ADAMAS 2017

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

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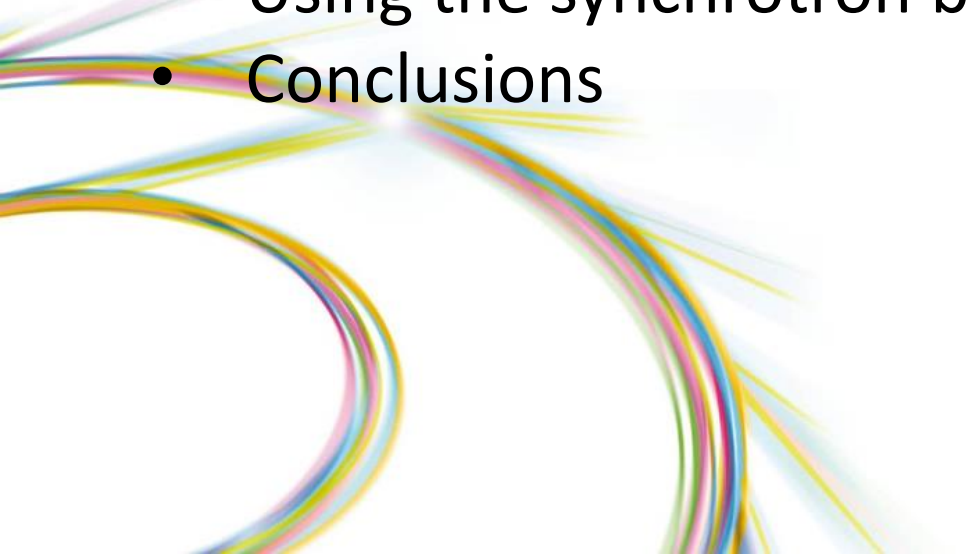
Strange results from synchrotron radiofrequency beam position measurements using sc-CVD diamond detectors at DLS

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



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Using diamond as a position sensitive detector

How to measure the position of micron-sized X-ray beams - and why!

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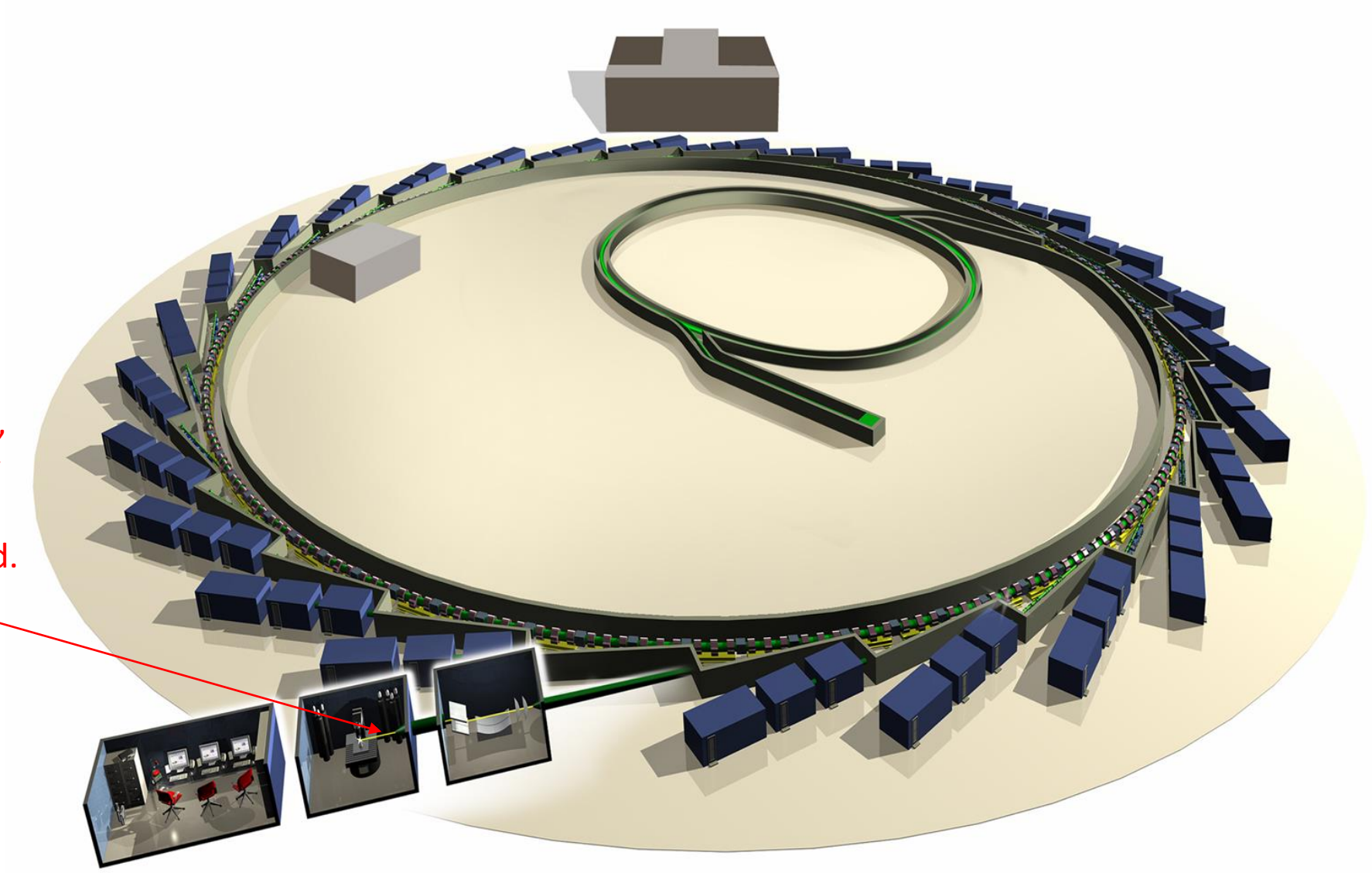
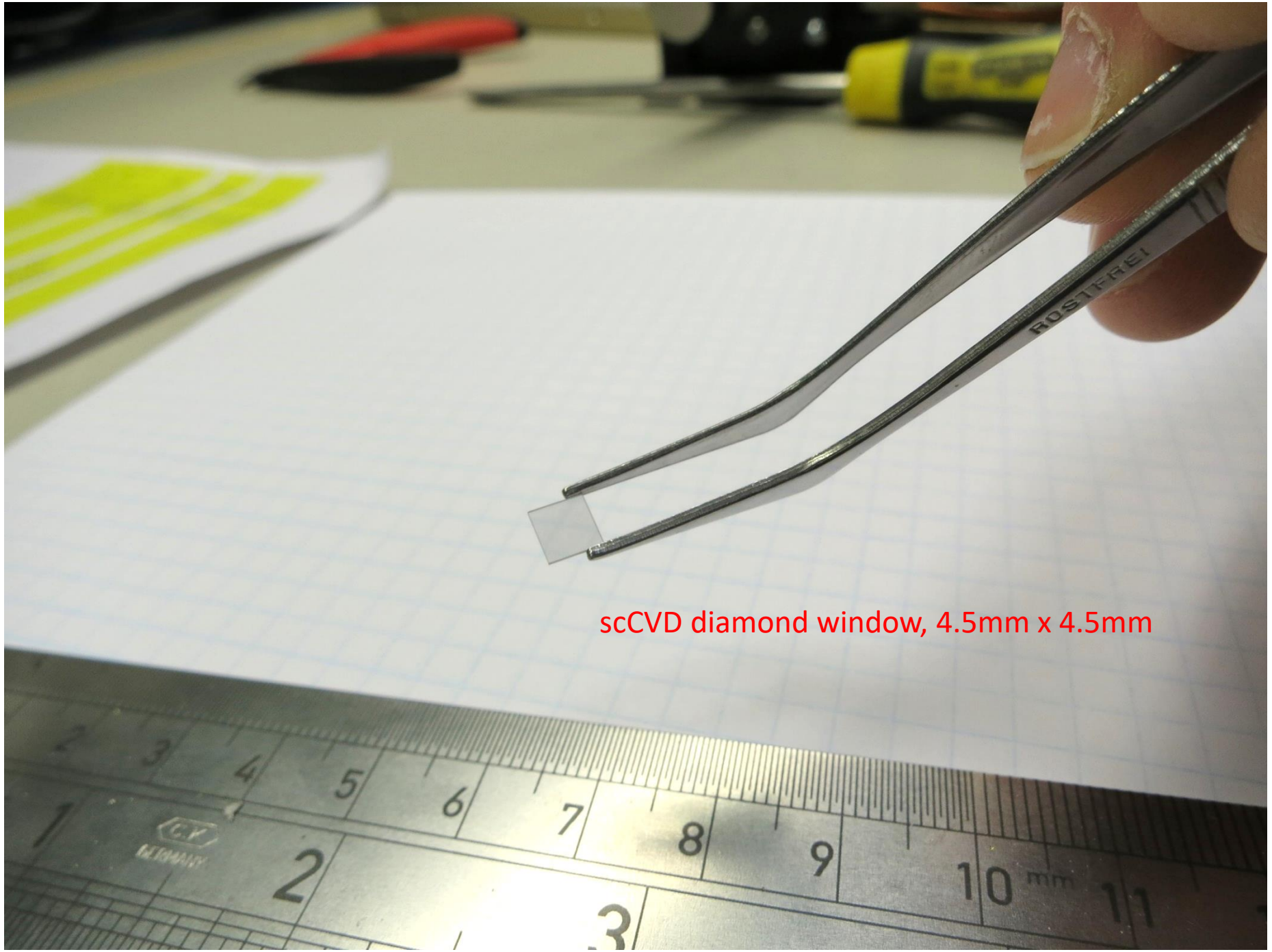
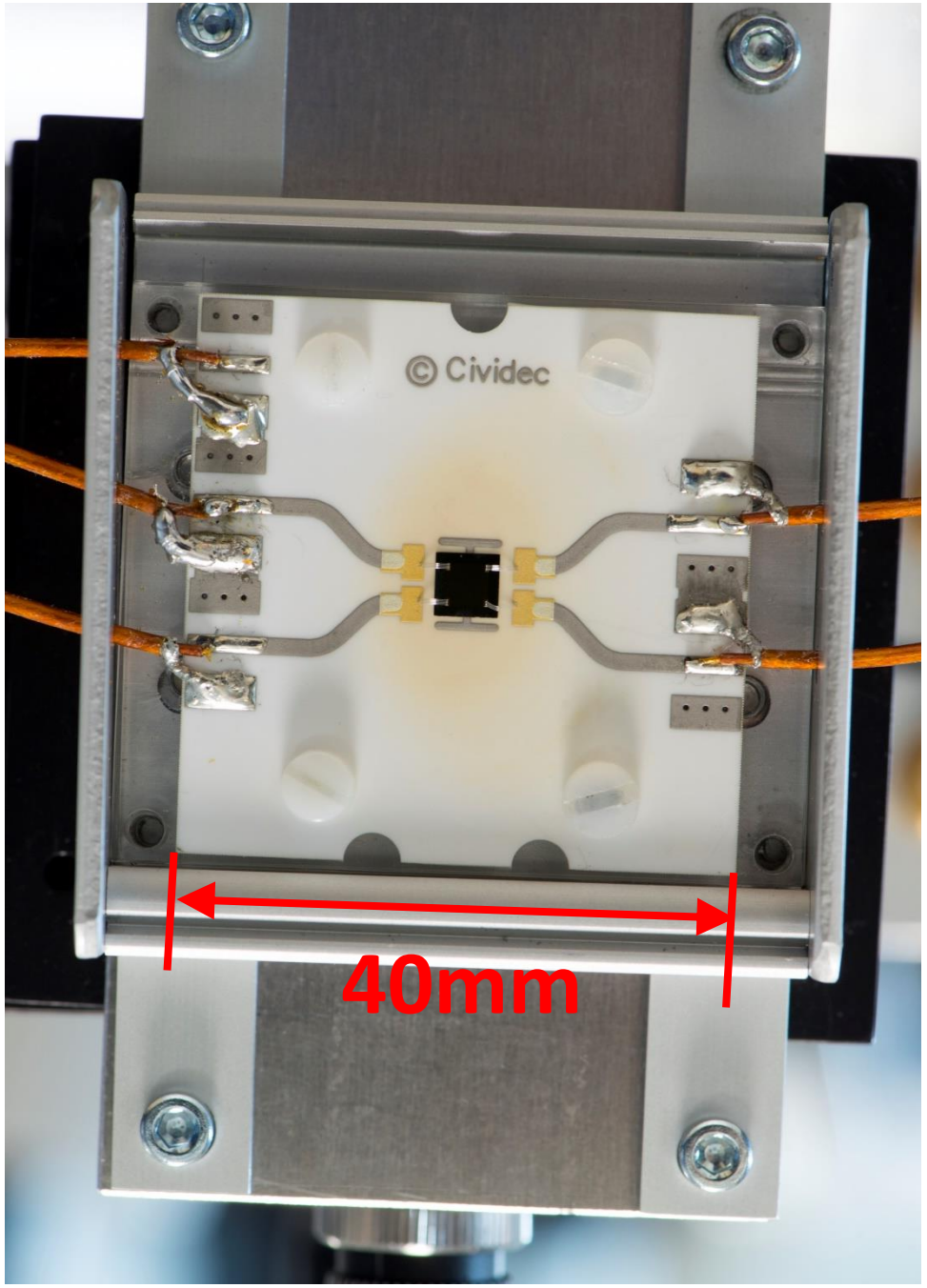
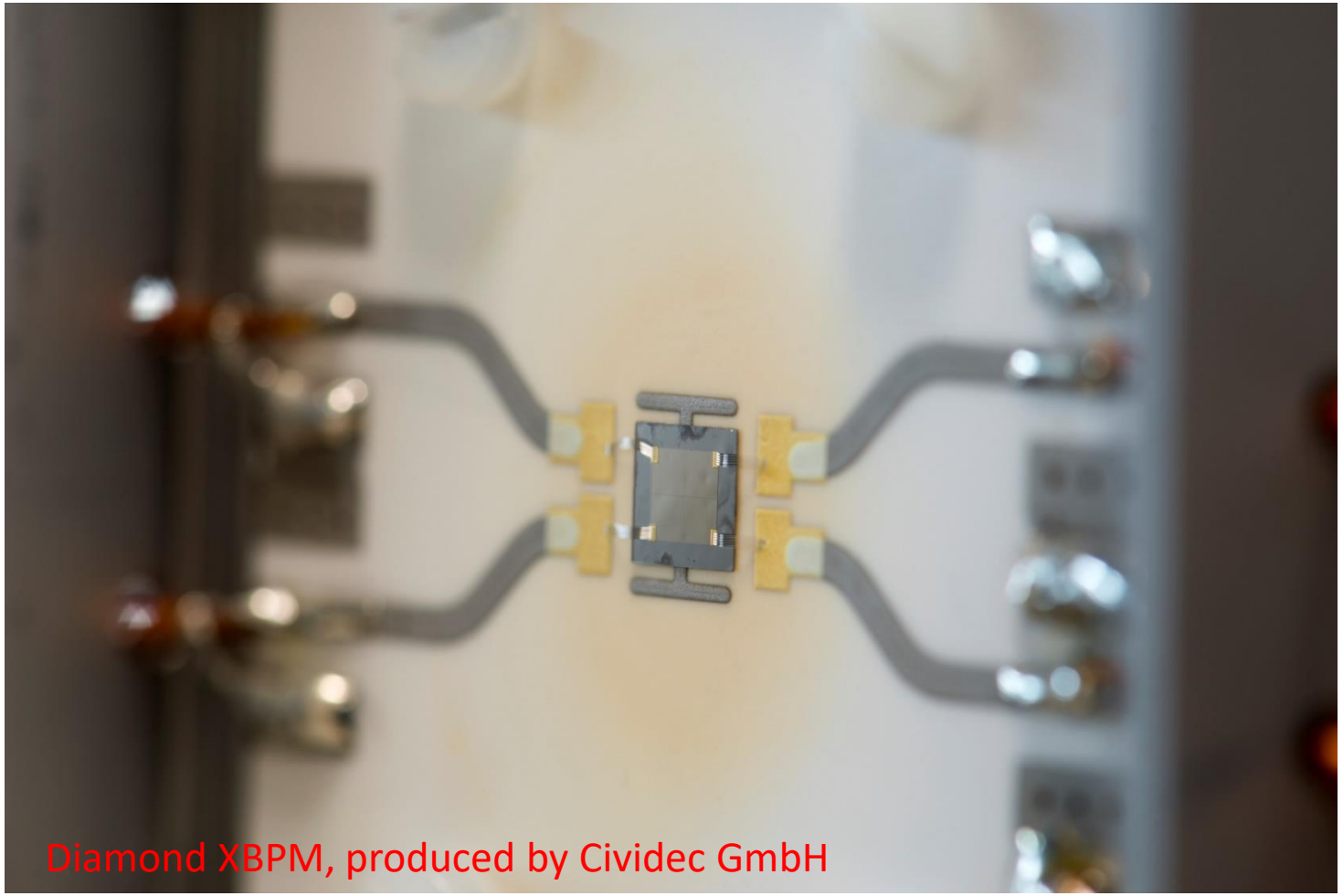
Diamond Light Source

