



MOISL

Structured-Illumination Quantitative Phase Imaging

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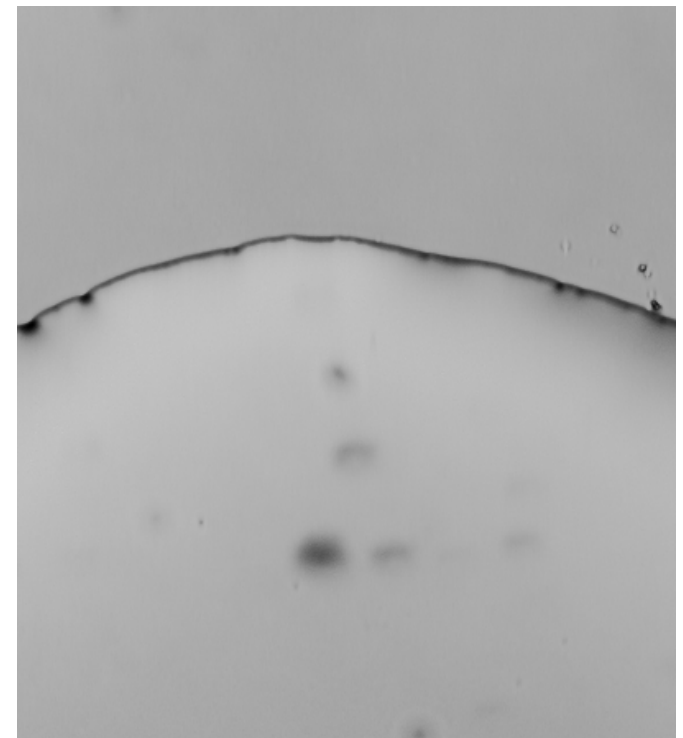
Phase Imaging

Goal: To measure the phase of an object

- Transparent objects like biological cells cannot be seen in transmission microscopy, as they don't absorb light.

Problems:

- Imaging of phase objects with fluorescent dyes is invasive.
- Phase objects cannot be accurately measured with Phase contrast and DIC as they are non-quantitative techniques.
- Interference microscopes have phase wrapping issues.

