Overview of performance and improvements to fixed exit double crystal monochromators at Diamond

Andrew Dent,
Physical Science Coordinator, DLS

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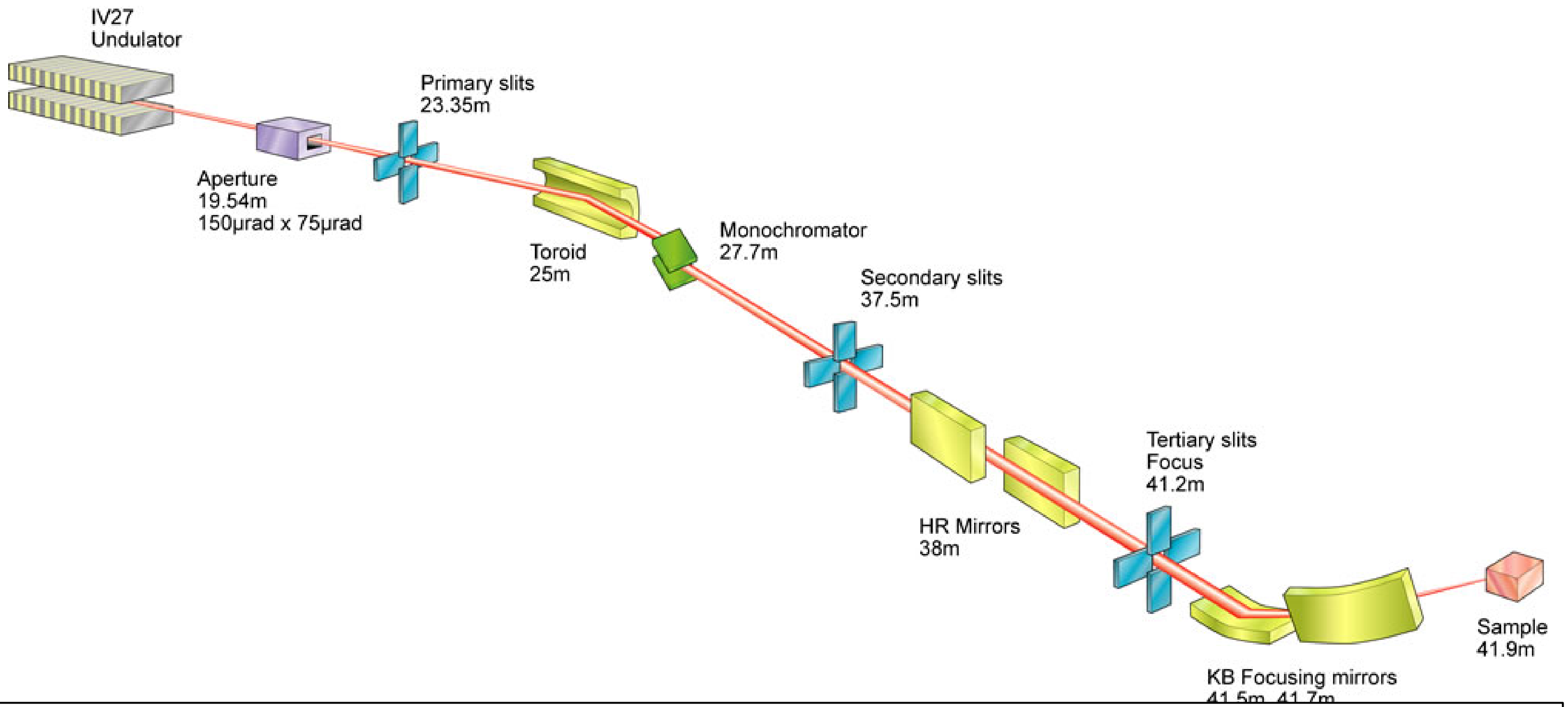
Overview



$$\sigma_{final} = \sqrt{\sigma_{diff}^2 + (M\sigma_{x,y})^2 + (M\Delta_{x,y})^2 + \Delta_{BL}^2 + \Delta_{inst}^2}$$