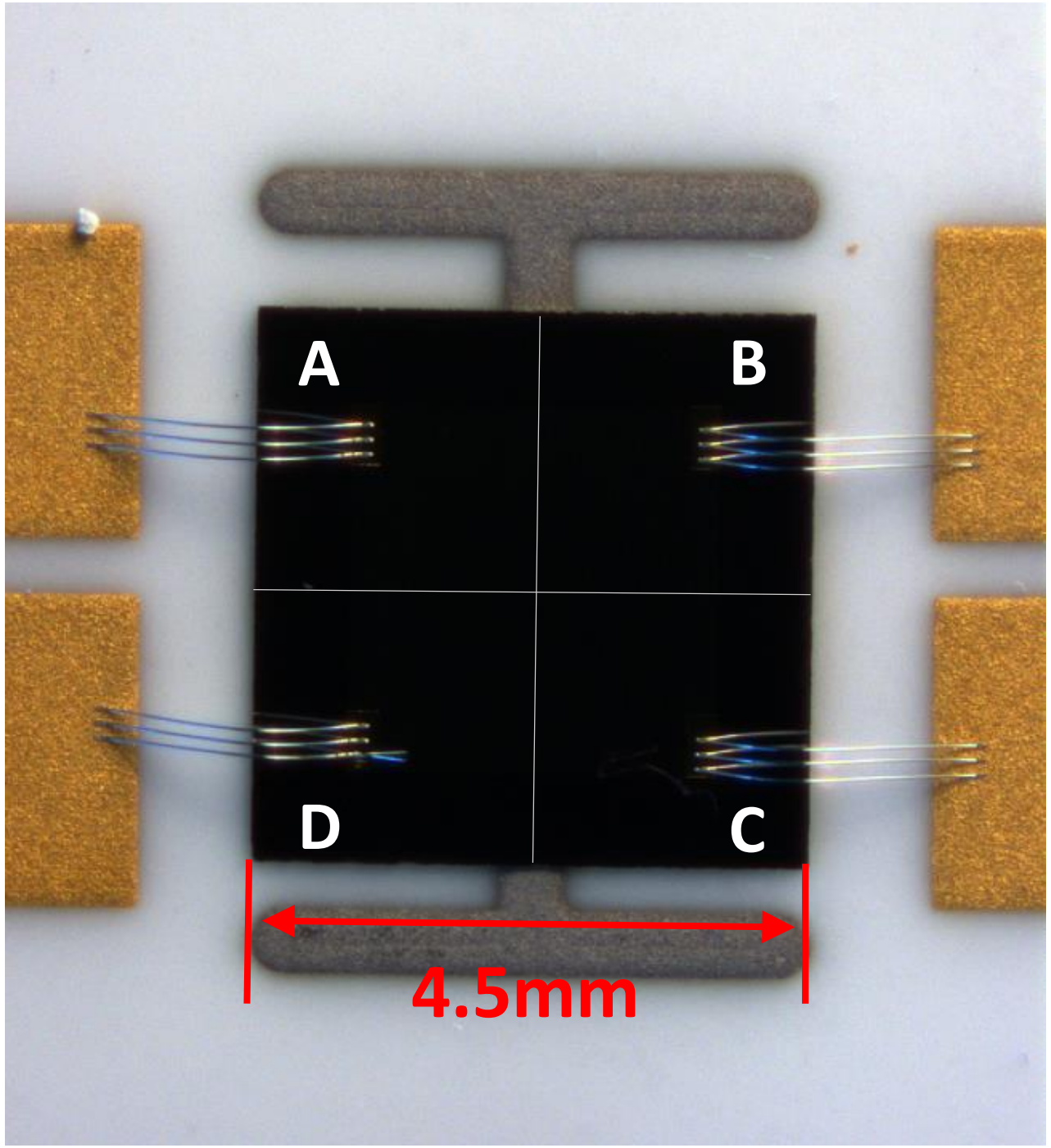
Single-crystal CVD diamond detectors live in the experimental hutch, observing the X-ray beam striking the samples being tested.

