Spatial Light Modulator

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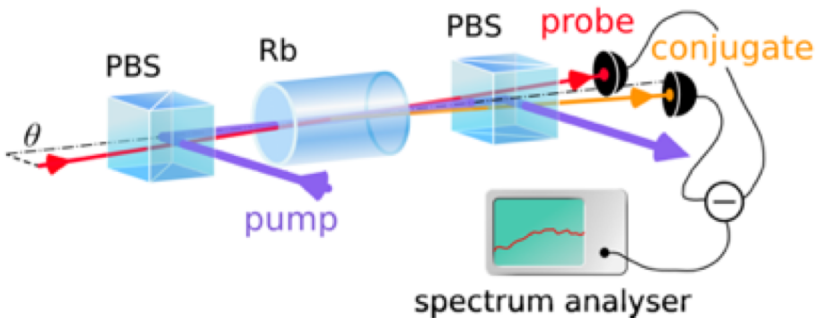
REU 2018 Summer Project

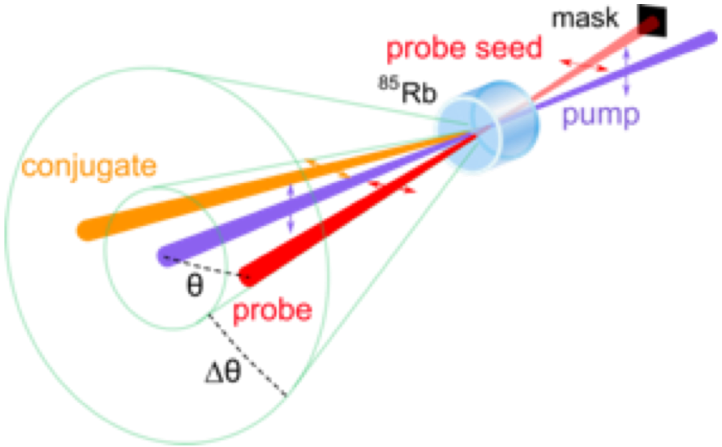
Project Background - Four Wave Mixing (4WM)



Four-Wave Mixing Setup

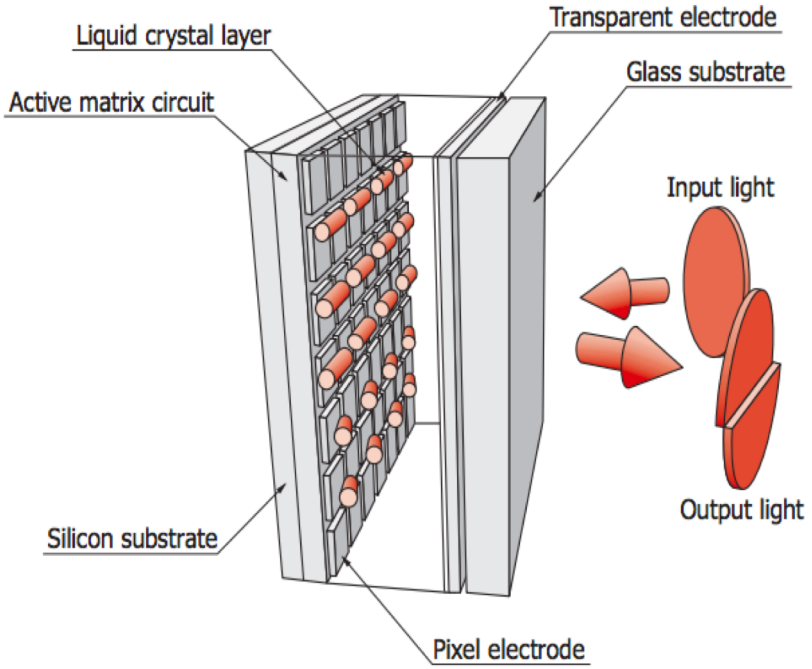
- Pump profile may change area of correlation
- Spatial Light Modulator (SLM) will change the spatial profile of the pump

- 4WM generates entangled twin beams - probe and conjugate
- Seek greater control over areas of correlation between the two beams



C.F. McCormick, A.M. Marino, V. Boyer, and P. D. Lett, *PRA* **78**, 043816 (2008).
V. Boyer, A.M. Marino, R.C. Pooser, and P.D. Lett, *Science* **321,** 544(2008).

Spatial Light Modulator



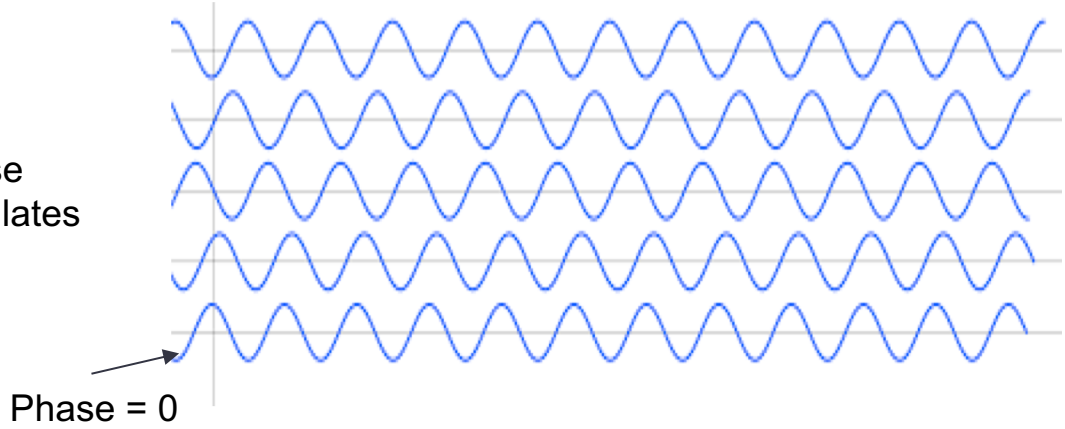
- Birefringent liquid crystals controlled by grid of pixel electrodes - refractive index changes with tilt
- Able to change phase of the wavefront
- Goals:
  - Learn to control phase and amplitude
  - Determine what set-up works best
  - See what images are clear and uniform

