Strange results from synchrotron RF beam position measurements using sc-CVD diamond detectors at DLS

Or: how I learned to stop worrying and love DC measurements
Strange results from synchrotron radiofrequency beam position measurements using sc-CVD diamond detectors at DLS

Or: how I learned to stop worrying and love DC measurements

Overview:
• How to measure the position of micron-sized X-ray beams - and why!
• Measuring the resolution of X-ray Beam Position Monitors (XBPMs)
• Using the synchrotron bunch structure to make RF measurements
• Conclusions
Using diamond as a position sensitive detector

How to measure the position of micron-sized X-ray beams - and why!
Single-crystal CVD diamond detectors live in the experimental hutch, observing the X-ray beam striking the samples being tested.
scCVD diamond window, 4.5mm x 4.5mm
Diamond XBPM, produced by Cividec GmbH
Charge carriers liberated from the bulk diamond by absorbed X-rays migrate to one of the surface electrodes under the influence of an electrical bias.
Charge carriers liberated from the bulk diamond by absorbed X-rays migrate to one of the surface electrodes under the influence of an electrical bias.
• 50μm thick diamond
• 1kHz acquisition
• 12.7keV photons
• 6μm beamsize, σ
• Signals obtained are from scanning the XBPM across the face of the incident X-ray beam using the beamline goniometer

Gradient of the slope gives a “scale factor”, K, to convert the dimensionless Δ/Σ into a real beam position in [μm]

Position, $\Delta/\Sigma = \frac{(A+D) - (B+C)}{(A+B+C+D)}$
Feedback, beam alignment, and fault-finding are the primary use of the XBPMs.
Measuring the resolution of these position monitors

How small an X-ray beam movement can they resolve?
Three scCVD diamond XBPMs monitoring the same incident X-ray beam, synchronously, at 5kHz sampling frequency.
Position resolution is better than 0.1% of the beamsize, or a few 10nm at kHz bandwidth!
Observing the synchrotron bunch structure

Can individual electron bunches be observed?
Observing the synchrotron bunch structure

Typically ~700 electron “buckets” filled, out of 936 buckets
Synchrotron bunch structure observed with the detector and an oscilloscope
Agilent Infiniium DSO91304A 13GHz
Observations of the synchrotron bunch train with a diamond XBPM.
Observations of the synchrotron bunch train with a diamond XBPM.
Using the synchrotron bunch structure to make RF measurements

Are these any better than normal, boring DC measurements?

A wise man once said (paraphrasing...!)

“Does your experiment have a lock-in amplifier?
Because it should have a lock-in amplifier.”

(G. Morley, my PhD supervisor at Warwick)
These measurements are nothing too new. See also past ADAMAS presentations!
Transimpedance amplifier
24bit ADC
100kSample/s
5kHz analogue low-pass filter

Using the synchrotron bunch structure to make RF measurements

Results from an off-the-shelf XBPM
DLS I04 beamline

**DC measurement**

Position measurement [μm] vs. X-ray beam position [μm]

**RF measurement**

Position measurement [μm] vs. X-ray beam position [μm]

**RF measurement**

Measured RMS beam motion [μm] vs. X-ray beam position [μm]

@ 1.0kHz
DC measurement

RF measurement

Measured RMS beam motion [\mu m]

@ 1.0kHz
DLS I04 beamline

Synchronous position measurements when beam is centered on XPBM
Conclusions 1

• DC measurements are good enough!
• RF measurements conducted here are simply more noisy.  
  (...unless our experimental set-up was somehow terrible?)
• ...however, these measurements were done using a “normal” detector. 
  What about a detector specifically designed for RF measurements, with 
  electronics built in, to allow 500MHz signals to pass out to the detector.
Using the synchrotron bunch structure to make RF measurements

Results from a specifically made RF XBPM
Custom detector, with LC resonators on each quadrant output, each peaking at ~500MHz (i.e. the synchrotron RF frequency).
Produced as a joint DESY (H. Graafsma), ESRF (J. Morse), Dromedar (B. Solar) project.
Spectra of DC measured position noise using CIVIDEC XBPM and TetrAMM when:
- beam is just in one quadrant, - beam is between quadrants.

Spectra of RF measured position noise using DESY/ESRF/ Dromedar XBPM when beam is centred on four quadrants: for multiple bias voltages.
Conclusions 2

• DC measurements are good enough!
• RF measurements show results that I don’t understand.
• There are clearly additional complications with the RF measurement.
• DC measurements are good enough!
Many thanks for your attention

Also, special thanks to:

• DESY (H. Graafsma), ESRF (J. Morse), Dromedar (B. Solar) for their RF XBPM, and for answering my many dumb questions.
• CIVIDEC, for helping with various tests, and for being helpful when I fried a detector.
• DLS beamlines for giving me beamtime, in particular I24, I04, and B16, and for putting up with me in general!