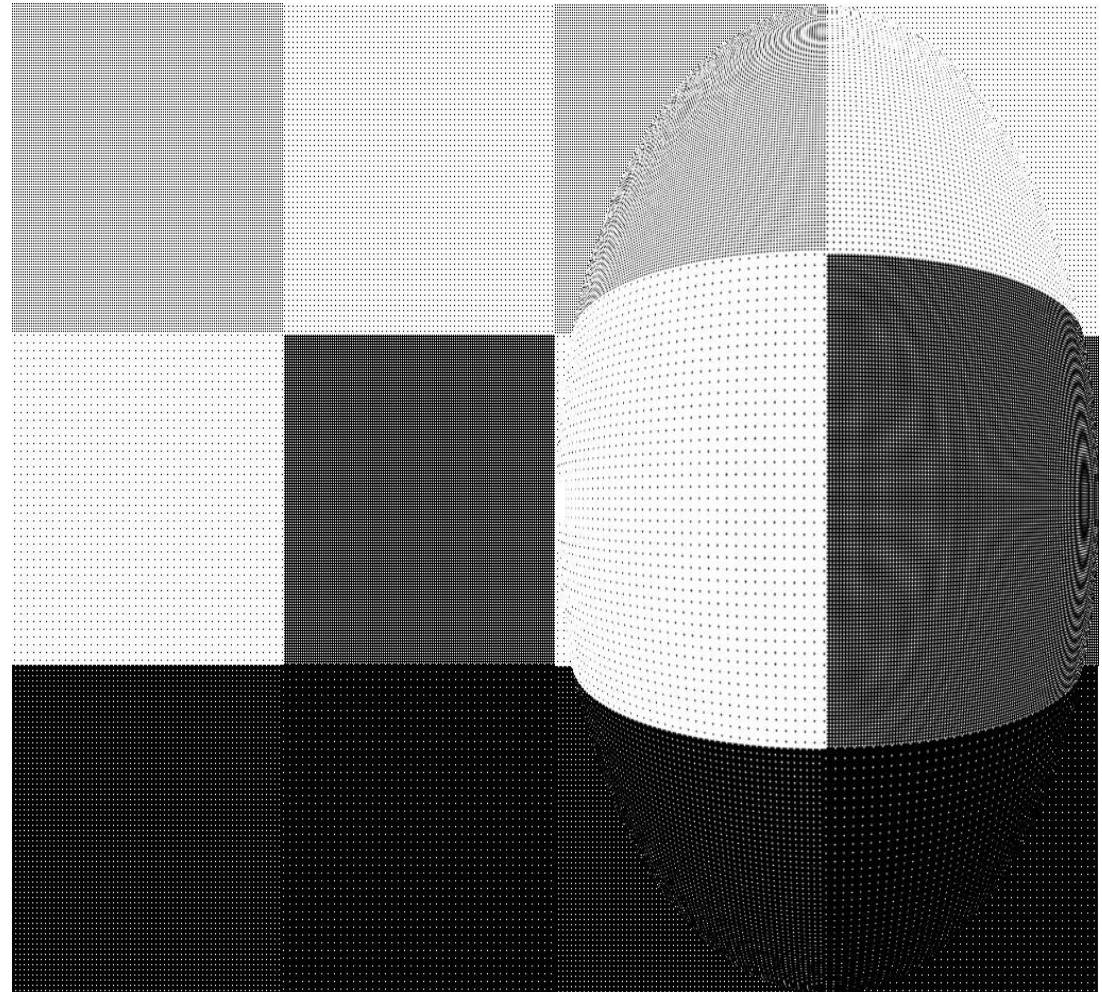


Brightfield image of a water droplet

Structured Illumination

Our solution:

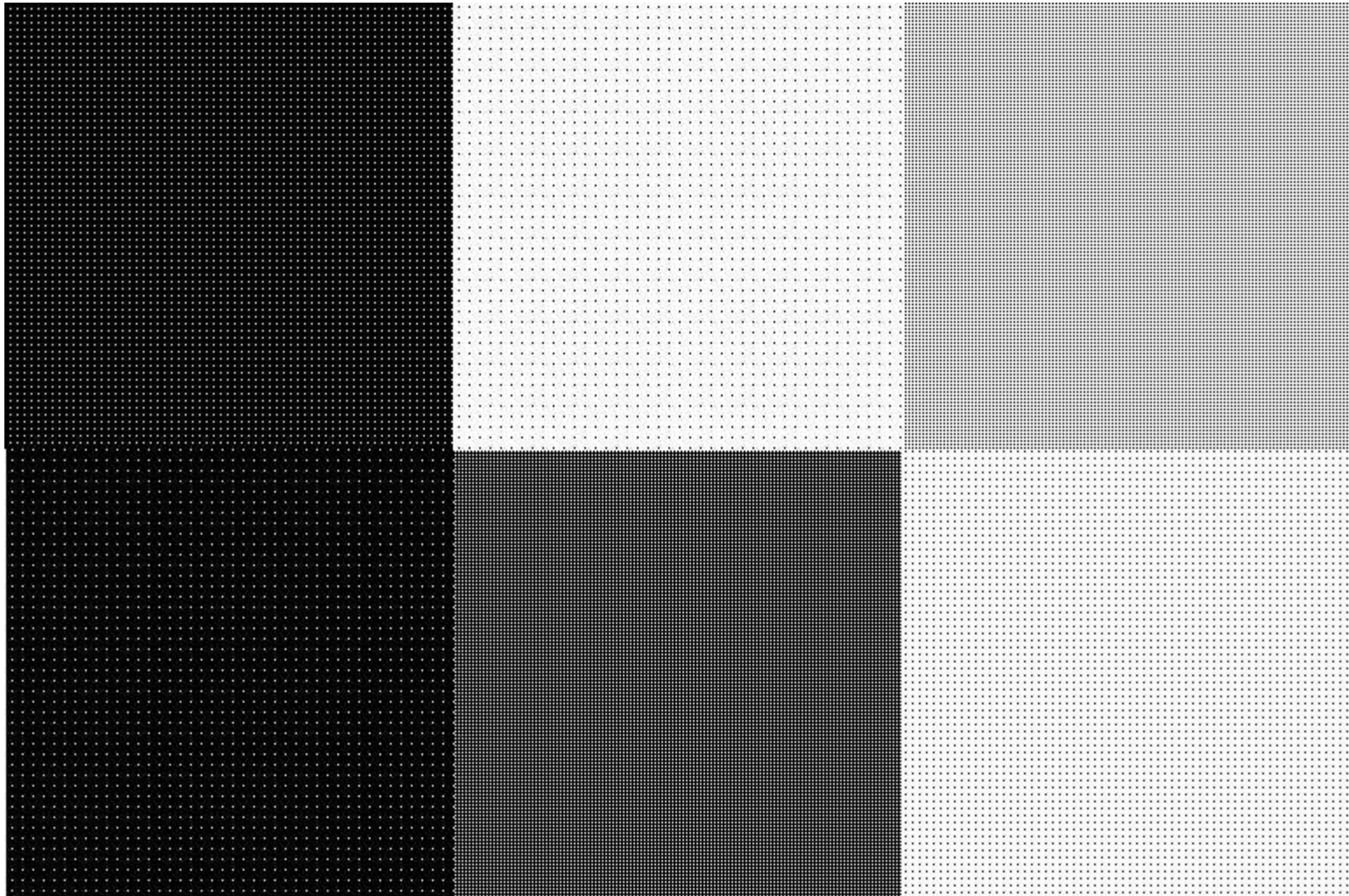
- Illumination is structured with a known periodic pattern and is passed through the phase object.
- The phase object deforms the structure
- Phase is measured from the deformation of structure.