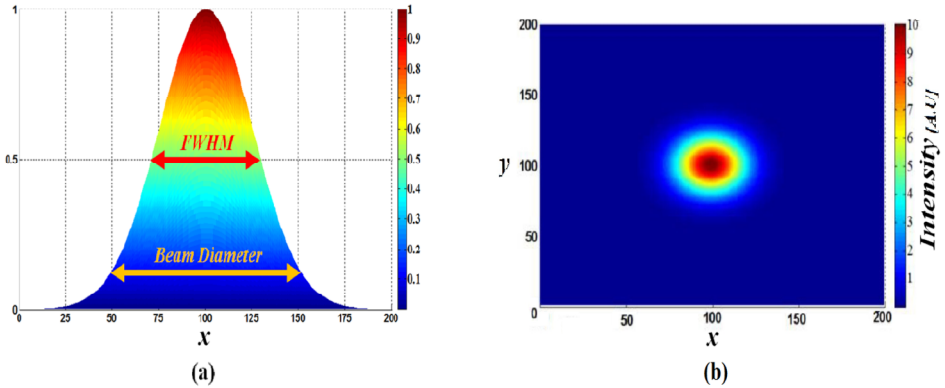
"Phase Spatial Light Modulator LCOS-SLM." *Hamamatsu Photonics*, www.hamamatsu.com/resources/pdf/ssd/e12_handbook_lcos_slm.pdf.

Phase/Amplitude

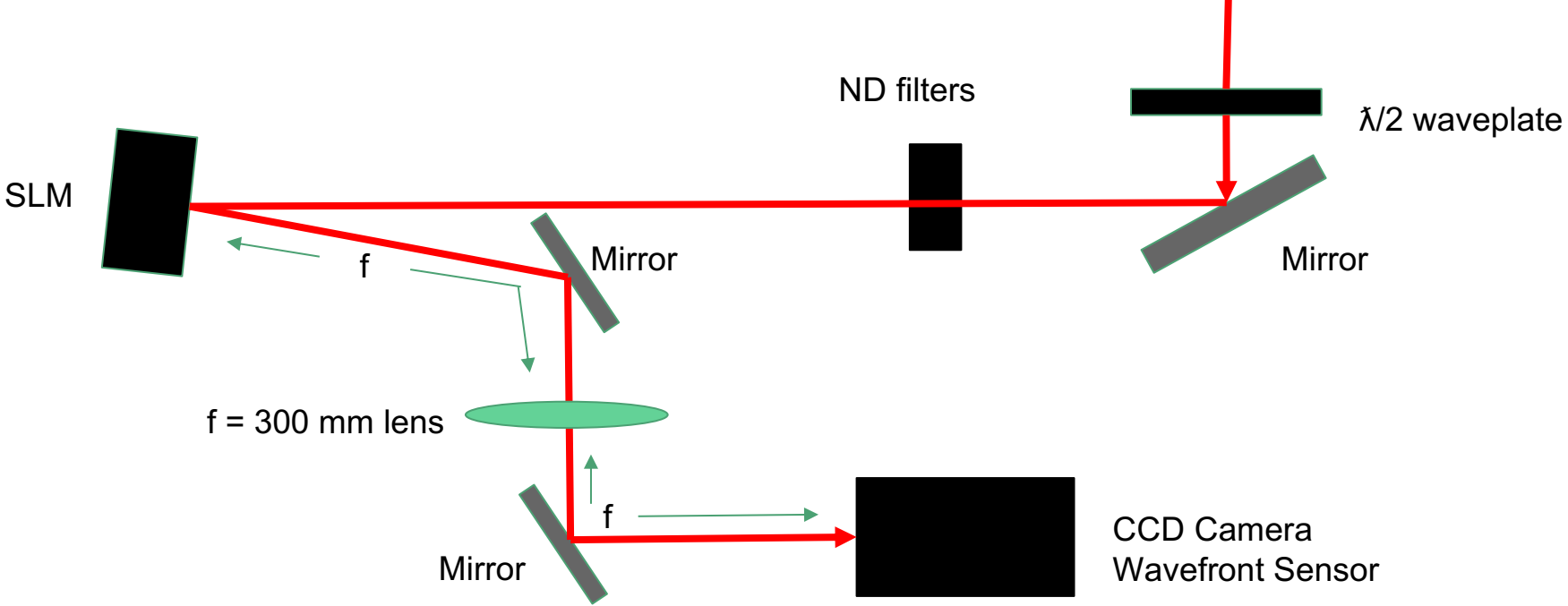
- Able to control phase with SLM using phase patterns, generates interference that modulates amplitude

