Thin Film Metrology Using Wavefront Sensing

D M Faichnie, A H Greenaway, I Bain*

Physics, Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, Scotland, EH14 4AS

**Scalar Technologies Ltd, 5 Bain Square,*

Kirkton Campus, Livingston, Scotland, EH54 7DQ

Durham Workshop, Dec 2005

Acknowledgements.

OMAM Collaborators

UK Astronomy Technology Centre
BAE SYSTEMS
smartoptics
NPL National Physical Laboratory
UCL
ZEEKO
Scalar technologies

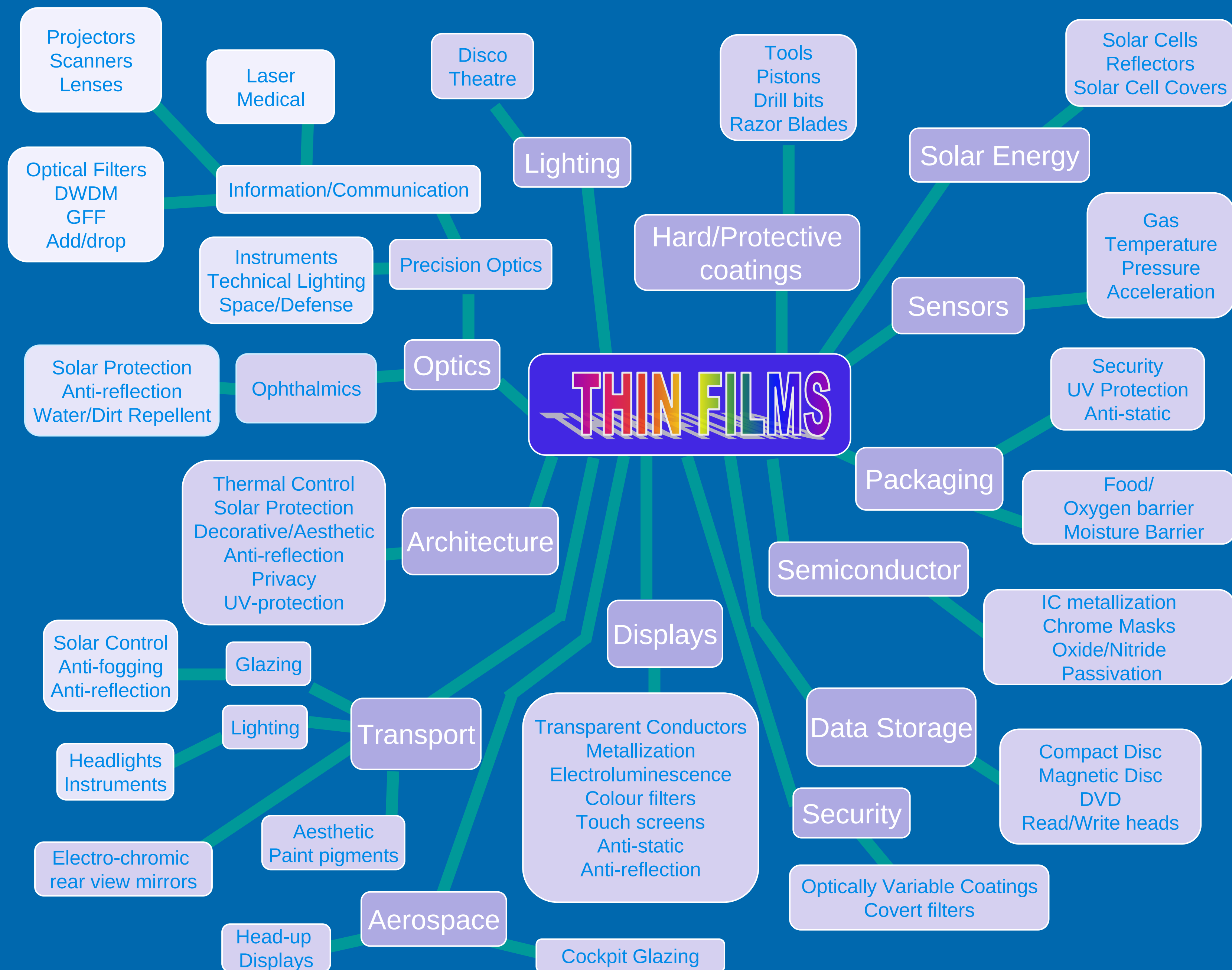
Funding Institutions

[dstl]
Faraday Partnership
EPSRC
PPARC
dti

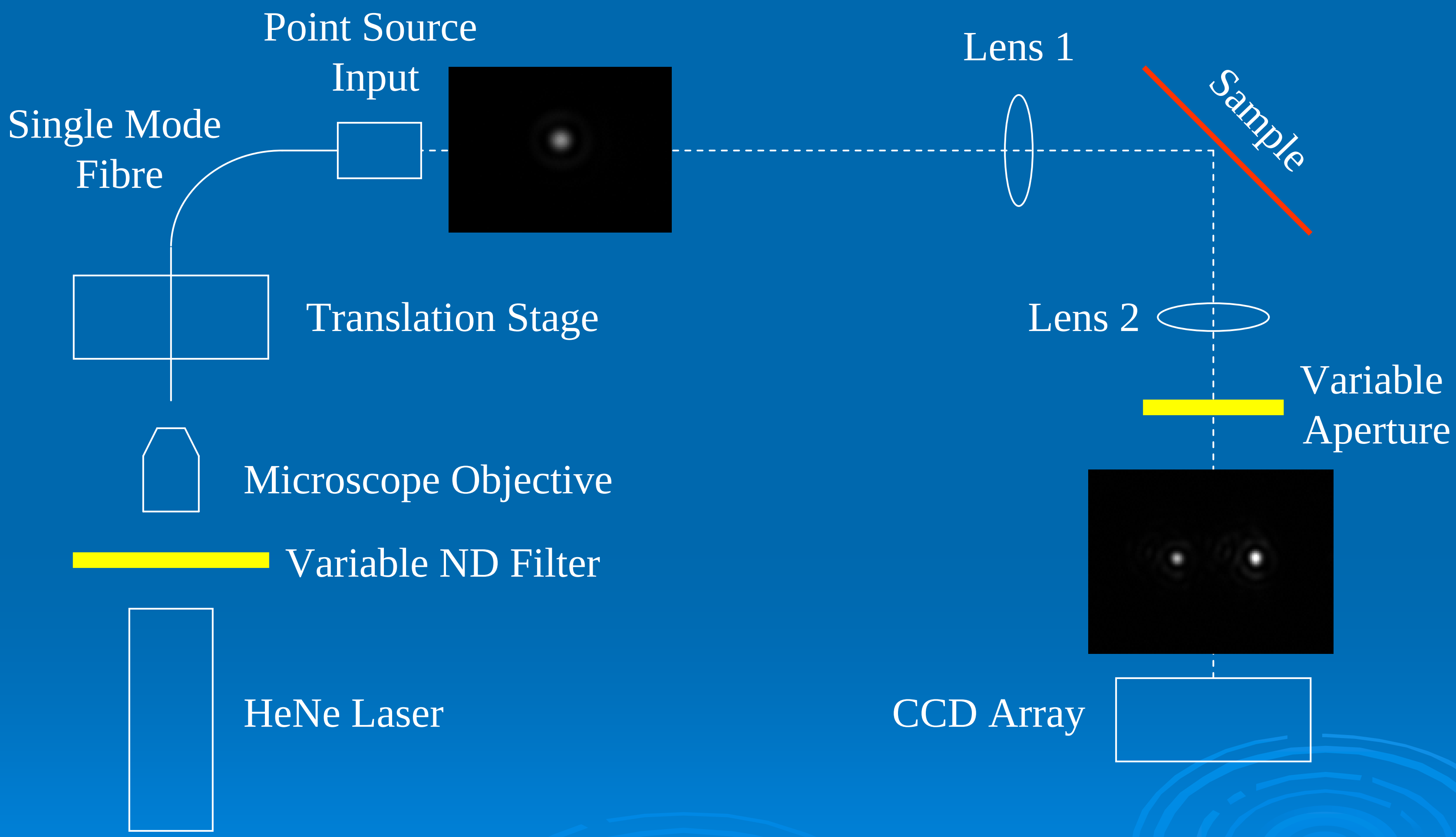
Overview Of Presentation.

- Current measurement and problems.
- Film Modelling to investigate level of aberrations introduced by thin film structure.
- Method to measure thickness and surface tilt simultaneously with single measurement.
- Experimental Results.
- Conclusions and future work.

