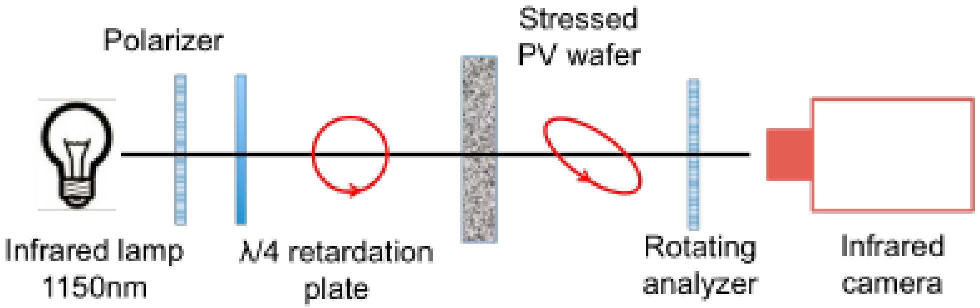
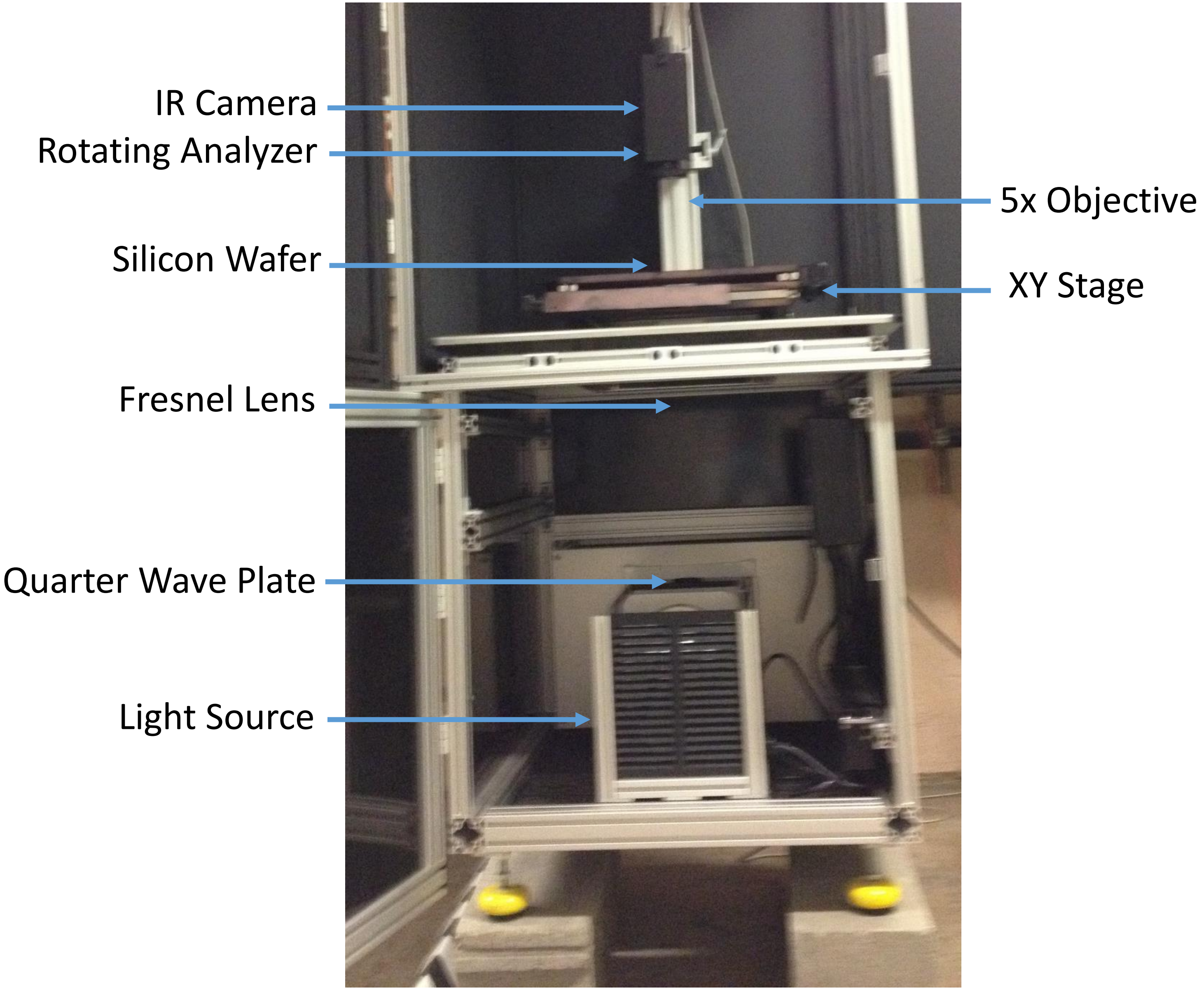
Overview of IR-GFP Wafer Image Data Set