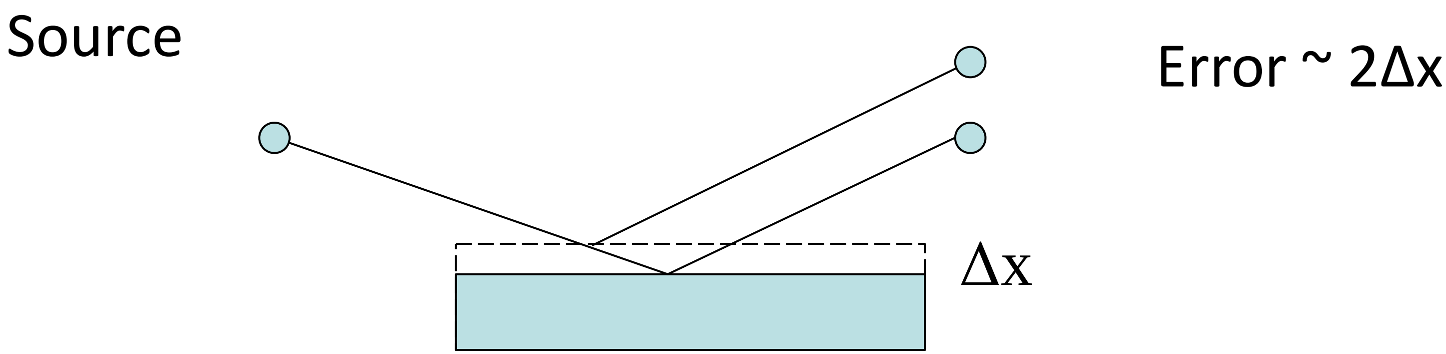
Diffraction limit

Geometric magnification

Source movement

Beamline and instrumentation movement

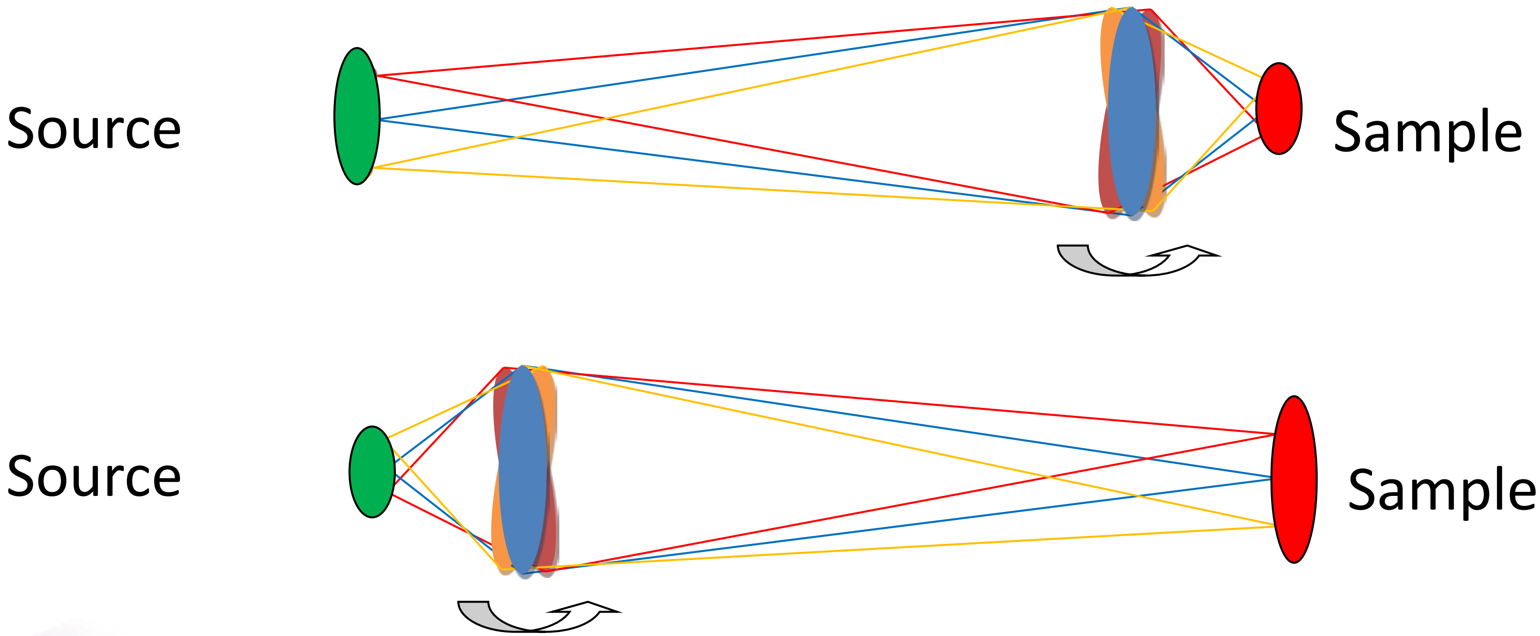
Positional stability



Positioning resolution of mono motion usually << source size

Floor vibrations ~ 20 nm   << source size

Angular Stability



Error ~ 2Δθ*d

- Intensity stability
- Beam size/stability
- Transverse coherence length

Frequency response…

At the end (sample, slit, focussing optic...)

“Blurred” image if collection time >> rate of vibration

Lots of movement if collection time ~ rate of vibration

Collection time < rate of vibration but beam position is somewhere within +/- $4\sigma_{vibration}$)

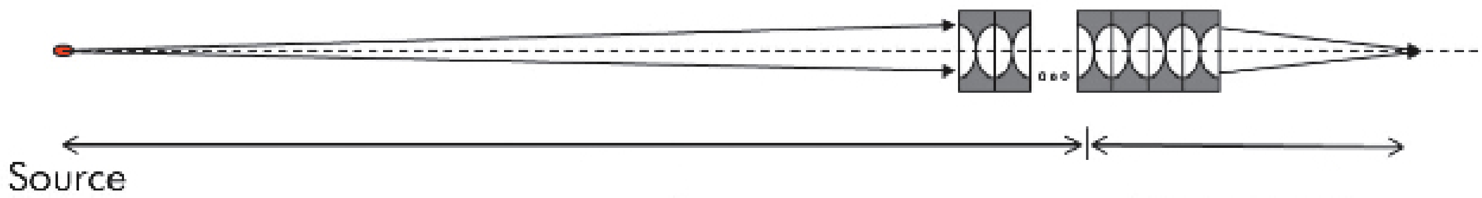
Two frequency requirements: Slow --- drifts
Fast --- vibrations

Example of impact on DLS beamline

I04 Example

Compound Refractive lens to focus source

Optics design value - 0.5 µm at sample



Actual focus = 2.0 µm (averaged)

Monochromators vibrations produce effective source size x4 larger than actual

Requirements (Past)

Instability < %10 beam size

2nd Gen source, mono typically at 20m, Source size 100 µm (rms)

