PHOTON BEAM POSITION MEASUREMENTS USING CVD DIAMOND BASED BEAM POSITION SENSOR AND LIBERA PHOTON AT SWISS LIGHT SOURCE

P. Leban, D.Tinta, Instrumentation Technologies, Solkan, Slovenia
C.Pradervand, Swiss Light Source at PSI, 5232 Villigen, Switzerland

Abstract

Measurements were performed at the Swiss Light Source on the beamline X06SA using a four-quadrant CVD diamond sensor which was connected to Libera Photon, a new photon BPM device from Instrumentation Technologies. The outputs of the sensor are 4 current signals in the nA range and are directly connected to the measuring unit without any pre-amplifiers. External bias voltage was applied, although the Libera Photon can supply internal bias voltage. Measurements consisted of: scanning the measurement range, frequency analysis of the beam movement and analysis of the photon beam flux influence on the measured position. The Sensor was mounted on a motorized XY stepper motor stage. Acquired data consisted of raw signal amplitudes and processed positions. Acquisitions were taken at 10 kHz and 10 Hz rate.

Figure 1: The CVD diamond based sensor used for testing.

INSTRUMENTATION

Libera Photon is a photon beam position processor, which features current-to-voltage conversion, digitalization and signal processing. The output data flows are delivered with different rates (100 kS/s, 10 kS/s and 10 S/s) and can be accessed simultaneously. The acquisitions were taken and analysed with Matlab.

The beam position monitor for synchrotron radiation is based on a 10 µm thick CVD-diamond membrane with 4 Ti/Al electrodes. The signals are obtained from an array of 4 metal pads on top of the diamond surface. The gap between the pads is 20 µm. The synchrotron radiation beam has a normal angle of incidence with respect to the diamond membrane. A field of typically 1 kV/mm is applied between the 4 pads on one side of the membrane and the counter-electrode on the other side. The absorption of the X-ray beam locally generates charge carriers in the diamond layer and hence a photocurrent is induced between the 4 electrodes and the counter-electrode. The pads measure 1,5 by 4,5 mm^2, the membrane has an area of 3,6 by 9,6 mm^2 and is 10 µm thick, see Figure 1.

The output currents from the sensor, measured by Libera Photon were in the range of 200 nA per pad. The bias voltage of 20 V was applied using an external voltage supply. The measurement setup was installed at the beamline X06SA at the Swiss Light Source.
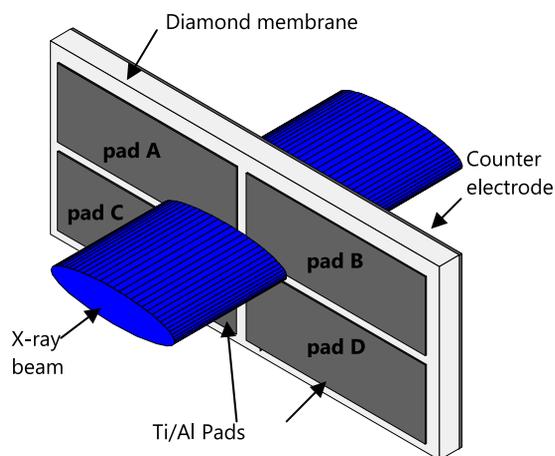
MEASUREMENTS

The following measurements were carried out: scanning the measurement range by moving the sensor, frequency analysis of the beam movement and performing the analysis of the beam current dependence by changing the flux of the photon beam.

For most of the measurements in this paper, the 10 kS/s data on demand was acquired. This data is extracted from the circular buffer in Libera Photon and is named as DD buffer data. It is derived from the ADC data which samples the input signals with 100 kHz sampling rate. The bandwidth of the DD buffer data is typically 2 kHz, only for the lowest measurement ranges it is 1 kHz (Range 1) and 0,5 kHz (Range 0).

As the bandwidth of the data is high enough, it can nicely represent fast beam motion and can be effectively used for diagnostic purposes and detailed studies in the beamline. The same data is available also as a stream which can be used for fast orbit correction in the storage ring. A snapshot from one of the measurements is presented in Figure 2, showing a clear anticorrelation of the signals of the top and bottom pads, indicative for vertical beam motion.
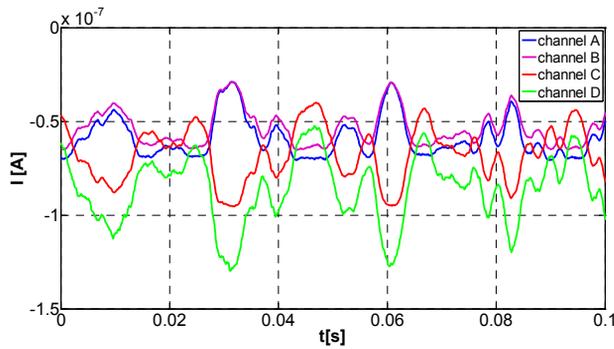
Figure 2: The DD buffer data.