IR-GFP Setup


Polarizer
Stressed
PV wafer
Infrared lamp
1150nm
λ/4 retardation
plate
Rotating
analyzer
Infrared
camera


IR Camera
Rotating Analyzer
5x Objective
Silicon Wafer
XY Stage
Fresnel Lens
Quarter Wave Plate
Light Source

Data Acquisition

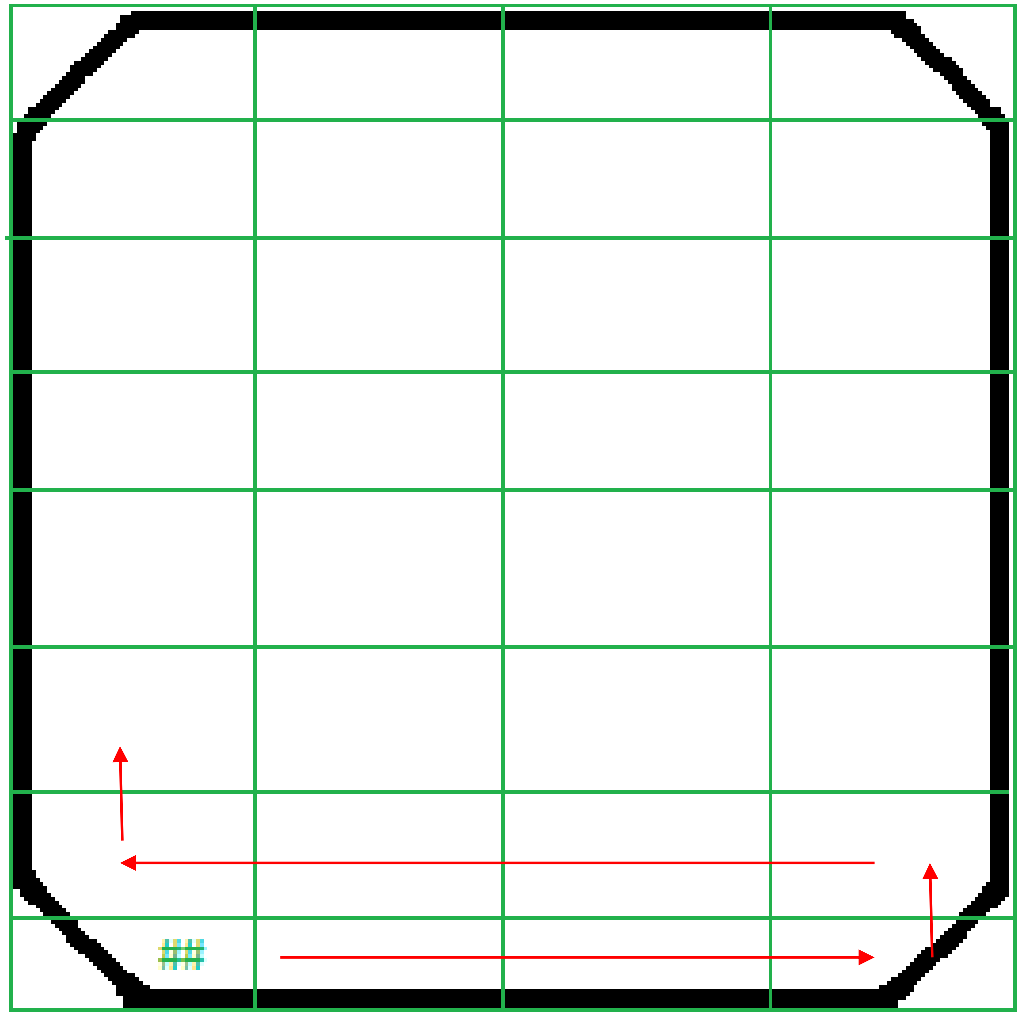
Each wafer has been imaged by the IR-GFP in a raster scan fashion starting at the lower left corner where the wafer number is written.