- Amplitude of initial beam is Gaussian

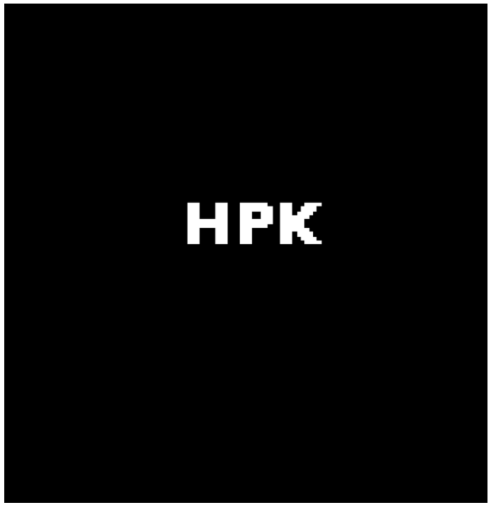




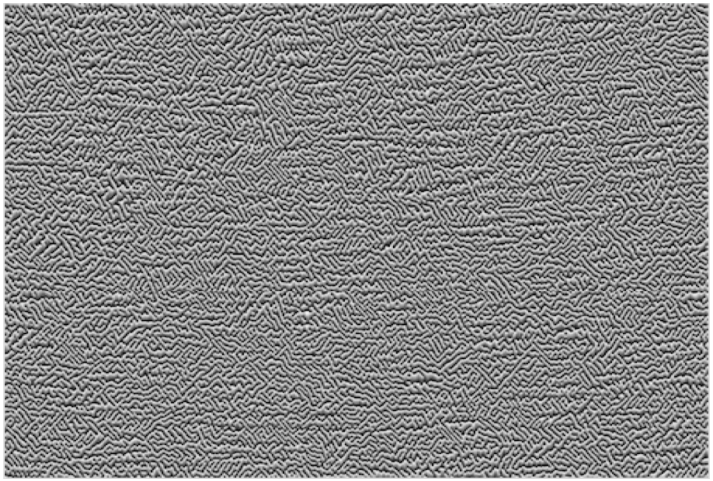
Set-up -- Fourier Transform



MATLAB

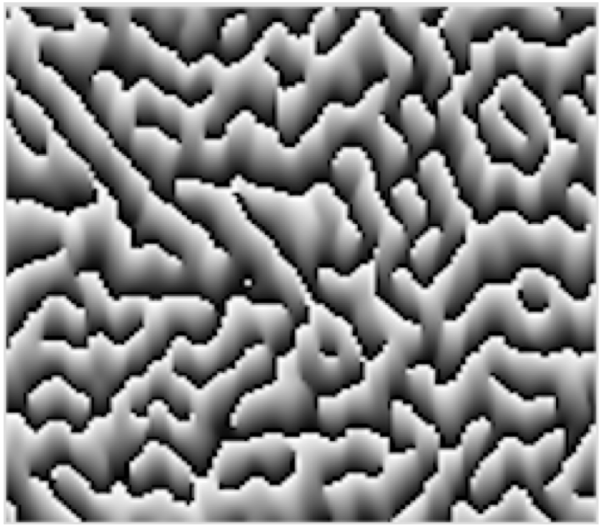


Original Image



Phase Image Sent to SLM

- MATLAB took Fourier transform using iterative code
- Phase information extracted from the result
- Info converted to 8-bit grayscale for SLM (2π = 255)



Computer Generated Hologram (CGH) Created by Software

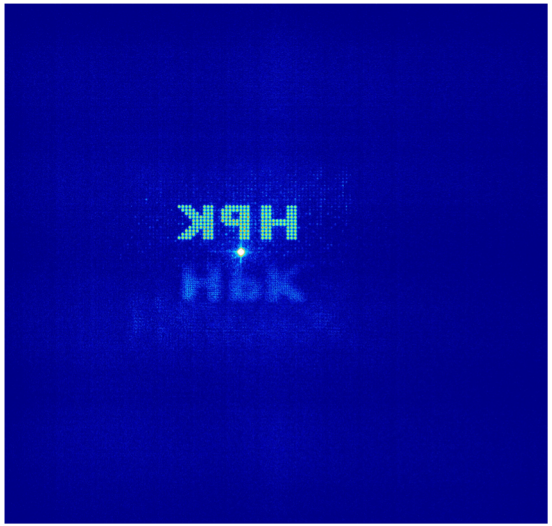
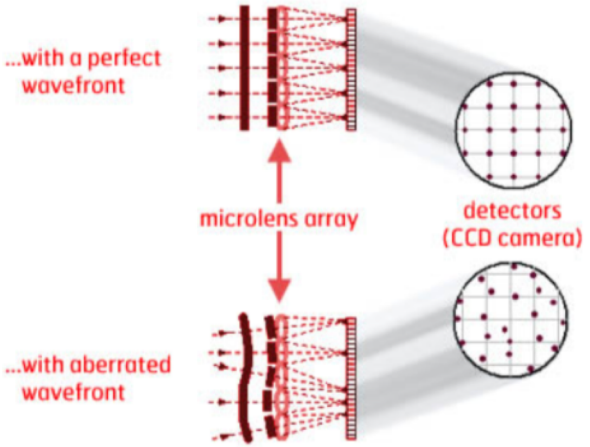


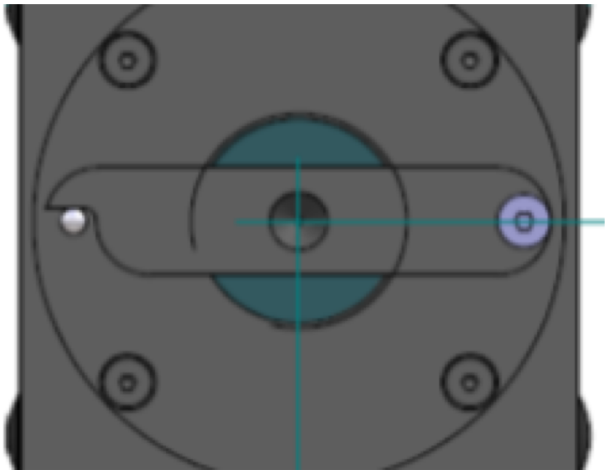
Image Seen on CCD Camera

- Problems with light efficiency -- too much in central order
- Used supplied software with images created in MATLAB
- After looking at intensity, we want to see phase

Wavefront Sensor

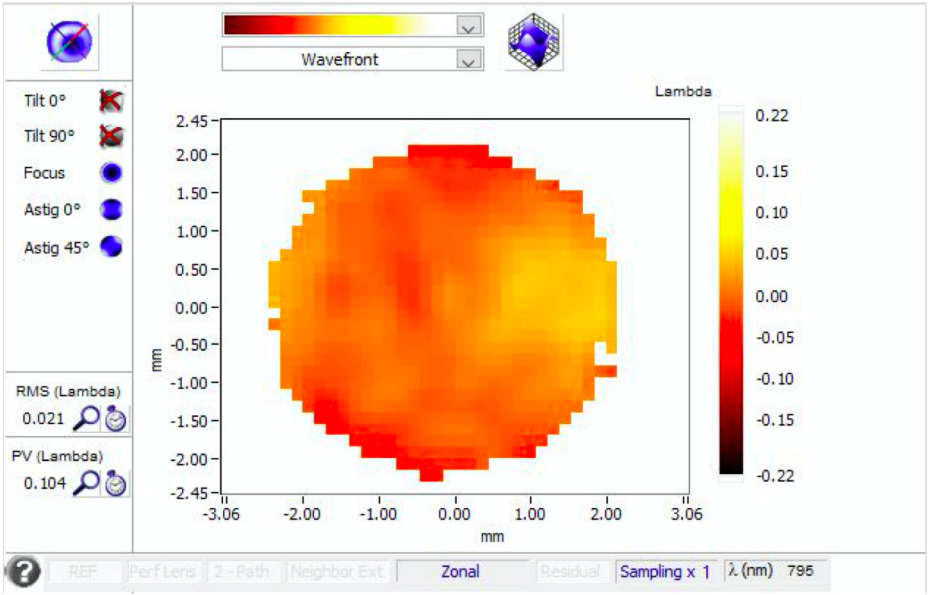
- Grid of micro lenses
- Changes in phase shift the focal spots
- Sensor knows which spots align with which lenses and can indicate how much the phase has changed
- Point of reference





