow peaks, i.e. bright and coherent radiation at specific harmonics. This specific peak spectrum and defined photon energy is the main advantage of undulator radiation. In general, an undulator generates radiation with the highest brilliance (the brilliance parameter describes the quality of the emitted radiation). Therefore, they are the workhorses for generating synchrotron radiation in current and future light sources.

An undulator is an insertion device and consists of two or more arrays of permanent magnets and CoFe-Poles, periodically arranged, generating an alternating magnetic field. The electrons are hence forced to follow the undulating trajectory.

At the storage ring BESSY II in Berlin-Adlershof, all undulators use permanent magnets based on the rare earth alloys NdFeB or PrFeB. Over the last few years, Cryogenic Permanent Magnet undulators (CPMUs) were developed [1-3]. A technical drawing of a CPMU can be seen in Figure 1. Compared to the conventional technology of ordinary undulators or in-vacuum undulators, the CPMUs feature an increased undulator peak field resulting in higher photon energies for the given electron energies. This feature qualifies this type of undulators in particular for free-electron laser sources.

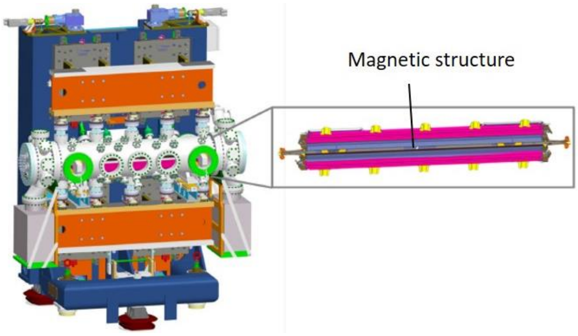

Figure 1: CAD model of a CPMU-17; developed by HZB (Kuhn, 2018).

Setup

The CPMU's magnetic properties are determined using a vacuum Hall-probe bench. The Hall-probe bench measures the magnetic field with two orthogonally orientated Hall-probes to control the performance of the undulator at different temperature levels. Later, the undulators will be cooled to about 77 K. By characterizing the undulators at different temperatures, thermal influences can be specified precisely.

The CPMUs move on a 2 m rail, parallel to the longitudinal dimension of the undulators' magnetic structure. The slide on the rail is driven by a slope drive. The longitudinal errors scale with the period length. With shorter period lengths, the geometric errors become more problematic, especially the longitudinal position errors. These are noticeable as phase errors of the emitted radiation.

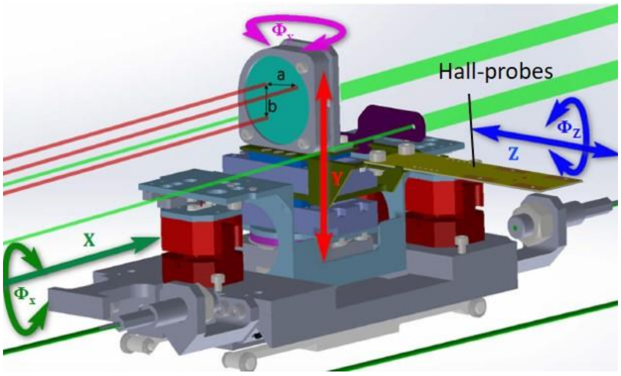

Figure 2: CAD model of the measurement slide.

The accuracy of the Hall-probe orientation relative to the magnetic axis of the undulator is aimed to reach 5 µm and 20 µrad. Three linear positioners of the model ANPz101 are responsible for the pitch and roll angle as well as the vertical position of the probes. An ANR240 rotator changes the yaw angle while two more linear horizontal positioners ECSx3030 are capable of moving the horizontal direction perpendicular to the horizontal direction of the bench. Together with the slope drive, these six positioners realized in total six degrees of freedom (see Figures 2 and 3).

The position of the Hall-probes is measured in five degrees of freedom by two optical systems. A three beam laser interferometer for the angles (pitch and yaw) as well as the longitudinal position, and additionally two position sensitive detectors for the transversal positions. A typical measurement tool for this purpose is the IDS3010 (not used in this particular setup) as it features the flexibility to be used in any kind of environment and the required precision of +/- 1 ppm (in ambient conditions).