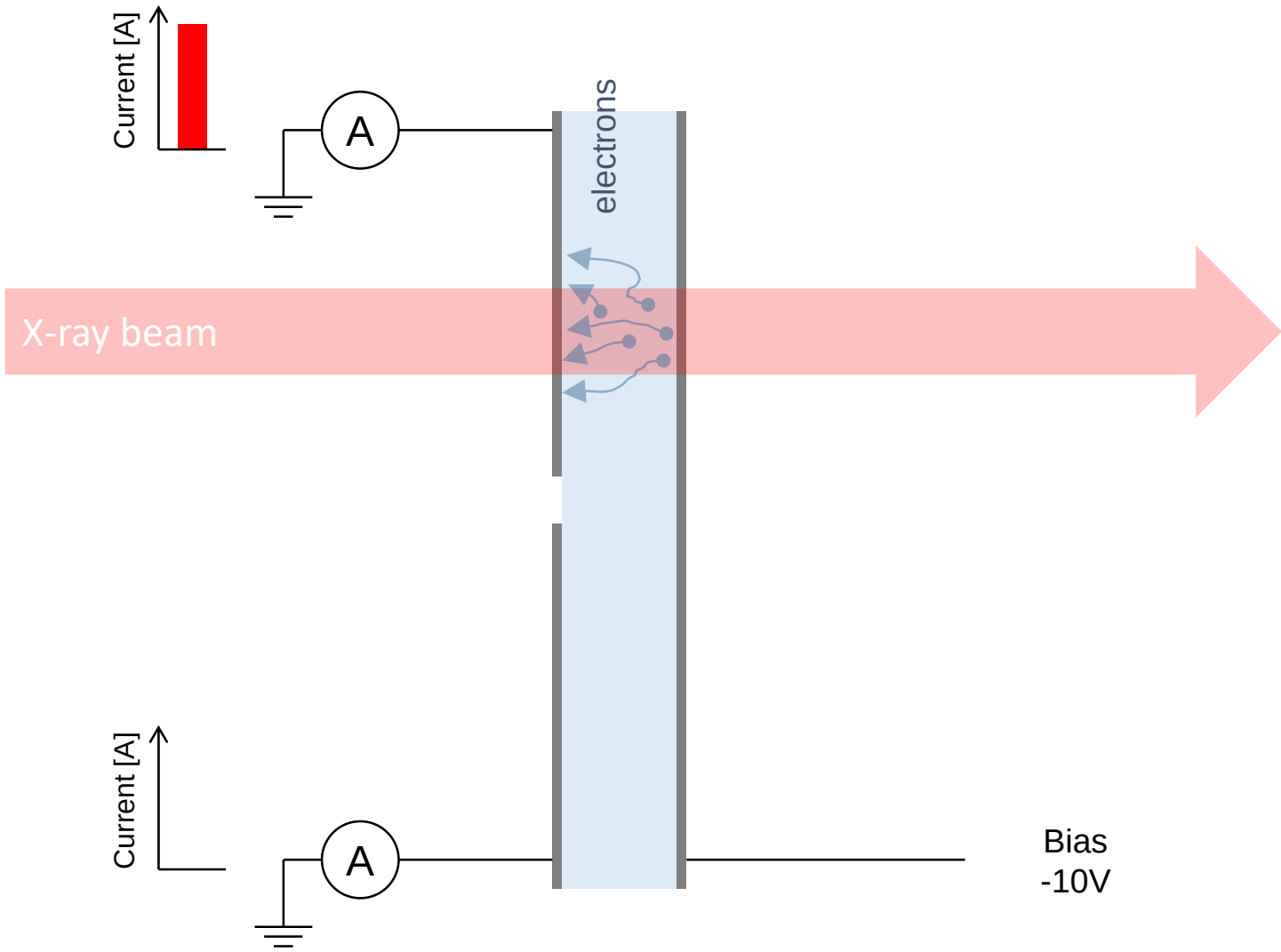



scCVD diamond window, 4.5mm x 4.5mm

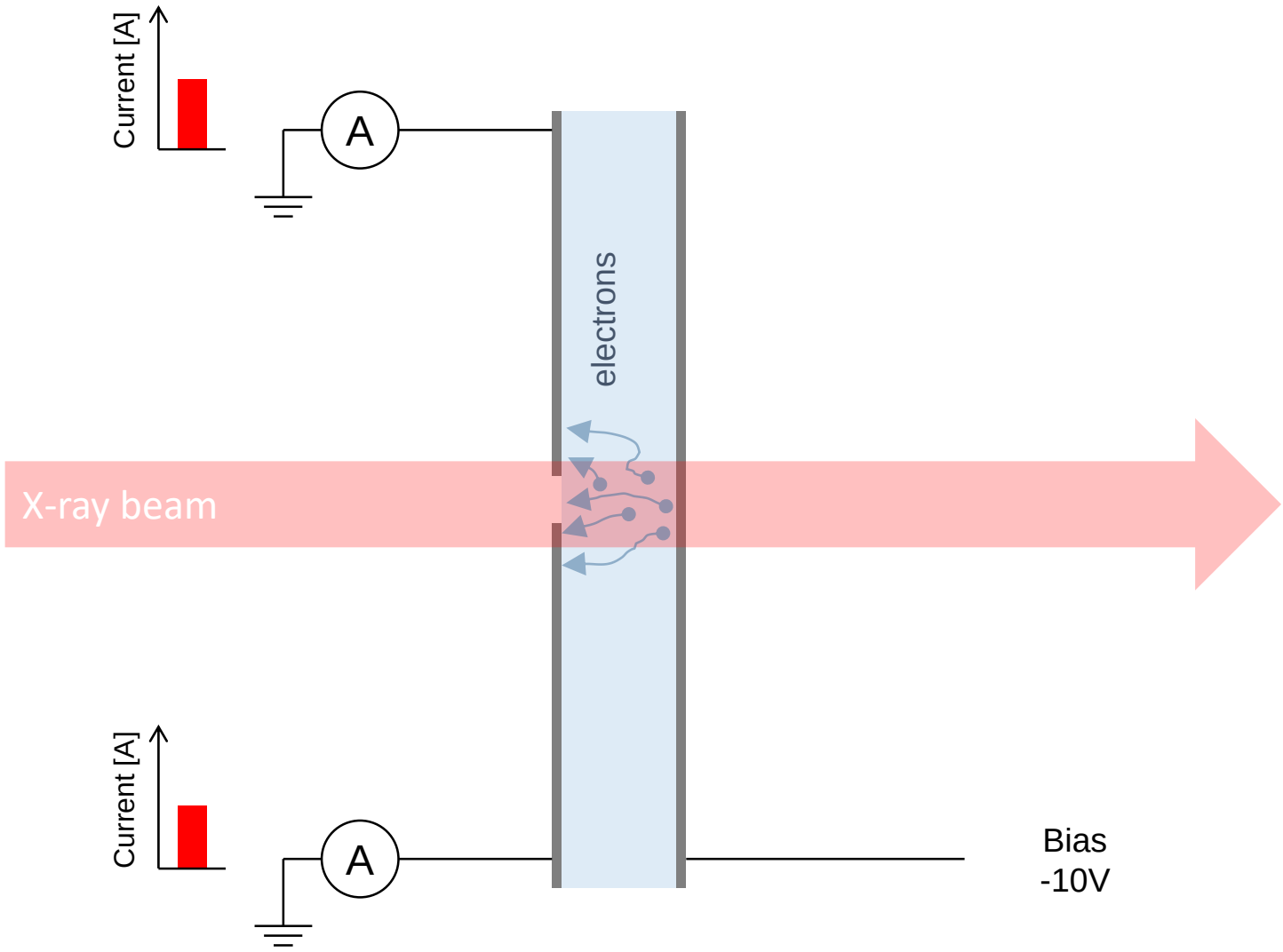

© Cividec
40mm


Diamond XBPM, produced by Cividec GmbH


A
B
D
C
4.5mm



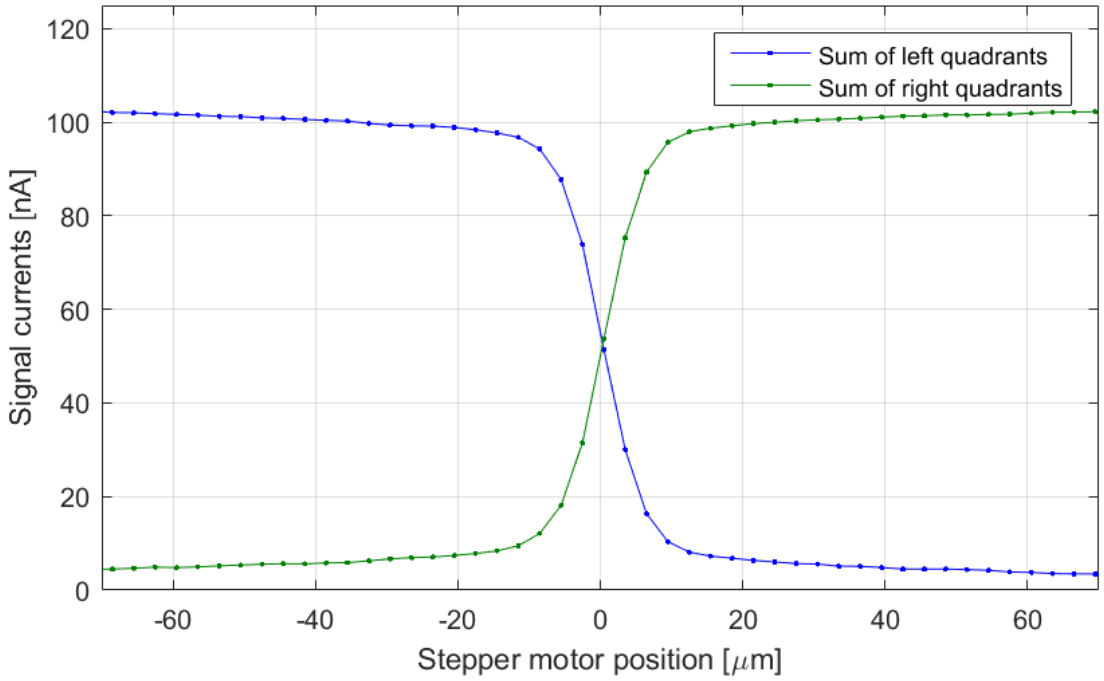
Charge carriers liberated from the bulk diamond by absorbed X-rays migrate to one of the surface electrodes under the influence of an electrical bias.

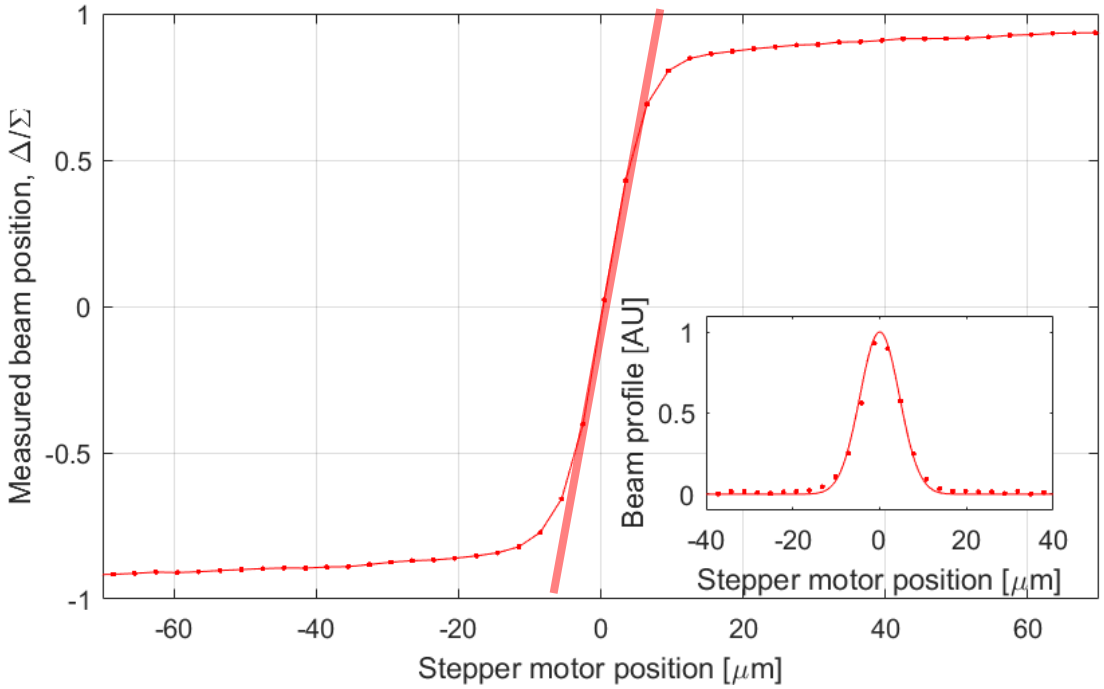


Charge carriers liberated from the bulk diamond by absorbed X-rays migrate to one of the surface electrodes under the influence of an electrical bias.

DLS I04 beamline

- **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**

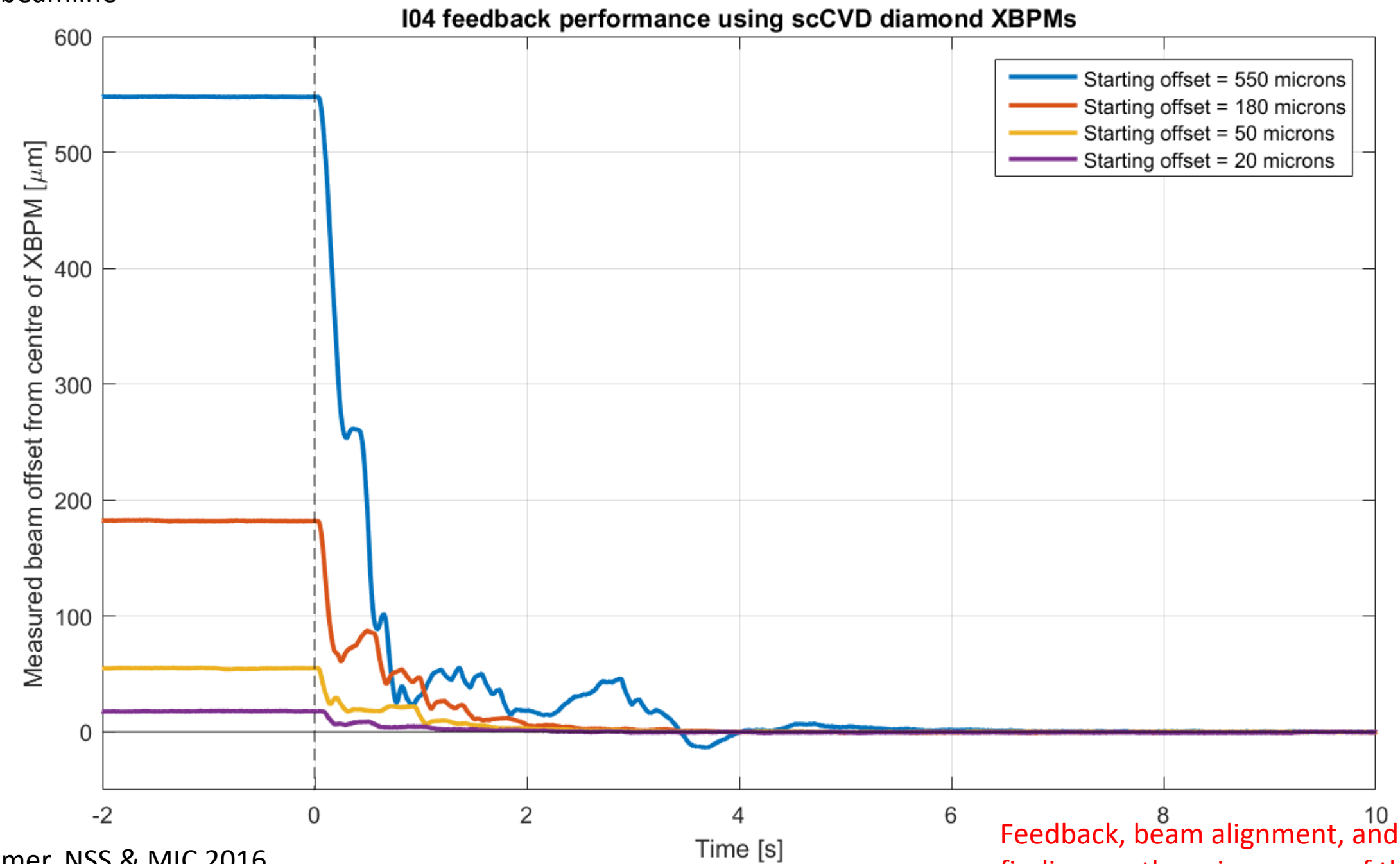




Gradient of the slope gives a "scale factor", K, to convert the dimensionless Δ/Σ into a real beam position in [µm]

$$\text{Position, } \Delta/\Sigma = \frac{(A+D) - (B+C)}{(A+B+C+D)}$$

DLS I04 beamline



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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?

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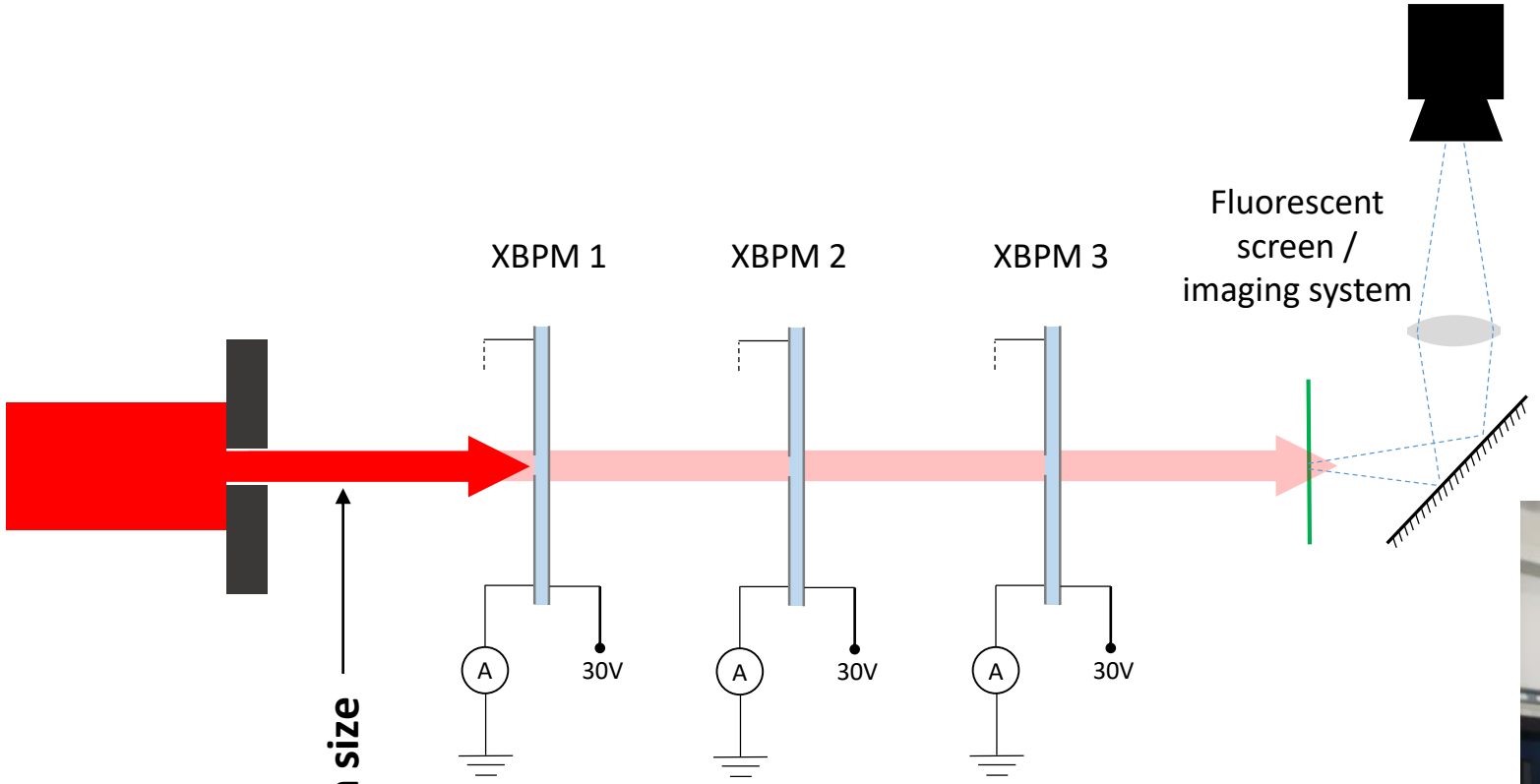
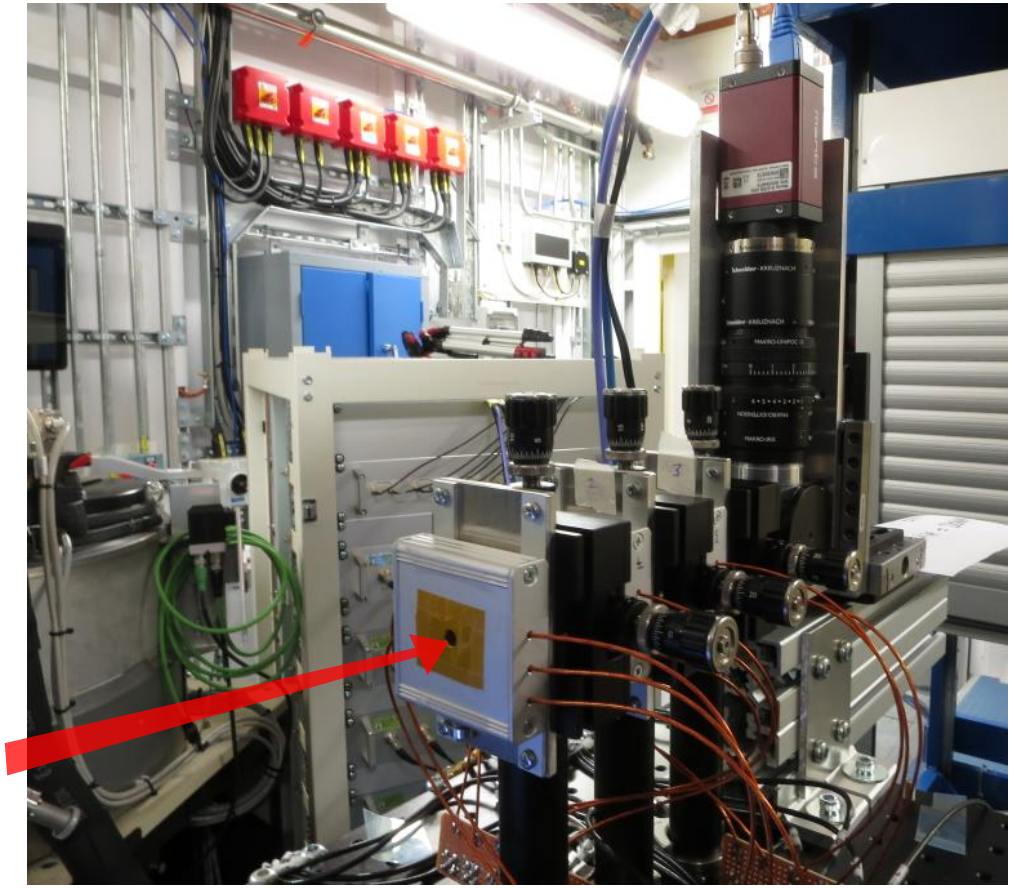


