Characterisation of a novel super-polished bimorph mirror

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Outline

- Motivation & Concept
- Metrology testing (Diamond-NOM)
- X-ray testing (Beamline B16)
- Summary and future

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The “ideal” synchrotron mirror

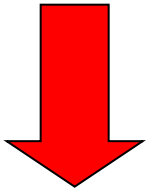
- “Pure” focal spot
  - Ellipse with slope & figure error ~100nrad & ~1nm rms
- Adaptive
  - Change focal distance / size
  - Correct upstream optical errors
  - Remove heat-load / mounting deformations

Can this be realised???

“Next generation” adaptive optics

No single technique can provide flexibility & quality, so combine two!

- Super-polished substrate: mid & high spatial frequency roughness **(JTEC)**
- Piezo bimorph (8 channels): figure / slope error **(SESO)**



Adaptive optic with exceptional quality

→ Micro- & nano-focussing

Coherence preservation

Wavefront correction, …

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Super-Polished Bimorph

- 8 piezo bimorph (SESO), 150mm long, fused silica substrate
- EEM treatment (JTEC) on central ~120mm

  [Figuring with sub nanometre-level accuracy by numerically controlled elastic emission machining, K Yamauchi et al, Rev. Sci. Instrum. **73**, 4028 (2002)]

- Elliptical pre-figure (p=41.5m, q=0.4m, θ=3mrad)

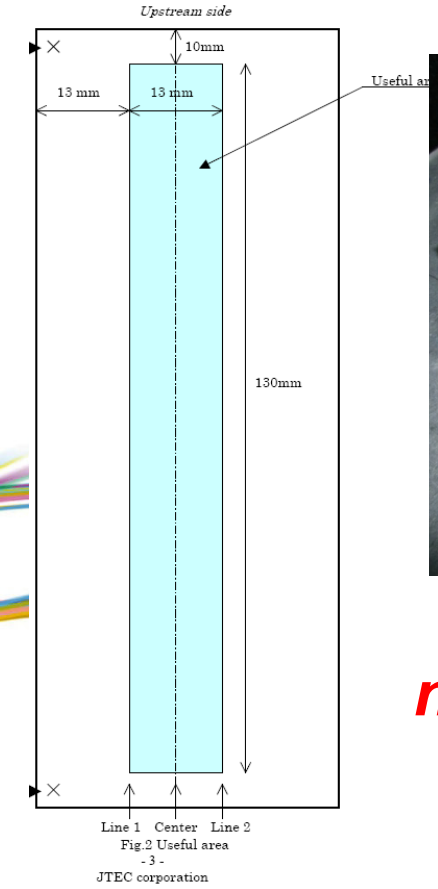
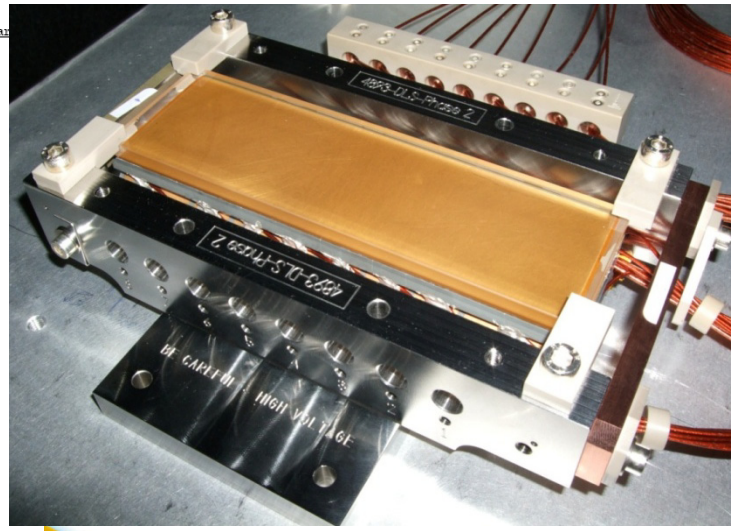
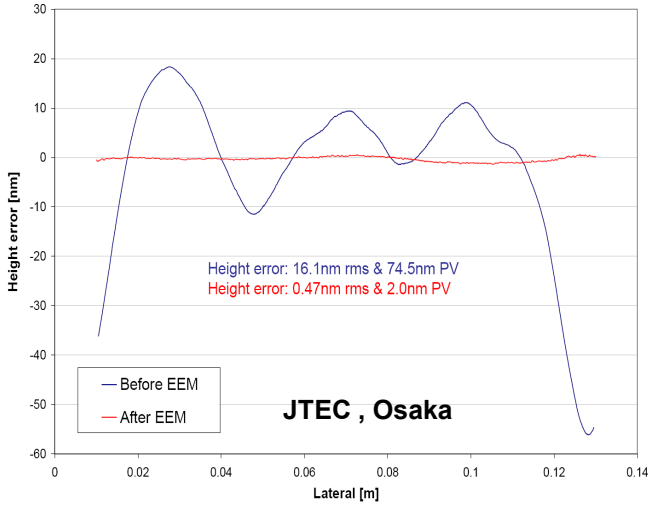


