The Small Scale Systems Integration and Packaging Center

*A New York State Center of Excellence*

# Roll-to-Roll Defect Inspection

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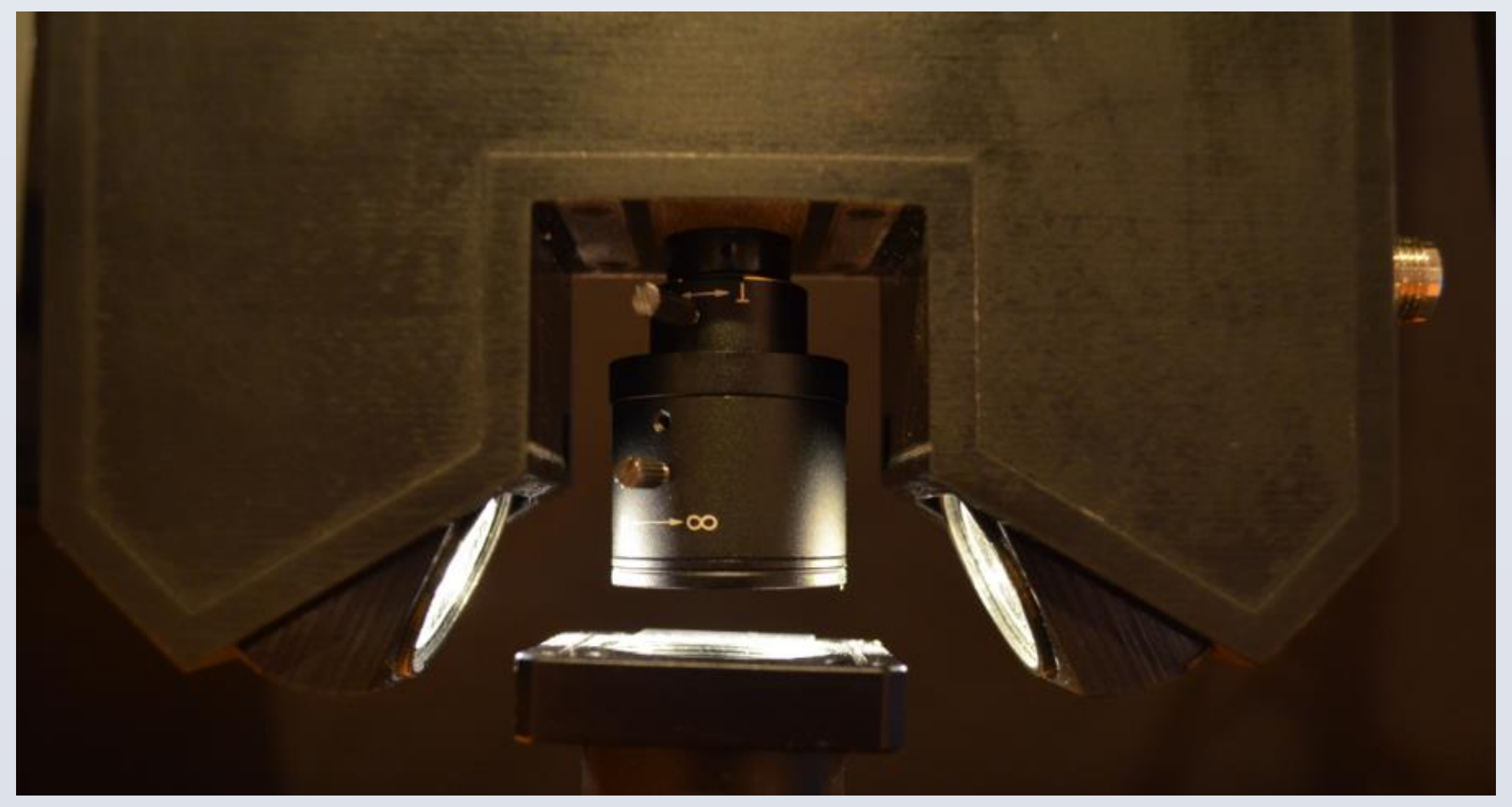
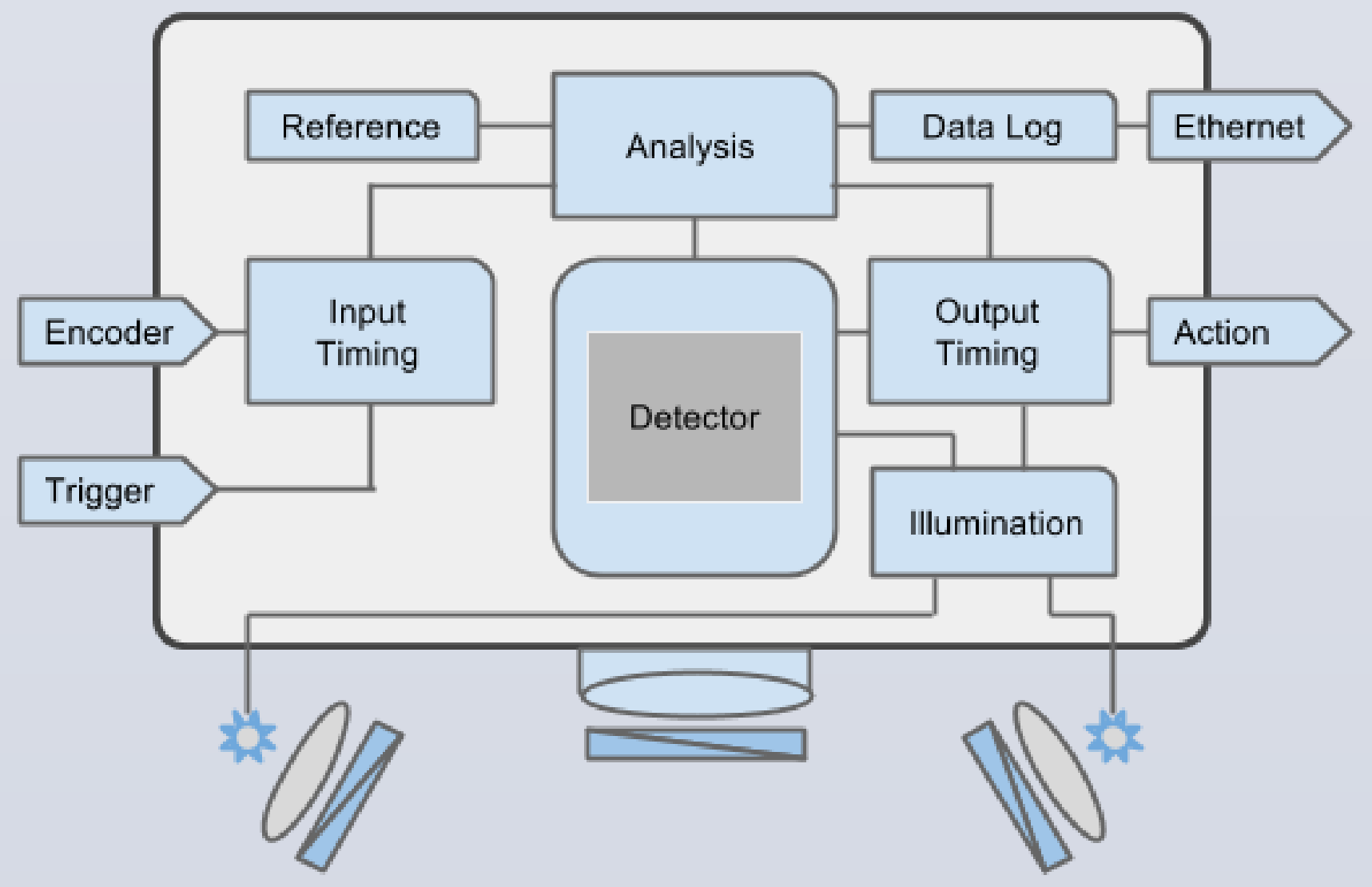
## Abstract