Three scCVD diamond XBPMs monitoring the same incident X-ray beam, synchronously, at 5kHz sampling frequency.



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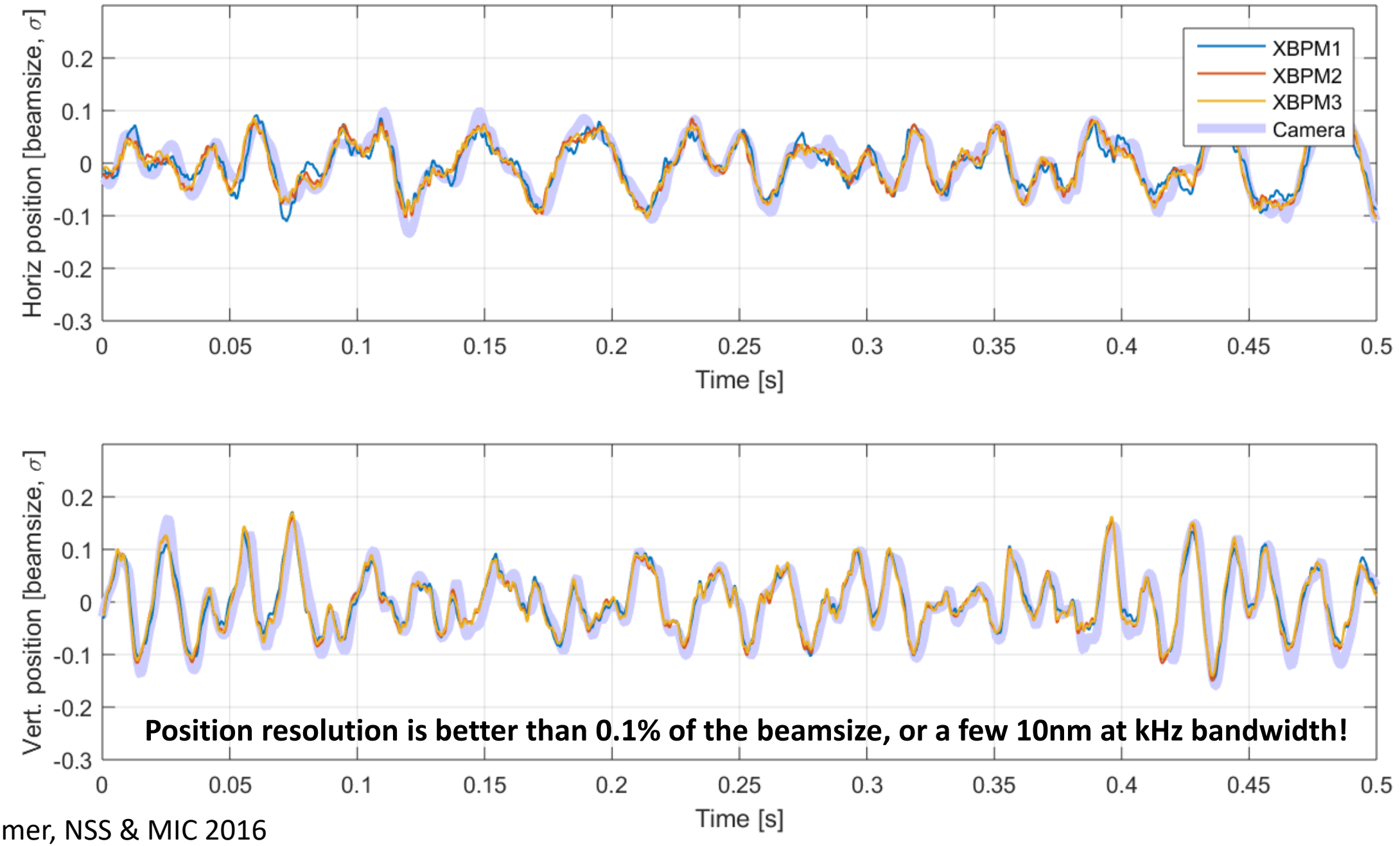
DLS I24 beamline



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Observing the synchrotron bunch structure

Can individual electron bunches be observed?

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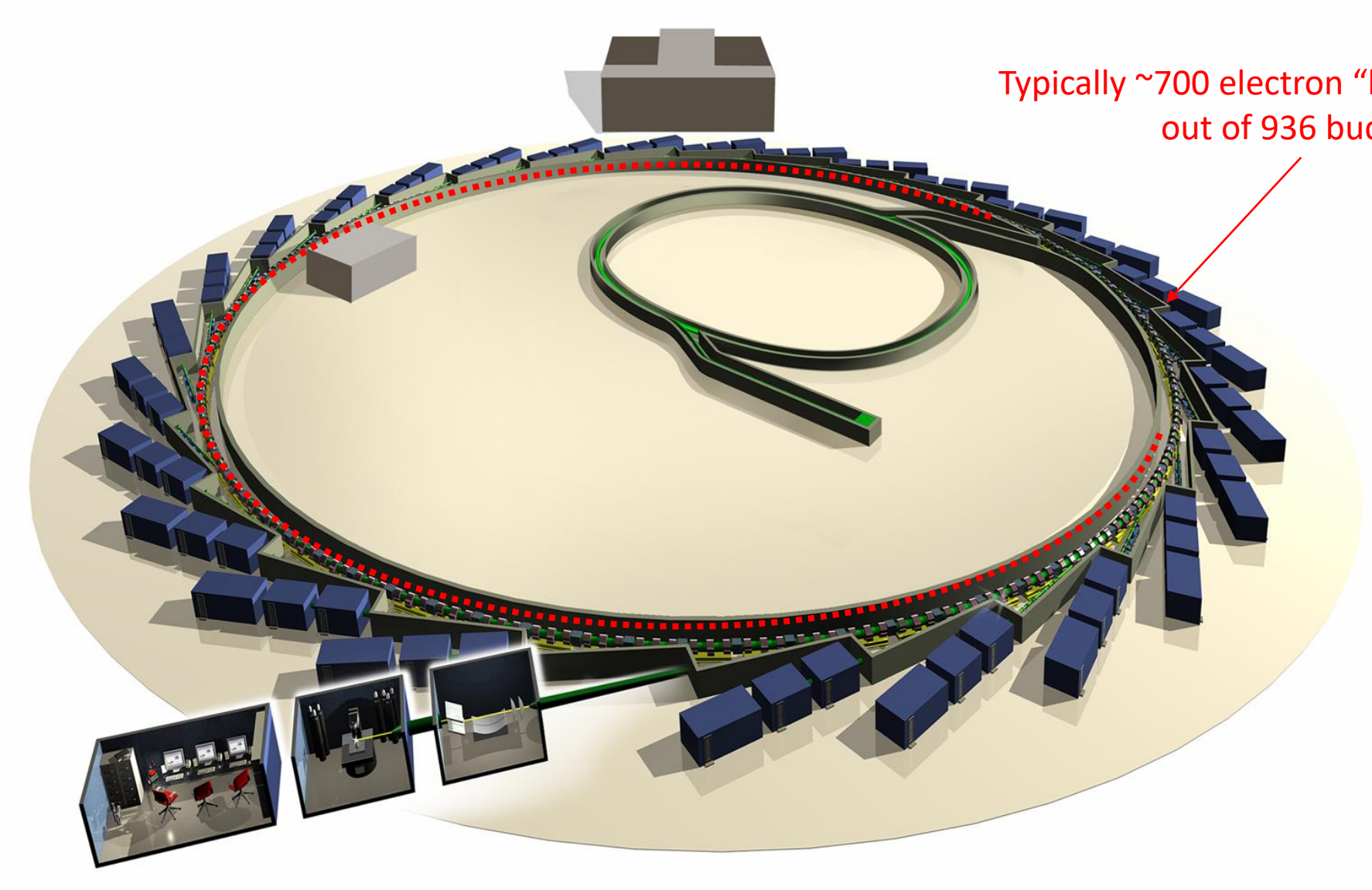
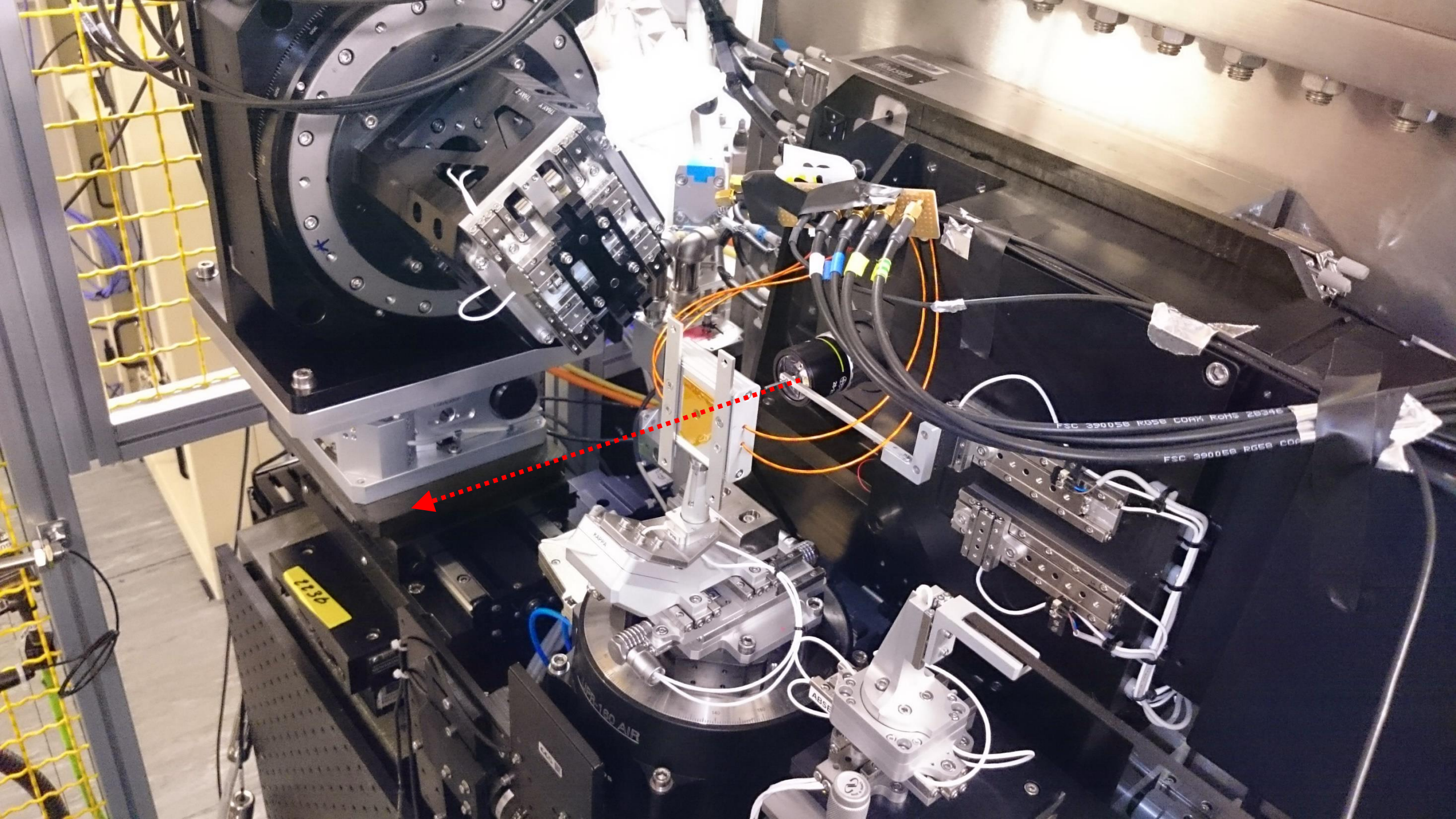
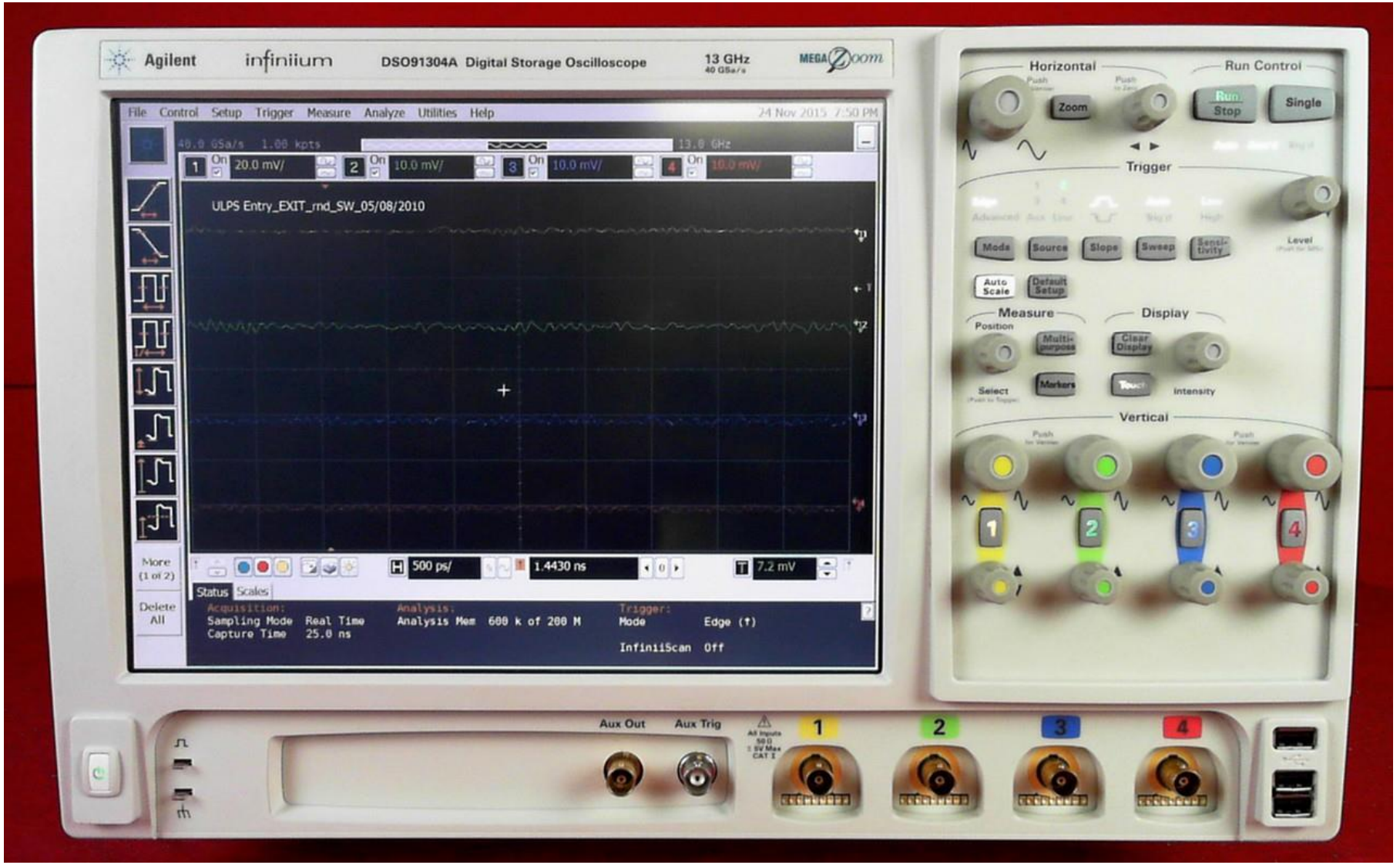
Observing the synchrotron bunch structure