Sensor HASO3 32 linked with IEEE 1394, Imagine Optic, 2015

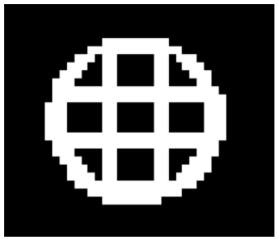
Characterizing the Beam



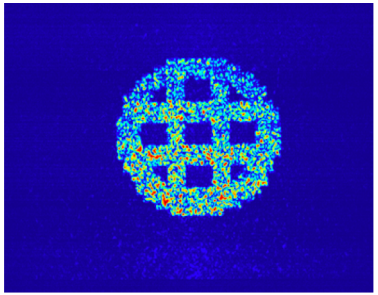
Beam Phase Profile with No SLM Pattern

- Used SLM as a mirror, uniform pattern
- Looked for extra phase added by the SLM in differences from a flat phase
- Color scale indicated the phase distribution
- RMS gave a numerical value for the variation as a spatial standard deviation

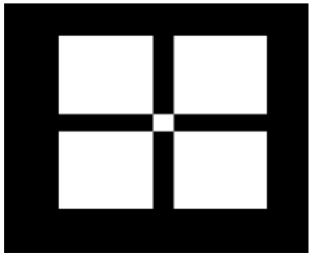
Images for Wavefront Sensor



- Tested size and location of custom images
- Central dot helped wavefront sensor
- Good contrast



