At-wavelength metrology with grating based shearing interferometer at DLS

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Outline

- Introduction
- Rotating shearing interferometer
- Characterisation of Parabolic refractive lens
- Characterisation of X-ray mirror
- Summary and Outlook

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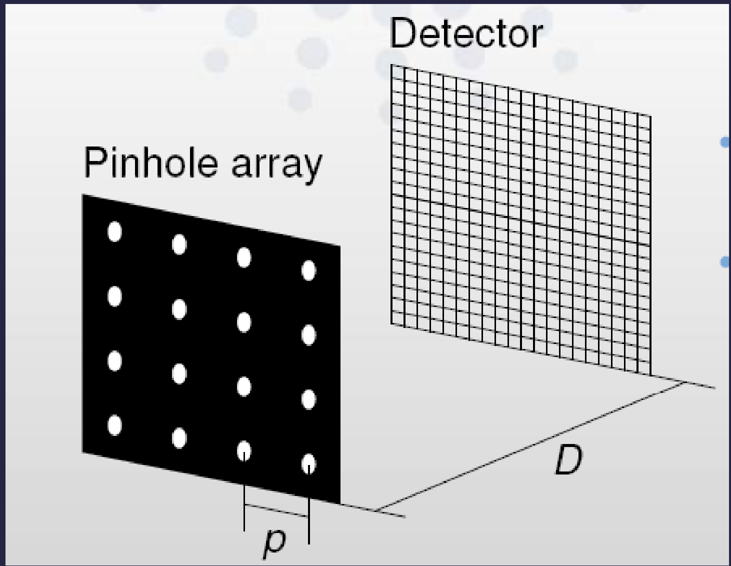
At-wavelength Metrology