For 1:1 focusing 10% movement corresponds ~ 250 nrad rms vertically

For DLS, mono typically at 30m, Source size 123 x 6.8 µm (rms)

For 1:1 focusing 10% movement corresponds ~ 11 nrad rms vertically

Requirements (now and future)

Instability < 2% beam size, coupling reduced from 1% to 0.3% (8 pm V emittance)

Mono typically at 30m, Source size 123x3.7 µm (rms)

For 1:1 focusing 2% movement corresponds ~ 1 nrad rms vertically. Other sources already proven 1 pm V emittance

Much more relaxed in the horizontal direction, but with new Multi-achromat sources and upgrades, FEL's; will become more important

Strongly depends on beamline design and requirements

Monochromator performance

Performance of cryo monochromators

Source	Vibration (rms)	Type
I18/I22	450 nrad*	Vertical bounce-up
MX (I04)	350 nrad	Vertical bounce-down
I11	~500 nrad	Vertical bounce-up

C Thomas *et al* 2012 *JINST* **7** P01014

*The initial value was higher than this, but simple clamping of pipes and other minor changes helped a lot. A full redesign was required to reduce further, see A. Peach talk on crystal cage update

Monochromator performance

Best of (some) of the rest….

Source	Vibration (vertical)	Estimate (rms)	Comment
Australian Light Source	0.5 µm @ 20m	<20 nrad	Horizontal DCM- low power

Performance – water cooled monochromator

Source	Vibration	Estimate (rms)
B18	1µm rms @ 12m	<40 nrad

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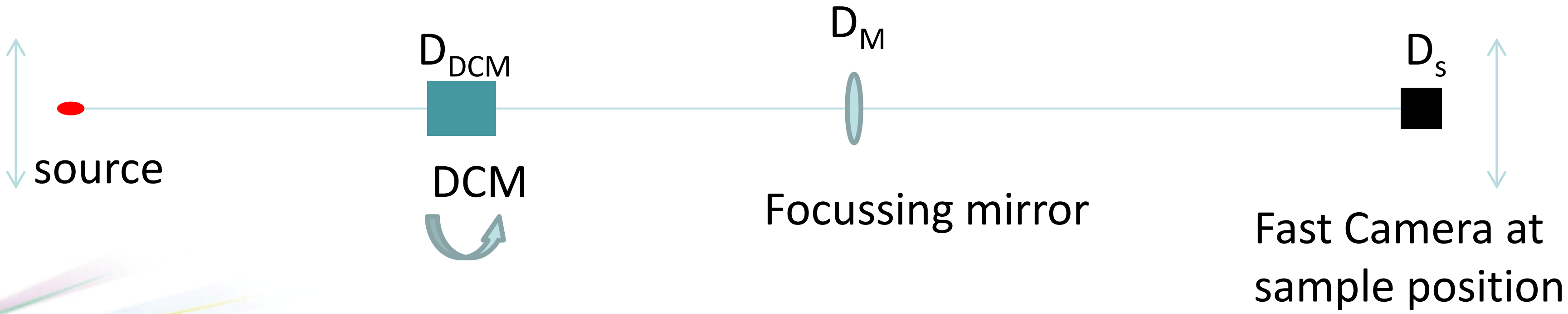
Overview of the Measurements

- Motion measured with fast X-ray camera (400 Hz)
- Assumed no contribution from mirrors
- DCM motion calculated from geometrical optics
- Source motion measured using BPM's sampled at 10 KHz