Measurement range scanning

Before first use, it was necessary to calibrate the unit. Coefficients and offsets for position calculation were defined by scanning the active area.

The sensor was centered in the beam. Then sensor was positioned by a motorized XY stage and scanned for ±20 µm in steps 2 µm horizontally and vertically. The position was recorded for each movement. The data was then analysed by using least square method to fit the curve and define kx, ky, x_offset and y_offset. These coefficients were then used for all the measurements presented in this paper.

Position is calculated using the following equation (example for horizontal direction):

$$X = Kx \cdot \frac{(Ia + Id) - (Ib + Ic)}{Ia + Ib + Ic + Id} + Xoffset \text{ , where}$$

Kx ... coefficient for horizontal position calculation
Xoffset ... offset for horizontal position
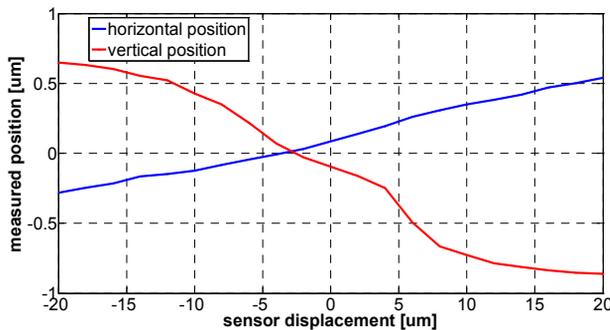*Ia, Ib, Ic, Id ... input currents*

Figure 3: Position reading with unity coefficients.

Before performing any calibration, the position was calculated using unity coefficients. In this case, Kx and Xoffset were 1 and 0, respectively. After fitting the data to the curve using least squares method, Kx and Ky were calculated. Calculation was done in Matlab using "polyfit" function. Figure 3 shows the data without using any correction coefficients and Figure 4 shows the data after applying Kx and Ky.
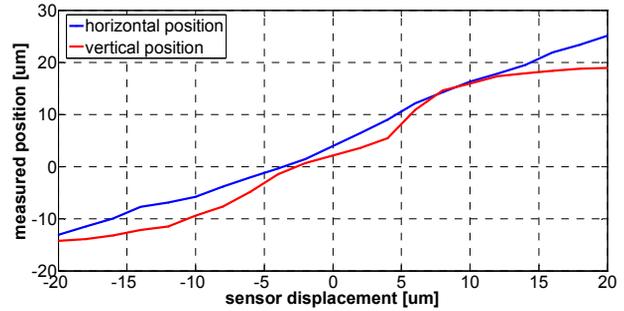
Figure 4: Position after applying Kx and Ky.

After applying Kx, Ky and both offsets, final result is presented in Figure 5.
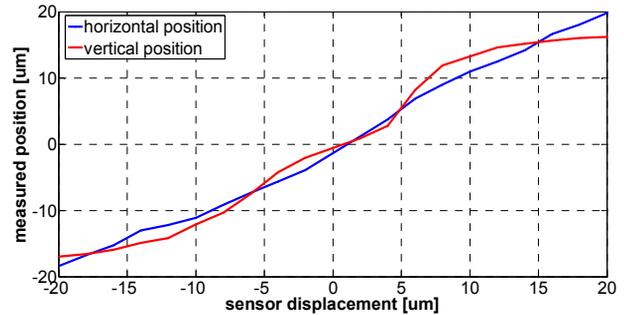
Figure 5: Position after applying Kx, Ky and offsets.

The following coefficients and offsets were calculated and applied for all the position calculations in this paper:

Kx = 46,512 µm   Xoffset = -2,693 µm
Ky = 21,978 µm   Yoffset = -5,297 µm

Frequency analysis of the beam movement

The next experiment was performed to observe the influence of the monochromator cryo cooling pump on the beam stability. The speed (frequency) was changed from 30 – 52 Hz in steps of 2 Hz. Acquisitions of 1 second of DD buffer data were done for each frequency setting. By analysing the data using FFT, integrated noise was observed.

It was seen that the majority of the added noise is in the range of 100 – 200 Hz. This is nicely seen in Figure 6 and Figure 7. Both dotted lines represent the maximum (at 36 Hz pump frequency) and minimum (at 50 Hz pump frequency) added noise on horizontal and vertical positions. Plots of other frequencies lie in between.
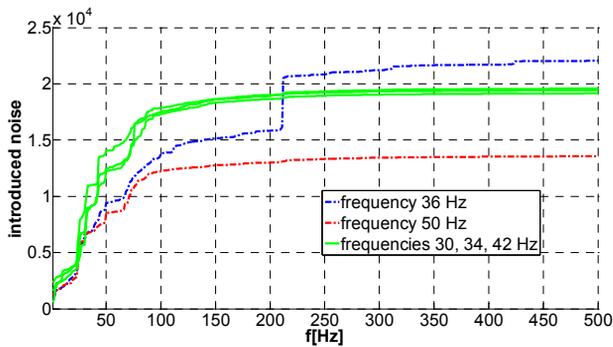
Figure 6: Integrated noise on horizontal position.