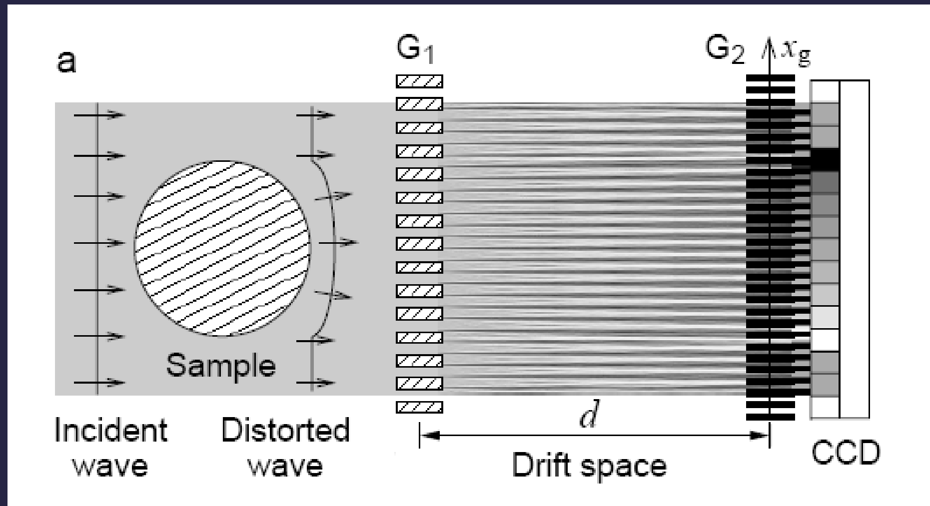
Hartmann sensor



☹Low photon efficiency
☹Restricted to near field
☺Two dimensional information

J. Hartmann, Z. Instrumentenkd. **20** (1900) 47–58

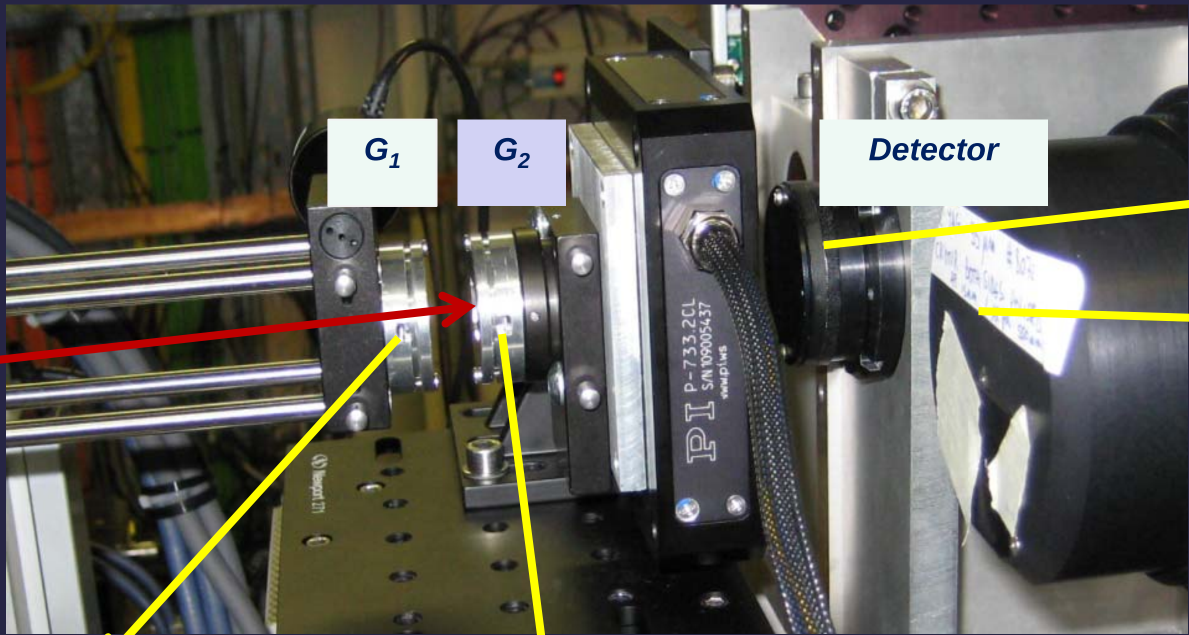
Grating shearing interferometer



☺High photon efficiency
☺ High sensitivity
☺ Gives information about coherence function
Two modes of operation:
(1) phase stepping (2) More Fringe analysis

T. Weitkamp, et al, Opt. Express, 13, 6296 (2005)
T. Weitkamp, et al., Appl. Phys. Lett. 86, 054101 (2005)
T. Weitkamp, et al., SPIE. 5533, 140 (2004)

Grating setup at DLS B16

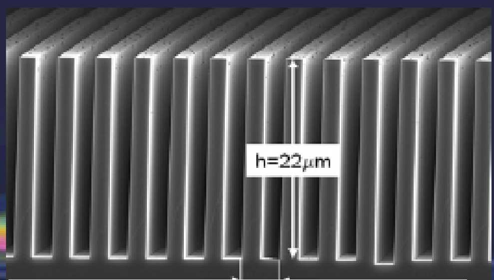


Beam In

Detector:
MFDI: 6.4µm/pix

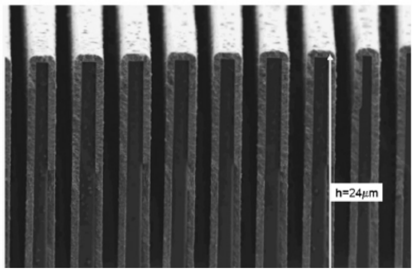
PCO 4000
4X: 0.9µm/pix
10X: 0.36µm/pix
20X: 0.18 µm/pix

Phase Grating (Si)



G1 Pitch: 4µm

Absorption Grating (Au on Si)