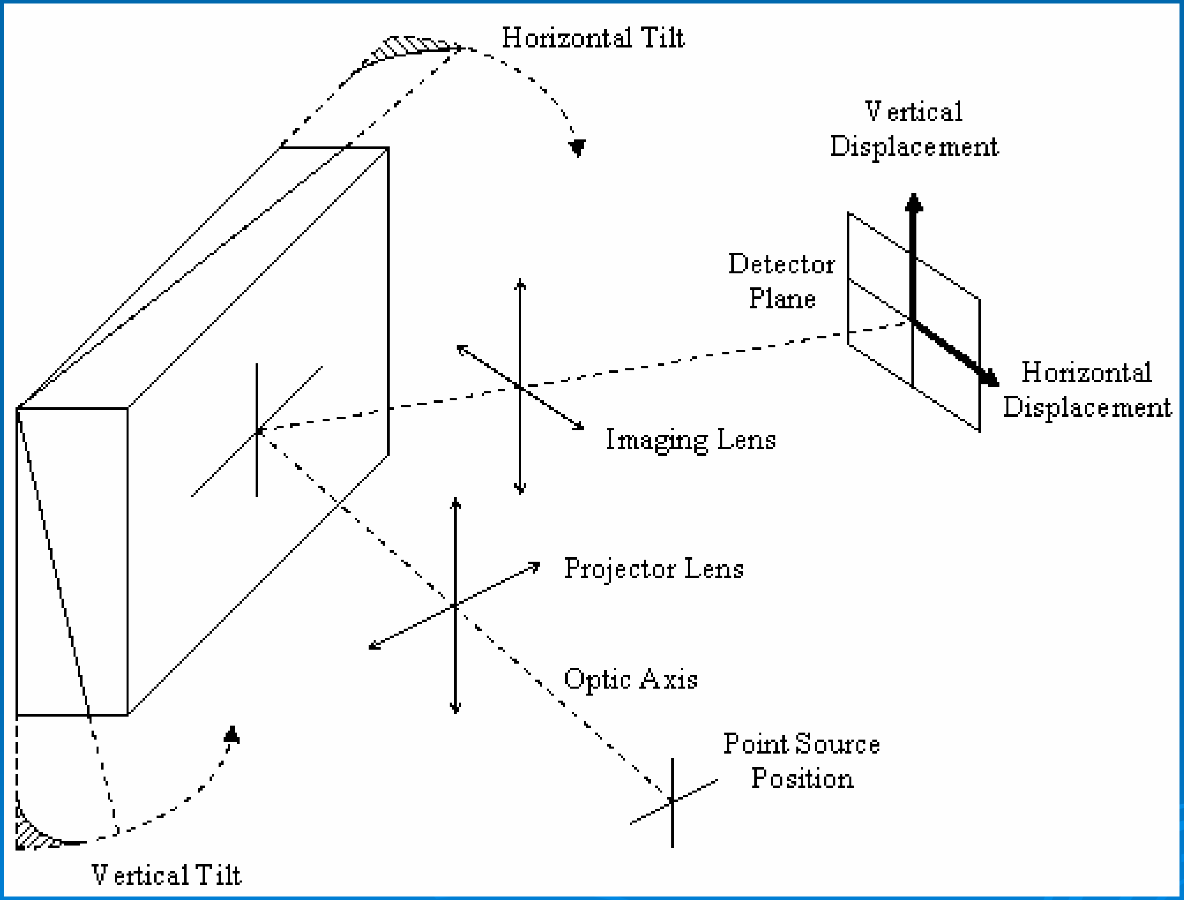
The Hundred Billion Dollar Industry No One Knows About



Experimental Set-up



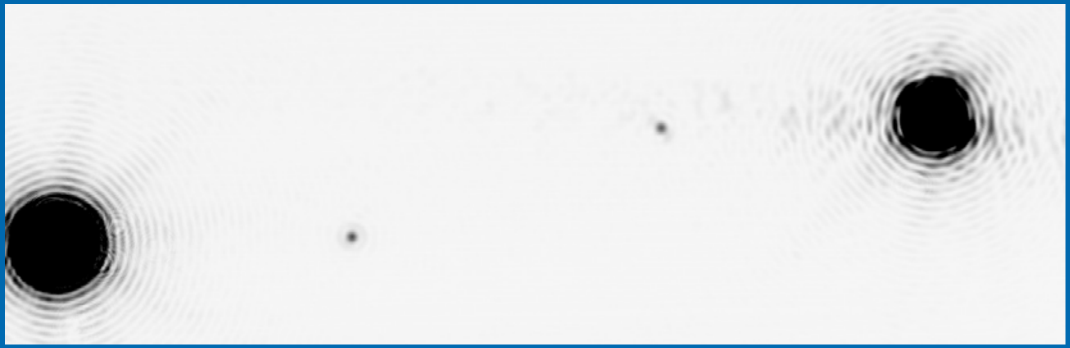
Definitions of Tilt.



