Photon Beam Position Measurements Using CVD Diamond Based Beam Position Sensor and Libera Photon At Swiss Light source

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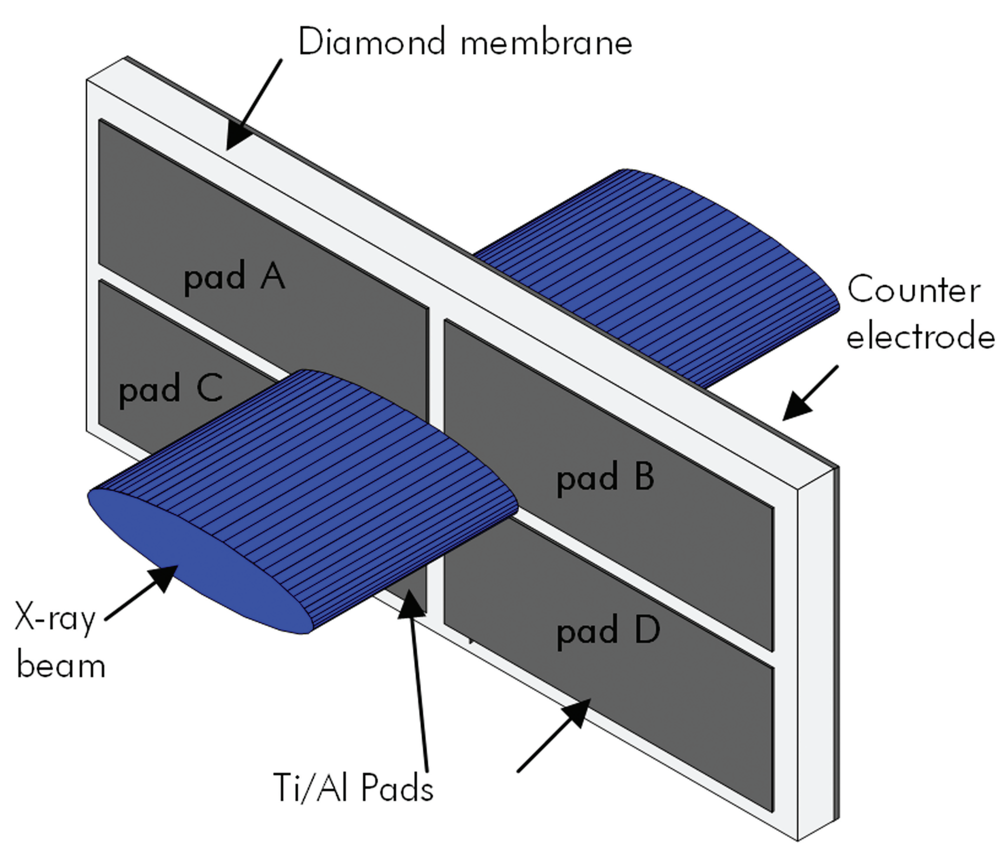
Abstract

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.

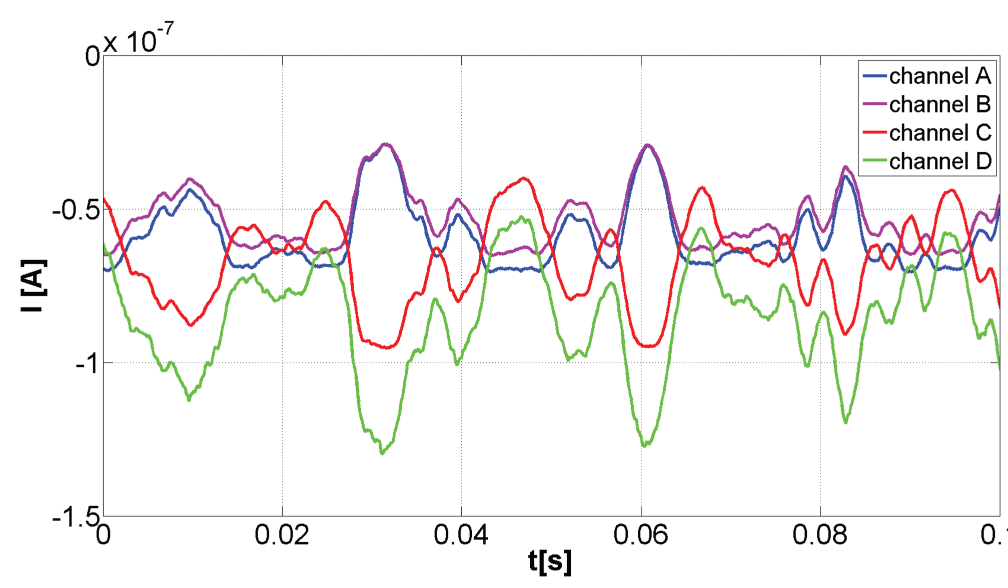
Instrumentation

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 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 CVD diamond based sensor used for testing

Measurements



The DD buffer data at 10 kS/s data rate.