Structure

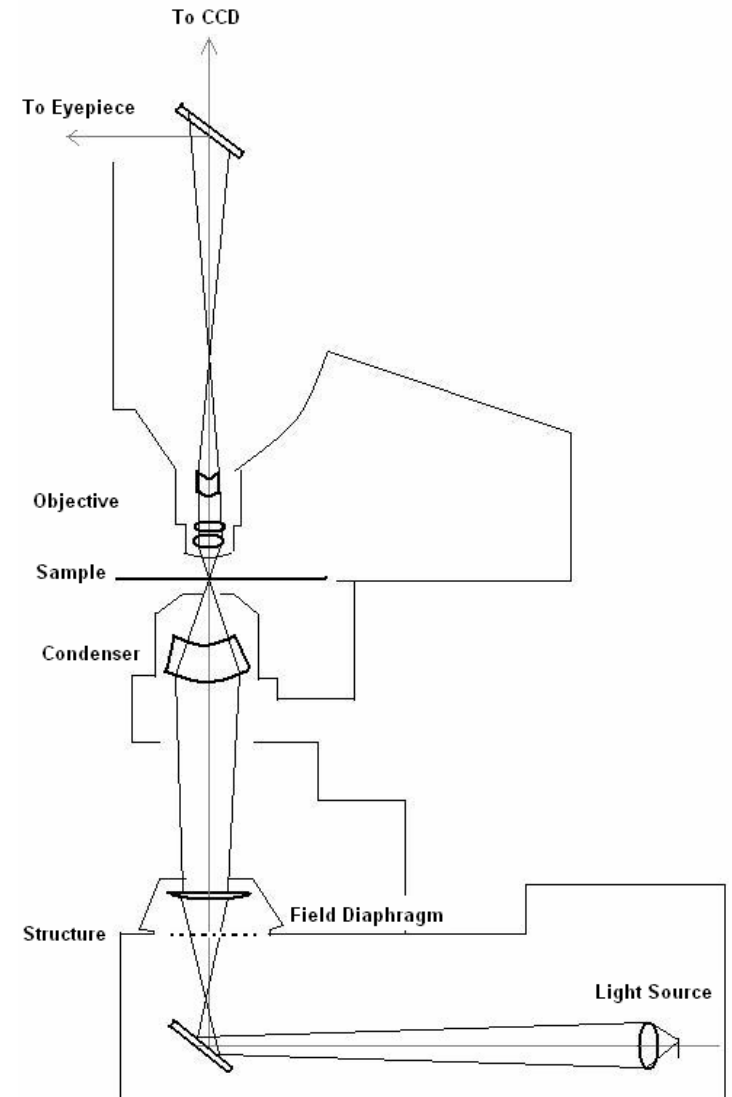
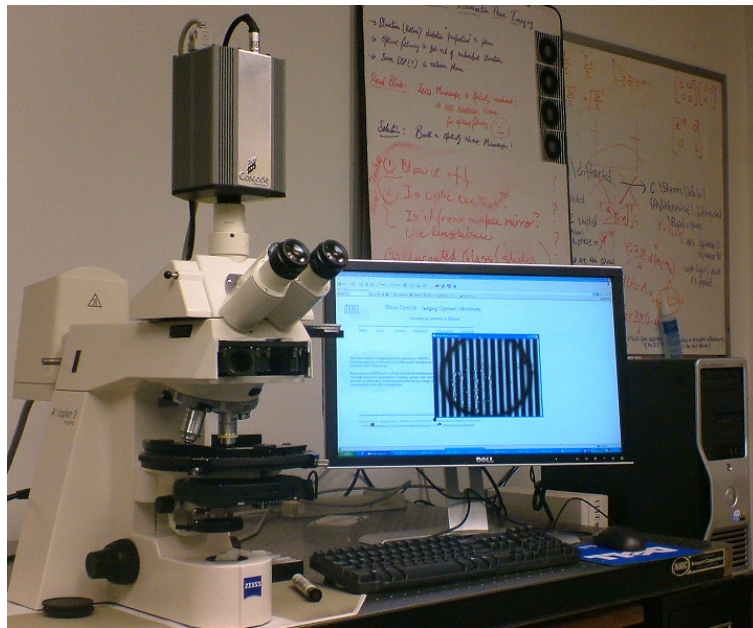
Deformed structure