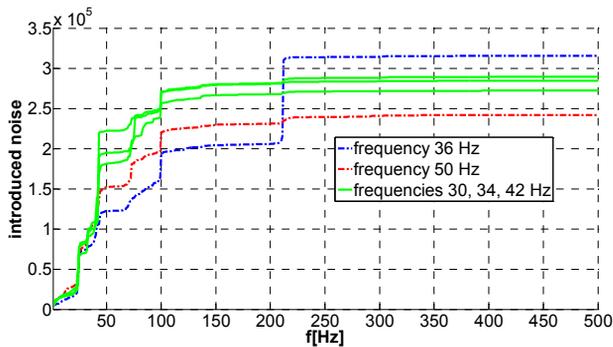Please note that the vertical scale on Figure 7 is 10 times higher.

Figure 7: Integrated noise on vertical position.

At 36 Hz pump frequency, the next significant frequency in the spectrum is 216 Hz, which is exactly 6 times the 36 Hz. The factor of 6 arises from the fact, that the pump has 6 blades.

With increasing pump frequency, vertical position was changing whereas horizontal position remained in the same level. Results are presented in Figure 8.
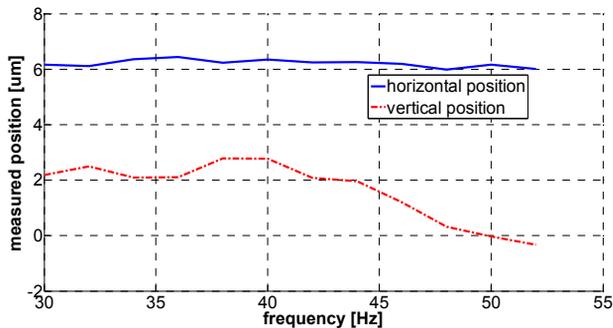

Figure 8: Position vs. pump frequency.

The standard deviation on the vertical position was very high so it does affect the correct position reading.

Photon beam flux dependence

The photon beam is measured in number of photons per second. The higher the number of photons per second, the higher the current. The goal of the last measurement was to observe the position change due to the photon beam change. Measurement started with $1,2 \times 10^{12}$ photons per second which correlates to approximately 50 nA in average of all 4 channels at x keV photon energy. The photon flux was decreased by using AL-filters. The lowest currents measured were less than 3 nA in average which corresponds to $0,02 \times 10^{12}$ photons per second. Measurements were done with fixed measurement Range setting (N°2) in Libera Photon. This measurement range covers currents in the ±200 nA current range. For each current level, acquisition of 1 second of DD buffer data done. Results are presented in Figure 9.
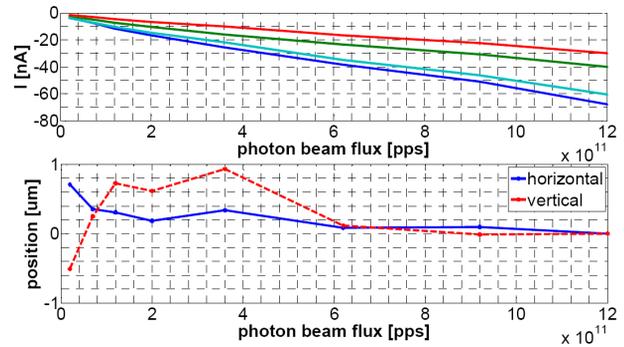

Figure 9: Photon beam flux dependence.

As mentioned in the upper paragraph, measured currents were ranging from 3 nA to 50 nA in average. For optimal results, Libera Photon should use two different measurement ranges (±20 nA and ±200 nA). To not distort the measurements, the range was always set to ±200 nA. This explains higher deviation in position at lower currents.

CONCLUSION

The CVD diamond sensors are fast detectors with relatively low current levels. Libera Photon is able to work with these signals and nicely represent currents from all four plates. Correctness of current and position reading was confirmed by oscilloscope. Since the bandwidth of the data is high enough, we were able to get good spectrum and read the characteristic frequencies.

Frequency analysis of the beam position identified the pump frequency, which significantly affects the beam stability. This gave us an indication, at which frequency the pump should not be operated. It was additionally discovered, that operating the pump at frequencies higher than ~40 Hz, affects on the absolute beam position.

The current dependence measured was well below 1 µm on horizontal direction. This fits to the Libera Photon specifications. However, it would be interesting to investigate also the contribution of the sensor to the overall measurement.

REFERENCES

[1] H.Sehr, C.Schulze-Briese, C.Pradervand, H.Schift, J.Gobrecht: A CVD-diamond based beam position monitor for synchrotron radiation, Technical Digest of Eurosensors XVIII, Rome 12-15 Sep 2004.