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.
The bandwidth of the output data is 2 kHz, so it can nicely represent fast beam motion and can be effectively used for diagnostic purposes and detailed studies in the beamline.

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.

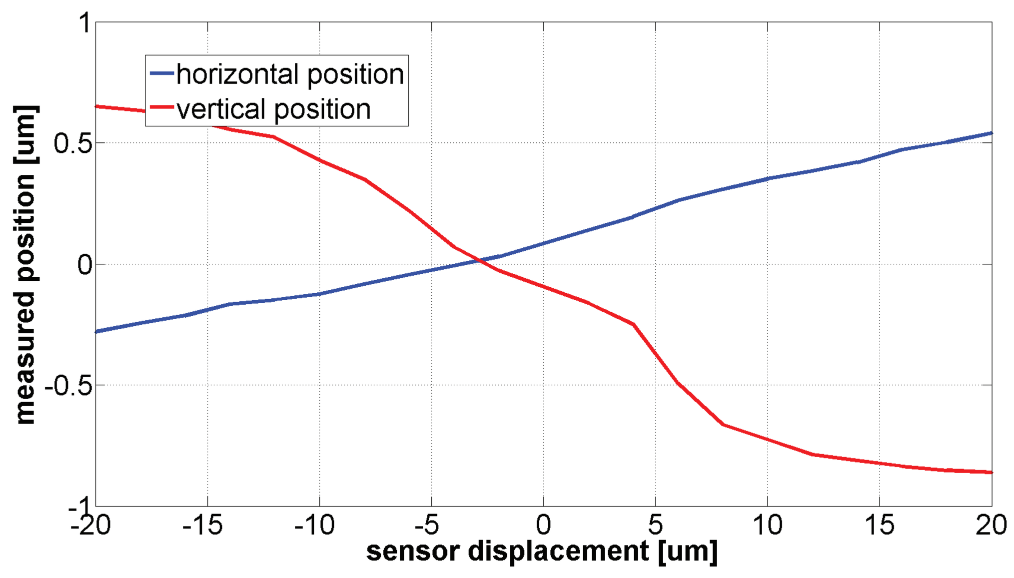
Measurement range scanning

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. Position is calculated using the following equation:

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

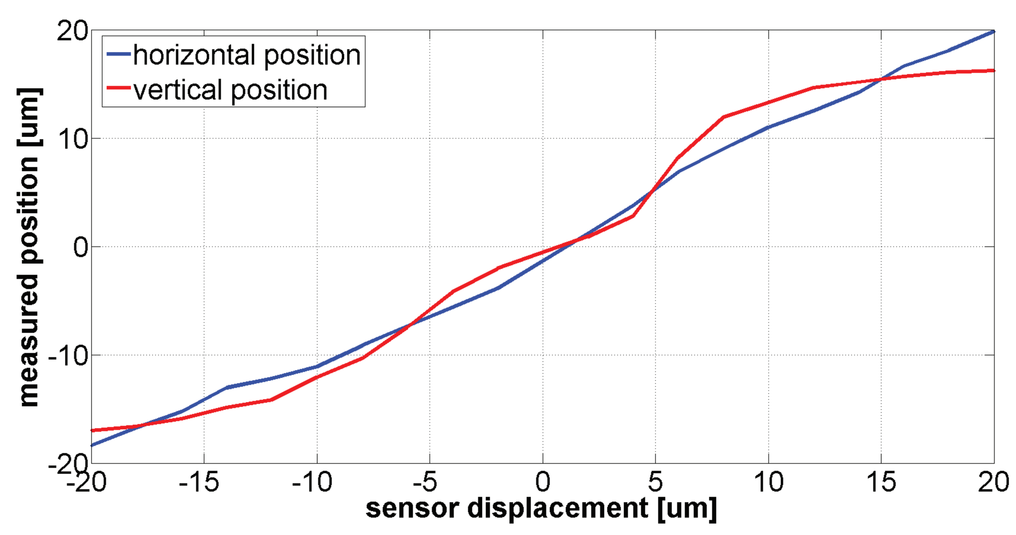
Kx ... coefficient for horizontal position calculation
Xoffset ... offset for horizontal position
Ia, Ib, Ic, Id ... input currents

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.



Position reading with unity coefficients.