Fig.2 Useful area
- 3 -
JTEC corporation



Height error before and after EEM polishing



novel super-polished bimorph mirror

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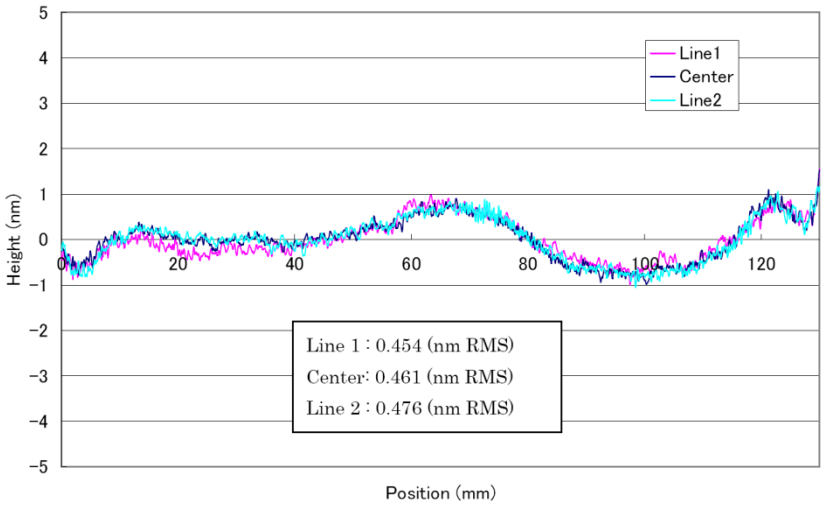
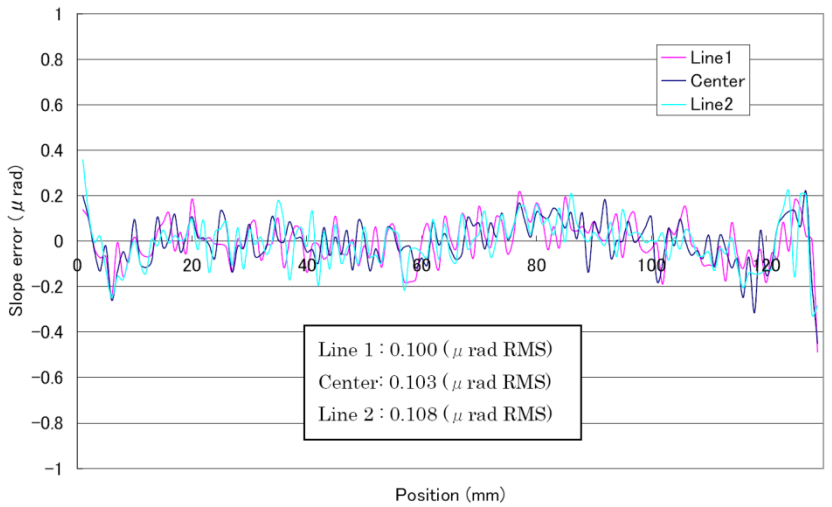
Super-Polished Bimorph

< 0.5 nm rms (< 2 nm PV) height error !



0.1 μrad rms slope error !



- Error profiles along the tangential direction from the nominal ellipse
- No bimorph corrections applied !

❖ JTEC, Osaka

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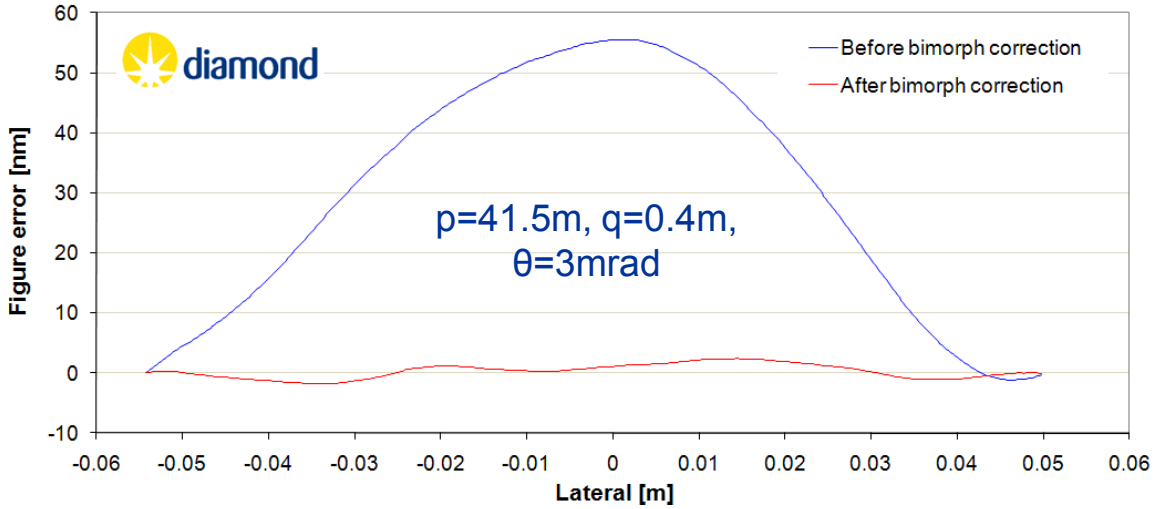
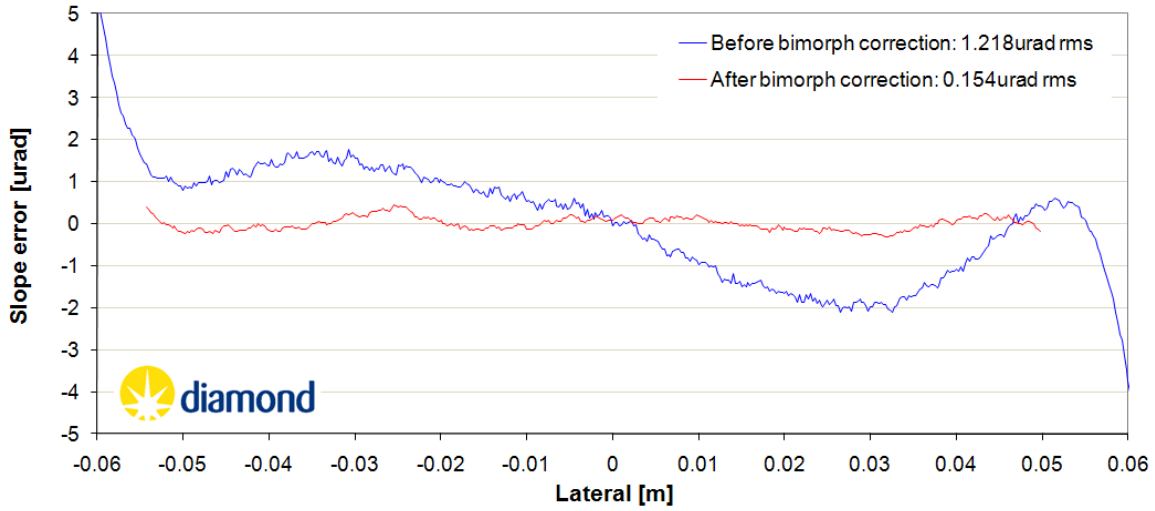
Figure Error

