Novel Two Channel Self Registering Integrated Macro Inspection Tool

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Verity Instruments, Inc.

Outline

- Technology Description
  - Principle of operation
- Simulated Reflectance map of spinning patterned wafer
  - Conventional approach
  - Verity’s approach
- Simulated real time difference image signal
  - “Die-by-Die” subtraction
- Hardware

Technology Snap-shot

- **(r-θ) spiral scan of the wafer surface**
  - Enables compact design and provides higher throughput
  - Eliminates pattern induced image inhomogeneity due to wafer rotation

- **Differential Diffractometer**
  - Real time difference image
    - Reduces noise from under layer pattern
    - Mitigates color (thickness variation) noise
    - Eliminates misalignment in “die-to-die” subtraction

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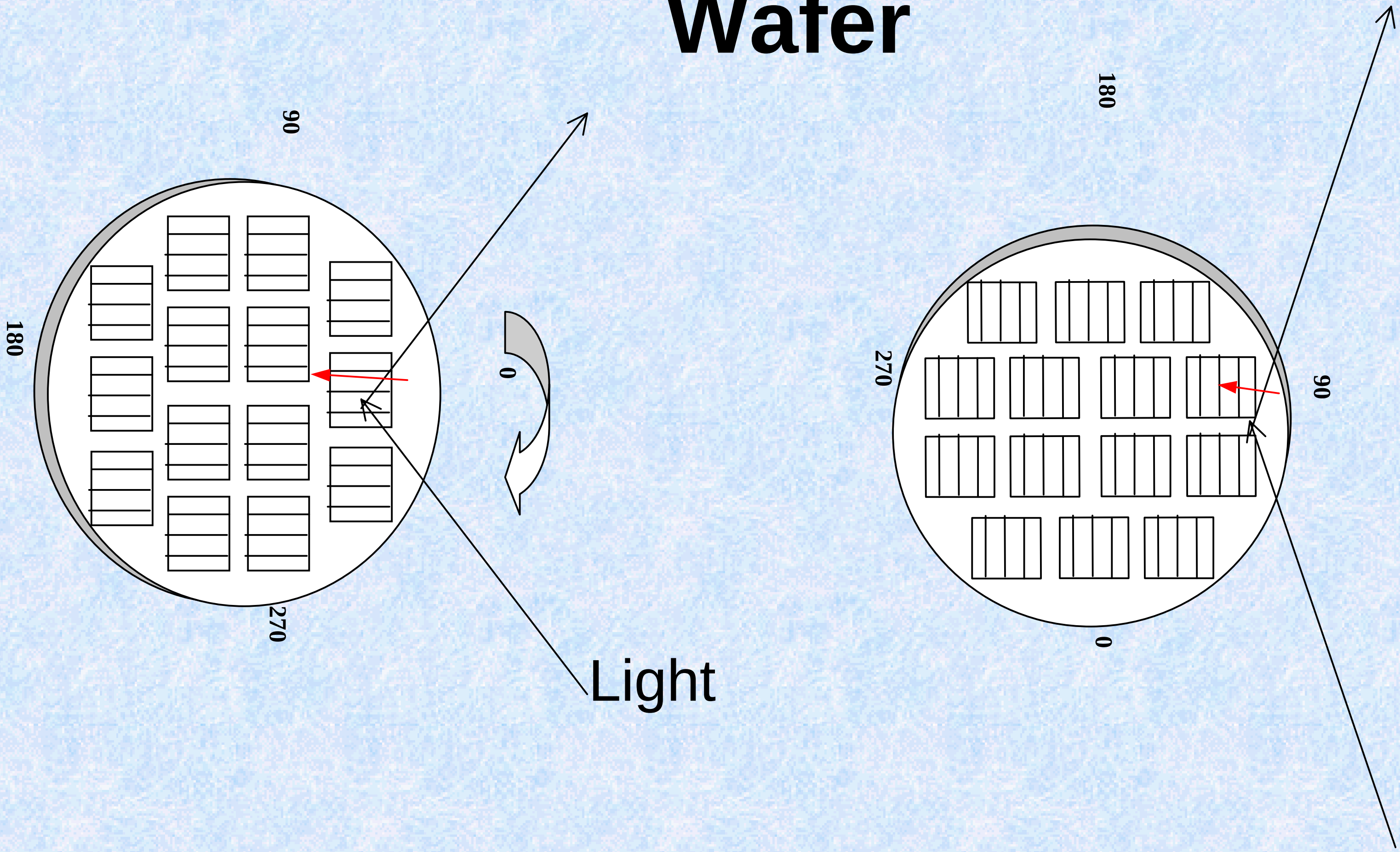
Spiral Scan of Patterned Wafer