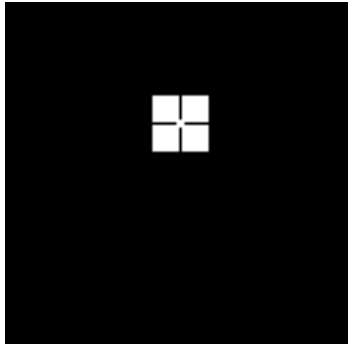
Circle Grid on CCD Camera

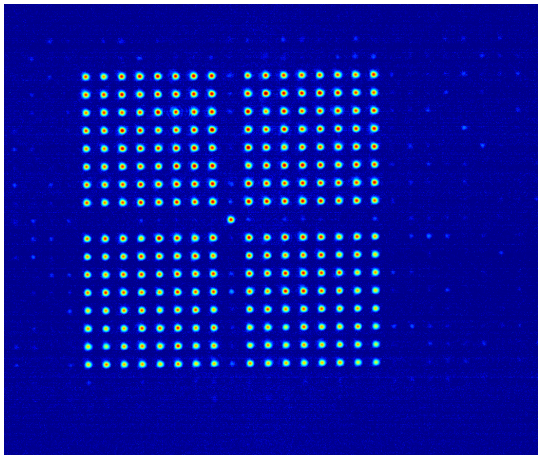


Test Pattern

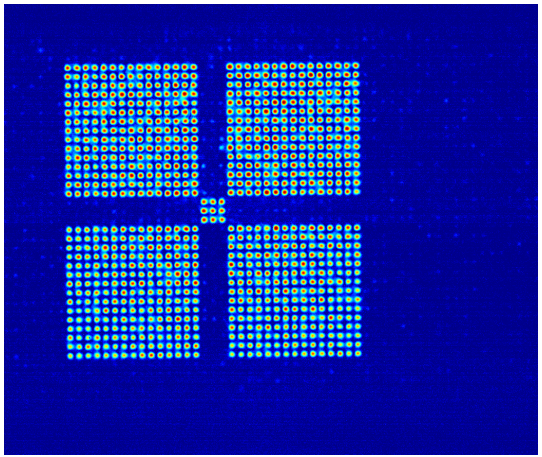
Testing Resolution

- SLM had a resolution of 1024 x 1272 pixels

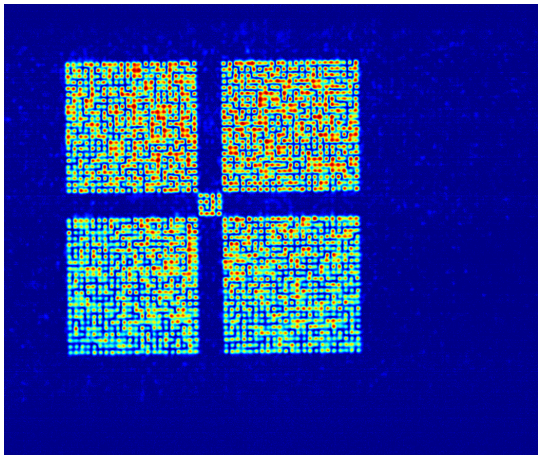




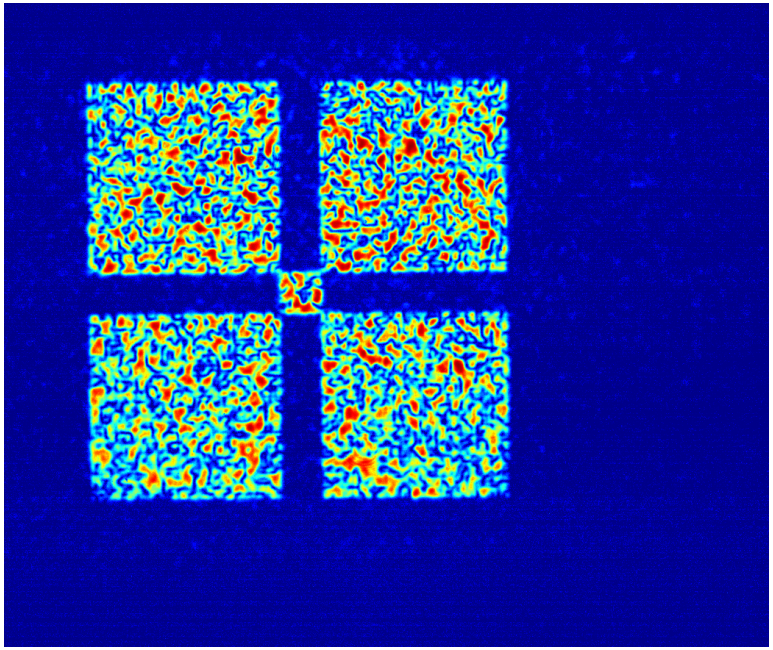
100 x 100 pixels



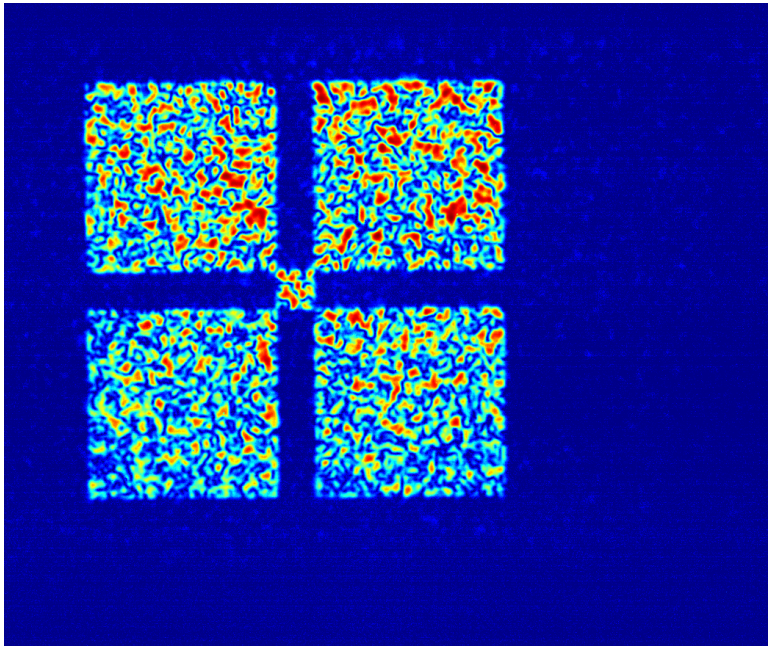
200 x 200 pixels



300 x 300 pixels



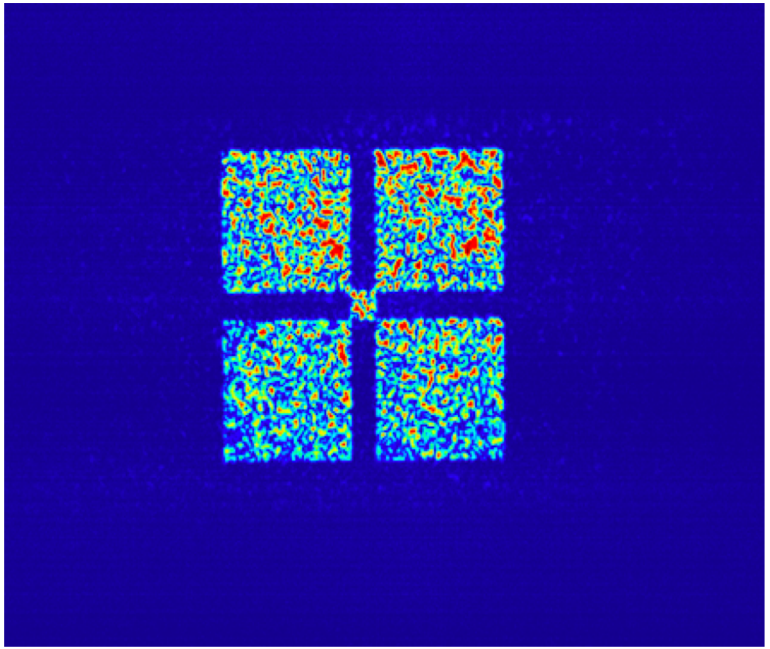
500 x 500 pixels



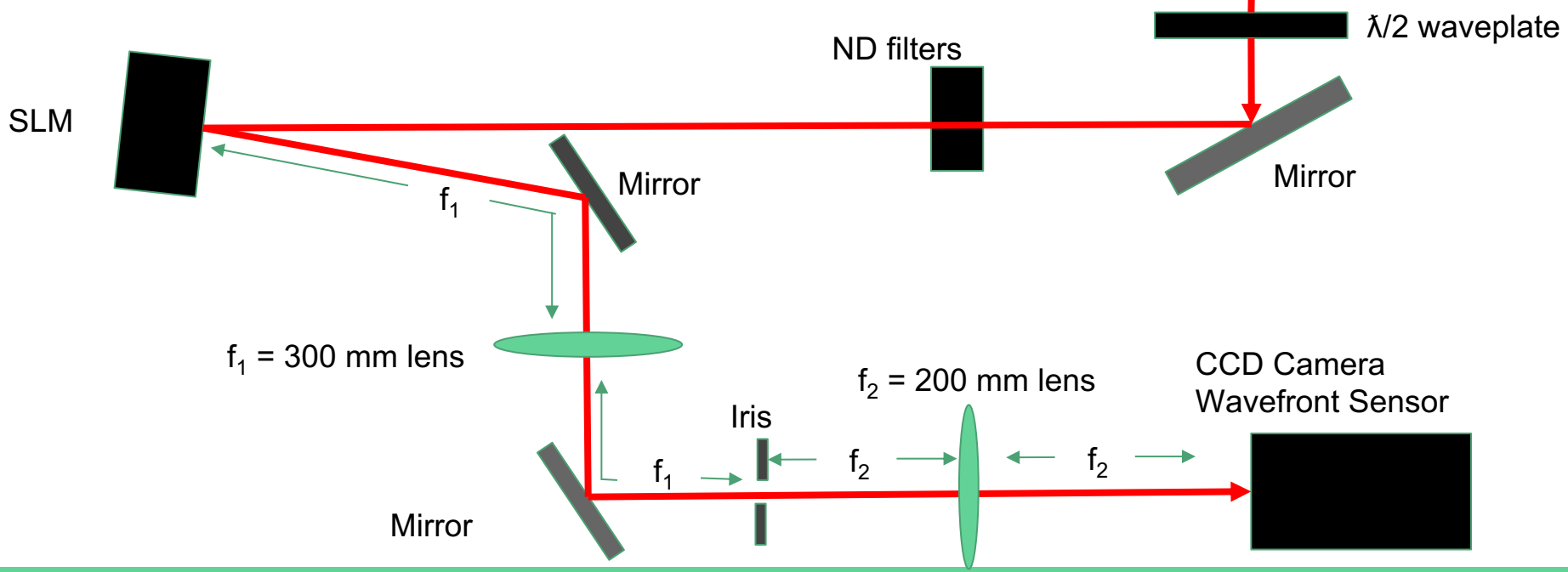
600 x 600 pixels

Limitations of Fourier Transform setup

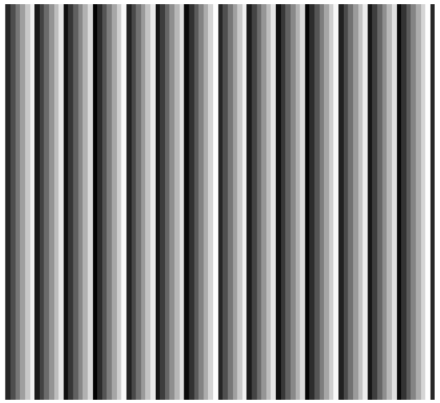
- Unable to control phase and amplitude
- Speckled images from phase interference