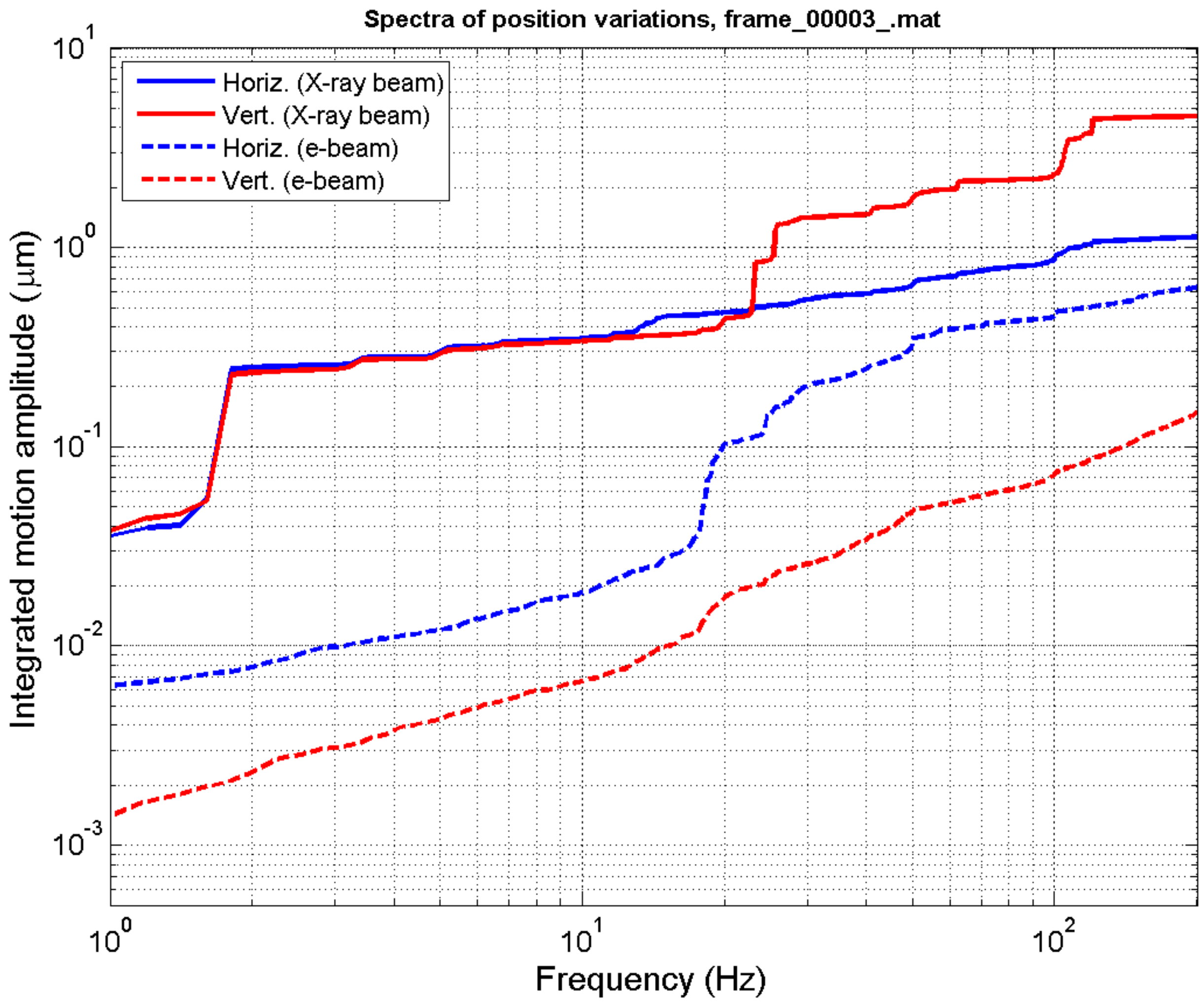


Motion amplitude:

1. Centroid motion recorded with camera images
2. FFT of the centroid
3. Cumulative integral of the FFT

Photon Beam Movement on I15

Source motion in unfocussed mode



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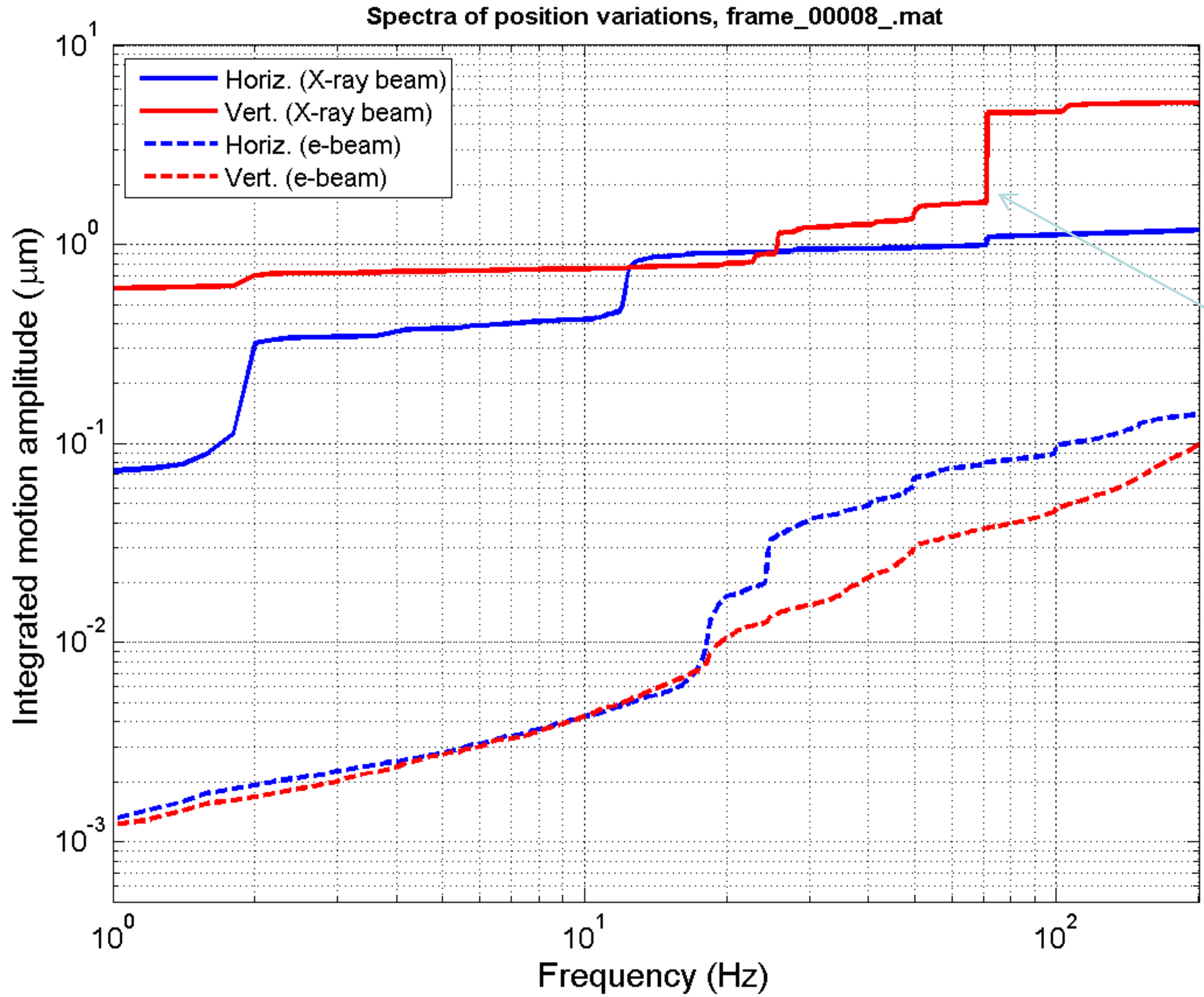
Photon Beam Movement on I15