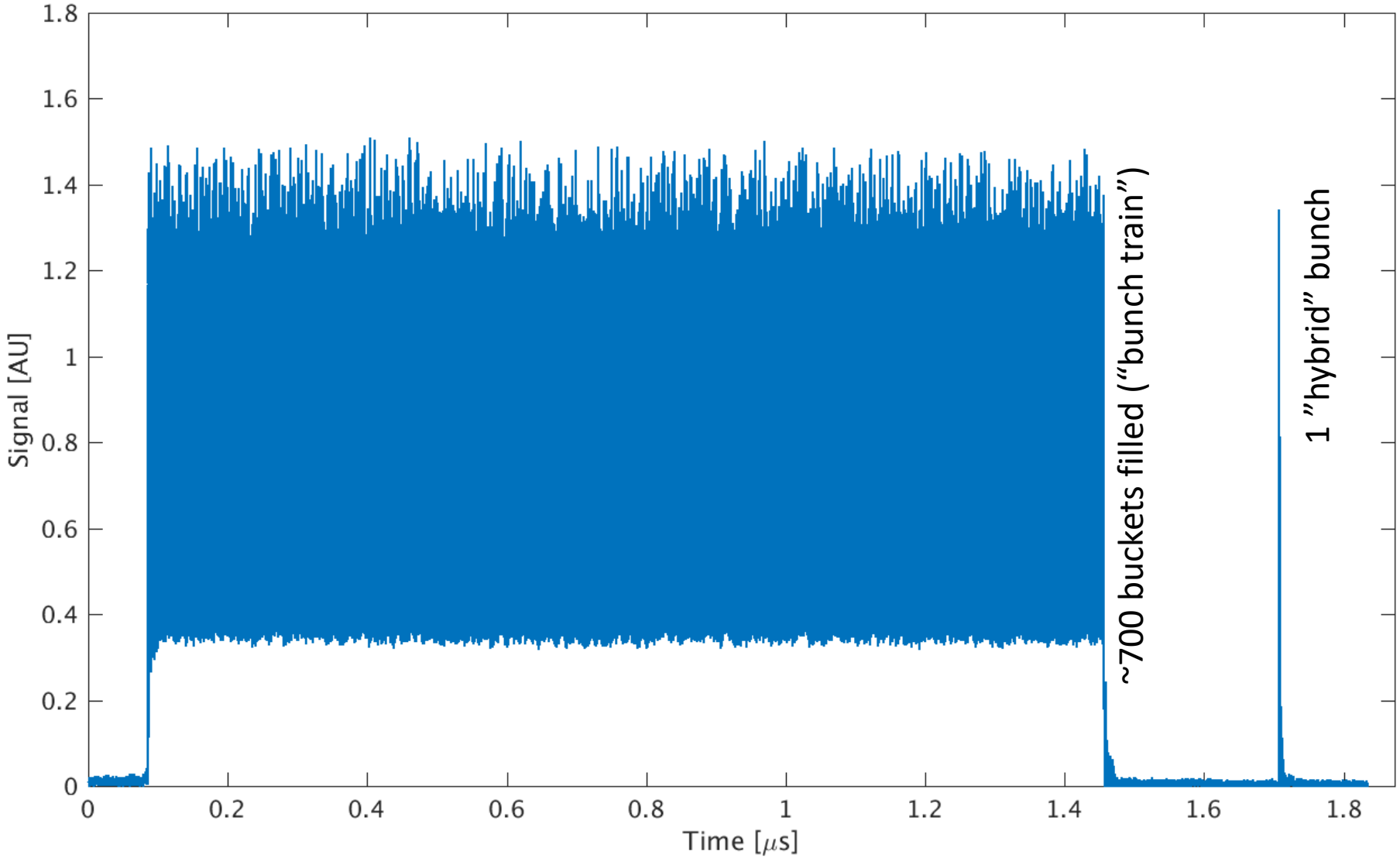




Synchrotron bunch structure observed with the detector and an oscilloscope
Agilent Infiniium DSO91304A 13GHz

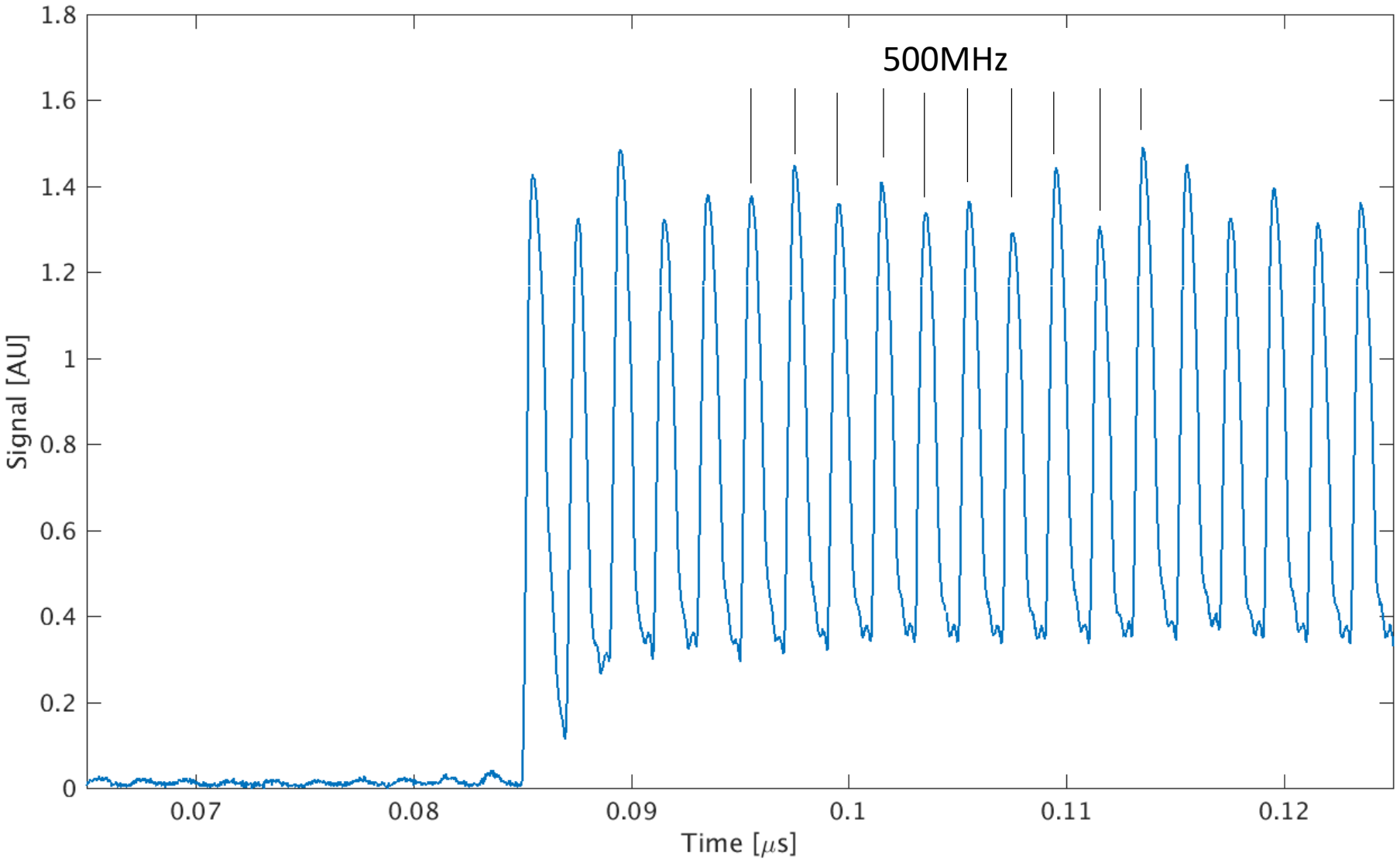


DLS I04 beamline



Observations of the synchrotron bunch train with a diamond XBPM.

DLS I04 beamline



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)

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research papers

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Radiation

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Diamond X-ray beam-position monitoring using signal readout at the synchrotron radiofrequency