Demo



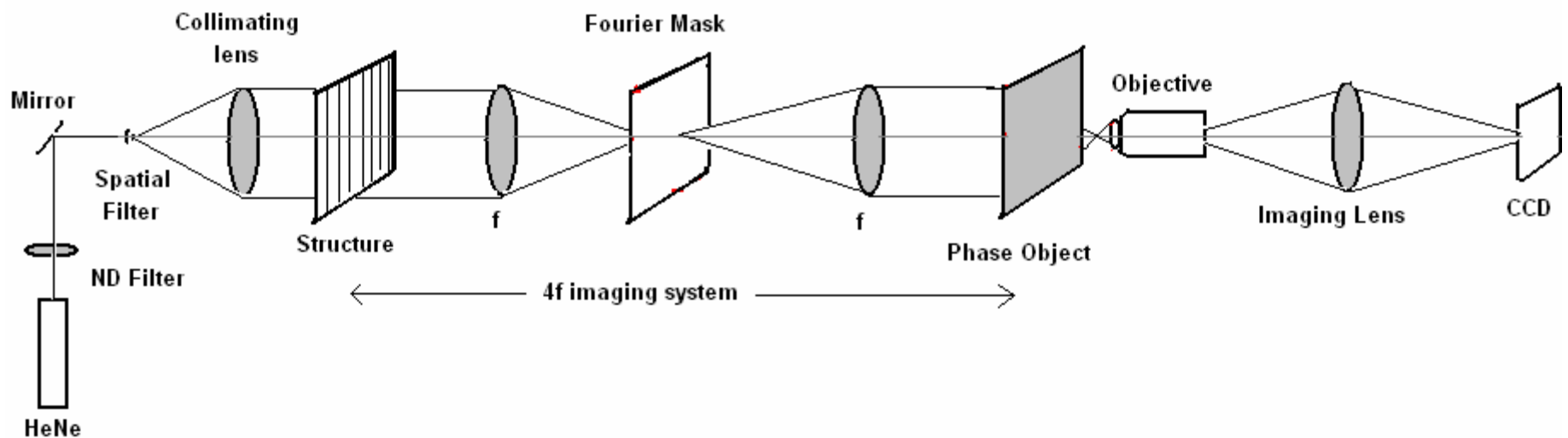
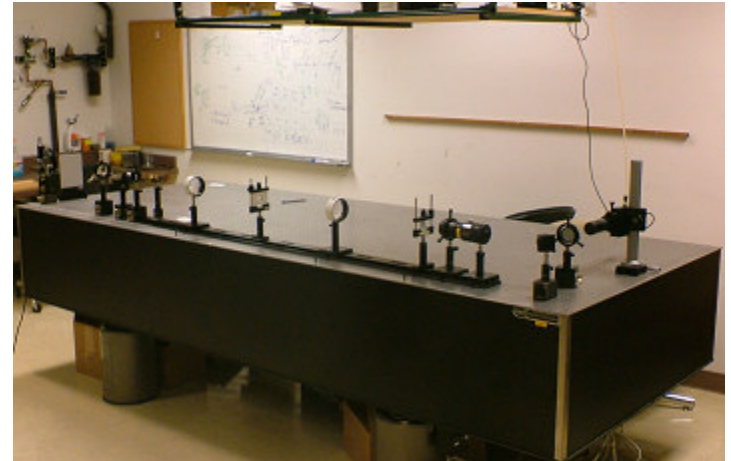
Structured Illumination Microscopy