Thin film electronic coatings and devices consist of multiple layers of half micron (or less) thick coatings of various dielectrics, semi-conductors and conductors. The circuit line and spaces range from single microns to tens of microns. Scratches and particles cause defects in coatings and circuitry leading to loss in yield and function. The ability to identify that a substrate is "clean" and defect free represents a significant but obtainable challenge. The goal of this project is to create a high-rate, efficient defect detection and classification algorithm for micron sized scratches and particles on the surfaces of flexible electronic grade substrates materials being developed for roll-to-roll (R2R) manufacturing. Micron sized defects can cause significant problems if gone undetected during roll-to-roll manufacturing. A non-invasive method of imaging the substrate during processing in real time is essential to effective defect detection.

## Sensory Hardware



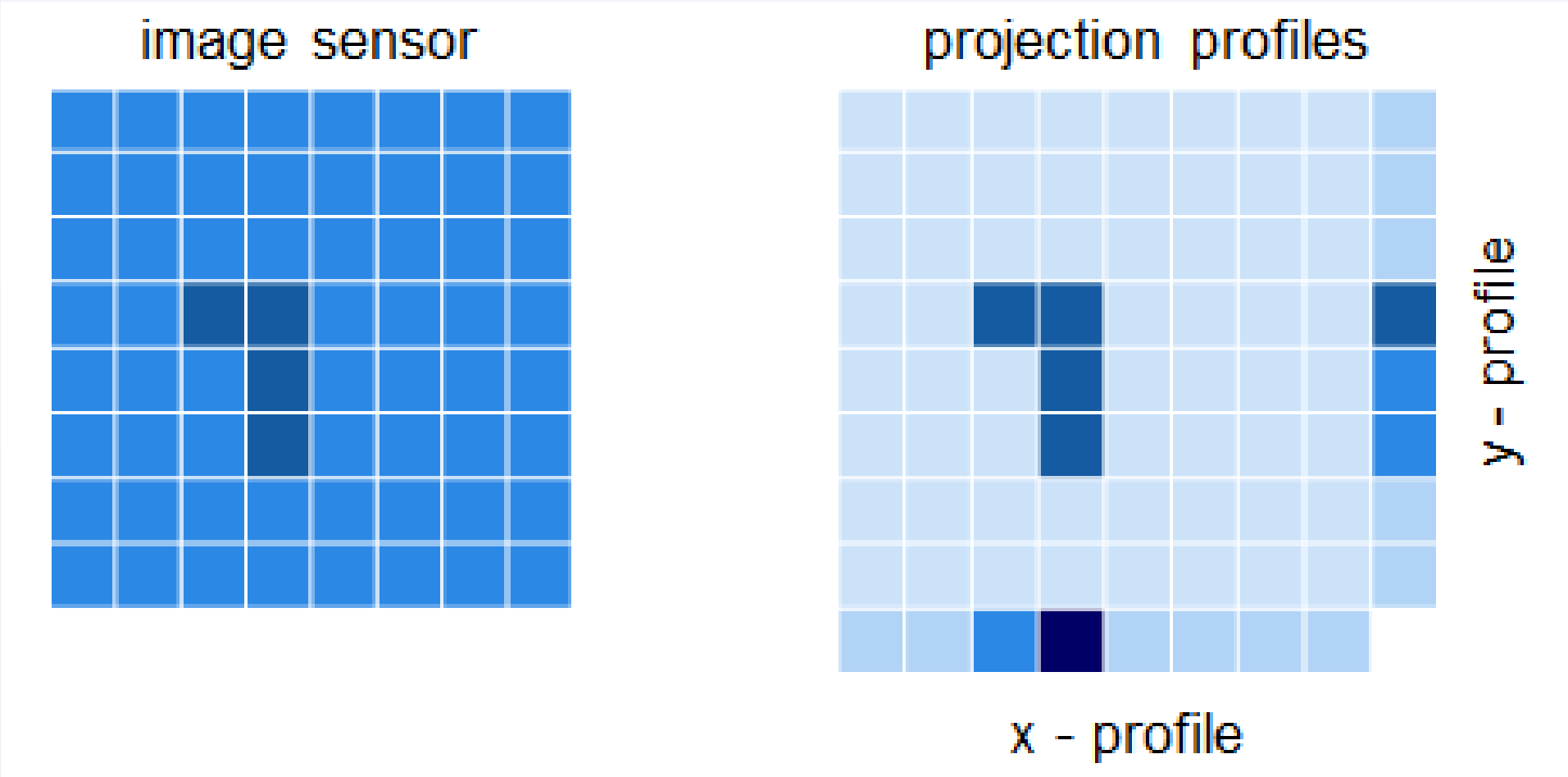
Optical Sensor by Sun Optical Systems



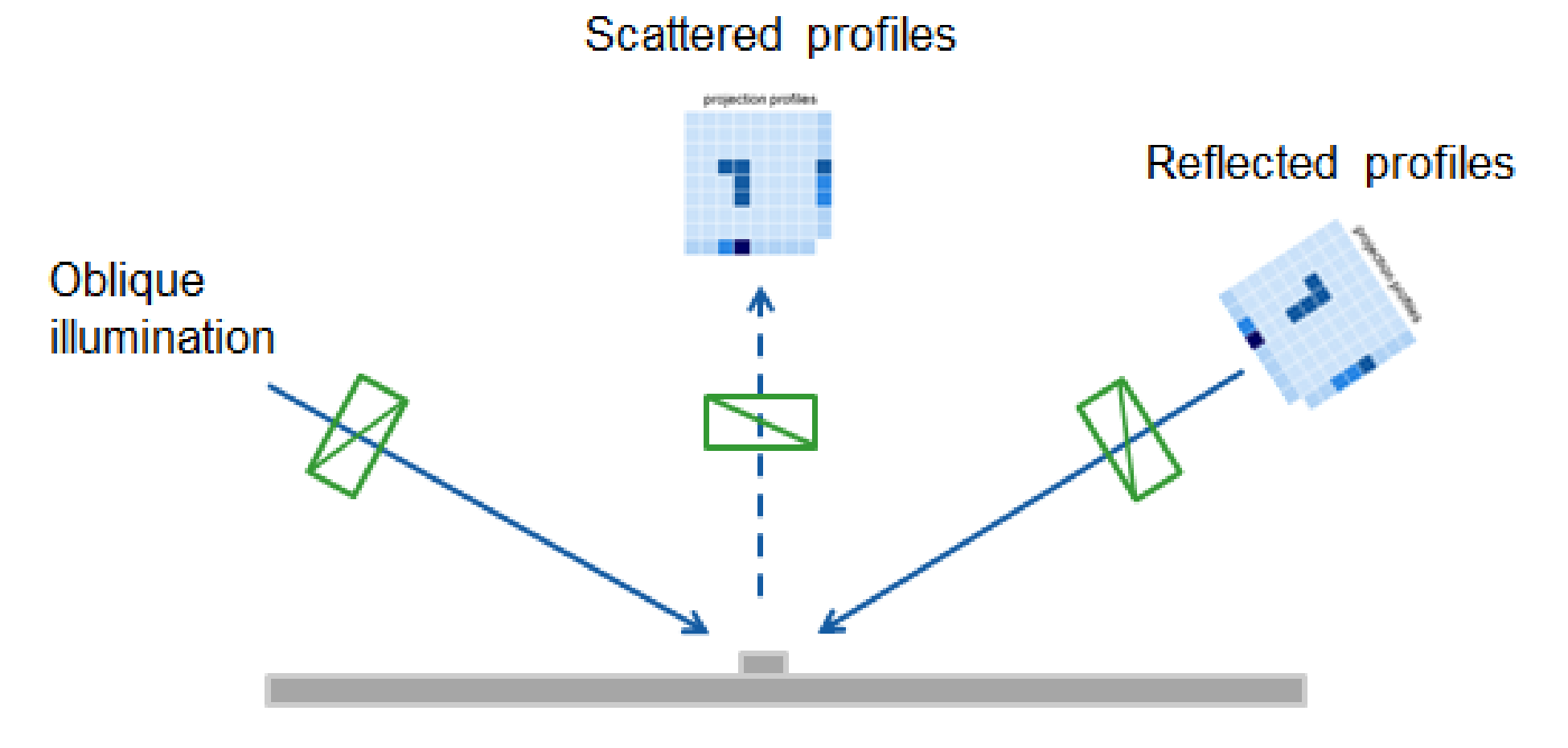
## Hardware Specifications

- 5µm pixel resolution with 9.6mm wide field of view
- Continuous imaging of moving substrate to a maximum web speed of 3 meters/minute
- Encoder that locates where defects are located if detected