G2 Pitch: 2µm

Grating Image Courtesy of C. David, Microelectronic Engineering, 84, 2007

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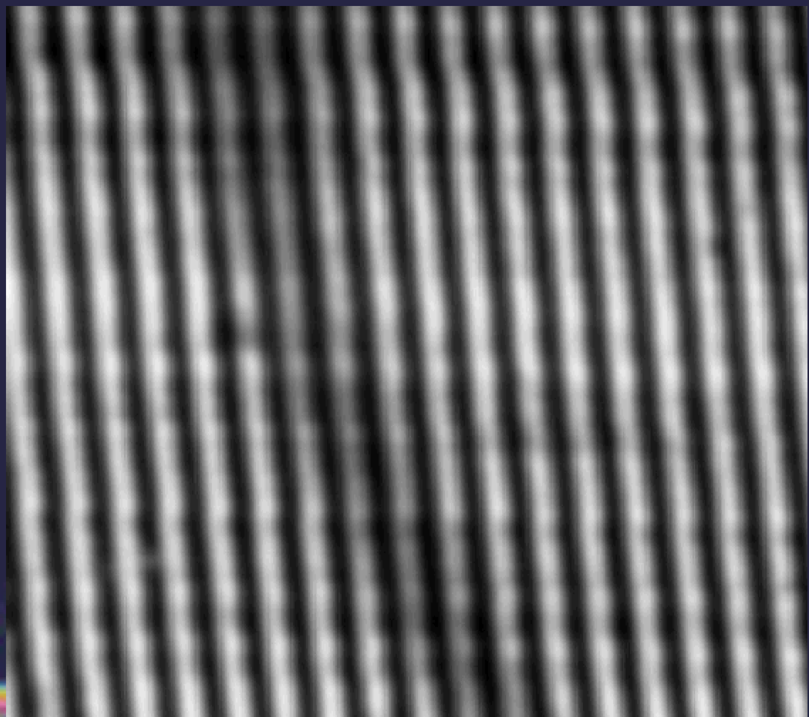
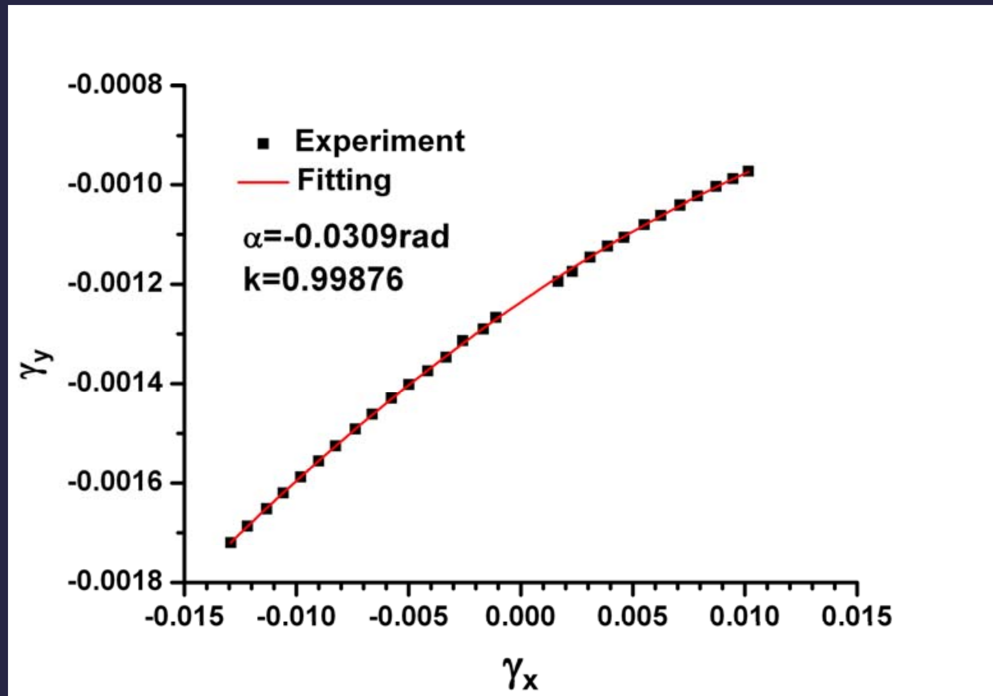
Rotating shearing interferometer





α→G2 misalign angle

k→ Wavefront Radius of Curvature

Experiment at DLS B16: Hongchang Wang and Kawal Sawhney

Radius of Curvature for Flat field Wavefront

d0 G1 Pitch

$$d_0 = 4\mu m?$$

d2 G2 Pitch

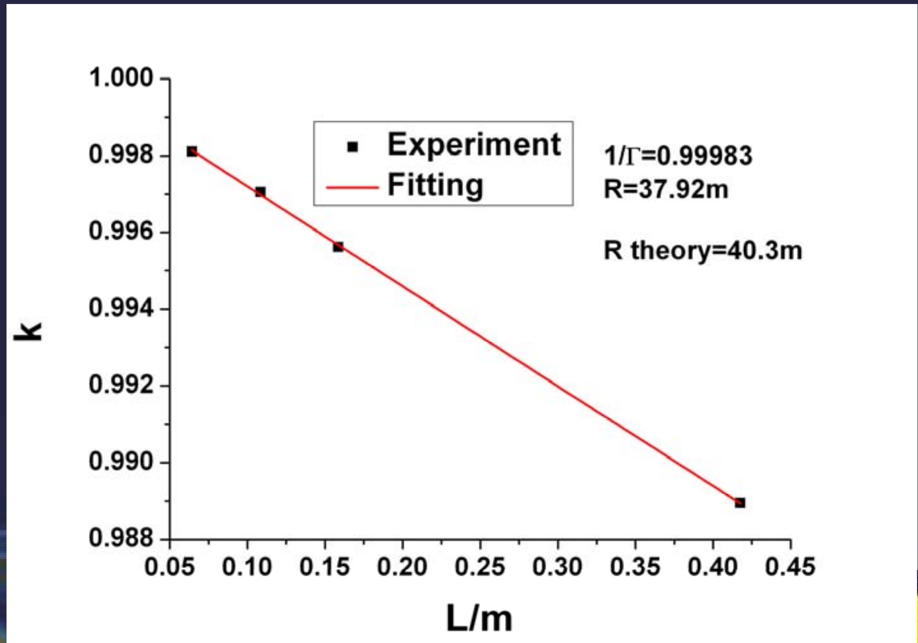
$$d_2 = 2\mu m?$$

Order	L/m	α/rad	k	R/m (Γ=1)
3rd	0.0643	-0.0351	0.9981	33.96
5th	0.1085	-0.0352	0.9971	36.67
7th	0.1585	-0.0352	0.9956	36.03
19th	0.4175	-0.0354	0.9889	37.20