- Structure is placed at the field diaphragm
- Field diaphragm is imaged on the sample
- Structure distortions are recorded with a CCD camera



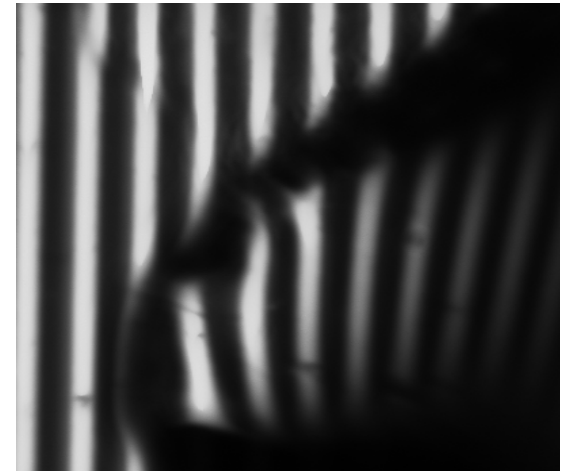
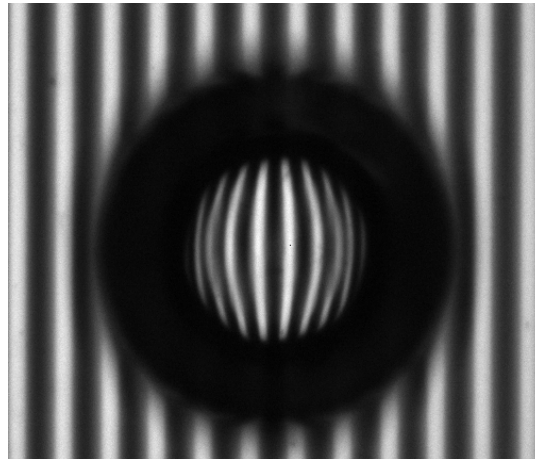
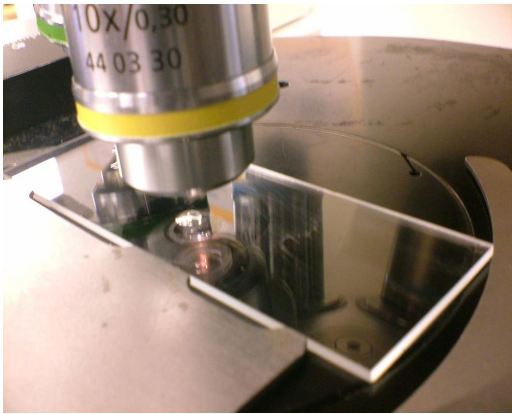
Coherent Optical System

- A 4f imaging system images the structure on the phase object
- Fourier mask is used to tweak the structure pattern
- An objective is used to image the structure distortions

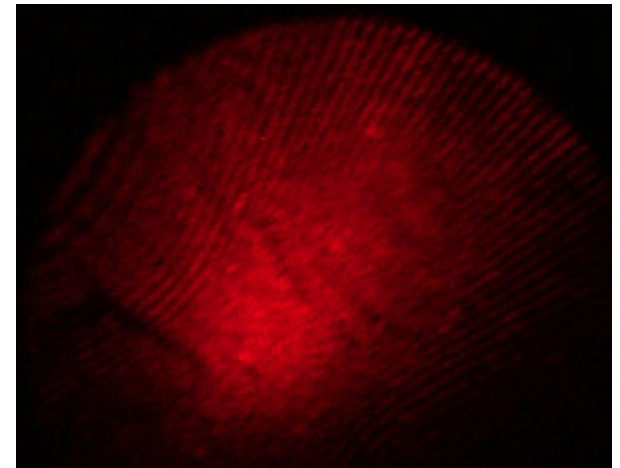
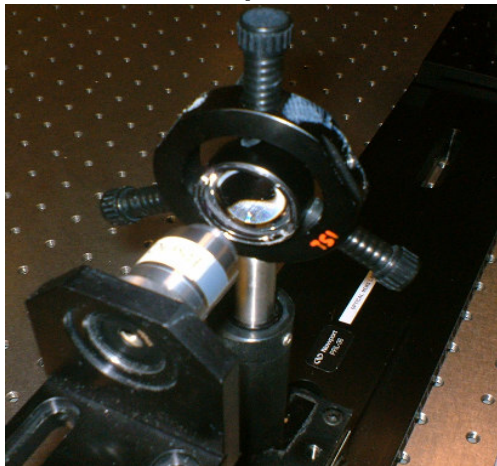