Etched wafers are 50 images across and N images vertically. N is usually 70 but only 66 are of the wafer, the extra images are of a mask around a wafer.

As-cut wafers are 49 images across and N images vertically.

Each image overlaps with its neighbor by approximately 10% (64 pixels) on the left and right and 5% (24 pixels) on the top and bottom.

60+ as-cut wafers have been imaged
19 etched wafers have been imaged

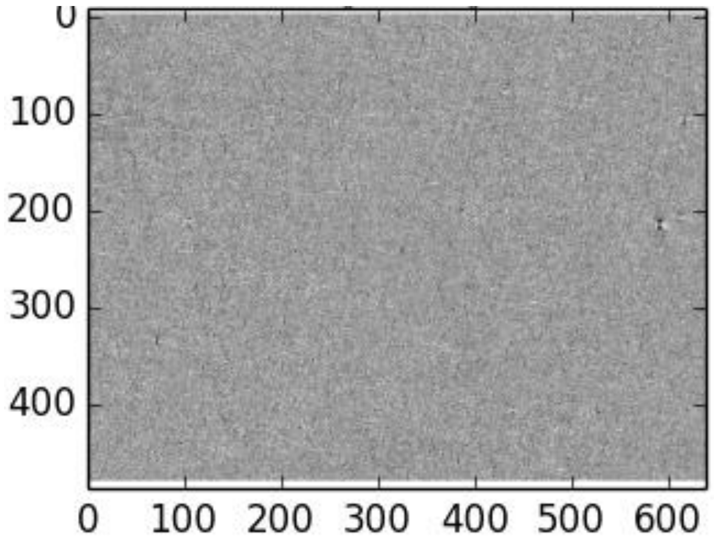


5x Images

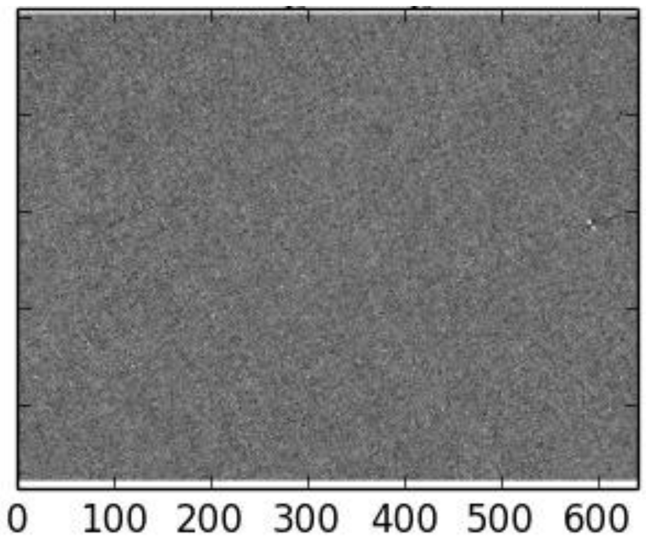
One measurement is taken at each location and saved as a dt1 file. Each dt1 file consists of 3 images, Shear 0, Shear 45, and IR Transmission (Light).

Each image is 640 by 480 pixels and is has a resolution of approximately 5 μm.