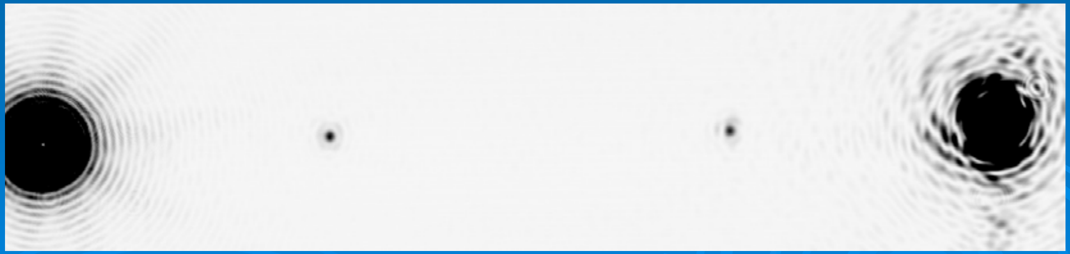
Example of Tilt.

Original Measurement.

Sample Rotated by 90.



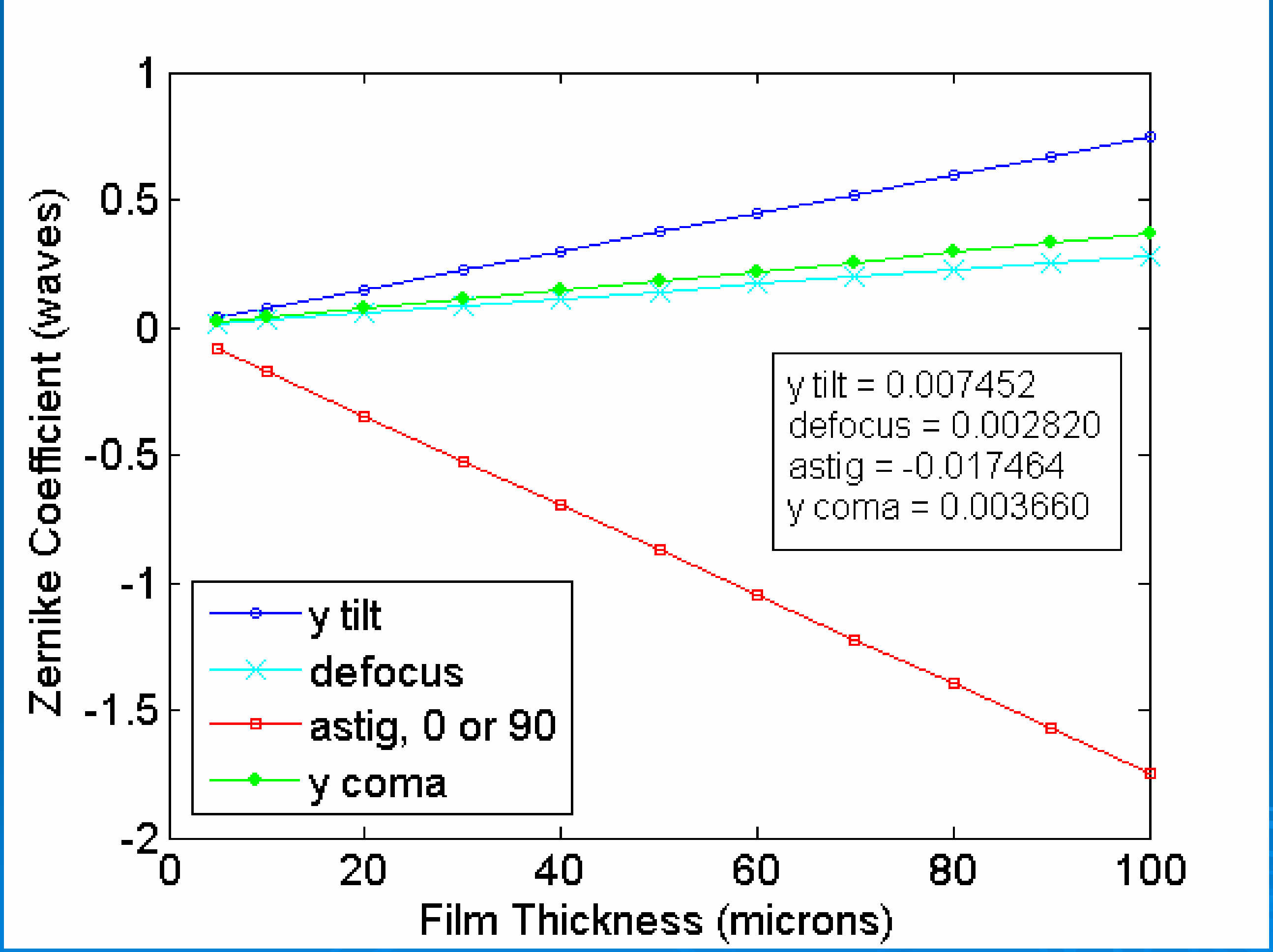
Measure from opposite side.