Figure error < 1nm rms



Diamond NOM

Slope error ~0.15 μrad rms



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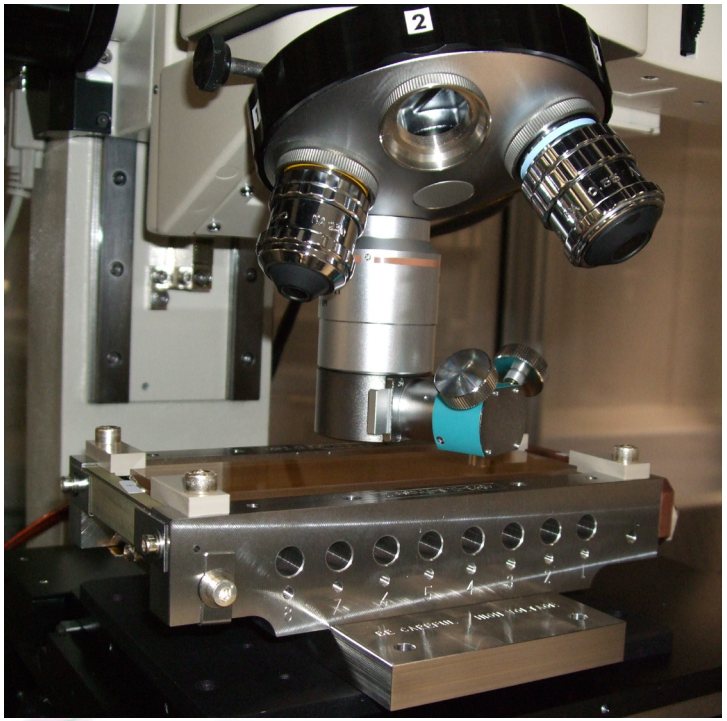
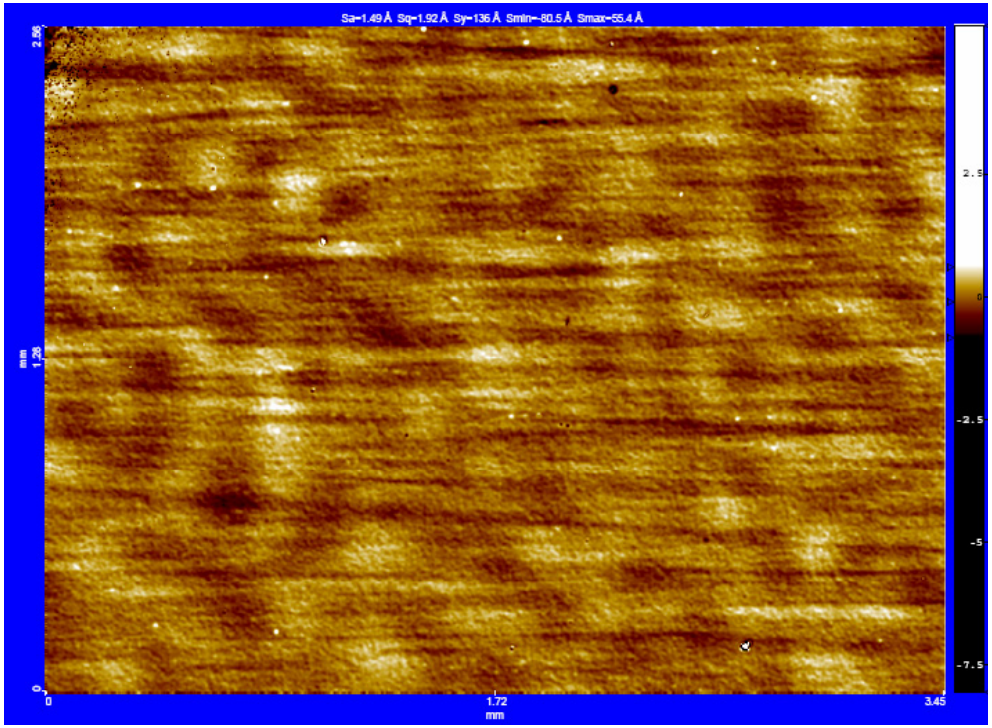
Micro-Roughness

Diamond Micro-interferometer





Objective	*Field of View*	*EEM region Sq*	*Non-EEM region Sq*
2.5X	*3446 x 2563µm*	*1.92Å rms*	*No data*
10X	*864 x 643µm*	*2.03Å rms*	*1.83Å rms*
50X	*173 x 129µm*	*1.90Å rms*	*1.91Å rms*

⇒ ***No change in micro-roughness by EEM polishing***

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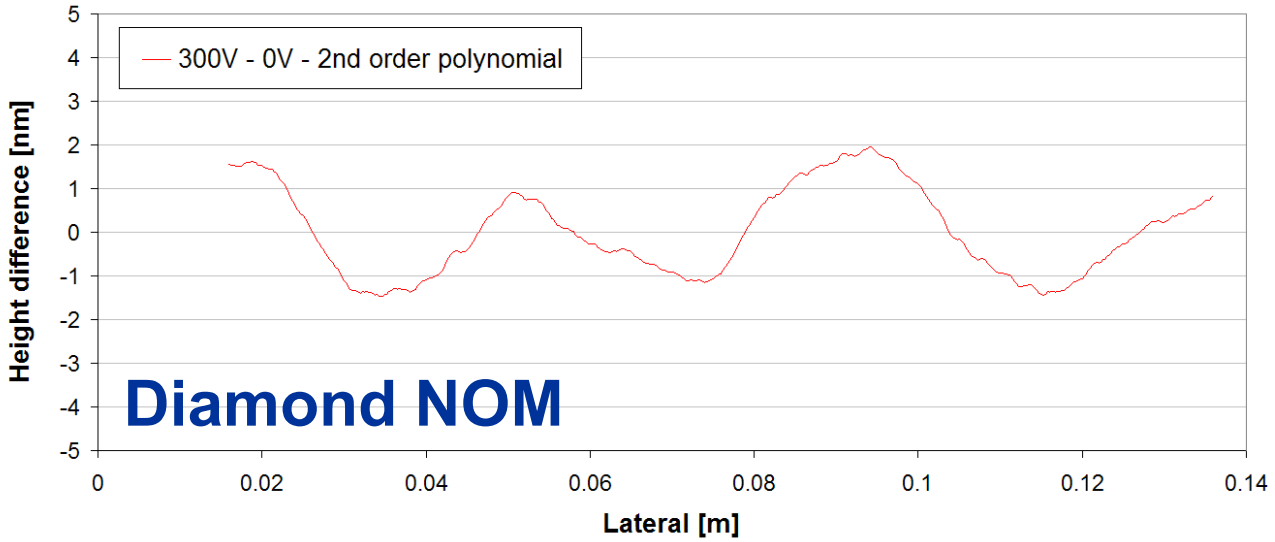
Range of Bending

	1	2	3	4	5	6	7	8	9	10	11
p (mm)	41500	40000	55000	40000	55000	55000	40000	41500	41500	41500	41500
q (mm)	400	400	400	350	350	475	475	290	270	425	200
α (mrad)	3	3	3	3	3	3	3	2,25	2	3,75	1,22
V2 (V)	0	-2	11	-398	-385	484	471	208	450	-740	1336
V1 (V)	0	-2	11	-1345	-1332	1355	1342	-1231	-1172	-1030	-1339
	NOMINAL CONFIGURATION										

p = 41.5 – 55m, q = 200 – 400mm, θ = 1.22 – 3mrad

Apply 300V. Does figure error worsen? Only by 1nm PV!