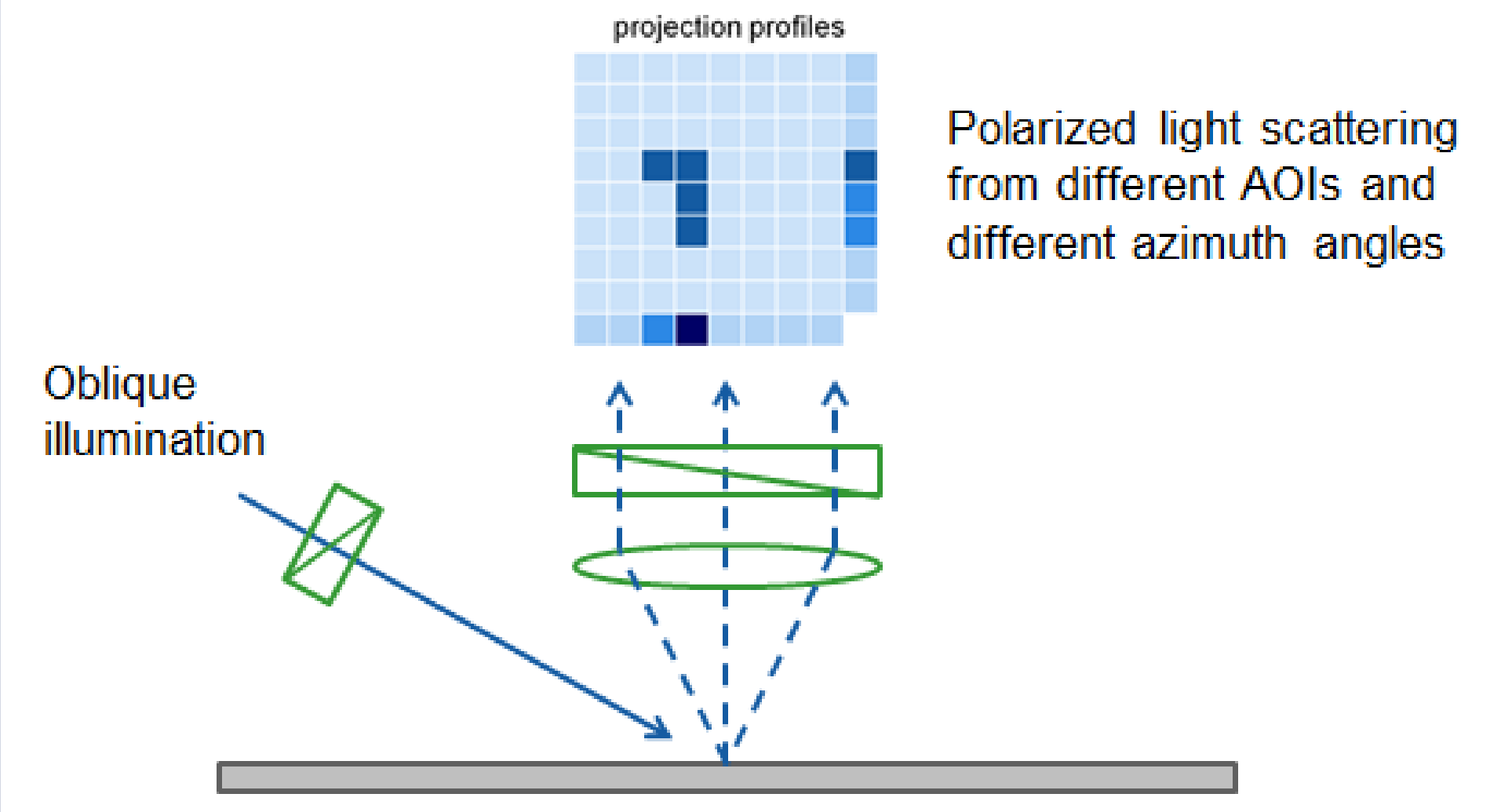
## Projection Profiling



- Traditional vision sensor read in all pixels with full information but requires N×N amount of data transfer
- Projection profiles are the sum of the pixels in columns and rows, which subtracts the shape and position while requires only 2N amount of data transfer.