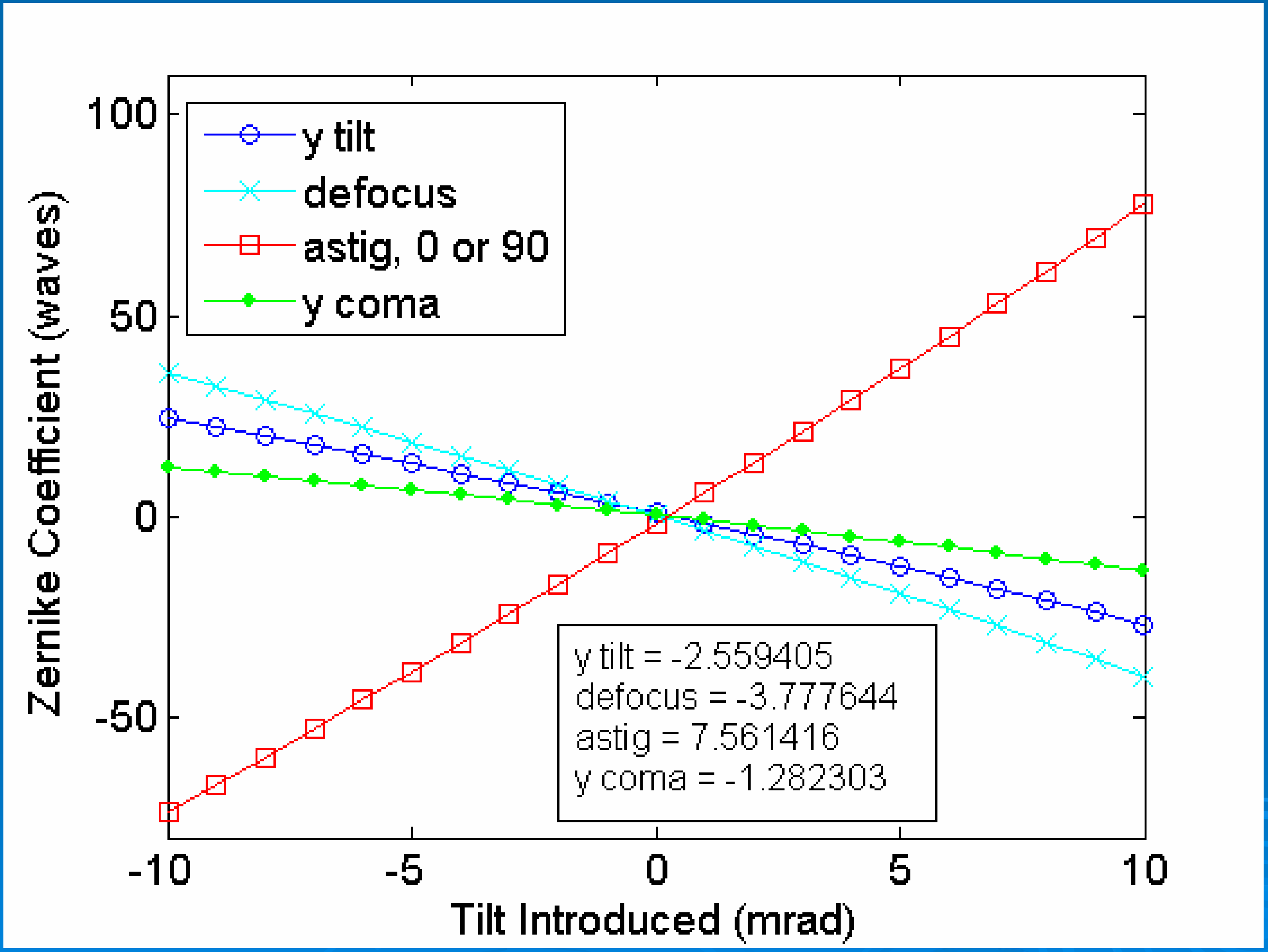
System Modelling

- System modelled using Optalix ray tracing software from Optenso.
- Model gives information on aberrations introduced by the film structure.
- Used to evaluate how aberrations change with thickness and refractive index.
- Investigate influence of horizontal and vertical tilts.

Thickness Variation.



Influence Of Horiz. Tilt.



Thickness and Tilt

- Each aberration coefficient can be written as a linear function

$$\sigma_m = \alpha_m d + \beta_m t$$

- If we select various Zernike coefficients we can write a matrix equation in the form

$$\Sigma = Mu$$

- Where :

$$M = \begin{bmatrix} \alpha_{m1} & \beta_{m1} \\ \alpha_{m2} & \beta_{m2} \\ . & . \\ \alpha_{mn} & \beta_{mn} \end{bmatrix} \qquad \Sigma = \begin{bmatrix} \sigma_{m1} \\ \sigma_{m2} \\ . \\ \sigma_{mn} \end{bmatrix} \qquad u = \begin{bmatrix} d \\ t \end{bmatrix}$$

- To calculate Thickness and tilt : $u = M^{\dagger} \Sigma$

Numerical Example.

Example: thickness = 100 microns, horiz tilt=1mrad

$$M = \begin{bmatrix} 0.007452 & -2.559405 \\ 0.002820 & -3.777644 \\ -0.017464 & 7.561416 \\ 0.003660 & -1.282303 \end{bmatrix} \qquad \Sigma = \begin{bmatrix} -1.8246472 \\ -3.512169 \\ 5.8394112 \\ -0.9215989 \end{bmatrix}$$