$$d_0 / 2 = \Gamma d_2$$

R: Radius of Curvature

$$\frac{R}{R+L} = \Gamma k$$



R_{exp}=37.9m

R_{theory}=40.3m

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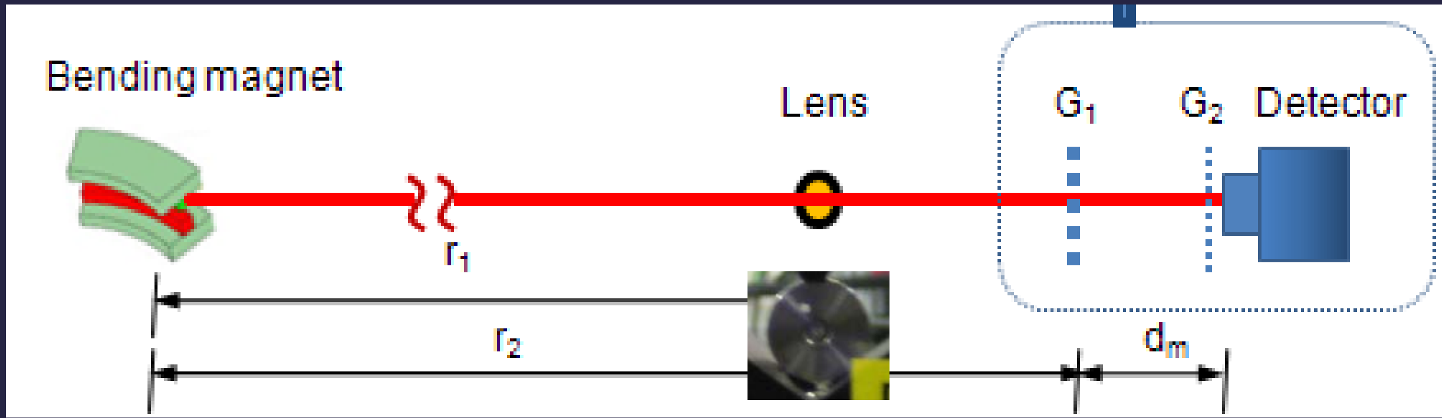
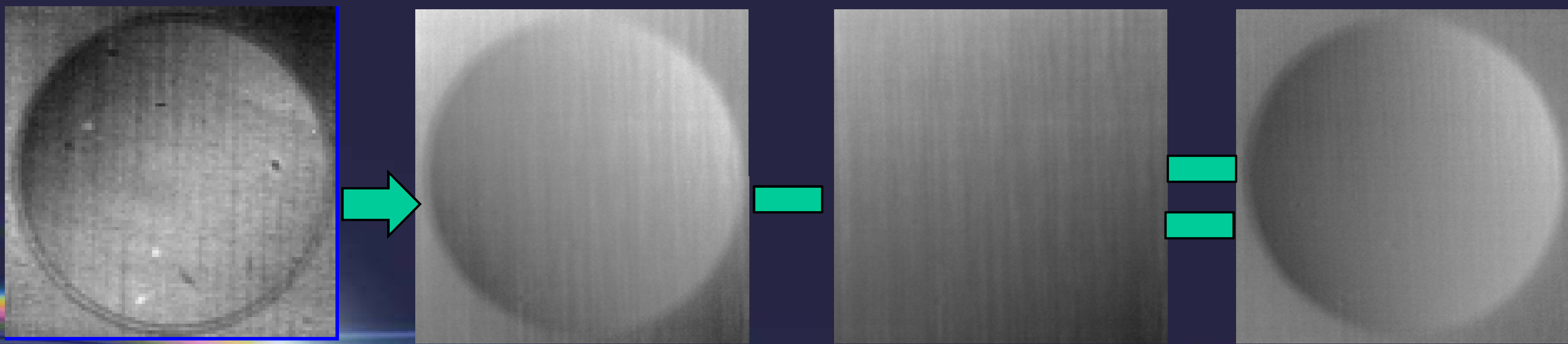
Experiment at ESRF BM05: Sébastien Berujon , Eric Ziegler and Hongchang Wang, 2011