Experimental Results

Microscopy:

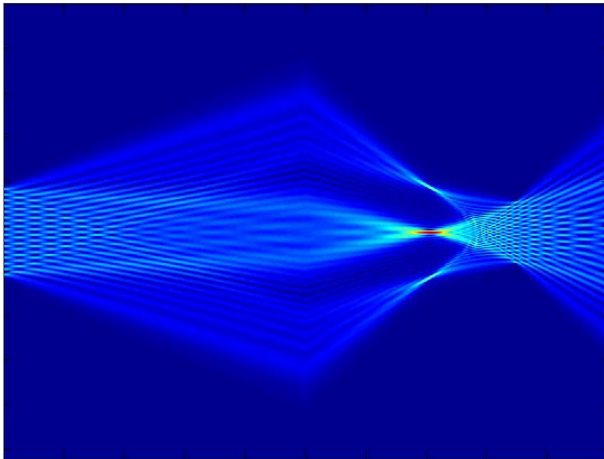


Coherent system:

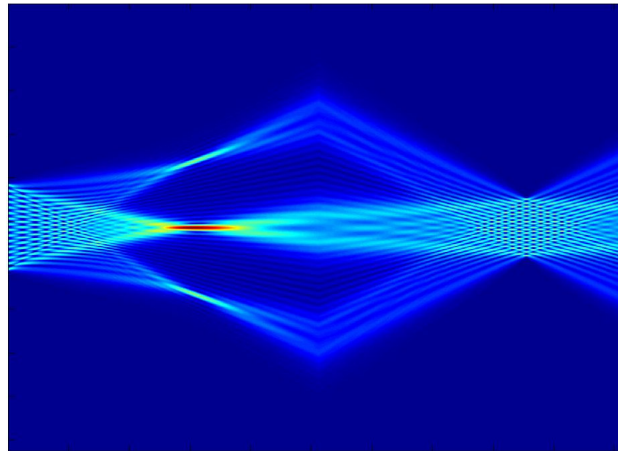


Numerical Simulations

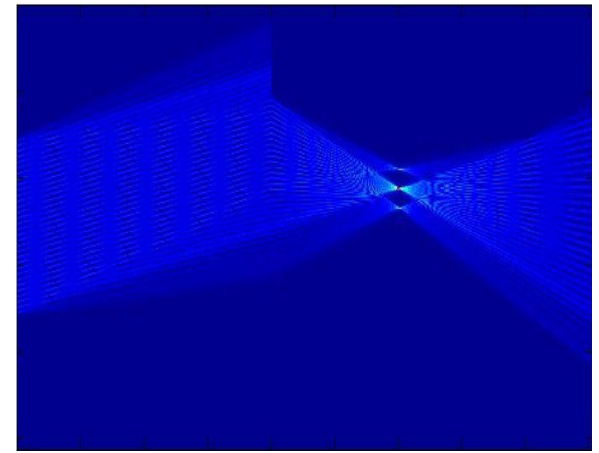
No phase object



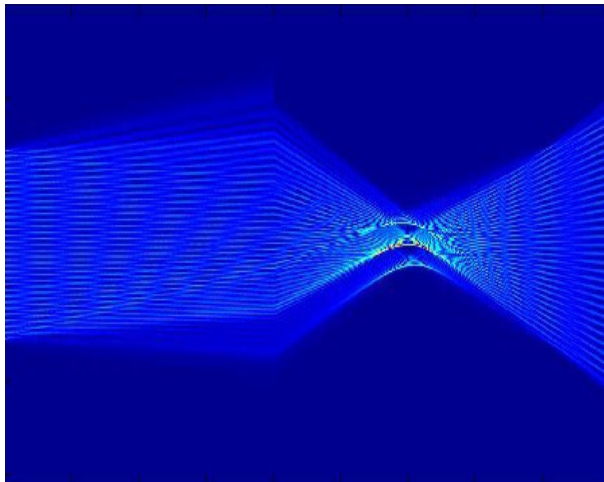
Quadratic Phase Object



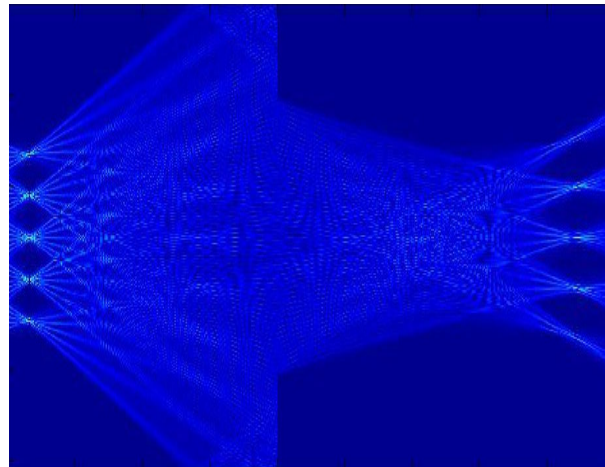