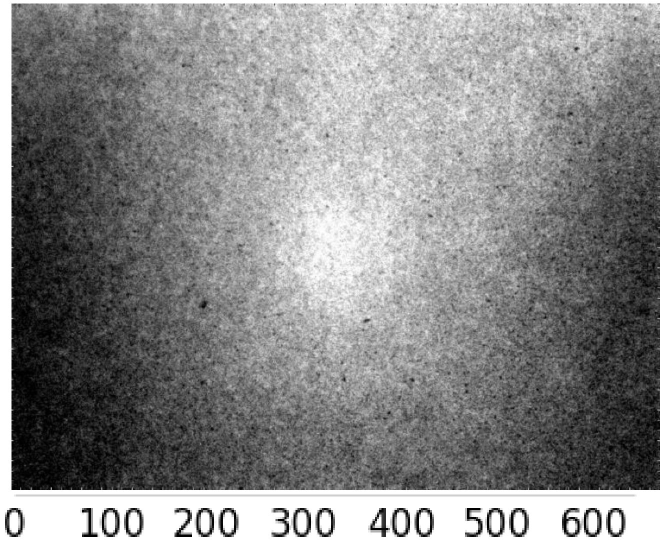
Shear 0



Shear 45



IR Transmission (Light)



5x Images

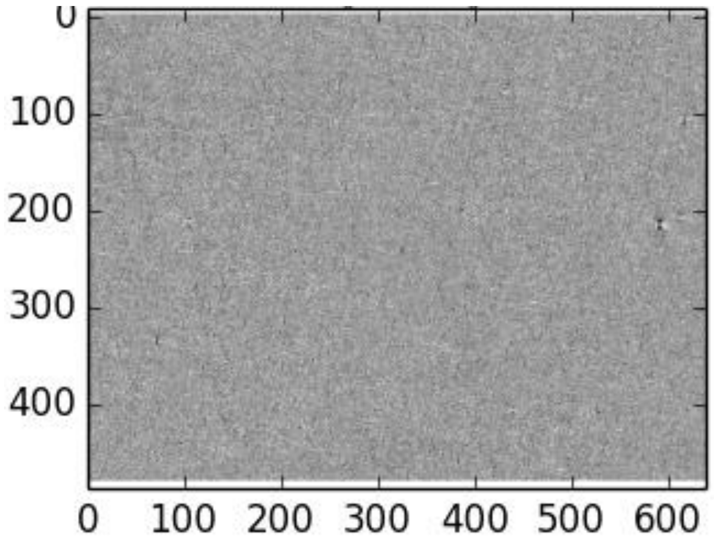
All of the data points are given in arbitrary units (θ). Shear 0 and Shear 45 data points can be converted into nanometers of retardation via

$$\delta = \frac{\lambda}{2\pi}\frac{\theta}{\theta_{pk}}$$

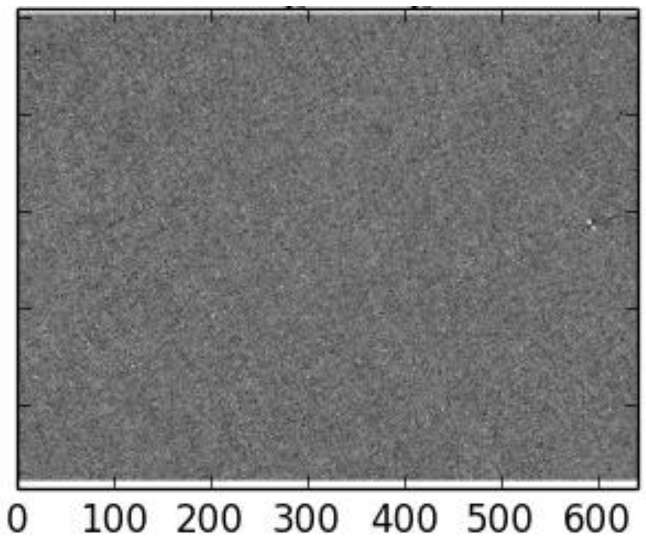
where λ is 1150 nm and for etched wafers θ_{pk} is 550.