In spiral scan, surface pattern continuously changes its orientation with respect to the incidence plane

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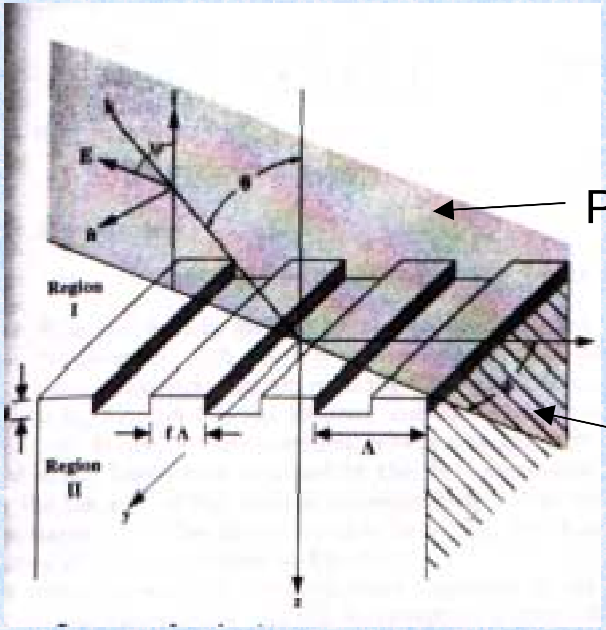
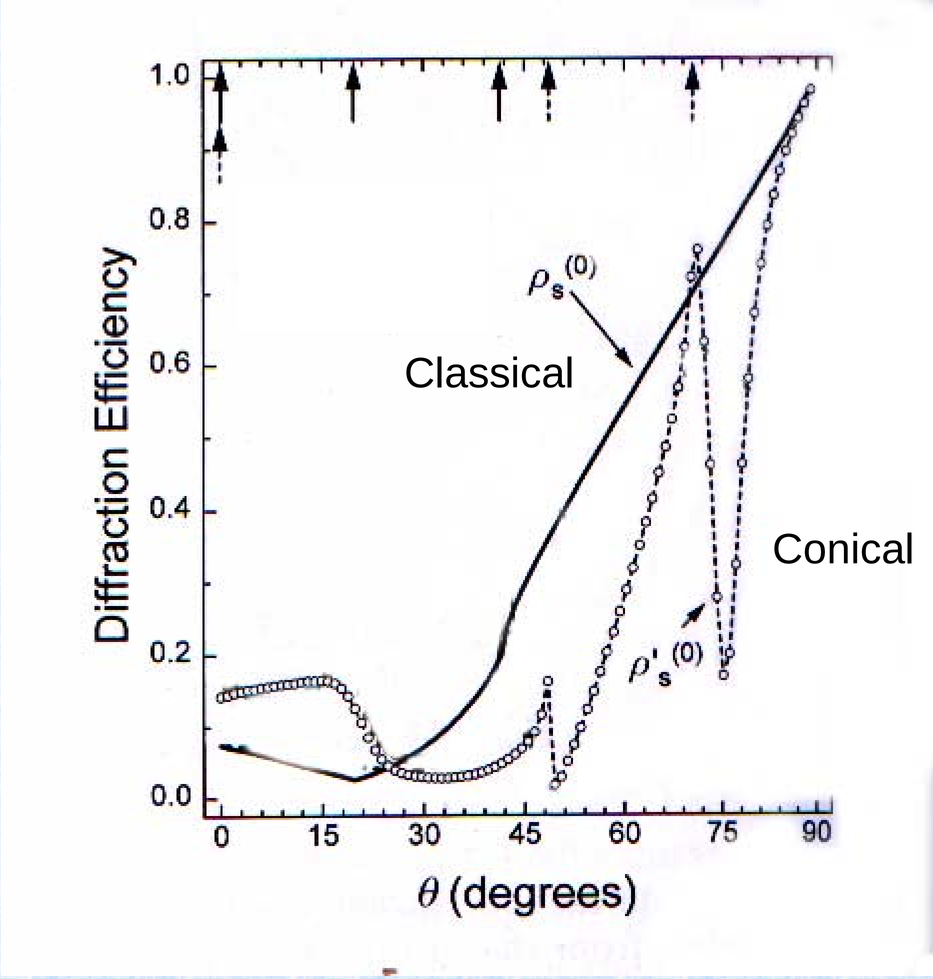
Classical and Conical Diffraction