Source motion in focussed mode



Modulation 71Hz

Bloomer et al J Phys Conf Ser 425 (2013), 042010

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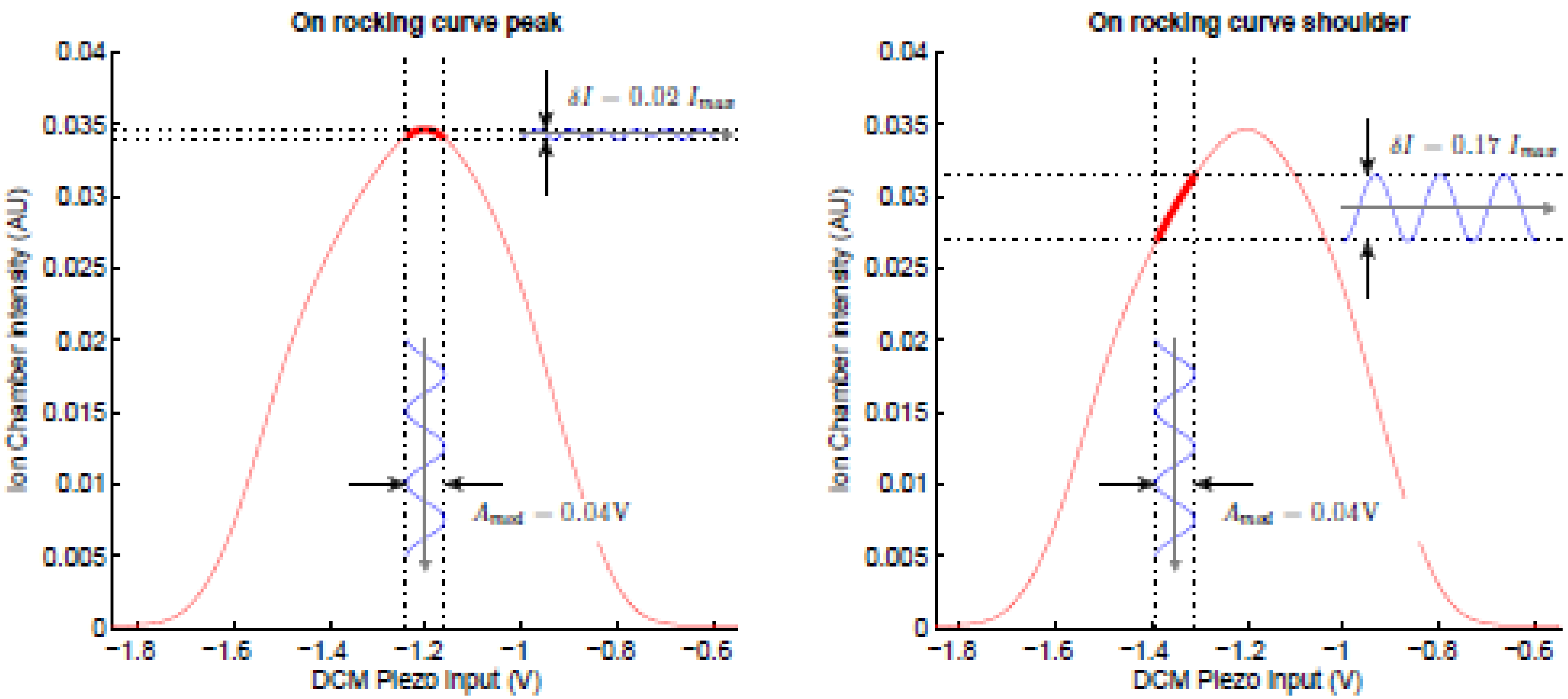
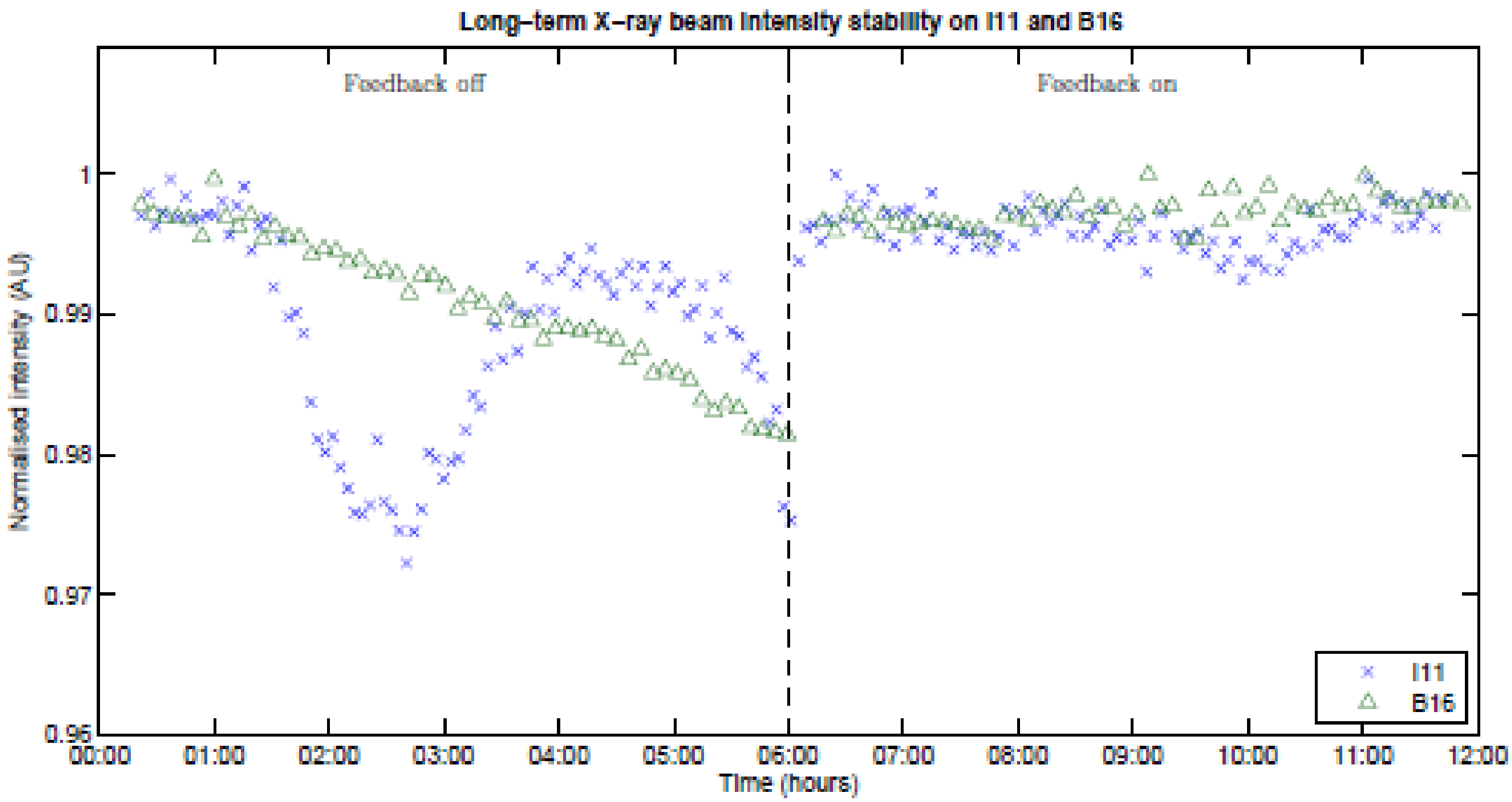
Photon Beam Movement on I11