The shear 0 image shows the retardation caused by a difference in normal strain along the $\pm 45°$ directions. Likewise the shear 45 image shows the retardation caused by a difference in normal strain along the XY directions.

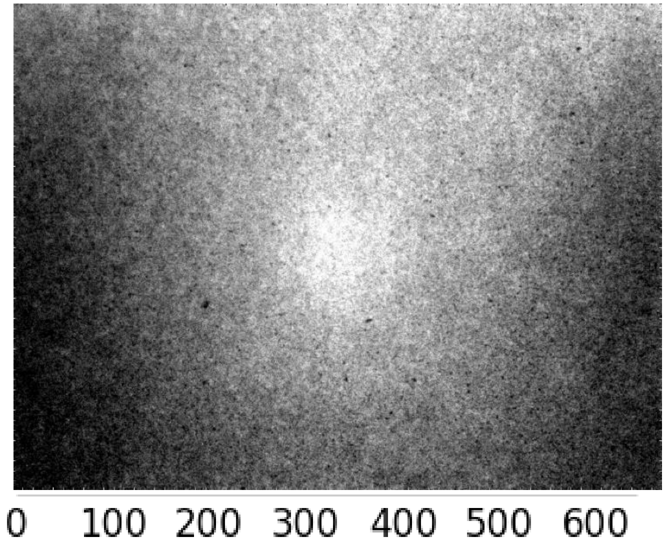
Shear 0



Shear 45



IR Transmission (Light)



Data Structure

Folders are named after the number marked on each wafer and each folder contains 3,500 dt1 files that are each named according to the timestamp of when they were saved.

Each dt1 file consists of the following:

1. Header
   - Components of the header are prefaced by @**@
2. Light Image
   - 307,200 pixel values
3. Shear 45 Image
   - 307,200 pixel values
4. Shear 0 Image
   - 307,200 pixel values

Reading dt1 Files

1. Read the dt1 file in binary mode
2. Search backwards for the index location of @**@Data
3. The first data point of the light image will be 34 bytes after this index
   - Reshape the first 307,200 values into a 640 by 480 array
4. The first data point of the shear 45 image will immediately follow the light image
   - Starts at index+34+307200
5. The first data point of the shear 0 image will immediately follow the shear 45 image

Image Formation

To form the shear 0 and shear 45 images each array must be normalized by the light image

$$\text{Shear } 0 = \frac{\text{Array of Shear 0 data points}}{\text{Light Image}}$$

$$\text{Shear } 45 = \frac{\text{Array of Shear 45 data points}}{\text{Light Image}}$$

Post Processing

The raw shear 0 and shear 45 images contain several undesirable elements:

- Images of the wafer mask
- Optical aberrations that result from the imaging setup
- Hypersensitive pixels