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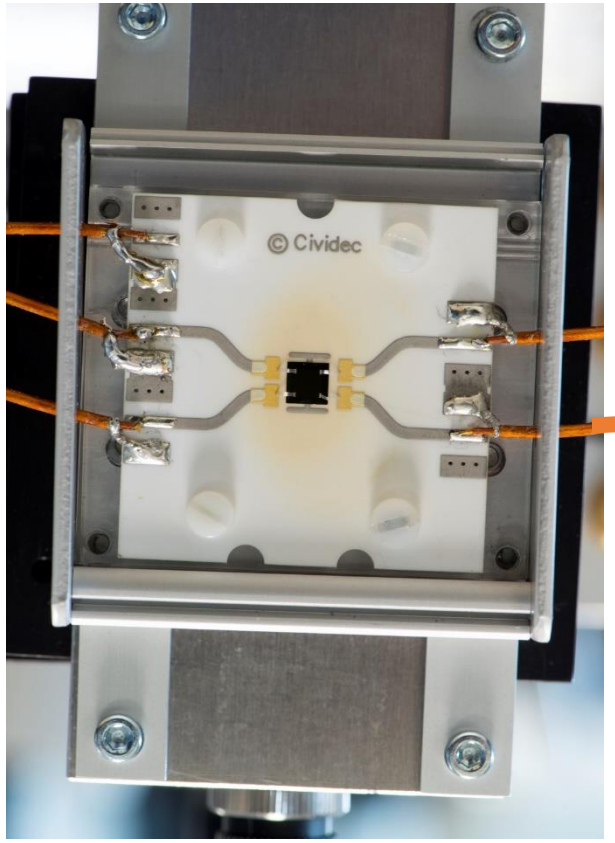
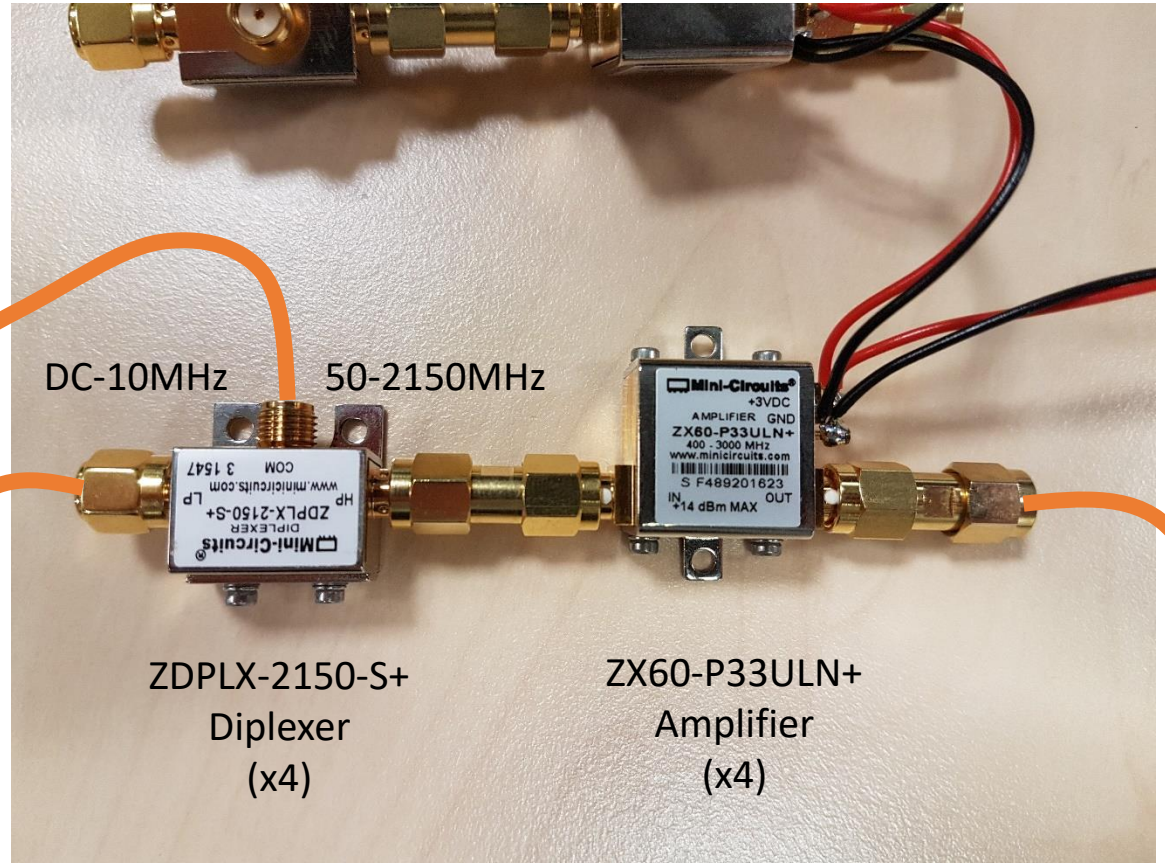
E-mail: morse@esrf.fr

Single-crystal diamond is a material with great potential for the fabrication of X-ray photon beam-position monitors with submicrometre spatial resolution. Low X-ray absorption combined with radiation hardness and excellent thermal-mechanical properties make possible beam-transmissive diamond devices for monitoring synchrotron and free-electron laser X-ray beams. Tests were made using a white bending-magnet synchrotron X-ray beam at DESY to investigate the performance of a position-sensitive diamond device using radiofrequency readout electronics. The device uniformity and position response were measured in a 25 μm collimated X-ray beam with an I-Tech Libera 'Brilliance' system. This readout system was designed for position measurement and feedback control of the electron beam in the synchrotron storage ring, but, as shown here, it can also be used for accurate position readout of a quadrant-electrode single-crystal diamond sensor. The centre-of-gravity position of the F4 X-ray beam at the DORIS III synchrotron was measured with the diamond signal output digitally sampled at a rate of 130 Msample s^{-1} by the Brilliance system. Narrow-band filtering and digital averaging of the position signals resulted in a measured position noise below 50 nm (r.m.s.) for a 10 Hz bandwidth.

These measurements are nothing too new. See also past ADAMAS presentations!





ZDPLX-2150-S+
Diplexer
(x4)

ZX60-P33ULN+
Amplifier
(x4)

117MHz acquisition
14bit ADC

CAENels TetrAMM [1]

Libera Spark ER [2,3]

Transimpedance amplifier
24bit ADC
100kSample/s
5kHz analogue low-pass filter

[1] http://www.caenels.com/products/tetramm/
[2] http://www.i-tech.si/accelerators-instrumentation/spark-er-erxr
[3] M. Znidarcic, Proc. IPAC 2015

Using the synchrotron bunch structure to make RF measurements

Results from an off-the-shelf XBPM

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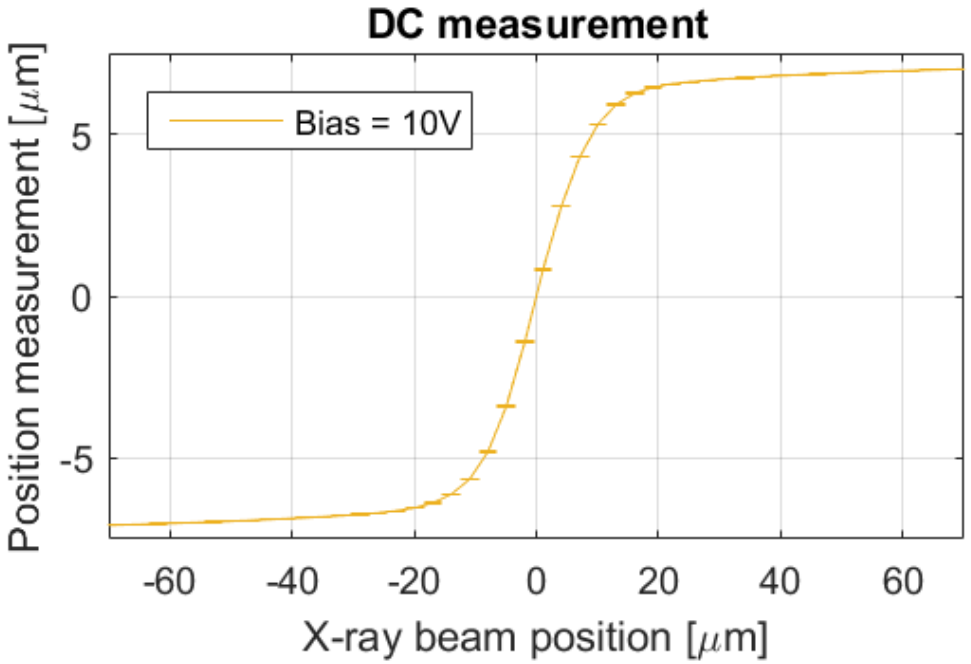
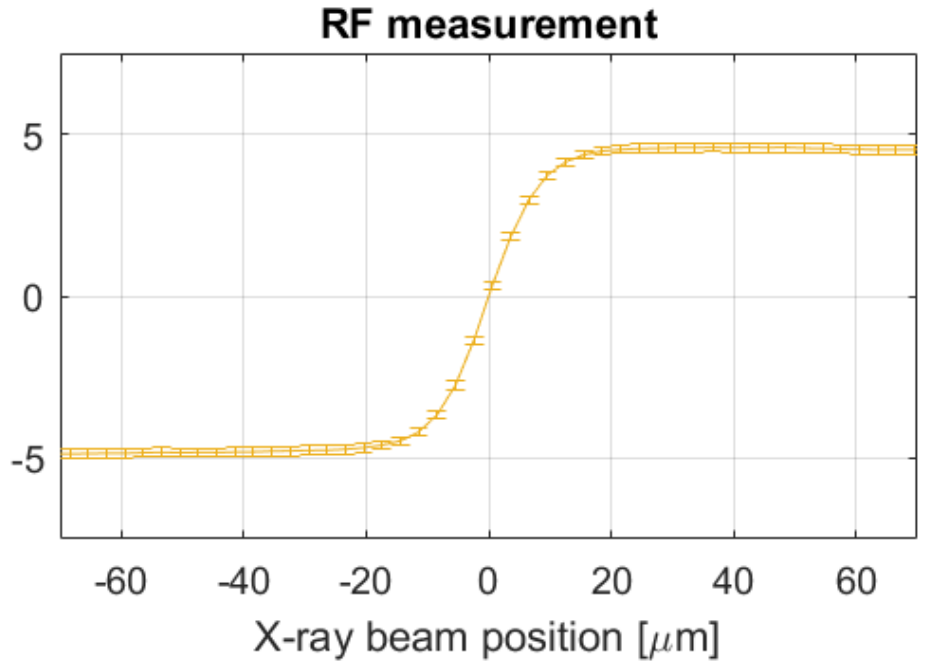
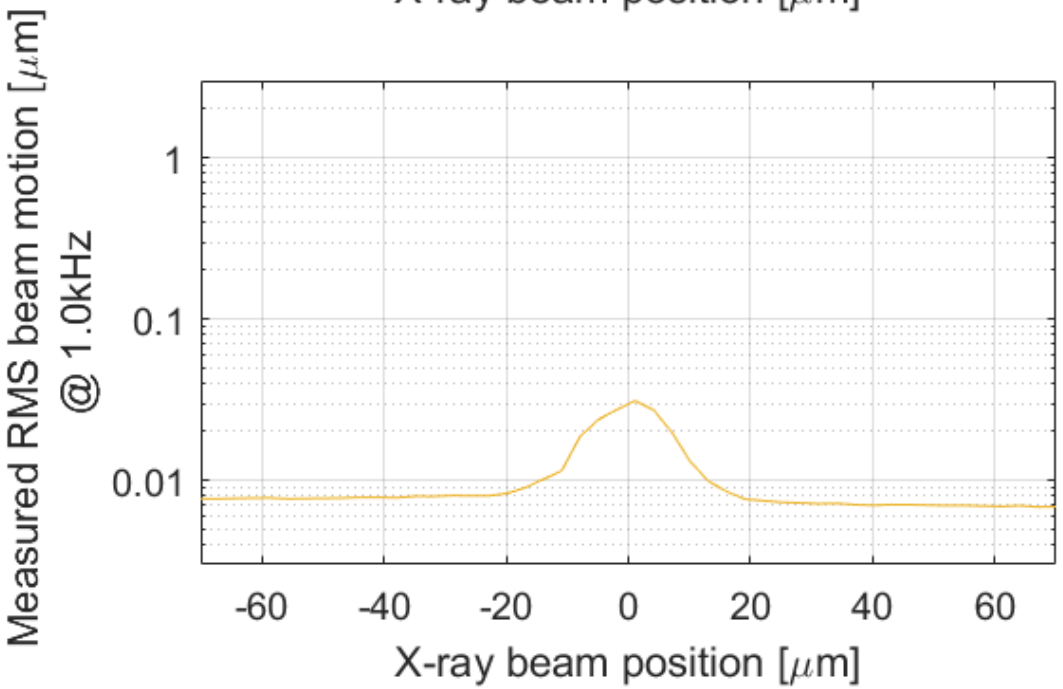
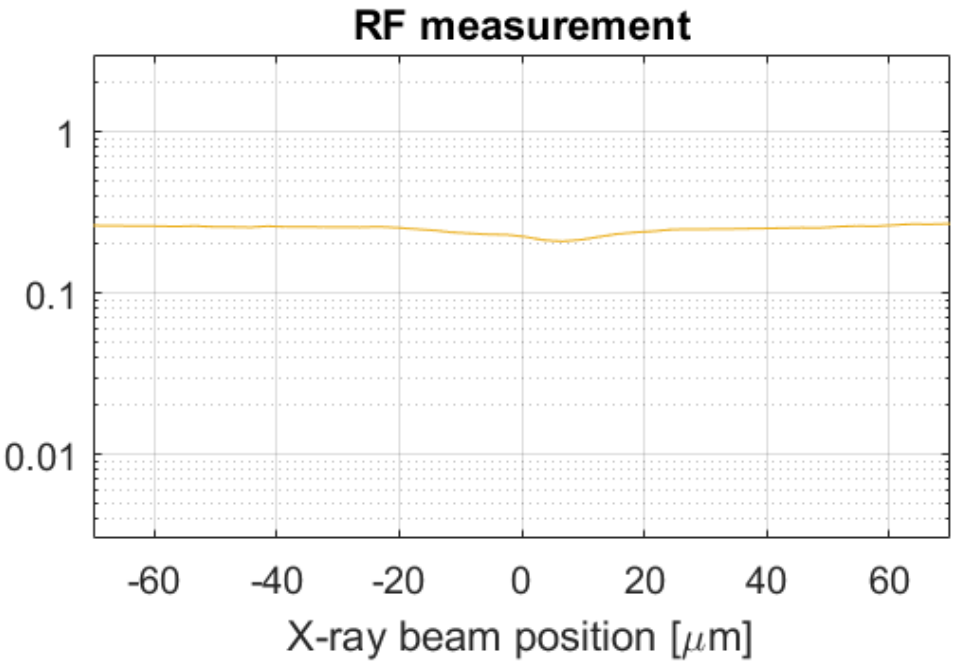
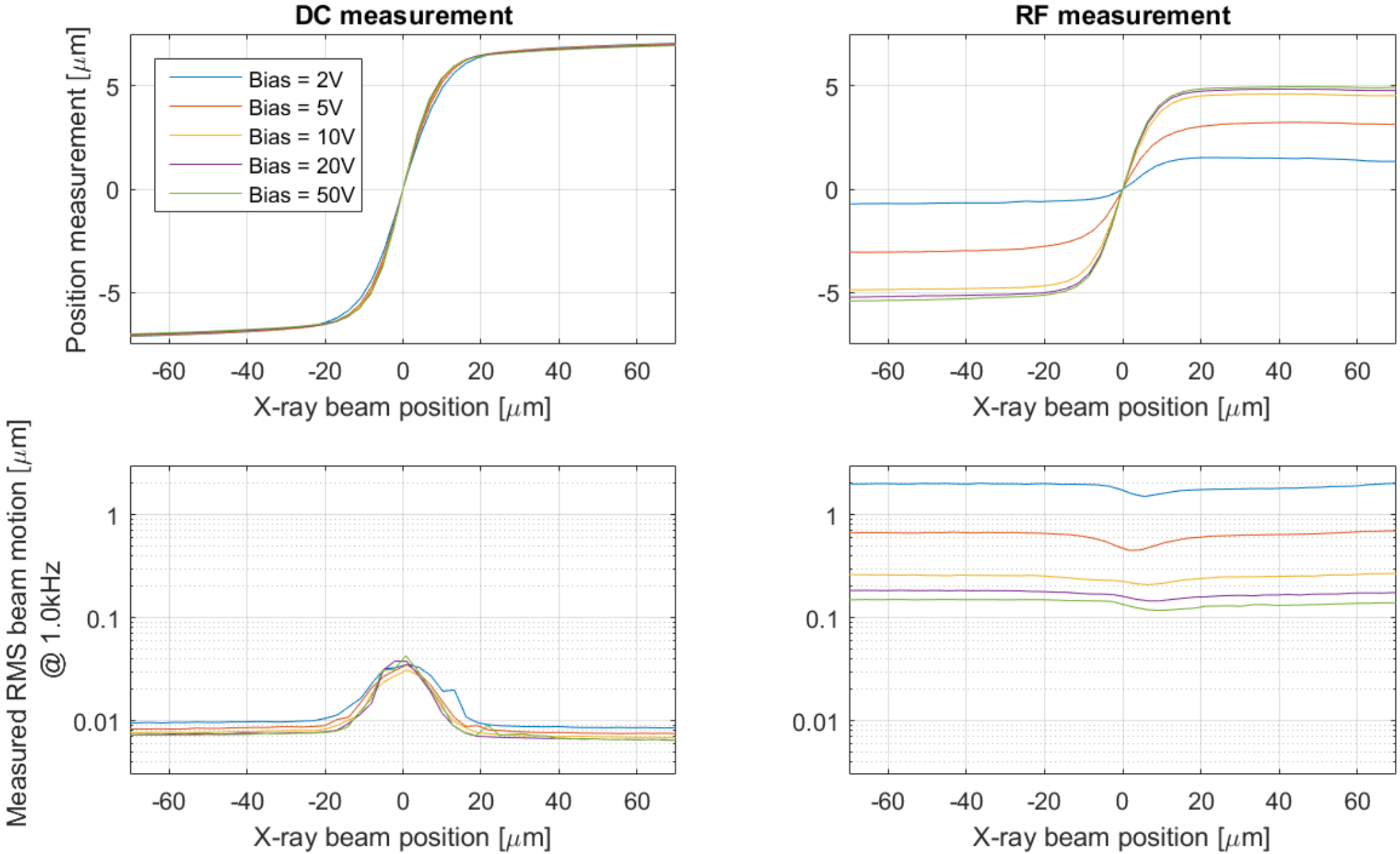