Bloomer et al J Phys Conf Ser 425 (2013), 042010

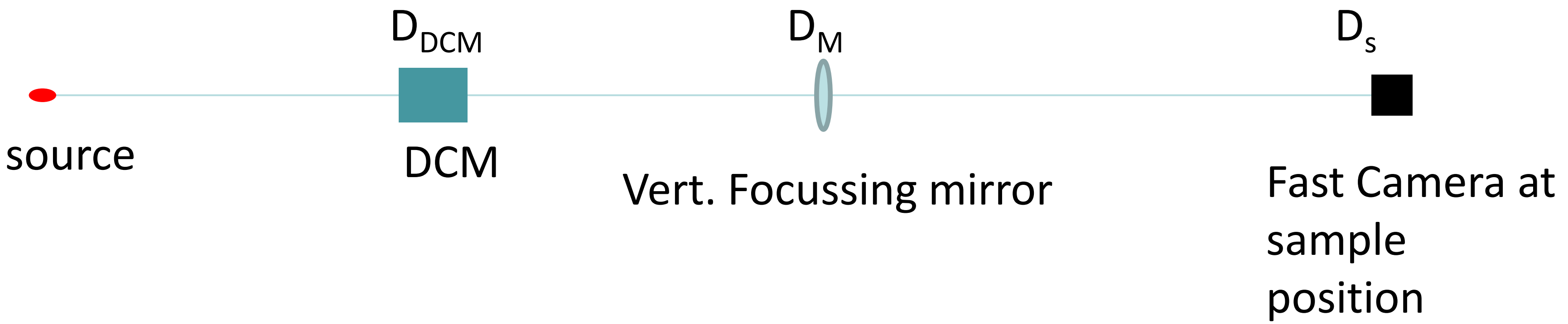
Long Term Stability on I11 and B16



	Feedback off	Feedback on
I11	0.76% rms	0.15% rms
B16	0.49% rms	0.10% rms

Depending on crystal cage mass, can reject vibrations to ~ 50 Hz

Geometric Calculations



α: angular motion of the DCM inducing 1μm vertical displacement at sample; no focusing $\alpha = 1/2(D_S - D_{DCM})$

General beamline layout above, but it is different for I10, I11, I16

For each case the layout as given on beamline web pages has been used to calculate a geometrical factor α

Focusing: $$M = \frac{D_S - D_M}{D_M} \qquad \alpha = \frac{1}{2 D_{DCM} M}$$

Geometric Values

Beamlines	D_{DCM} (m)	D_M (m)	D_s (m)	α (nrad / μm)
I07	25	28	47	**30**
I04	28	33	40	**84**
I10 (PGM)	-	-	-	**286**
J04 (Horz)	24	38	44	**132**
I15	25	29	47	**23/32**
I11	27	-	47	**25**
I16	DCM now channel-cut with additional focussing: example ID01 A. Diaz et al. JSR 17, (2010), 299			
I24	33.6	39.2, 45.7	46.4	**590**
B18	22	25	37.5	**45**