- Measure defects 3D position and shape – by the difference from reference profiles
- Establish a profile database for defects correlation
- Area or line illumination dependent on area of interest
- Polarization optimized for sensitivity



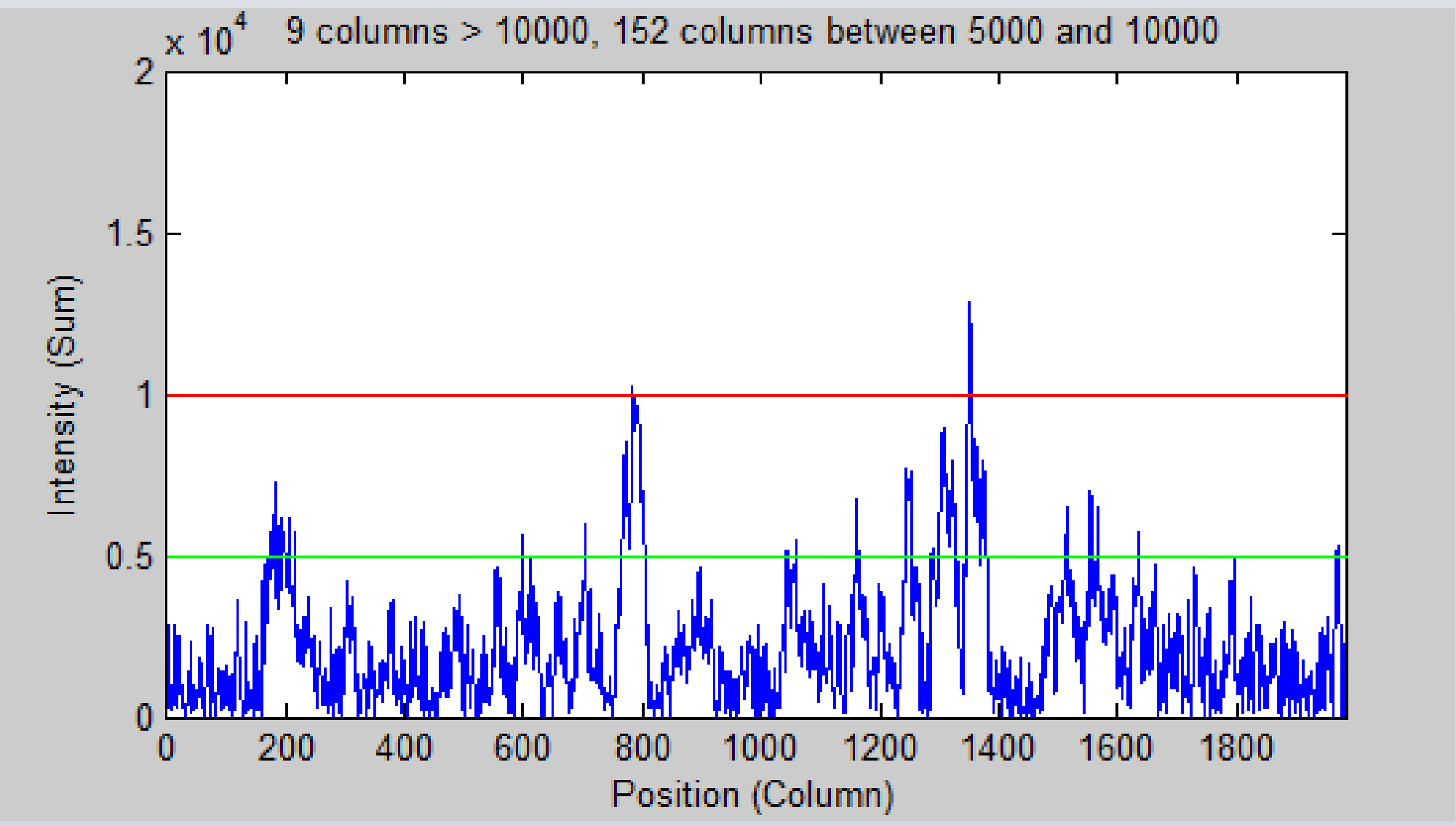
- Analyze empirical mapping surface roughness from polarized scattering measurements
- Confocal arrangement is necessary to avoid backside reflection from the transparent substrate

## Measurement Possibilities

- Surface defects / particles – minimum dimensions
- Surface scratches – width, depth, length
- Surface micro-roughness
- Embedded defects – size, material
- Local stress – δn sensitivity
- Edge shape – ± µm deviation from normal
- Edge cracks – width, depth, length
- Flatness – profile tolerance
- Thickness variation – 100µm ± µm tolerance
- Thin films – thickness, index, composition