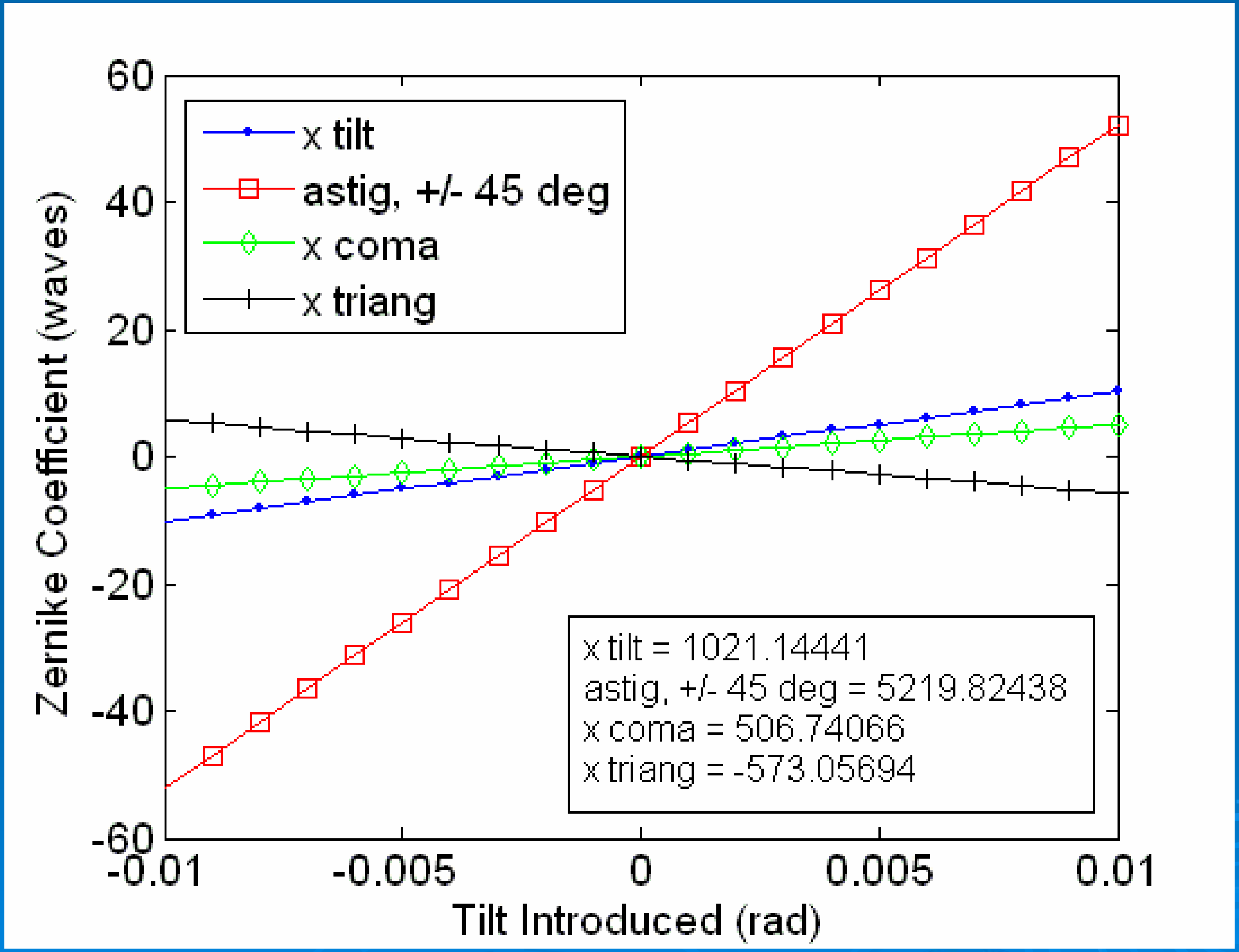
Data From Simulation

$$u = \begin{bmatrix} d \\ t \end{bmatrix} = M^{\dagger}\Sigma = \begin{bmatrix} 100.4805 \\ 1.0045 \end{bmatrix}$$

Film Thickness (100.4805)

Horizontal Tilt (1.0045)

Influence Of Vert. Tilt.



Vertical Tilt

- Each aberration coefficient can be written as a linear function

$$\sigma_m = \beta_m t_v$$

- If we select various Zernike coefficients we can write a matrix equation in the form

$$\Sigma = Mu$$

- Where :

$$M = \begin{bmatrix} \beta_{m1} \\ \beta_{m2} \\ . \\ \beta_{mn} \end{bmatrix} \qquad \Sigma = \begin{bmatrix} \sigma_{m1} \\ \sigma_{m2} \\ . \\ \sigma_{mn} \end{bmatrix} \qquad u = t_v$$