Vertical beam stability for DLS beamlines

Beamline (date)	Vert. r.m.s Beam size (μm)	Resonance (Hz)	Amplitude		DCM angular motion (nrad)	Total motion : @200Hz		DCM Total angular motion (nrad)
			(μm)	(% σ_V)		(μm)	(% σ_V)	
I07 (08/2010)	80	24.8 40 43	1.7 3.5 1.5	2.1 4.3 1.8	100 200 90	7.9	9.8	**240**
I04 (07/2010)	23	43 39 34 25	0.8 0.3 1.5 1.1	3.4 1.3 6.5 4.8	130 50 250 180	3.8	16.5	**320**
I04 (02/2013)	27	21 27 73	0.06 0.5 0.4	0.2 1.8 1.5	3.6 30.7 24.6	1.6	5.9	**134**
I10 (09/2012)	45	1/f noise motion	-	-	-	Hor. : 0.35 Vert. : 0.4	0.9	**100** **114**

Vertical beam stability for DLS beamlines

Beamline (date)	Vert. r.m.s Beam size (μm)	Resonance (Hz)	Amplitude		DCM angular motion (nrad)	Total motion : @200Hz		DCM Total angular motion (nrad)
			(μm)	(% σ_V)		(μm)	(% σ_V)	
J04 (02/2013) (hor.)	24	22 24 71	0.04 0.03 0.16	0.16 0.12 0.66	5 3 19	0.46	1.9	**61**
I15 (03/2013)	37 (focussed)	1.6 22 24 104	0.2 0.2 0.1 1.0	0.54 0.54 0.27 2.7	6.7 6.7 3.3 33	2.6	7.0	**122**
I11 (03/2012)	120 (slit)	65 43 24 15	2 2 2.4 2.6	-	50 50 60 65	19	-	**475**

Vertical beam stability for DLS beamlines

Beamline (date)	Vert. r.m.s Beam size (μm)	Resonance (Hz)	Amplitude		DCM angular motion (nrad)	Total motion : @200Hz		DCM Total angular motion (nrad)
			(μm)	(% σ_V)		(μm)	(% σ_V)	
I16 (04/2007)	60	68 48 31 19	4.7 1.4 0.7 0.9	7.8 2.3 1.1 1.5	-	8.7	14.5	**-**
I24 (12/2012)	4.4	21 39	0.7 0.11	15 2.5	330 47	1.0	23	**590**
I24 (12/2012) piezo off	4.4	21 39 **1/f noise**	0.1 0.15	2.5 3.4	47 51	0.6	13	**355**
B18 (03/2010)	60	50 19 **1/f noise**	0.02 0.02	0.03 0.03	1 1	0.96 **mostly 1/f**	1.6	**43**

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Monochromator improvements

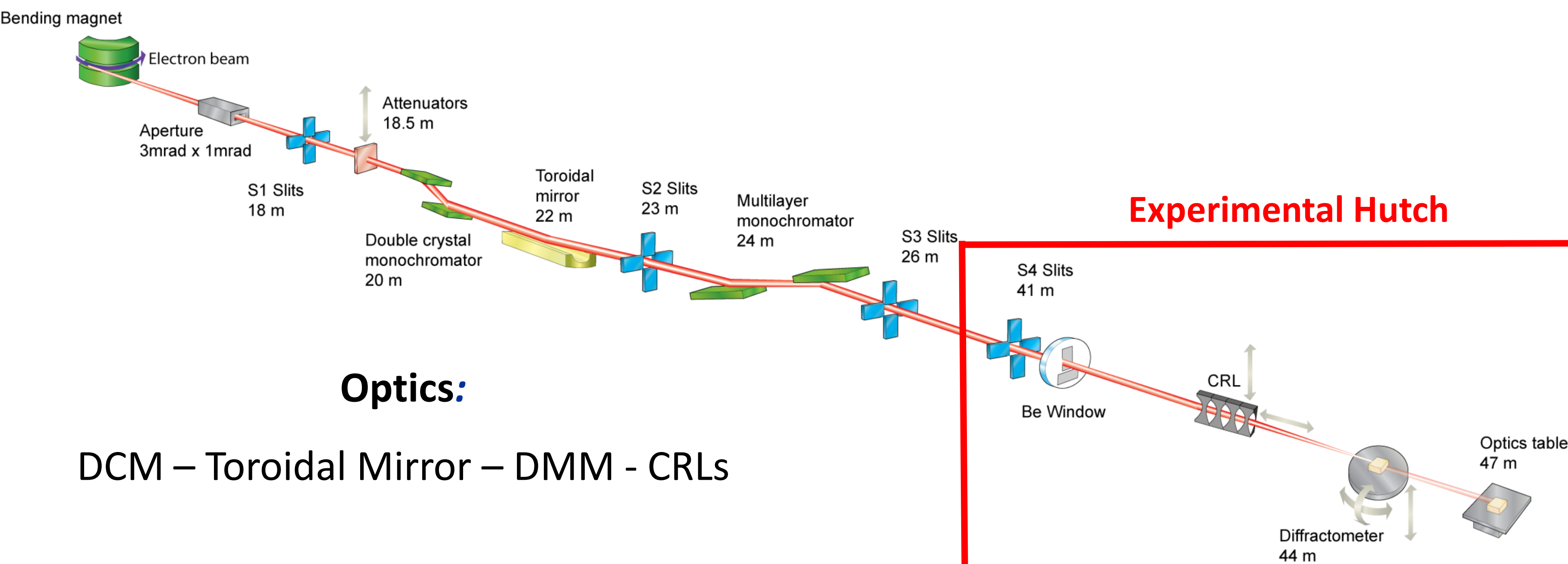
I18/I22 Improved crystal cage: Andy Peach
I09, I23 DLS built DCM using DC motor, air bearing: Jon Kelly