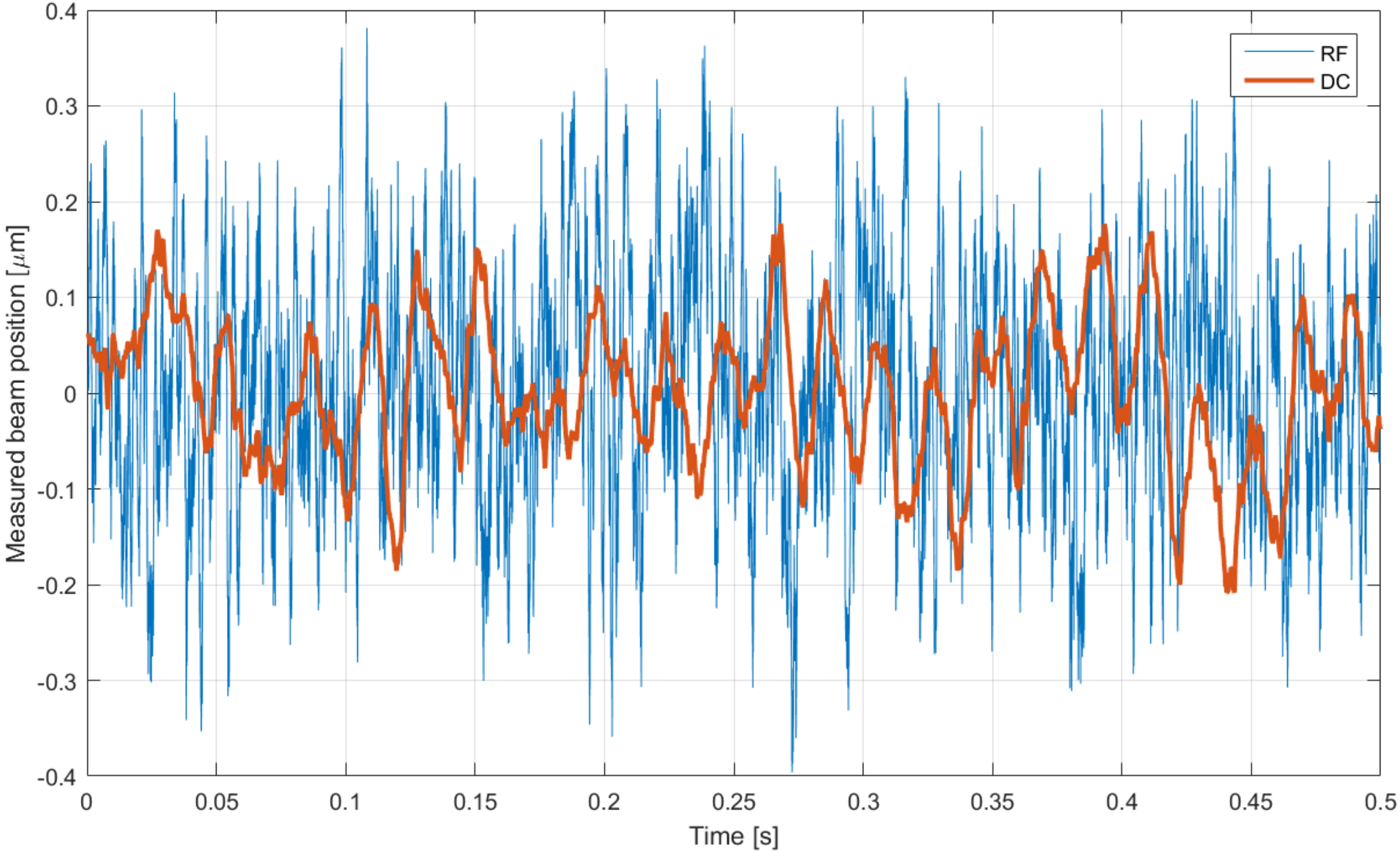


DLS I04 beamline



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.

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Using the synchrotron bunch structure to make RF measurements

Results from a specifically made RF XBPM

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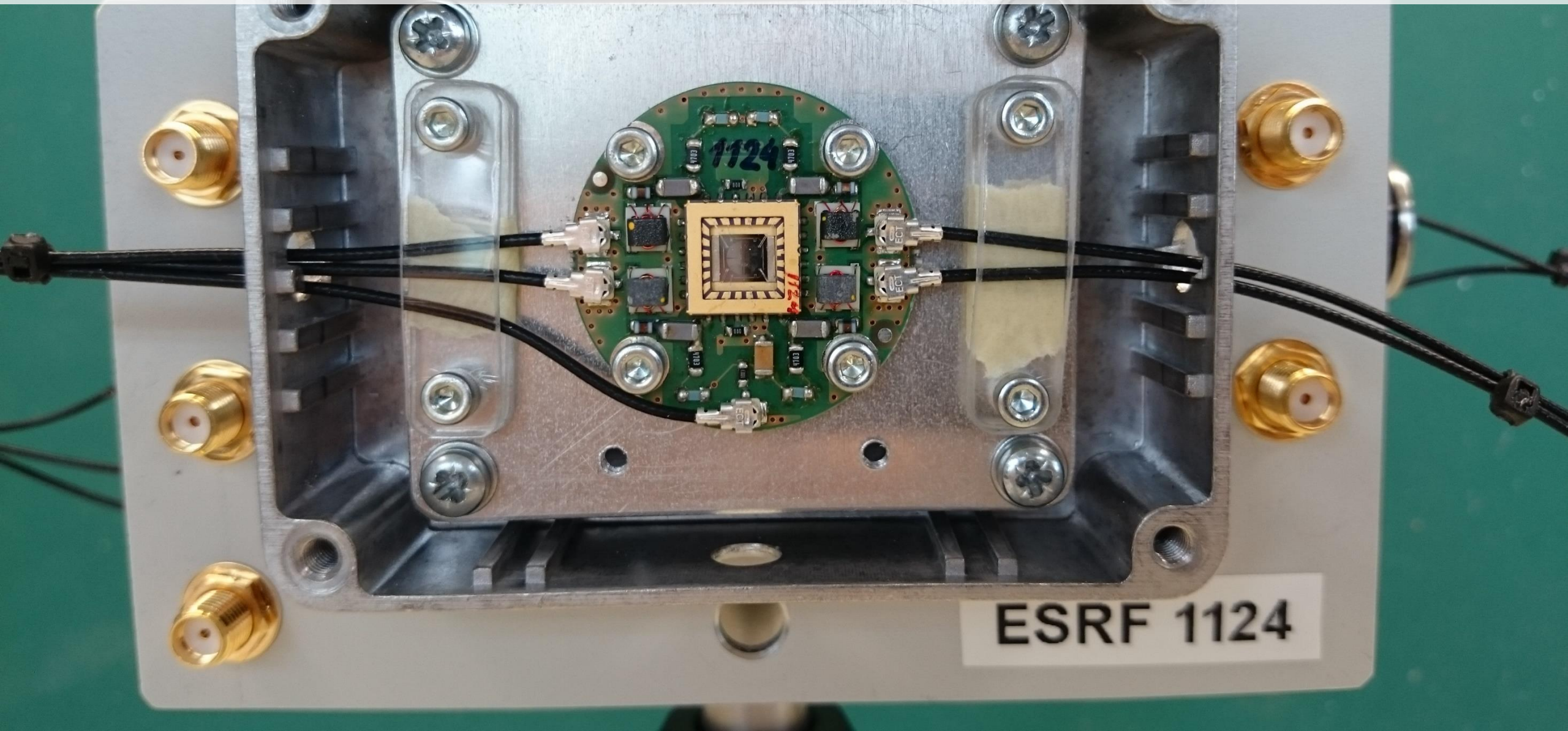
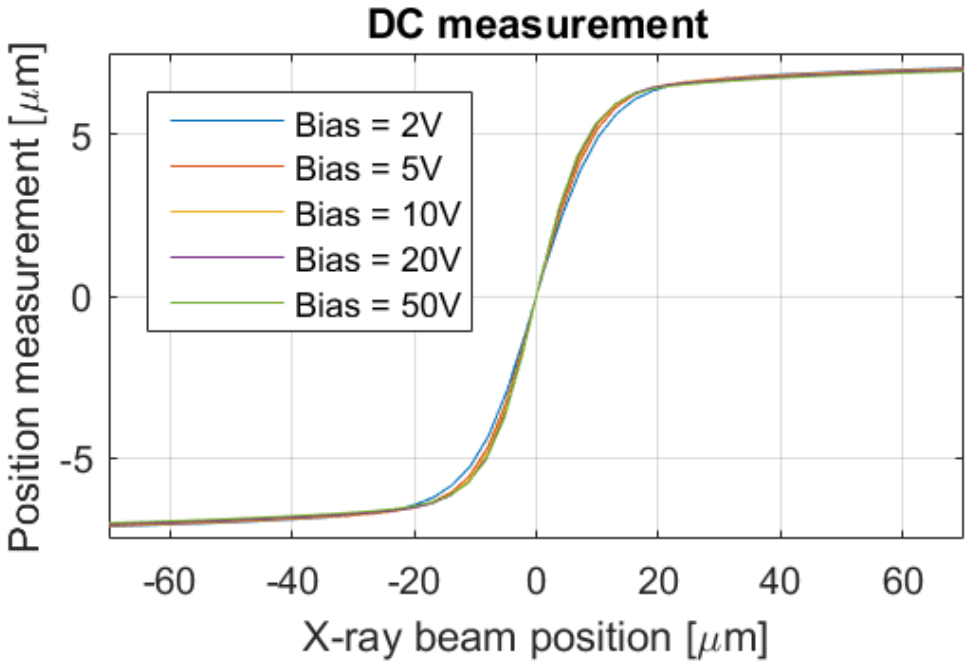
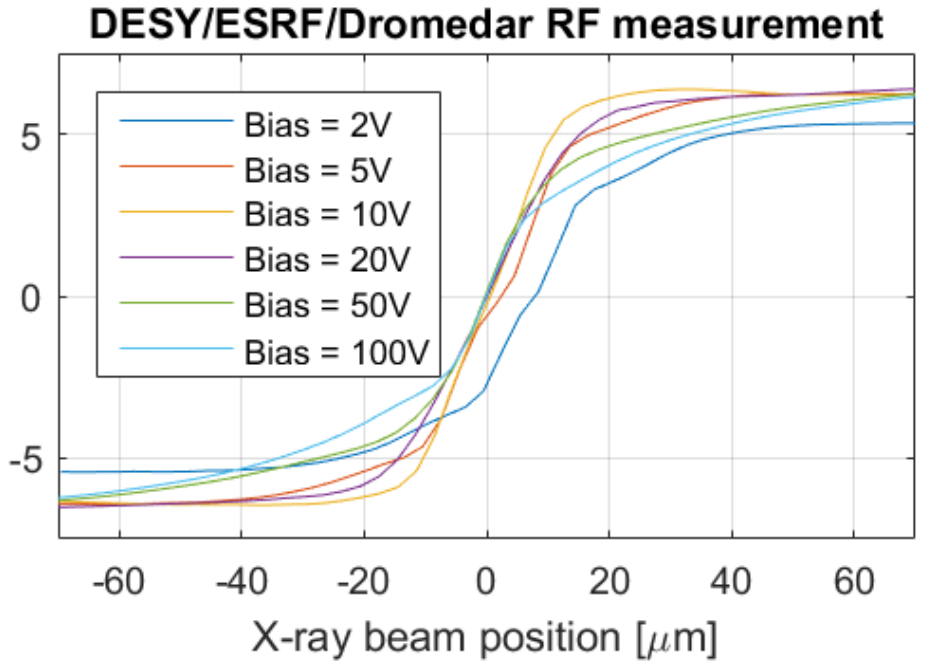
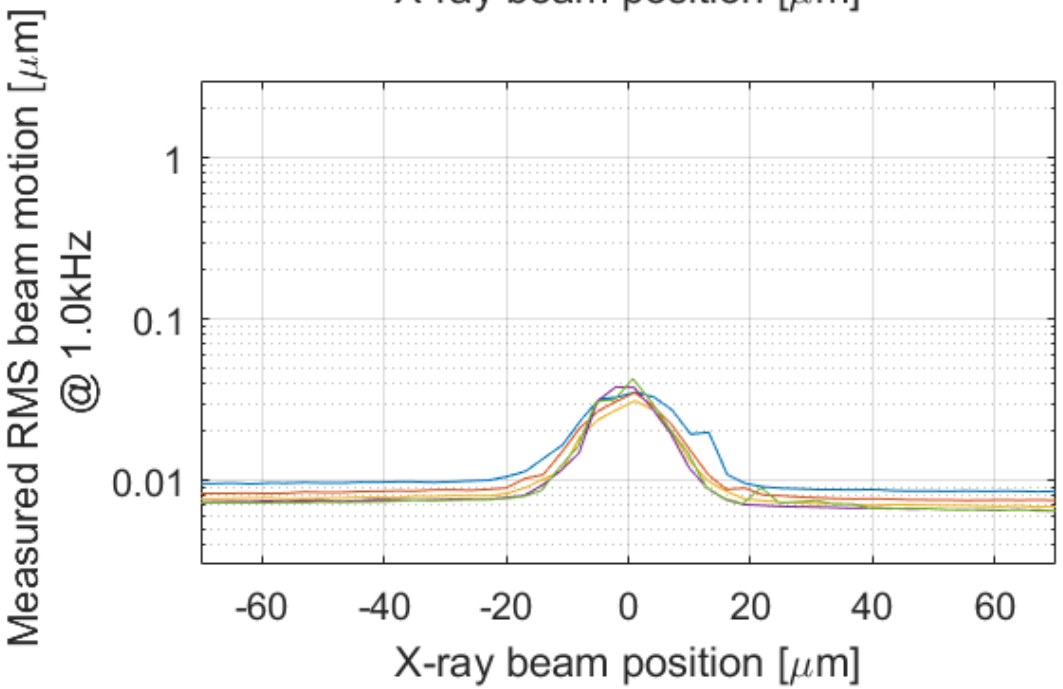
Custom detector, with LC resonators on each quadrant output, each peaking at ~500MHz (i.e. the synchrotron RF frequency).
Produced as a joint DESY (H. Graafsma), ESRF (J. Morse), Dromedar (B. Solar) project.