Linear Phase Object



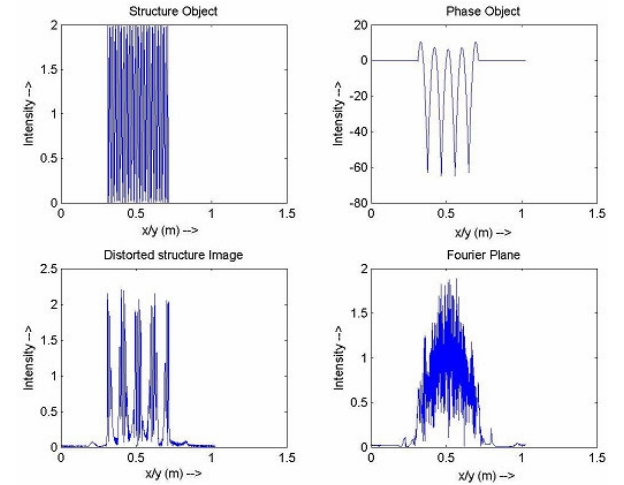
Cubic Phase Object



Micro-lens Phase array



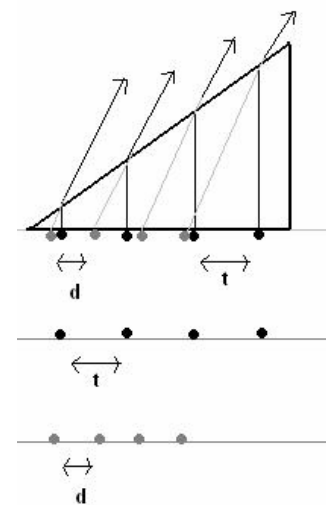
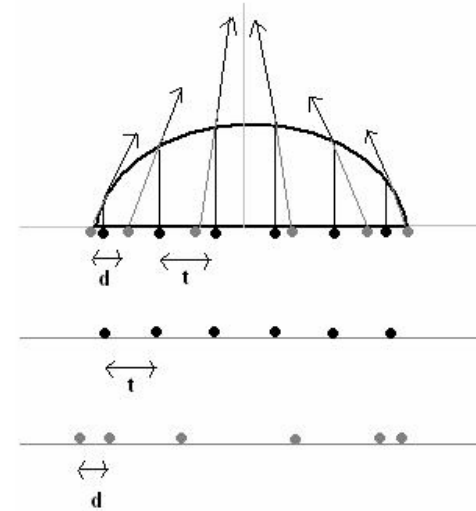
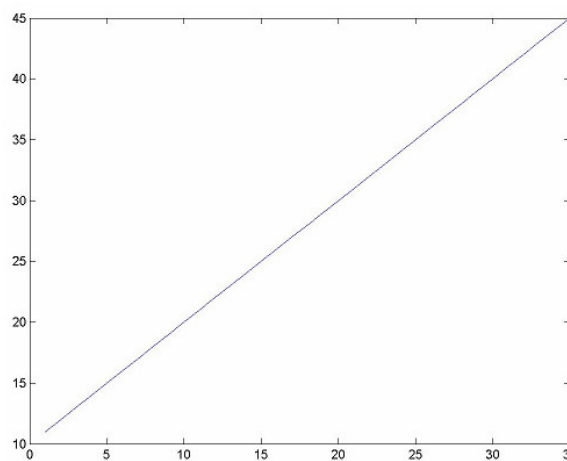
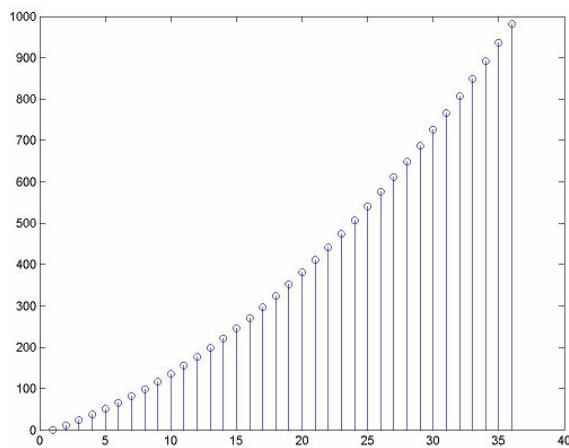
Micro-lens Phase array plots