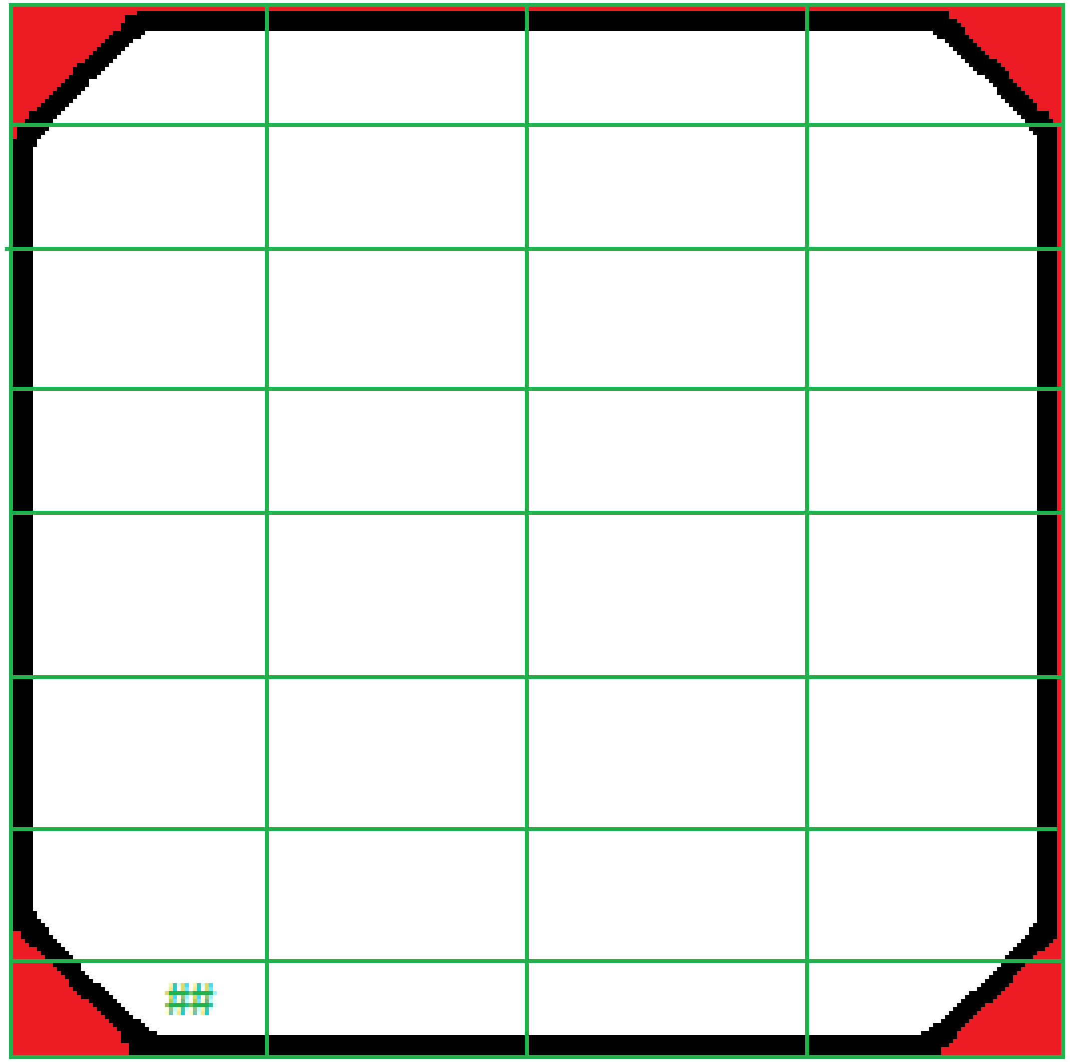
The next few slides briefly explain how we chose to address each one.

Post Processing: Images of the Wafer Mask

The raster scan pattern of each wafer also imaged regions of wafer mask along the edges and corners of the wafer.

Images of the wafer mask have a lower average light level and higher standard deviation of pixel values in the light image.

By comparing the average light level of an image and standard deviation of pixel values in a light image to that of the rest of the wafer, the images of the light mask can be sorted out of the data set.