## Analysis Techniques

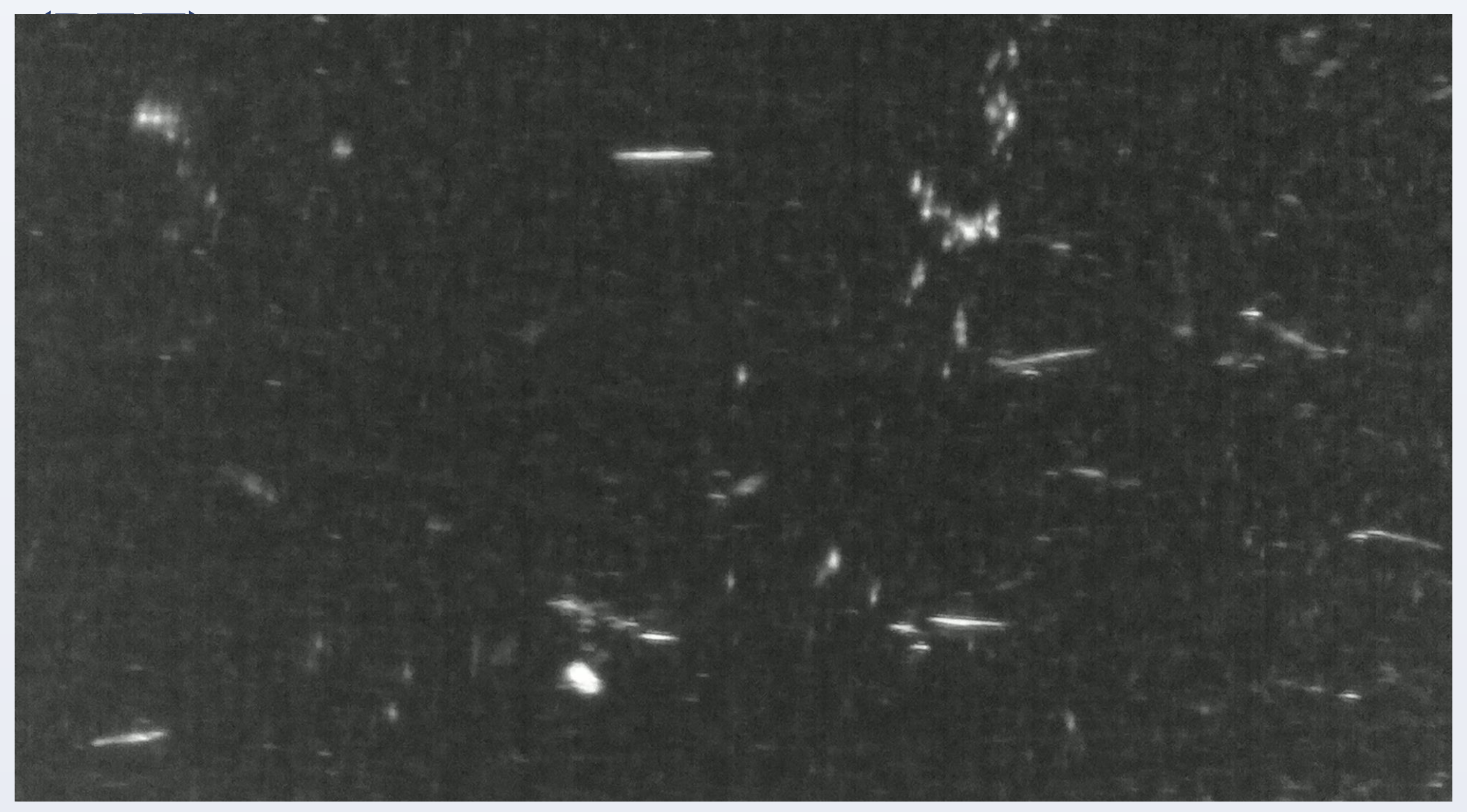
**RGB to Binary Conversion** – In order to accurately detect defects in a sampled image, we have to differentiate the background from the defects. To do so, we have to convert the RGB image to a binary image, in which black is the background, and what we consider to be defects, are white. This is done through thresholding. We implemented a local thresholding method because it is known to produce more accurate results on more non-uniform backgrounds. Instead of using deviations from the mean intensity value of the entire image (global thresholding), we used more localized averages. Pixels are converted to a '1' (white) if their intensity value is more or less than three standard deviations from their localized mean, and '0' (black), otherwise.