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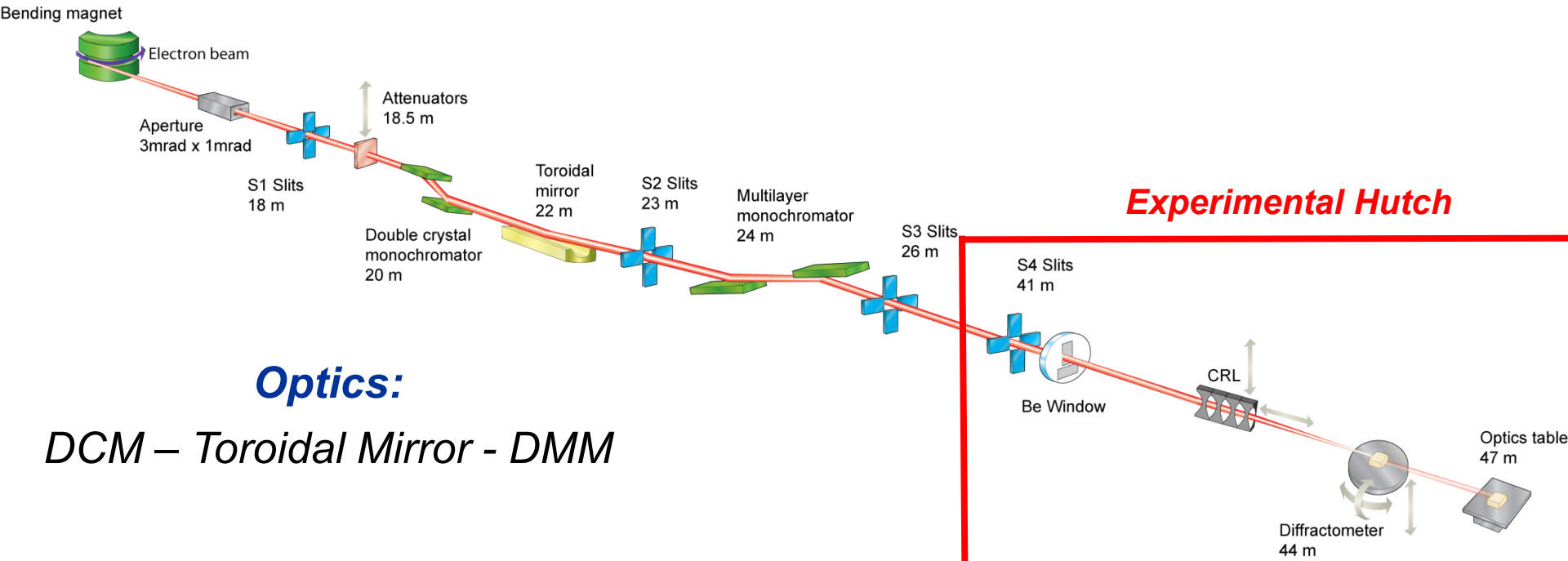
B16 Test Beamline

- ***For testing optics & detectors***
- ***For developing novel experiments & techniques***
  - *Flexibility & versatility to enable wide range of experiments*
  - *Large energy range (2 keV – 25 keV)*
  - *Several operational modes: mono, white, micro-focused, …*
  - *Range of beam sizes : 1 micron to 100 mm*



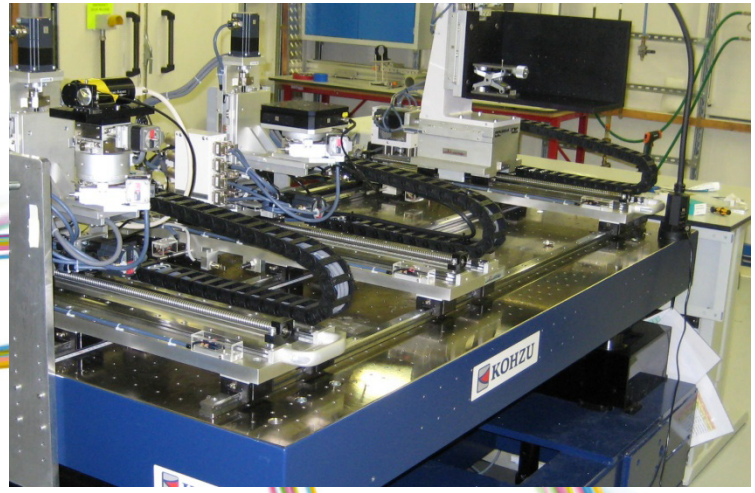
Optics:

DCM – Toroidal Mirror - DMM

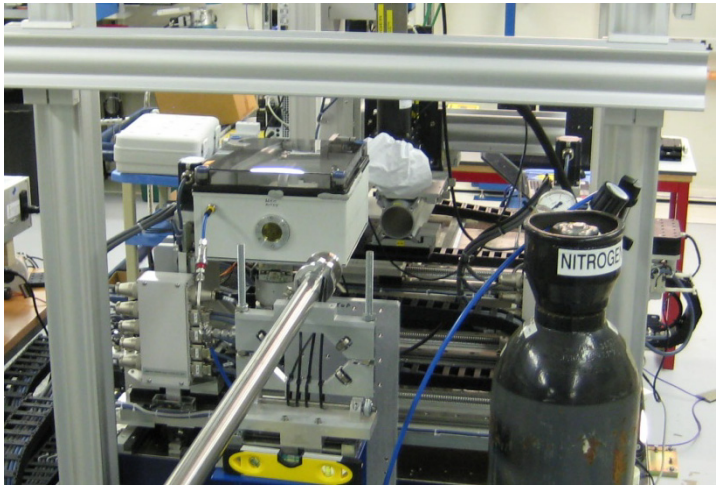
B16 experimental

- Monochromatic, unfocused beam: 8 keV
- Double Multilayer Mono (Ni/B4C) for higher order suppression
- Detectors:
  - Au-wire scan on piezo stage
  - X-ray eye camera (for initial alignment)
  - High resolution X-ray Microscope: (20x objective, 5μm-thick Eu:LuAG scintillator, PCO CCD camera, 0.18μm effective pixel size)

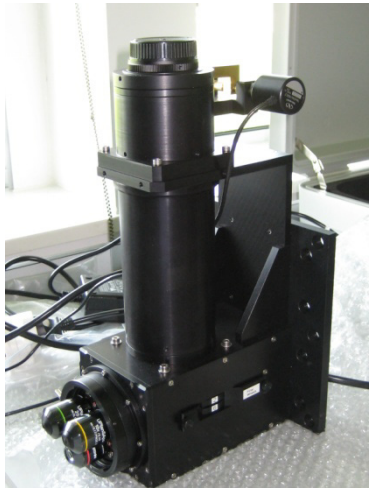
Optics Table



EEM Mirror



"Optique Peter"