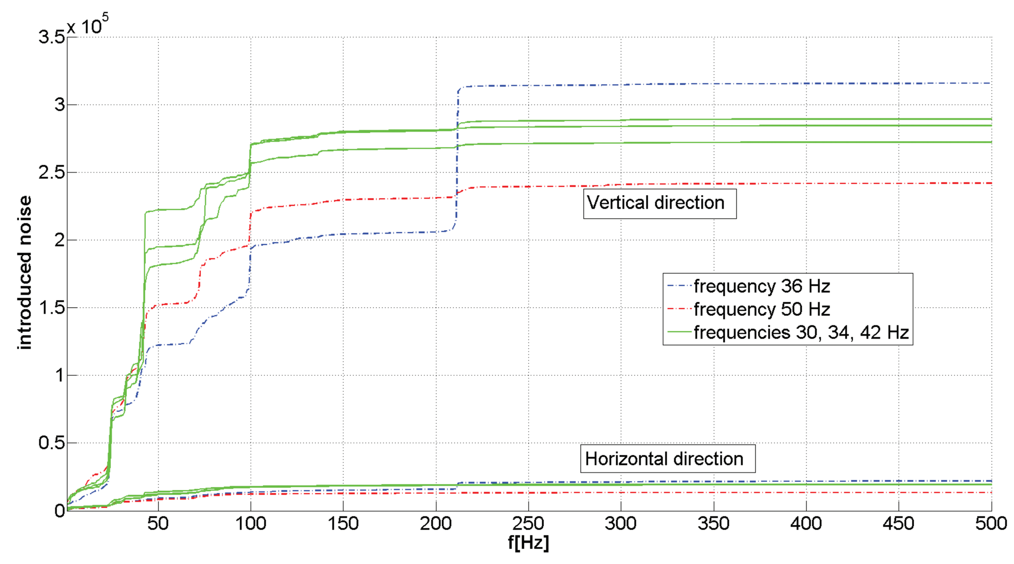
The data was then analysed by using least square method to fit the curve and define kx, ky, x_offset and y_offset for calibration coefficients. These coefficients were then used for all the measurements presented in this paper. Results after applying calibration coefficients are presented in Figure 4.



Position after applying Kx, Ky and offsets.

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.
The majority of the added noise is in the range of 100 – 200 Hz. 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.

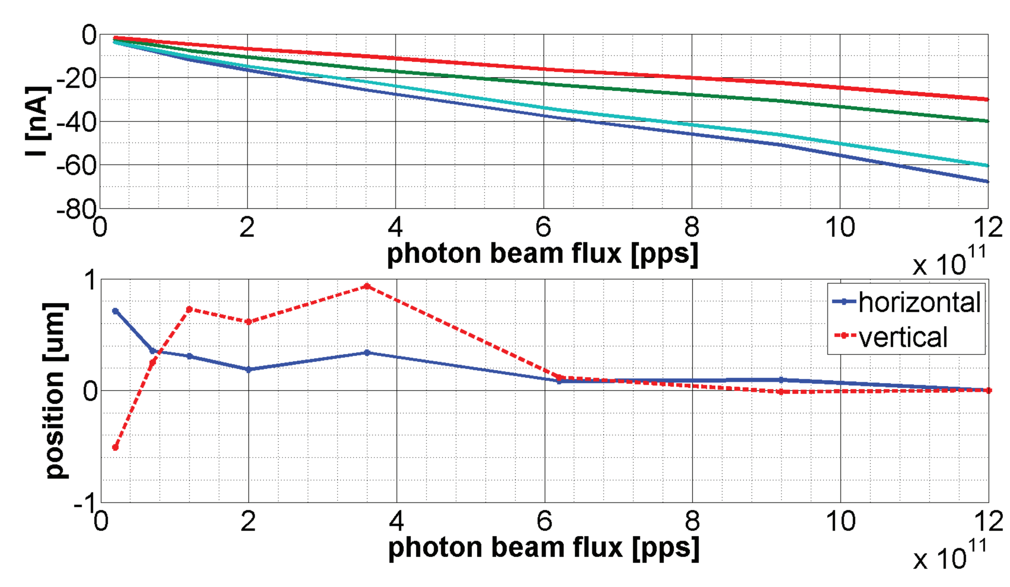


Integrated noise on horizontal and vertical direction.

The integrated noise on the vertical direction is higher for a decade compared to horizontal direction.

Photon beam flux dependence

The goal of the last measurement was to observe the position change due to the photon beam change. The photon beam is measured in number of photons per second. The higher the number of photons per second, the higher the current. Measurement started with 1,2x10^{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 0,02x10^{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.



Photon beam flux dependence.

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

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.

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