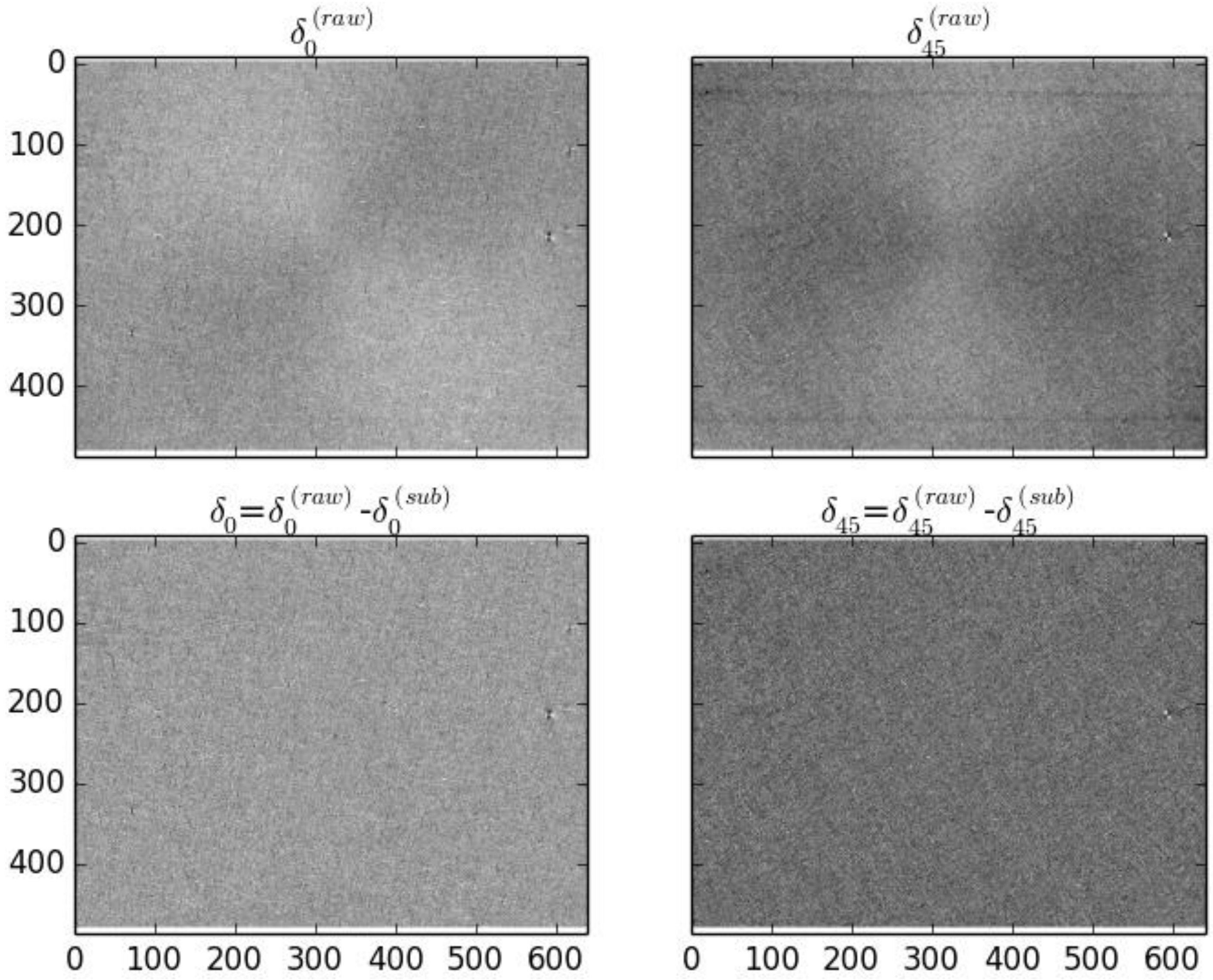
Post Processing: Optical Aberrations

Optical aberrations can arise due to several factors, such as an imperfectly circularly polarized light source, the detector, or inserted optics such as the Fresnel lens.

The aberrations are such that they appear the same in every image. Thus they can be removed by a subtraction image.

A subtraction image is only used on shear 0 and shear 45 images. It is generated by averaging N images and then subtracting the mean value.

$$\delta^{(sub)} = \frac{1}{N}\sum_{i=1}^{N}\left(\delta_{(i)}^{(raw)} - \bar{\delta}_{(i)}^{(raw)}\right)$$