- To calculate vertical tilt : $u = M^{\dagger} \Sigma$

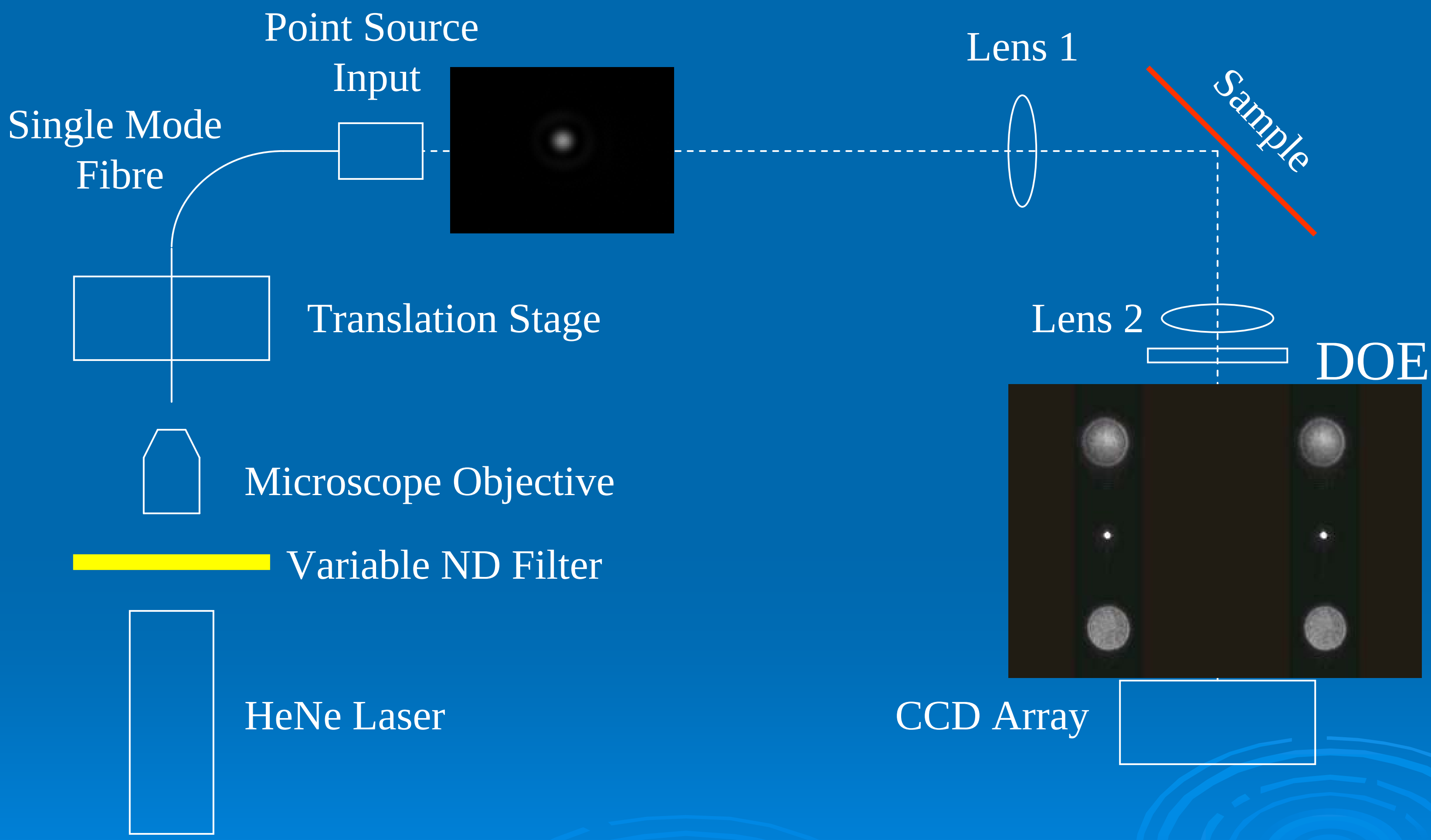
Numerical Example.

Example: 100 micron film, 1mrad vertical tilt

$$M = \begin{bmatrix} 1021.14441 \\ 5219.82438 \\ 506.74066 \\ -573.05694 \end{bmatrix} \qquad \Sigma = \begin{bmatrix} 1.0290642 \\ 5.2504343 \\ 0.5106799 \\ -0.5772438 \end{bmatrix}$$

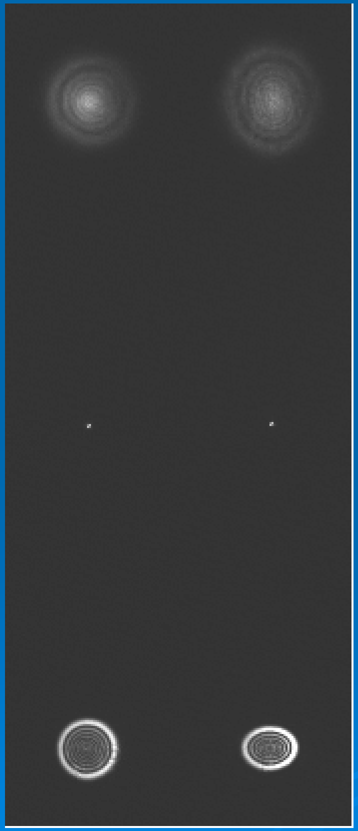
$$u = t_v = M^{\dagger}\Sigma = 1.0059$$ ← Vertical Tilt

Experimental Set-up



Experimental Results.

➢ Example of collected data:



Results indicate presence of:

- Tilt
- Defocus
- Astigmatism
- Coma
- Spherical Aberration

Problems.

- How to retrieve robust aberration values from measured data.
- Optimised grating required to measure thinner film structures.
- Do we see linear relationship with thickness and aberration level?
- Next look at effect of surface shape and roughness.
- Automation of system.
- Industrial trial?

Conclusions.

- Film structures affect reflected wavefront shape, info can be used to gain measure of thickness plus surface profile simultaneously.
- Thin film structure introduces tilt, defocus, astigmatism, coma, spherical and triangular aberrations.
- Single measurement of thickness and surface tilt simultaneously.
- Experimental results are encouraging to date.