Characterization of Parabolic refractive lens



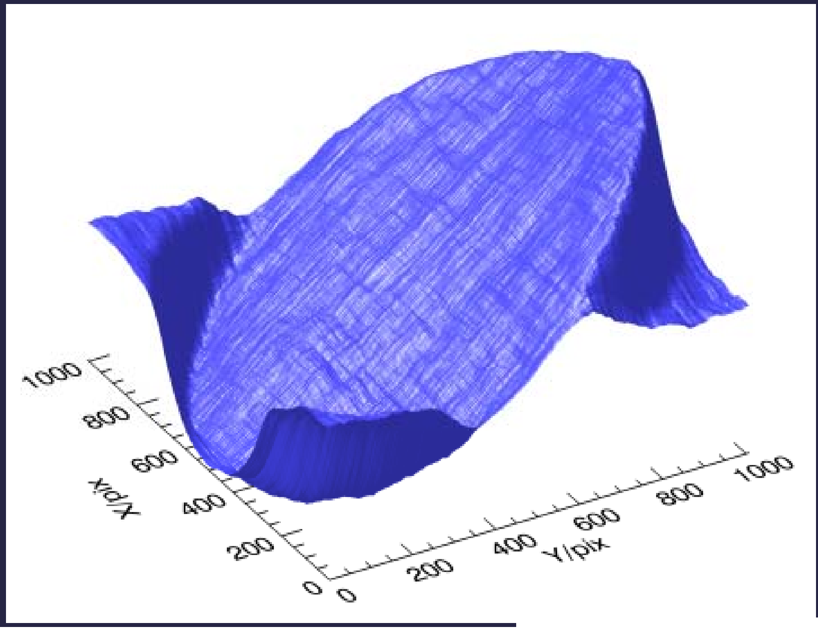
Phase stepping *Without Flat Field correction* *Flat Field* *With Flat Field correction*



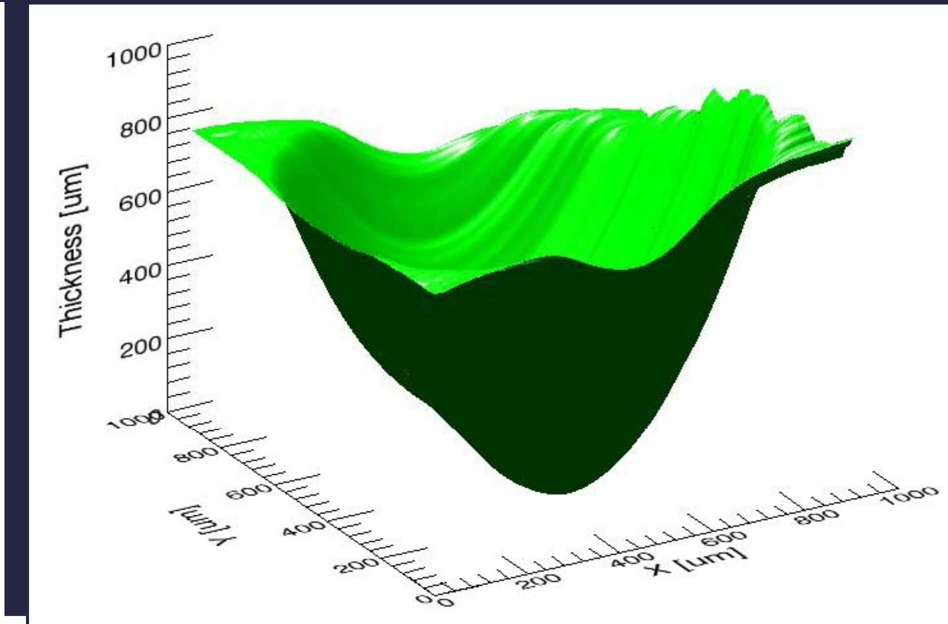
Experiment at DLS B16: Hongchang Wang and Kawal Sawhney, 2010

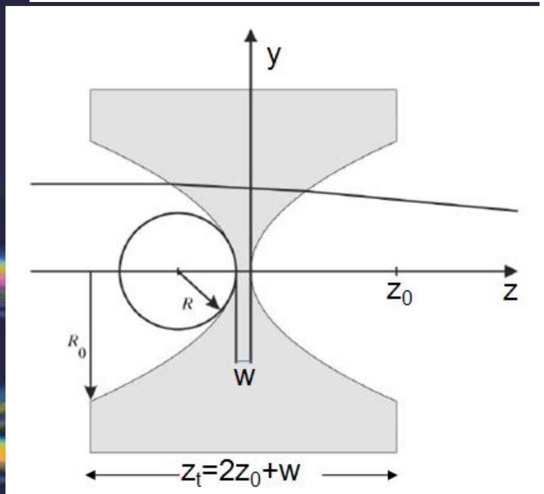
Characterisation of Parabolic refractive lens