Post Processing: Hypersensitive Pixels

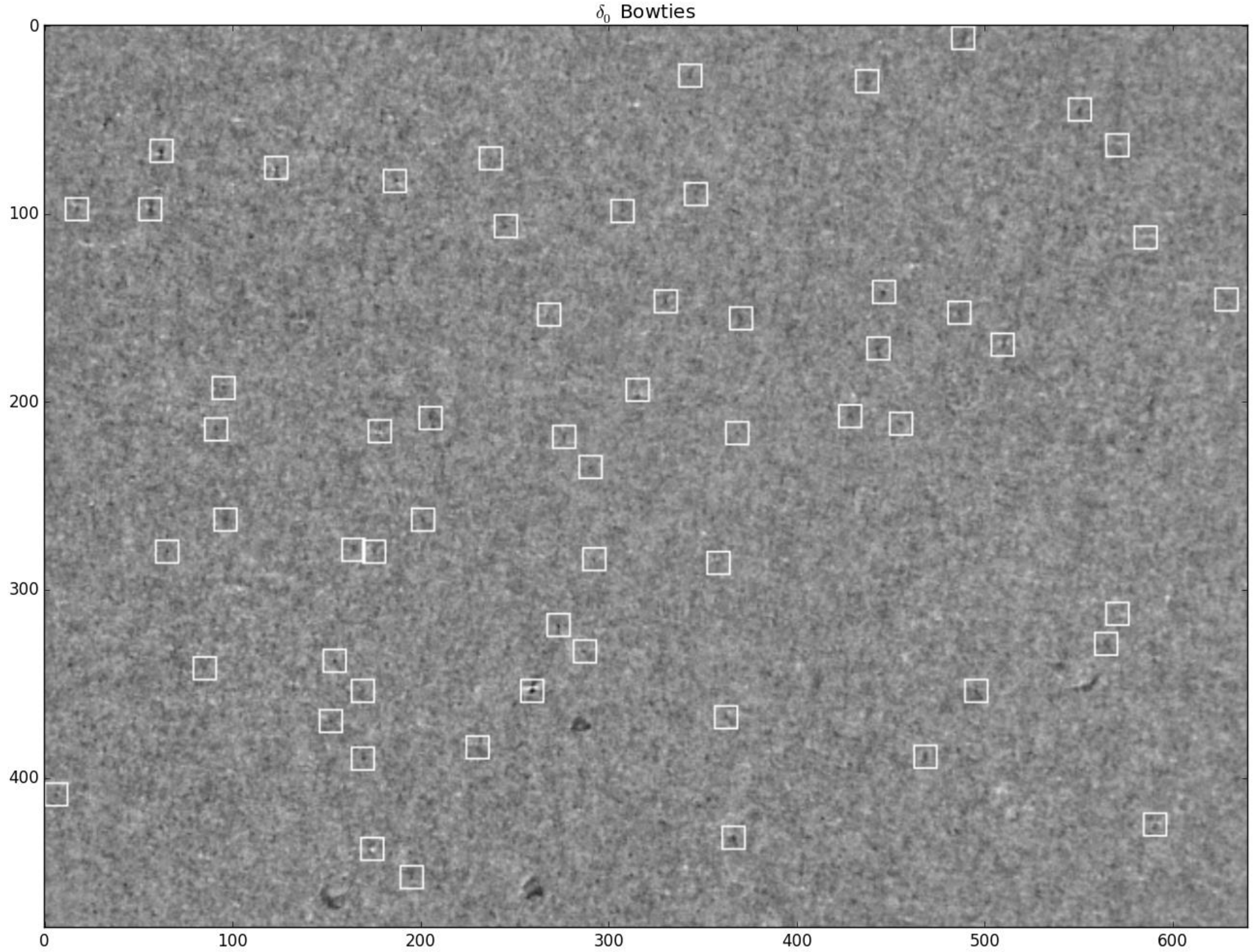
Hypersensitive pixels are pixels that frequently and incorrectly observes high retardation measurements.

The number of hypersensitive pixels increases with the amount of time the detector has been running without a chance to cool down.

These can be detected by counting how many times a pixel occurs as the location of greatest retardation over the course of a wafer. Since there are 307,200 pixels the probability of any one pixel occurring as the point of largest retardation more than 4 times is extremely small.

Pixels which are determined to be hypersensitive are set to the average value of their neighboring pixels and the next highest pixel is checked. This process is iterated until all of the hypersensitive pixels have been identified.

Bowtie Identification



Bowtie Identification