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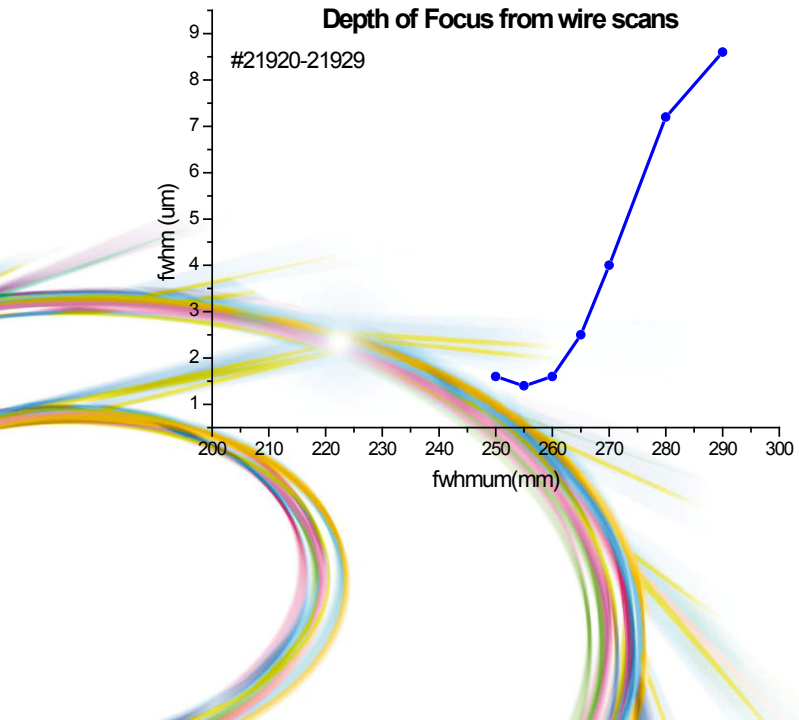
Preliminary X-ray Measurements B16

Mirror parameters:

As fabricated : 41.4m 0.3m 3 mrad

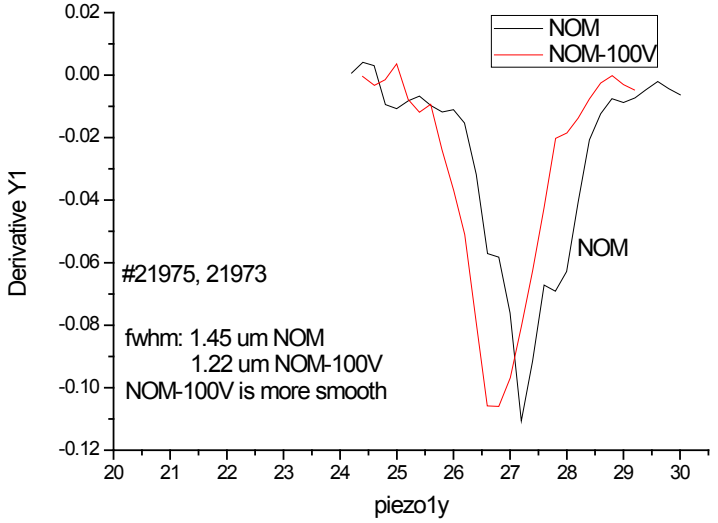
On B16 : 46.5m 0.3m 3 mrad

Depth of Focus



Variation of Bimorph Voltages

All electrodes -100V of NOM



Focal spot ~1.2 µm for NOM-100V

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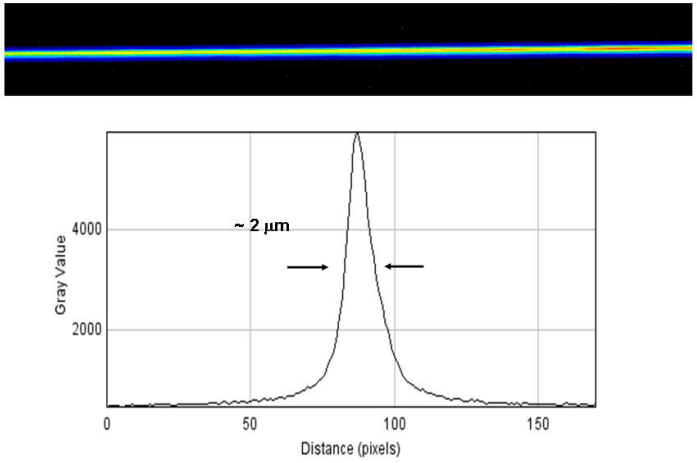
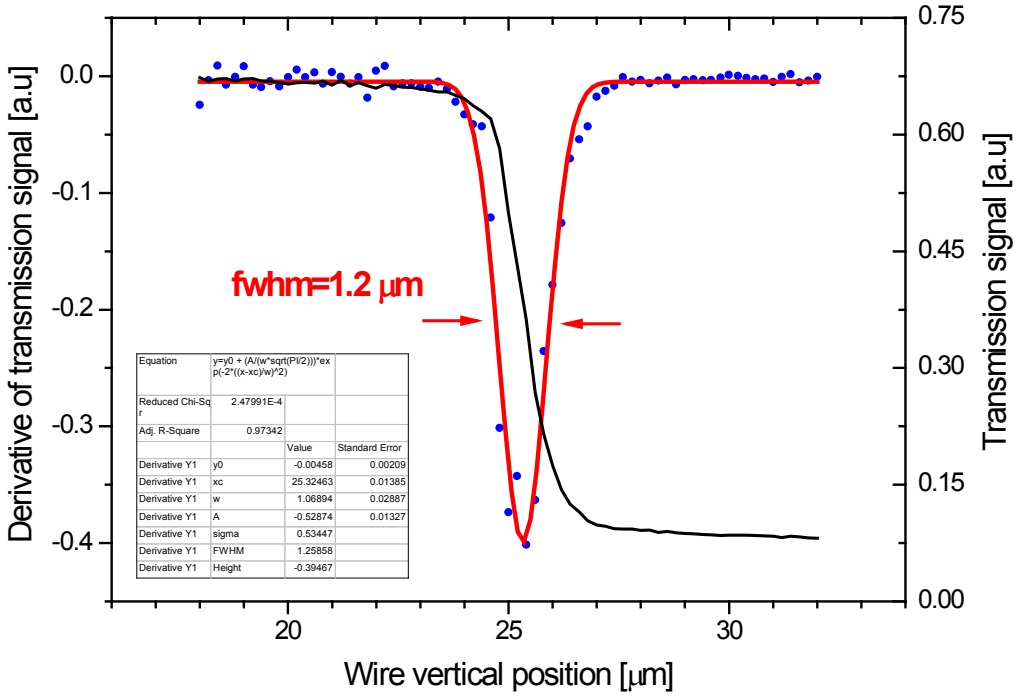
Measured Focus Size