Phase estimation

- Estimate phase by comparing the deformed structure to the original structure
- The phase is extracted from
 - Periodicity of the deformed structure
 - Size of deformed structure
 - Location after deformation

Wedge phase estimation:



Comparison

	Bright Field <i>(1590)</i>	Phase Contrast <i>(1934)</i>	DIC <i>(1955)</i>	Structured Illumination <i>(2006)</i>
Phase imaging?				
Quantitative?				
Cost?				

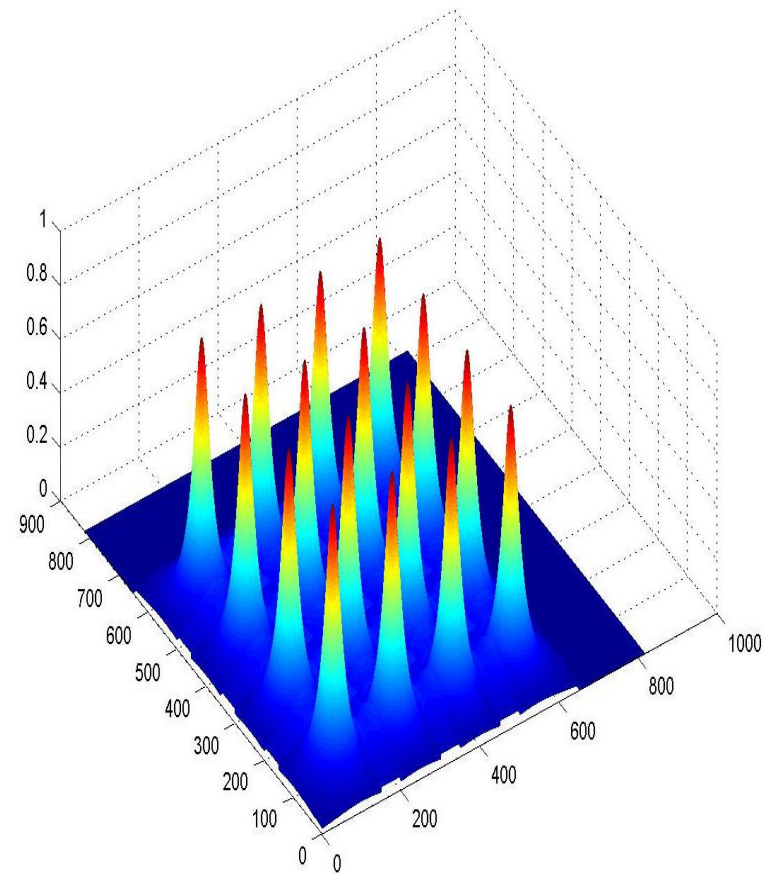
Looking ahead...

Conclusion:

- Structured-Illumination phase imaging is a novel quantitative phase imaging technique, which can be implemented in traditional imaging systems with simple, inexpensive modifications.

Future work:

- Experimental verification with biological cells
- Unified inverse problem solution
- Incoherent numerical simulations



Estimated phase of a micro-lens array