- Lack of uniformity



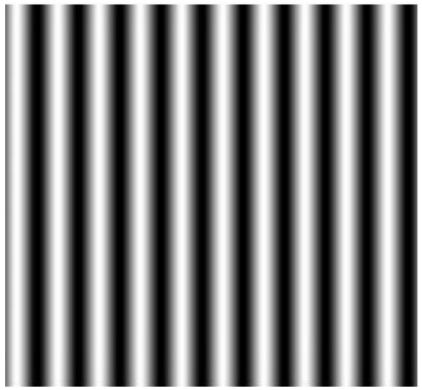
Set-up -- 4f system



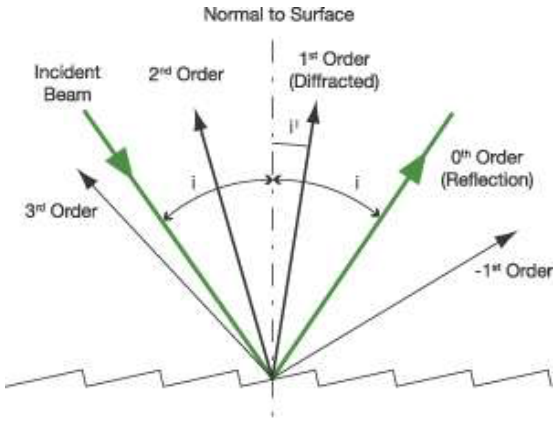
Gratings - Amplitude



Blazed Grating



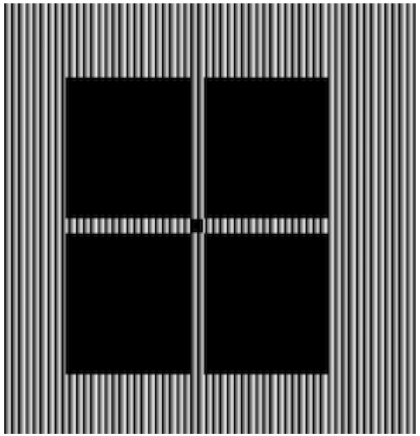
Sinusoidal Grating



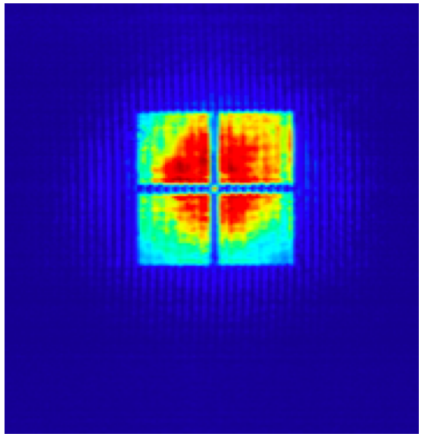
- Sine grating amplifies the zero order, blazed grating shifts light to the first order, acts like a mirror
- Found the diffraction efficiency of each grating with different line densities and resolutions
- Line density controlled spacing between orders

“Diffraction Gratings.” Andor, www.andor.com/learning-academy/diffraction-gratings-understanding-diffraction-gratings-and-the-grating-equation.