B16

Image & line profile using "Optique Peter" camera



Au wire scan



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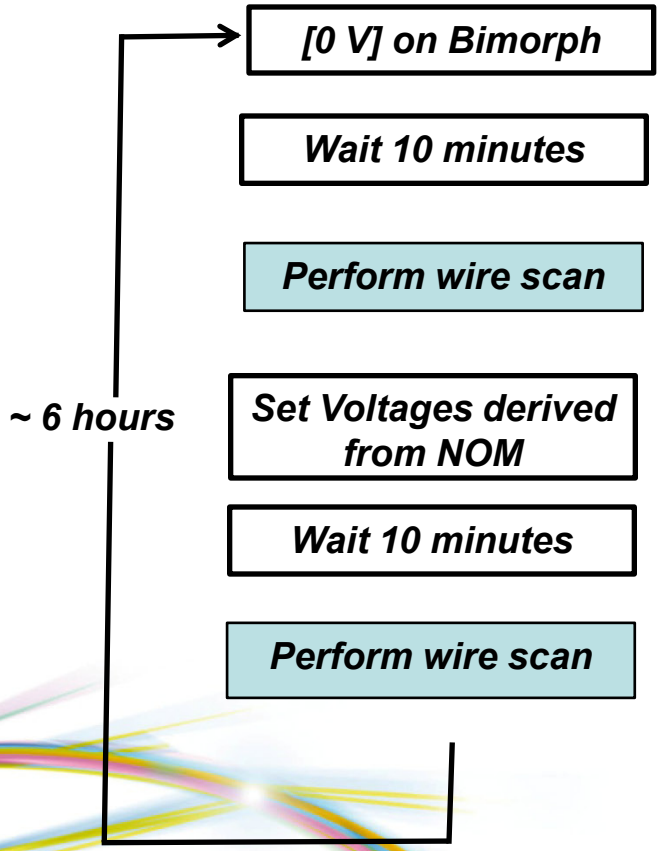
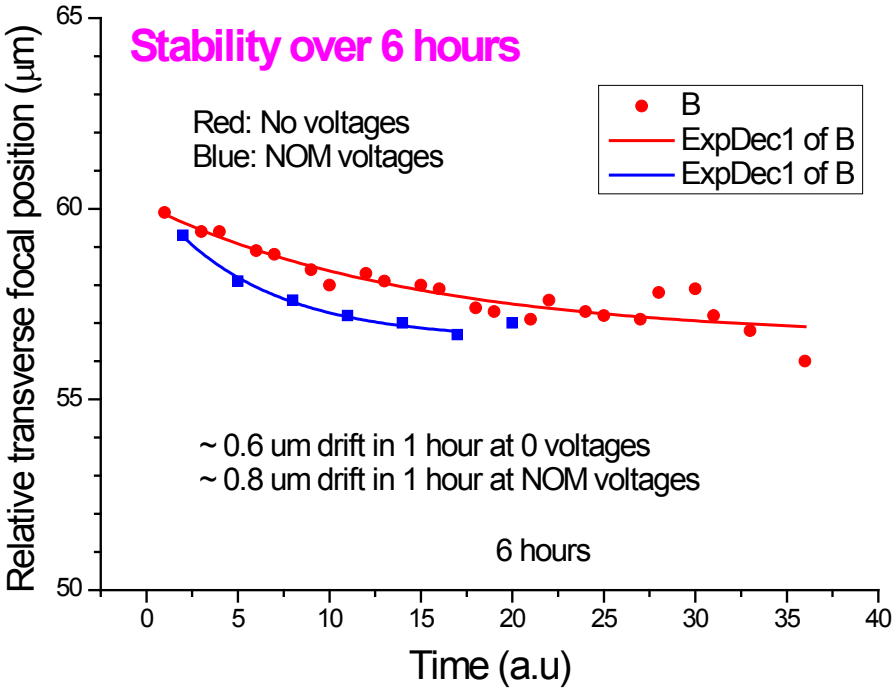
Stability/ Reproducibility Tests

B16





- No change in beam size
- Drift in peak position of <1 µm in 1 hour
- Cause of drift: bimorph / beamline?

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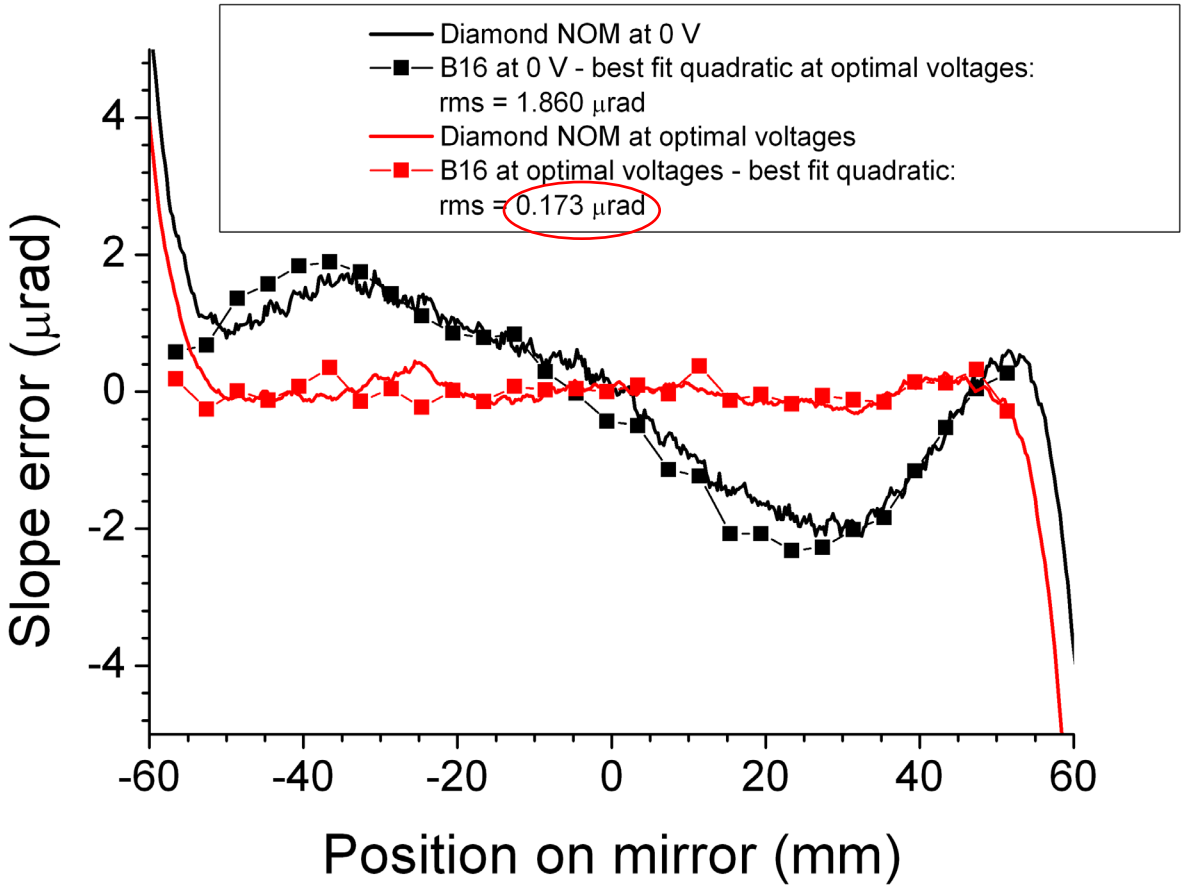
Ex-situ Vs in-situ