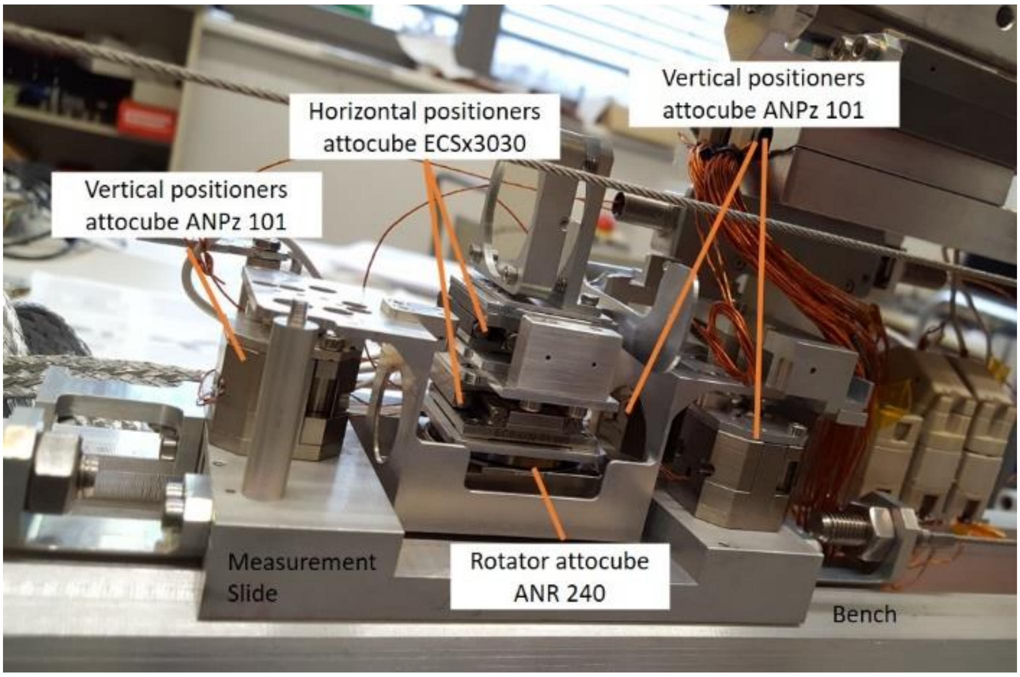

Figure 3: Measurement slide with integrated attocube positioners.

Measurement Results

The position setup for the Hall-probe as described above allows for longitudinal measurements of the magnetic flux density depending on the longitudinal and transversal position.

In order to specify and to investigate the thermal influences on the magnetic field, the Hall-probe bench is used to determine the magnetic flux density at different temperature levels. Figure 4 shows an increase of the magnetic flux density by about 15 % for lower temperatures for a CPMU prototype with 11 periods of 9 mm length and a magnetic gap of 2.5 mm. In other words, the higher magnetic flux density results in the possibility of using shorter period lengths and thus achieving higher photon energies for given electron energies. In addition, the resistance of the magnets to radiation damage caused by the electron beam increases.

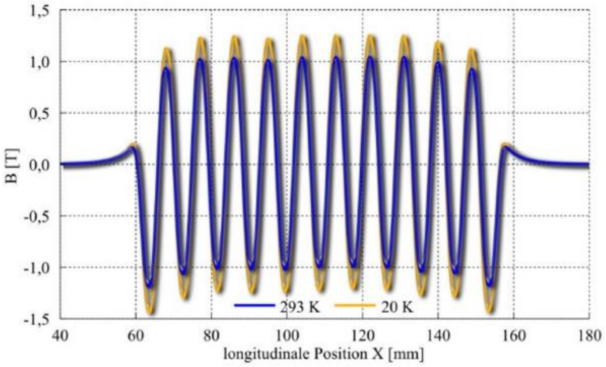

Figure 4: Longitudinal determination of magnetic flux density.

Conclusion

This Application Note demonstrates the capability of attocube's positioners to fulfill the highest requirements regarding accurate and repeatable position control. The combination of the interferometer with attocube's piezo motors allowed for a position accuracy of the Hall-probes of at least 5 µm and 20 µrad.

References

[1] Carsten Kuhn, "Development of manufacturing processes for a cryogenic undulator and the validation by magnetic measurements on a prototype", Dissertation, TU Berlin, 2016.

[2] Bahrdt J. & Kuhn C., „Cryogenic Permanent Magnet Undulator Development at HZB/BESSY II", Synchrotron Radiation News, pp. 9-14, 28 3 2015.

[3] C. Kuhn et al., Proc. of the IPAC, Shanghai, China, pp. 2126-2128, 2013.