**Intensity Projection Profile** – Take the sum of the intensity values of each column of pixels along the moving substrate. This is useful for detecting preliminary locations of defects.

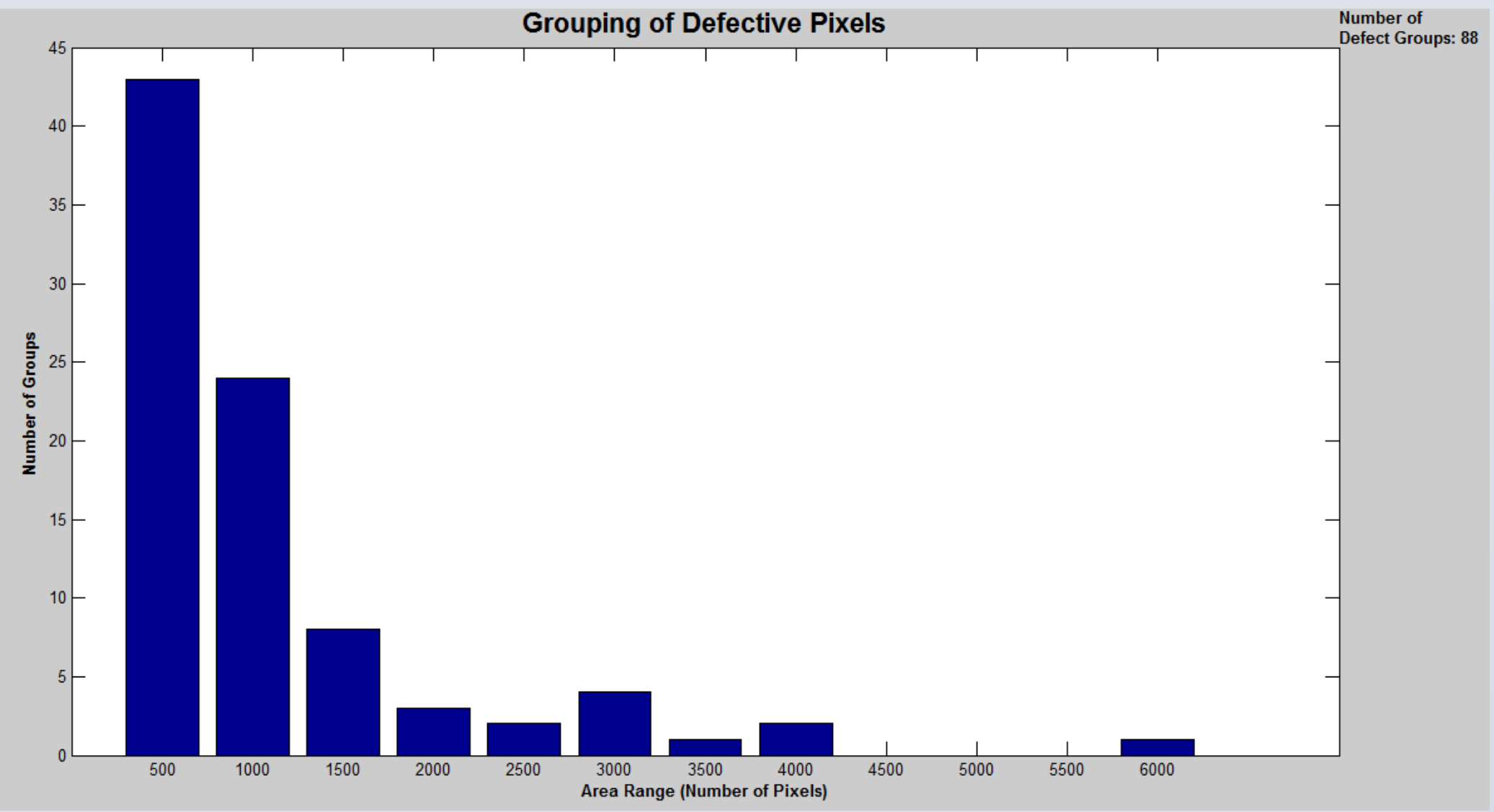
## Analysis Output

Original Image: Polyethylene Terephthalate



Binarization by Local Thresholding

Grouping of Defect Pixel Areas.



Coloring of Defect Groups based on Eccentricity