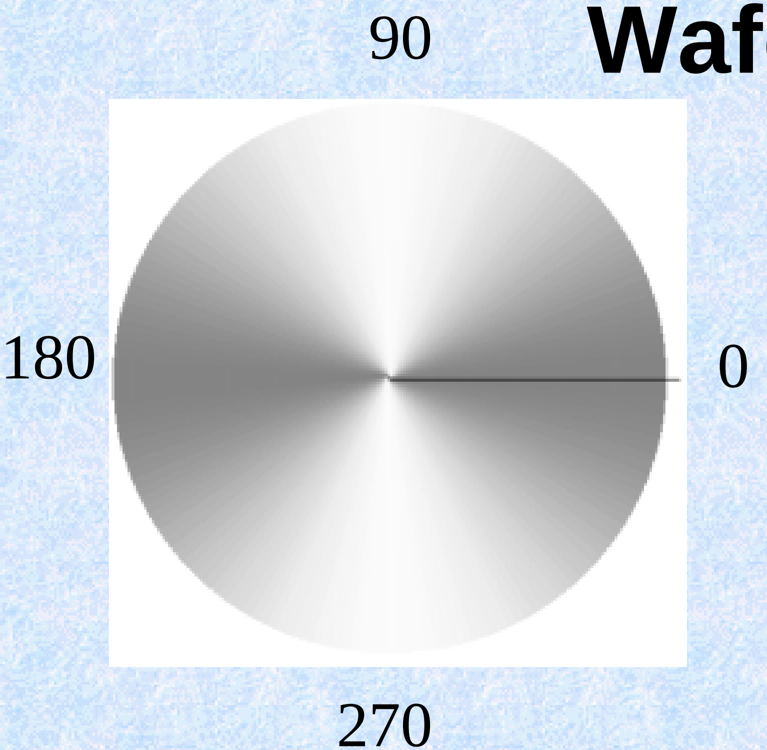
- **Diffraction Efficiency of zero order light from a L/S pattern**
  - $DE_{r,i} = |R_{s,i}|^2 \{k_{r,i}/(k_o.n.\cos\theta)\}$ where $k_{r,i} = [(k_o.n)^2 - k_{x,i}^2 - k_y^2]^{1/2}$
  - $k_o = 2\pi/\lambda_o$, $k_{x,i} = k_o[n.\sin\theta.\cos\phi - i\lambda_o/\Lambda]$, $k_y = k_o\ n.\sin\theta.\sin\phi$
    - Azimuth $\phi = 0^0$ classical diffraction
    - Azimuth $\phi = 90^0$ conical diffraction
    - Incidence angle θ
    - J.Opt Soc. Am. A **12** p.1068, 1995

Classical and Conical Diffraction

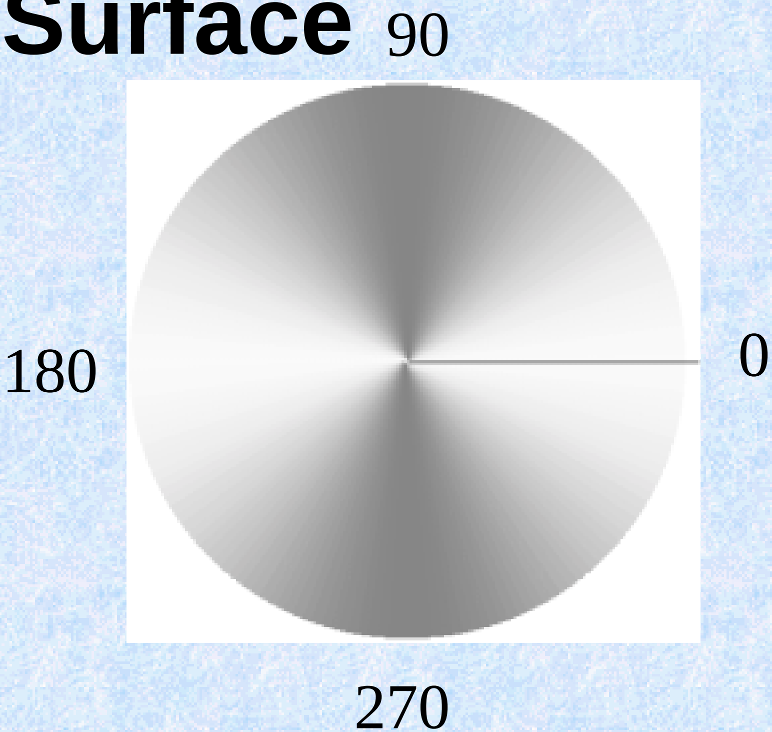


Source: Classical Optics and its Applications by Masud Mansuripur (Publisher Cambridge) p. 234