Phase Gradient distribution



Relative thickness distribution





$$\alpha_x = \frac{r_2}{r_1} \frac{d_2}{2\pi d_m} \phi_x$$

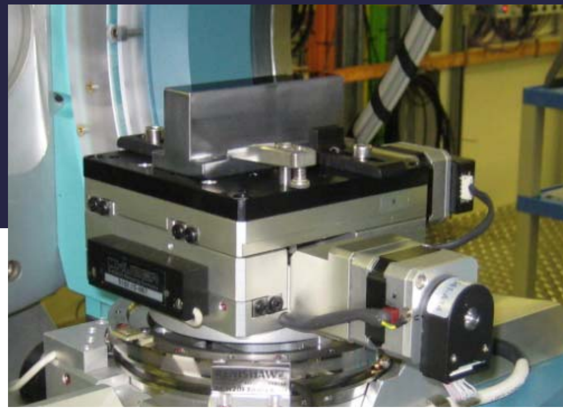
$$\Phi_{lens} = \int_0^{Lx} \frac{r_2}{r_1} \frac{d_2}{\lambda d_m} \phi_x dx$$

$$\Delta\Phi = \frac{2\pi}{\lambda} \times h \times \delta$$

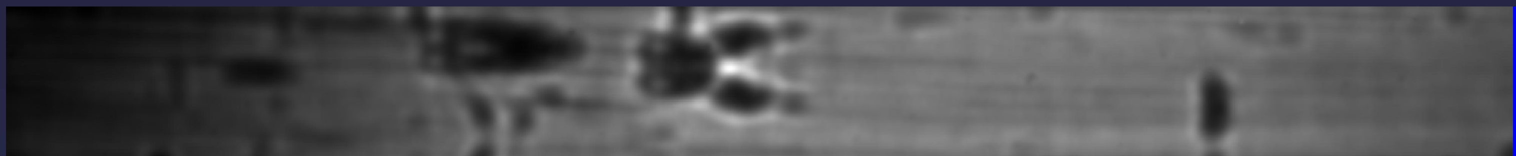
	R_0/µm	R/µm	f/m	$2z_0$/µm	$\Delta\Phi_{max}$/rad
Theory	400	200	64.5	800	93.2
Test	450	250	80.8	810	94.5

Plane mirror characterization

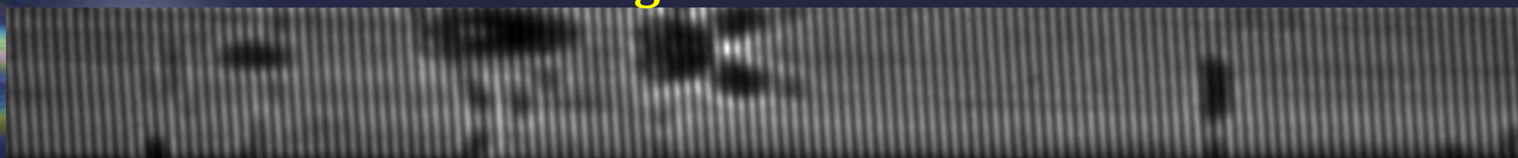
Plane Mirror:
100mm (L) *10mm (W)
Slope Error: 0.2μrad