B16

- Slope error measured by Diamond NOM and slit scans on B16



⇒ Good correlation between ex-situ (DLS-NOM) and in-situ (B16) measurements

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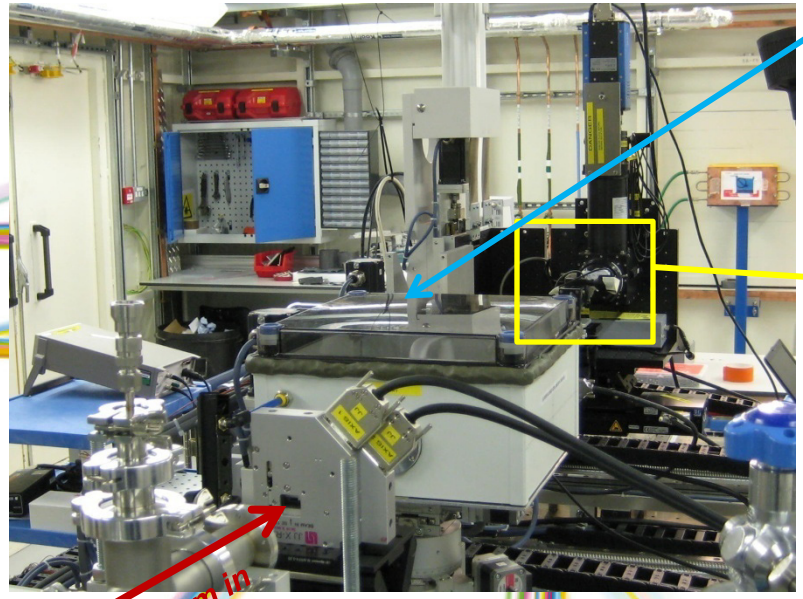
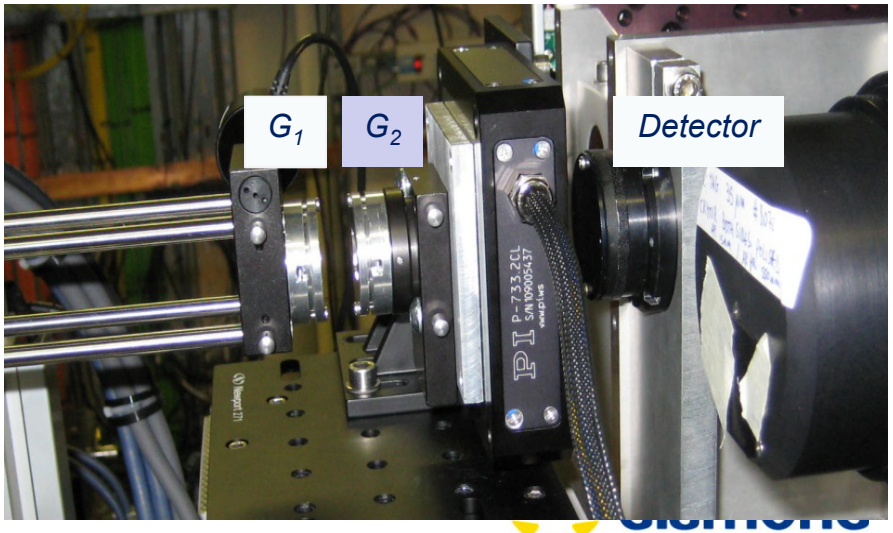
Wavefront Characterisation using Shearing Interferometer

- Interferometer placed out of focus (***E=14.8keV θ=0.05°***)