Source	Vibration (rms)	Type
I18/I22	80 nrad	Vertical bounce-up
I09	78-49 nrad*	Vertical bounce-up
I23	49-27 nrad*	Vertical bounce-up

*Vibration data was measured in commissioning and under different conditions, hence variation

B16 Test Beamline

- **Flexible & versatile** to enable wide range of experiments
- Large energy range (4 keV – 45 keV)
- Several operational modes: mono, white, micro-focused, …
- Range of beam sizes : 1 micron to 100 mm
- Essentially a general purpose beamline

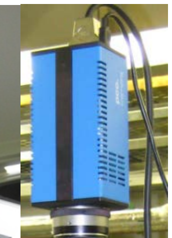


Optics:

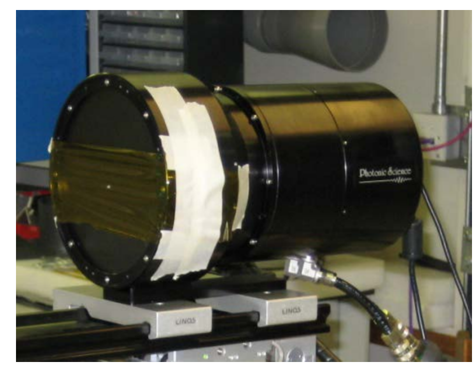
DCM – Toroidal Mirror – DMM - CRLs

B16 Experiments Hutch

High Spatial Resolution Detector



- <0.5μm ideal resolution
- 4008x2672 pixels, 44dia
- 2x to 40x objectives
- 16 bit dynamic range
- several scintillators



Detectors

- PCO4000 & PCO.edge high resolution
- Pilatus 300k area detector
- Image Star 9000 :135mm dia CCD
- Merlin (medipix based)
- VORTEX spectroscopy, APD, X-ray eye, PIPS diode

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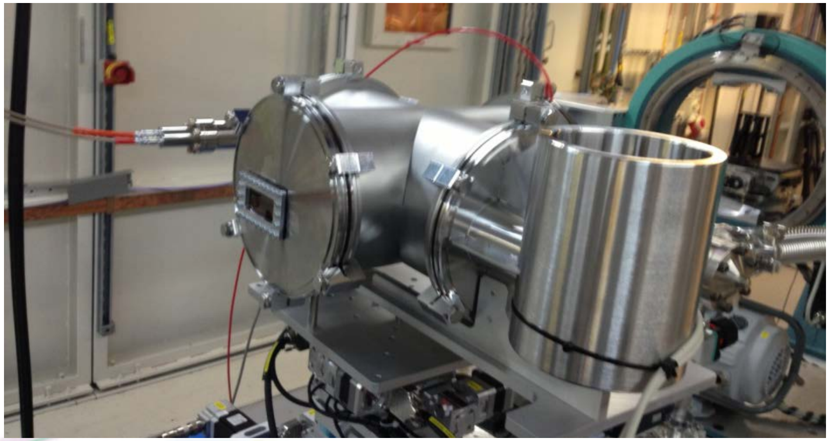
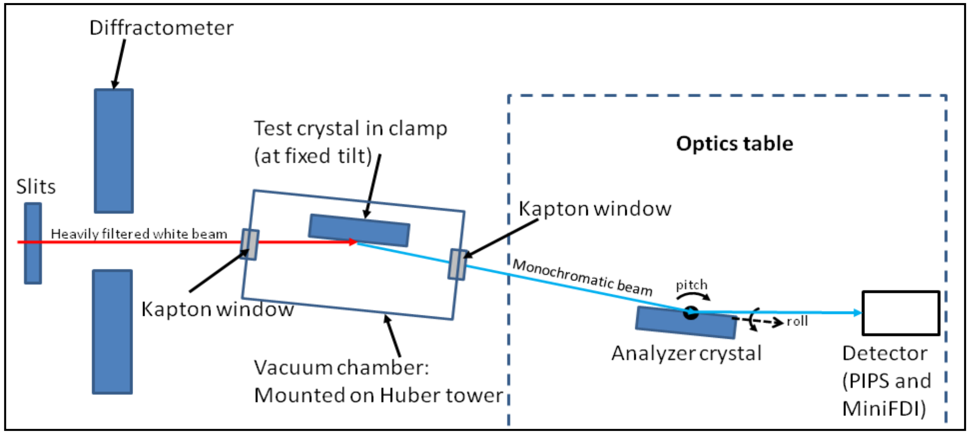
Thermal Issues

On I18 at long acquisition times (2-8s) get better data by reducing the heat load on the monochromator. Thermal load on I20 wiggler beamline not being well managed.

Measurements carried out on B16: Simon Alcock talk





Optimisation of Monochromator crystal configurations for increasing Synchrotron Powers
(PhD program)

Dr Peter Docker Diamond Light Source, Campus, Didcot, Oxon OX11 0DE
Professor Mike Ward Birmingham City University B4 7XG

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Conclusions

Scope for improvement across Diamond beamlines
New in-house designs and retrofits I09/I23/I20/I13/I22/I18

Need better interaction and collaboration with supplier
If we can get x6 improvements, so can they….
(precision metrology lab and B16): Simon Alcock

Licensing our knowledge or defining preferred designs
Mono tenders still specification based
Leaving the supplier to come up with solutions ??

Feedback control - A standard approach or hardware solution?

Acknowledgements

- Paul Quinn
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