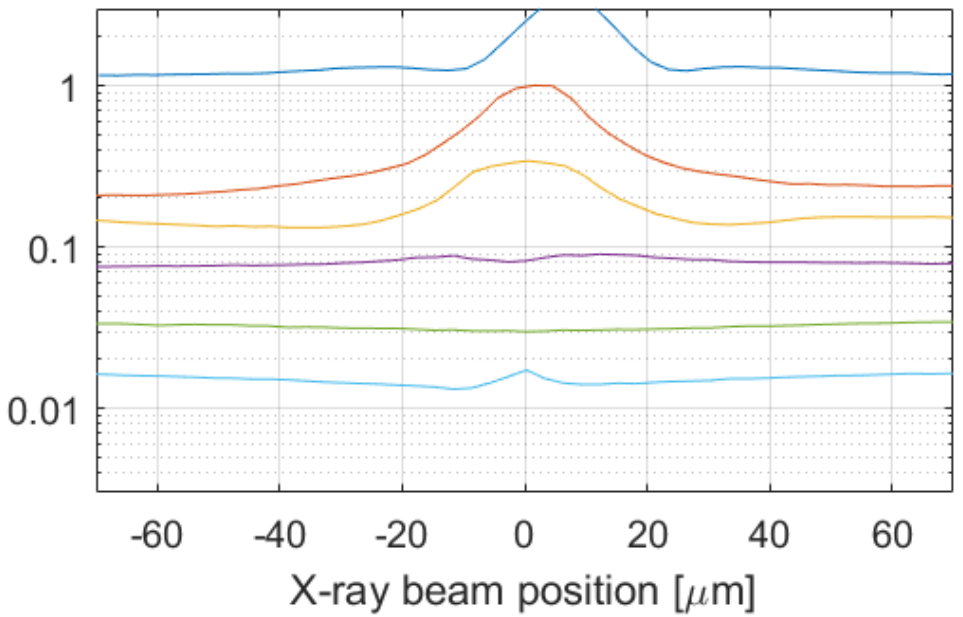


DLS I04 beamline



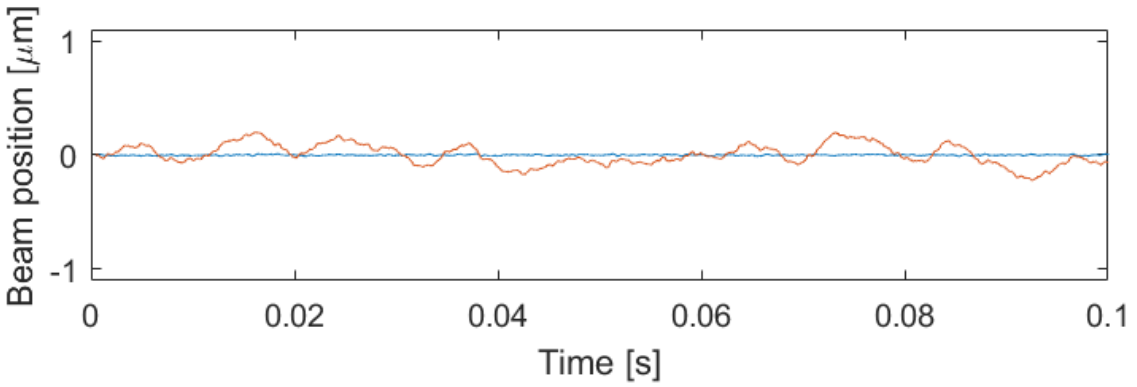


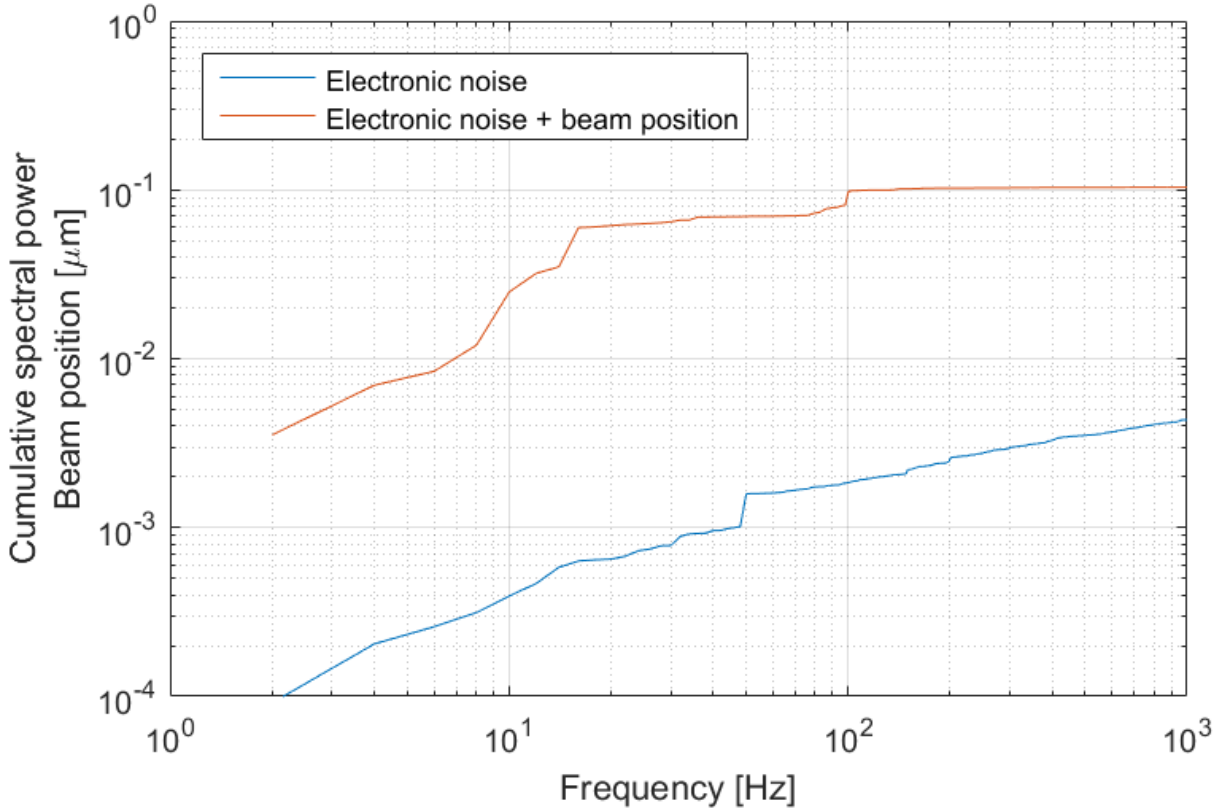




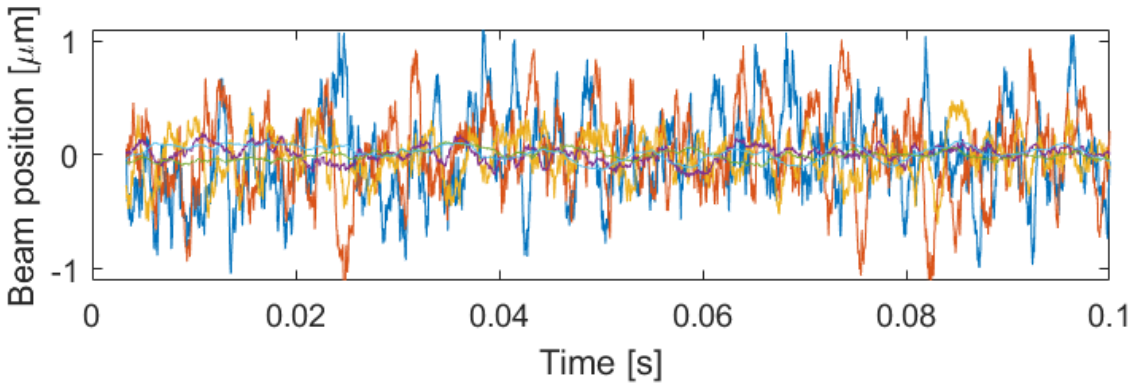
Spectra of **DC** measured position noise using CIVIDEC XBPM and TetrAMM when:

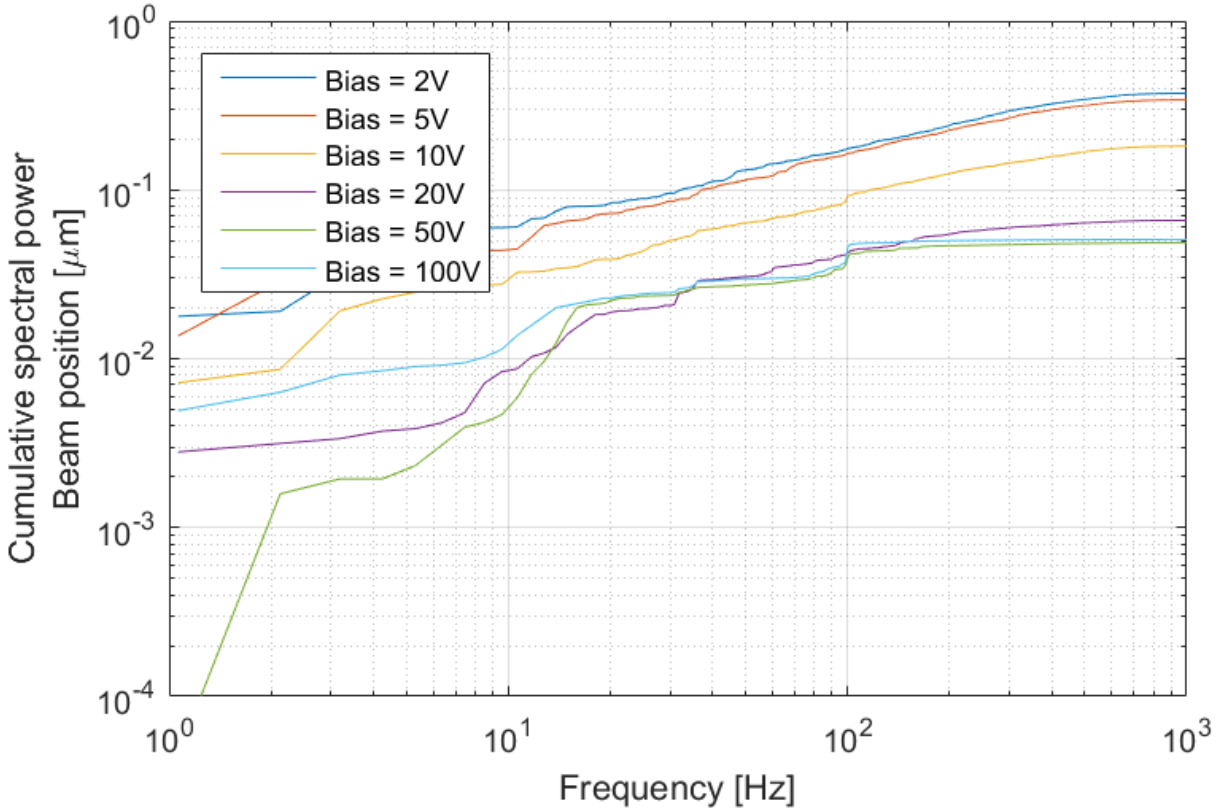
- beam is just in one quadrant, - beam is between quadrants.





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!**

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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!

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