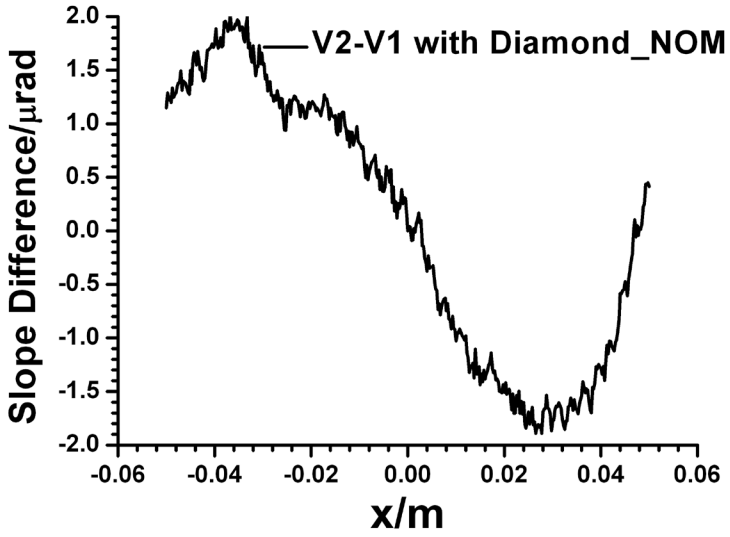
Interferometer



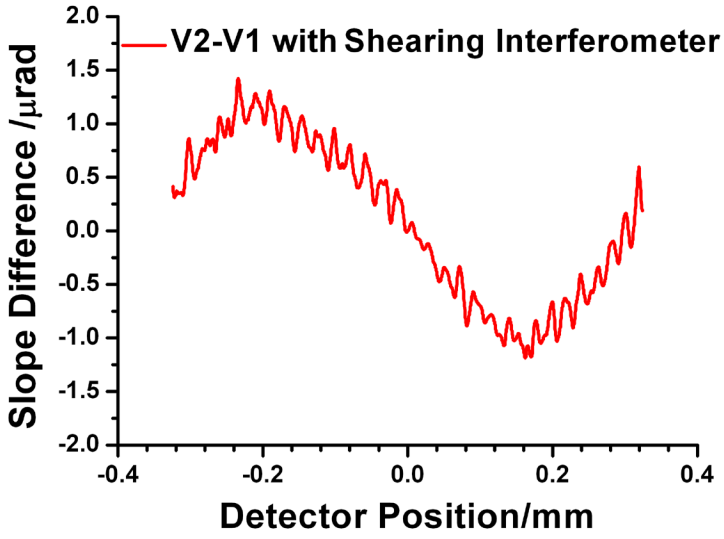
Shearing Interferometer: Moiré Fringe analysis method

- averages data along the whole width foV (~1.4mm)

Miror slope difference tested with Diamond_NOM



Wavefront slope difference tested with interferometer



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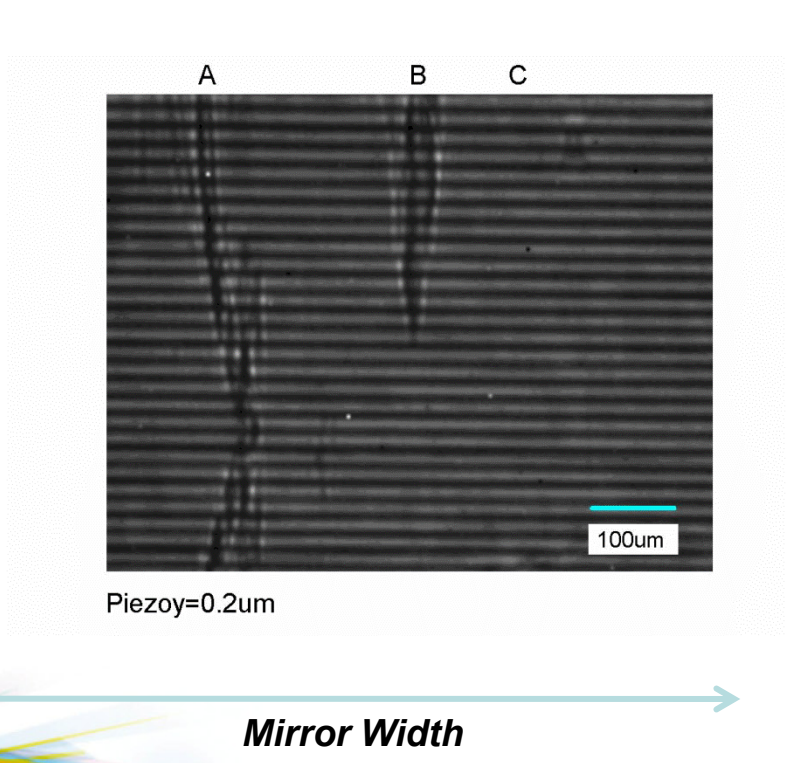
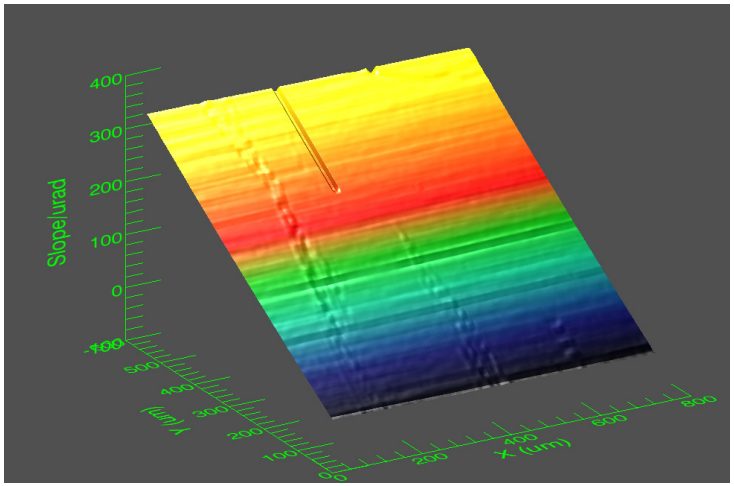
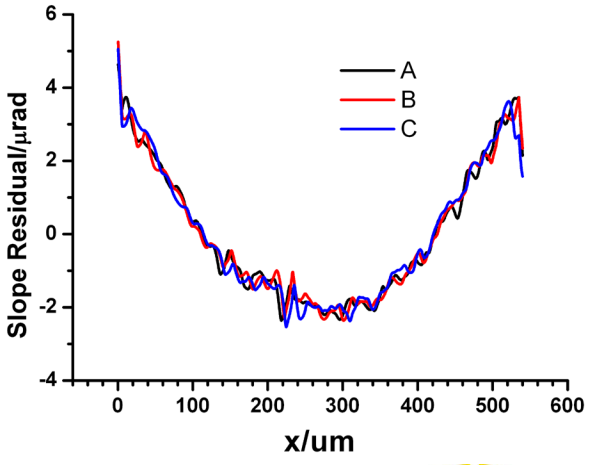
Shearing Interferometer: Phase stepping method



Wavefront Slope





- Phase stepping methods give high resolution for detailed information on wavefront
- divergence mismatch of the gratings
- Data still being processed

Summary / Future

- A novel “super-polished” bimorph mirror developed
- Characterised using Diamond-NOM and B16 Test beamline
- EEM gives elliptical shape with exceptional figure and slope error
- Bimorph provides wide range of elliptical shapes & sub-nm figure correction
- Preliminary X-ray tests performed on B16 Test beamline
  - Slit scans, wavefront analysis, …

- Use an ID beamline
- B16 : vary focal distance
  : out-of-focus beam (and minimise structures)
  : Wavefront analysis using shearing interferometer
  - use divergence matched gratings
- More tests on B16 in July 2011

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Acknowledgments

- B16: Igor Dolbnya, Andrew Malandain, Slava Kachkanov
- Geoff Ludbrook for micro-roughness data
- Lucia Alianelli
- Christian David, PSI for providing the gratings for the interferometer
- JTEC (Japan) for their expert EEM polishing skills
- SESO (France) for designing & manufacturing high quality, custom-built, bimorph optic
- Sincrotrone Trieste (Italy) for providing state-of-the-art, high voltage, power supply