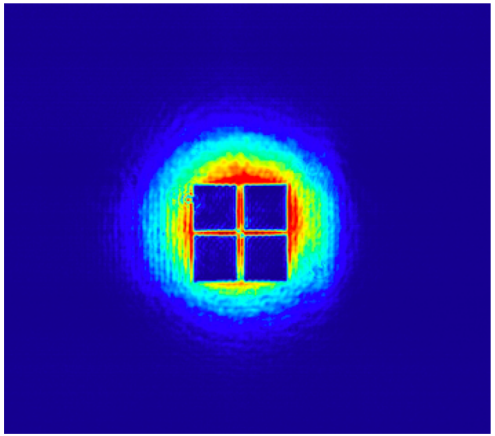
Masks



Pattern with Blazed Grating

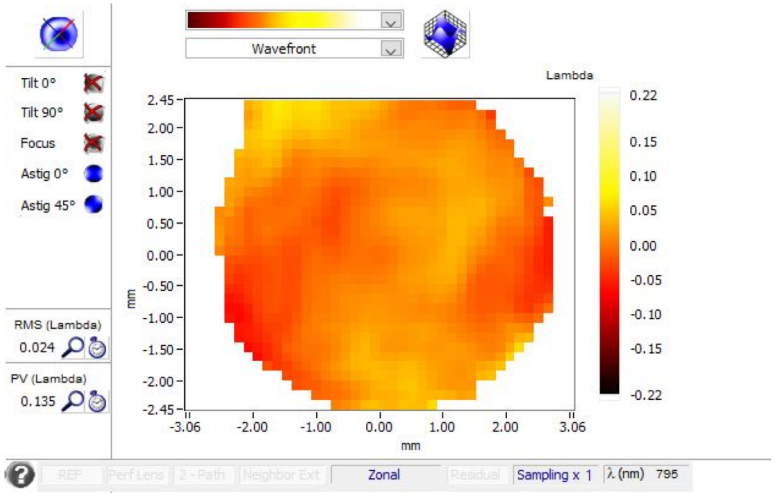


Blazed Grating - Central Order

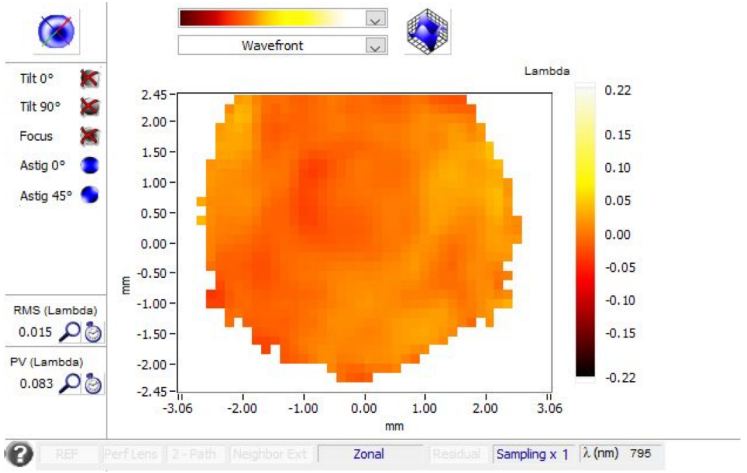


Blazed Grating - First Order

- Used iris to isolate the separate orders
- Black pattern reflects light to central order, blazed pattern reflects light to first order
- Smooth image, not pixelated or speckled -- advantage over the original system, though it has lower diffraction efficiency

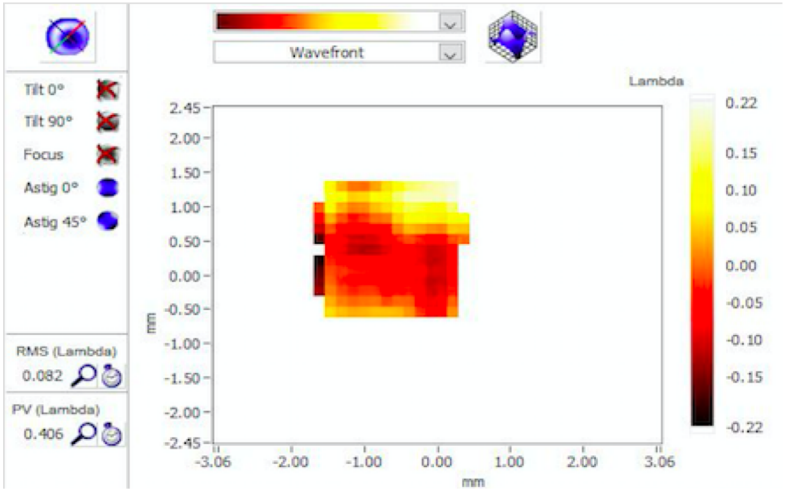


Blazed Grating - First Order Only

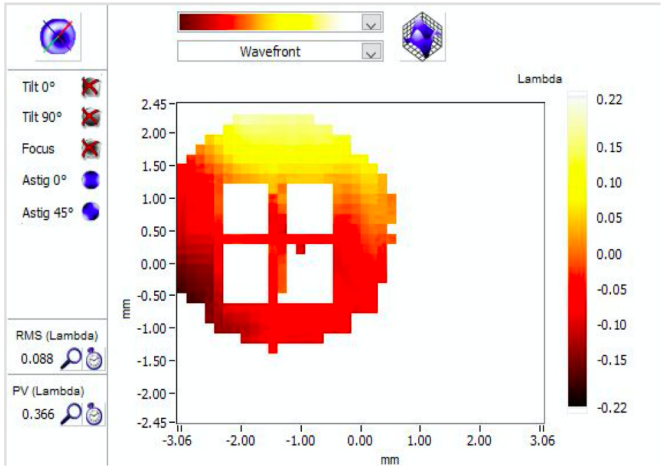


Blazed Grating - Zero Order

- Looked at phase profiles for the blazed grating
- Looked for extra added phase between the two main orders



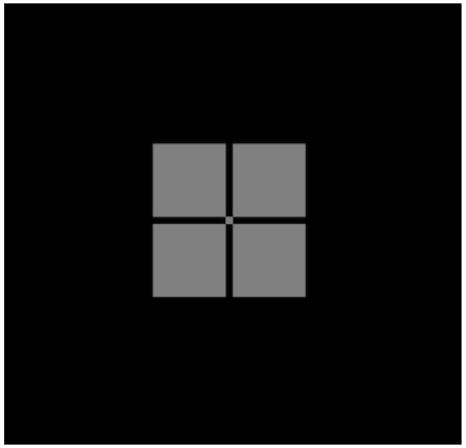
Blazed Grating - Zero Order

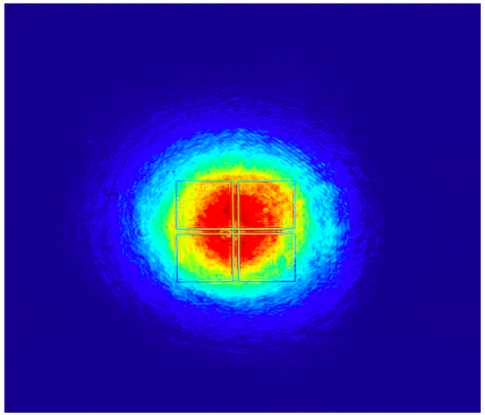


Blazed Grating - First Order

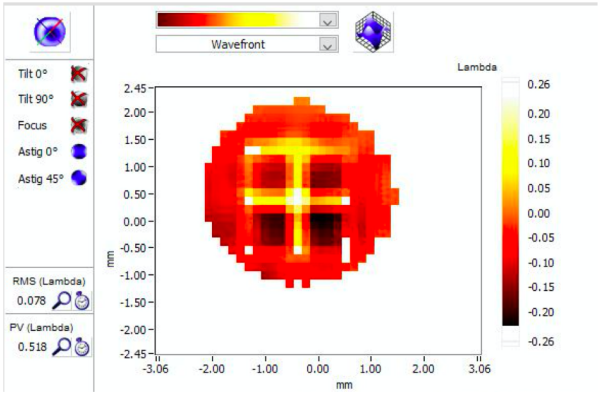
- First order had no phase information in the dark regions
- Nonuniform phase came from the initial wavefront