Phase Stepping



Moiré Fringe

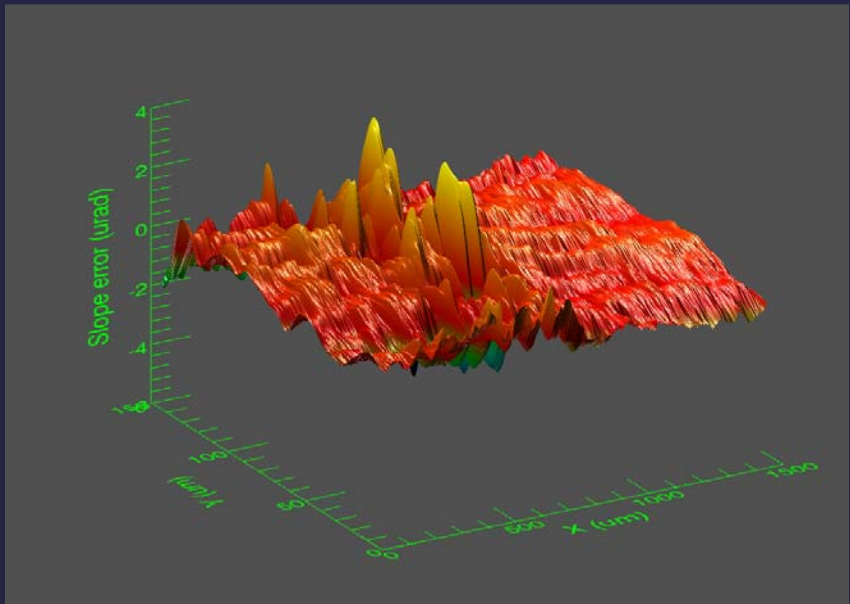


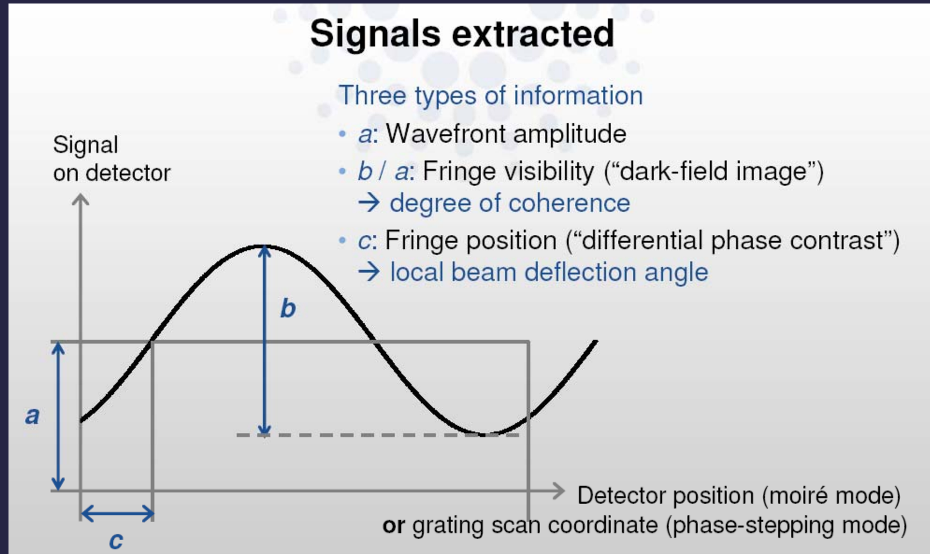
Mirror Length

Mirror Width

Data Processing

Phase Stepping



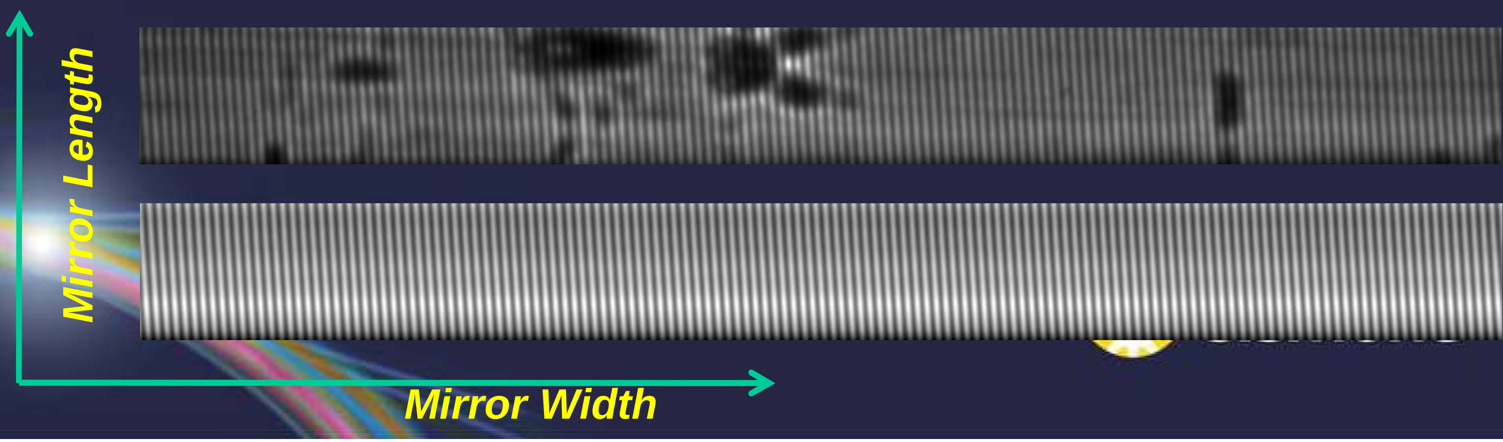


$$y = a_0 + b_0 \cos\left(\frac{2\pi}{d} x + \phi\right)$$

$$\delta = \frac{\alpha}{2} = \frac{d_2 \phi}{4\pi L}$$

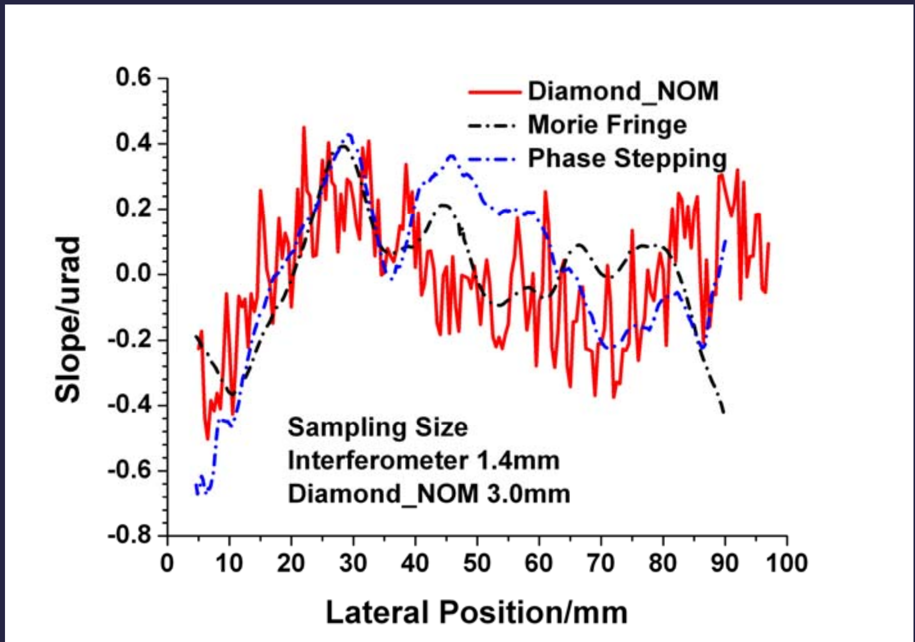
Moiré Fringe

FFT

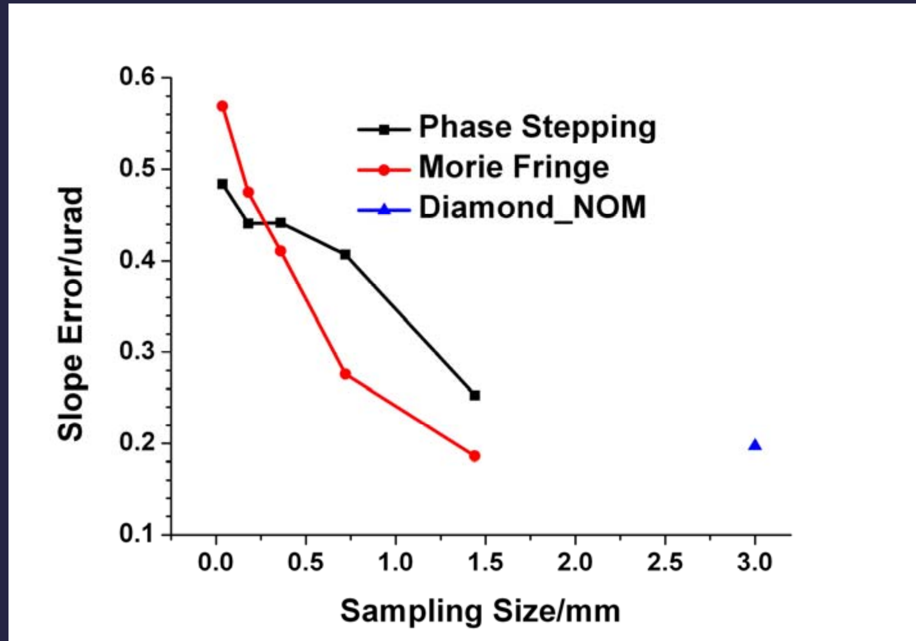


Plane mirror characterisation

Slope comparison



Slope Error vs. Sampling Size



Diamond_NOM test data from Simon Alcock

H. Wang, et al. Paper is in preparation (2011)

Phase Stepping vs. Moiré Fringe Analysis

	Phase Stepping	Moiré Fringe Analysis
No. of Image	>3 [10 in our test]	1
FFT	Intensity vs. G2 position	Fringe position
Grating Divergence Match	Desirable	Not required
Resolution	One pixel	One fringe
Advantage	2D high resolution	Fast
Disadvantage	Time-consuming	One dimension

Summary and Outlook

- Shearing interferometer has been developed at DLS B16
- Parabolic lens has been studied with phase stepping method
- Plane mirror was measured with shearing interferometer
- At-wavelength metrology in near future (Curved mirrors, Zone Plate, Multilayer Laue Lens (MLL)…)
- High resolution tests with 2D grating?

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Acknowledgements

Thanks to…

- Diamond Light Source
  - Optics & Metrology Group (Simon Alcock, Lucia Alianelli, John Sutter)
  - B16 (Slava Kachkanov, Igor Dolbnya, Stewart Scott, Andrew Malandain)
- Paul Scherrer Institut, Switzerland (Christian David)
- ……………………………

Thanks for your attention

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