Phase Control





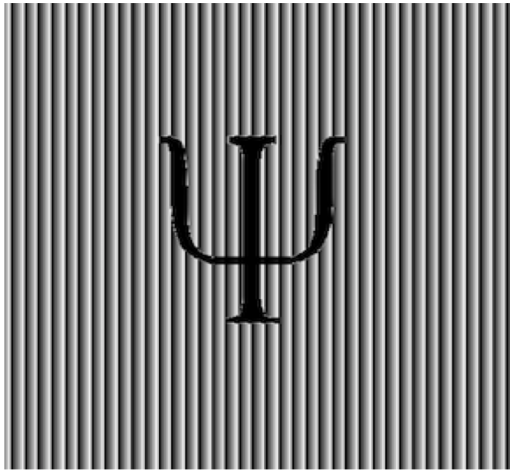
Pi in Squares



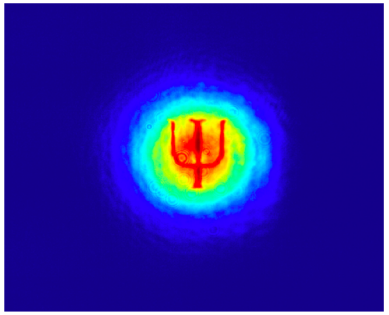
Pi in Squares

- Purely phase-only image where the squares = π (128 in grayscale), keeps light in the central order
- Image visible in camera because of sharp edges where phase switched from 0 to π
- Wavefront sensor shows the difference between the squares and the dark regions

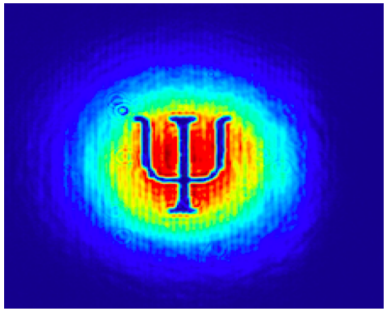
Psi pattern



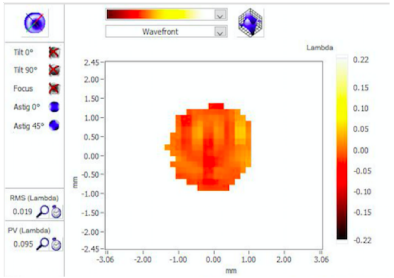
Psi with Blazed Grating



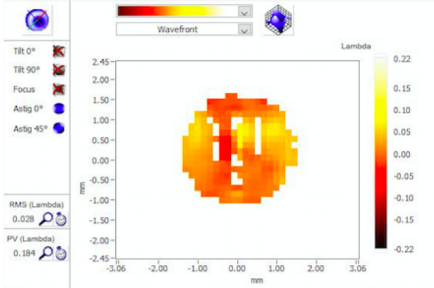
Zero Order



First Order

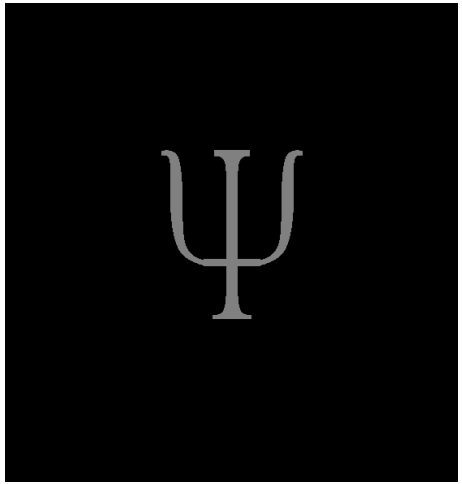


Blazed Grating - Zero Order

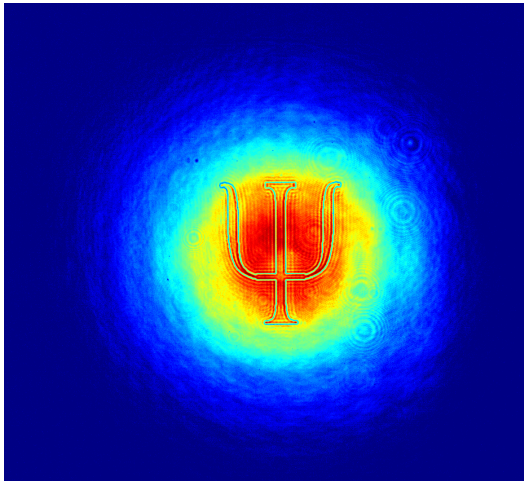


Blazed Grating - First Order

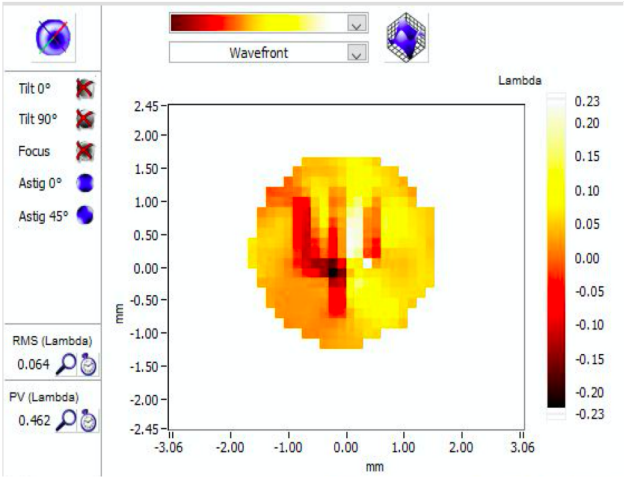
- Sized psi to fit within the main area of the beam
- Phase comes from the psi, amplitude comes from the grating
- White gaps in first order because of the dark image



Psi = π



Intensity Profile



Pi Phase with No Grating

- Intensity image again shows the outline due to sharp edges
- Psi much more distinct in the image with no grating

What We Accomplished

- Saw 4f setup worked better than the initial single Fourier transform setup to control the phase
- Used gratings to control amplitude for simple and more complex images
- Gained a greater understanding of how to implement the SLM

Questions?