Simulated Reflectance Map of a Wafer Surface



Spiral scan starts at Classical

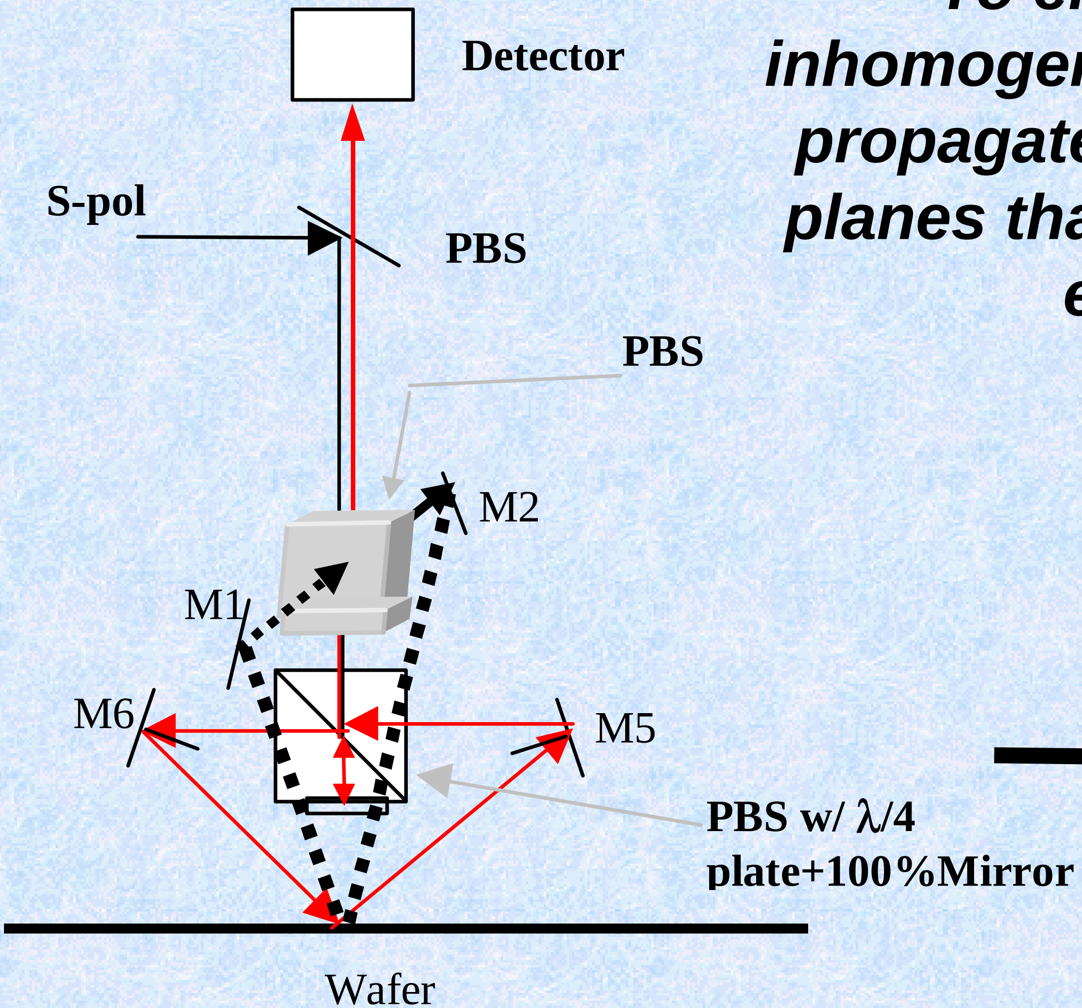


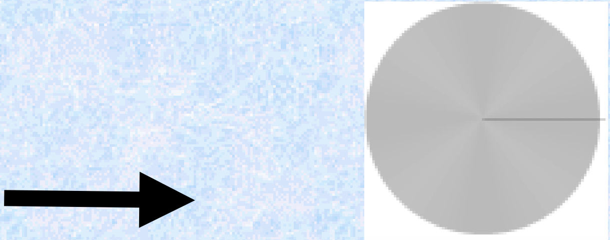
Spiral scan starts at Conical

Image non-uniformity 20%

Verity Approach to Suppress Bow-tie

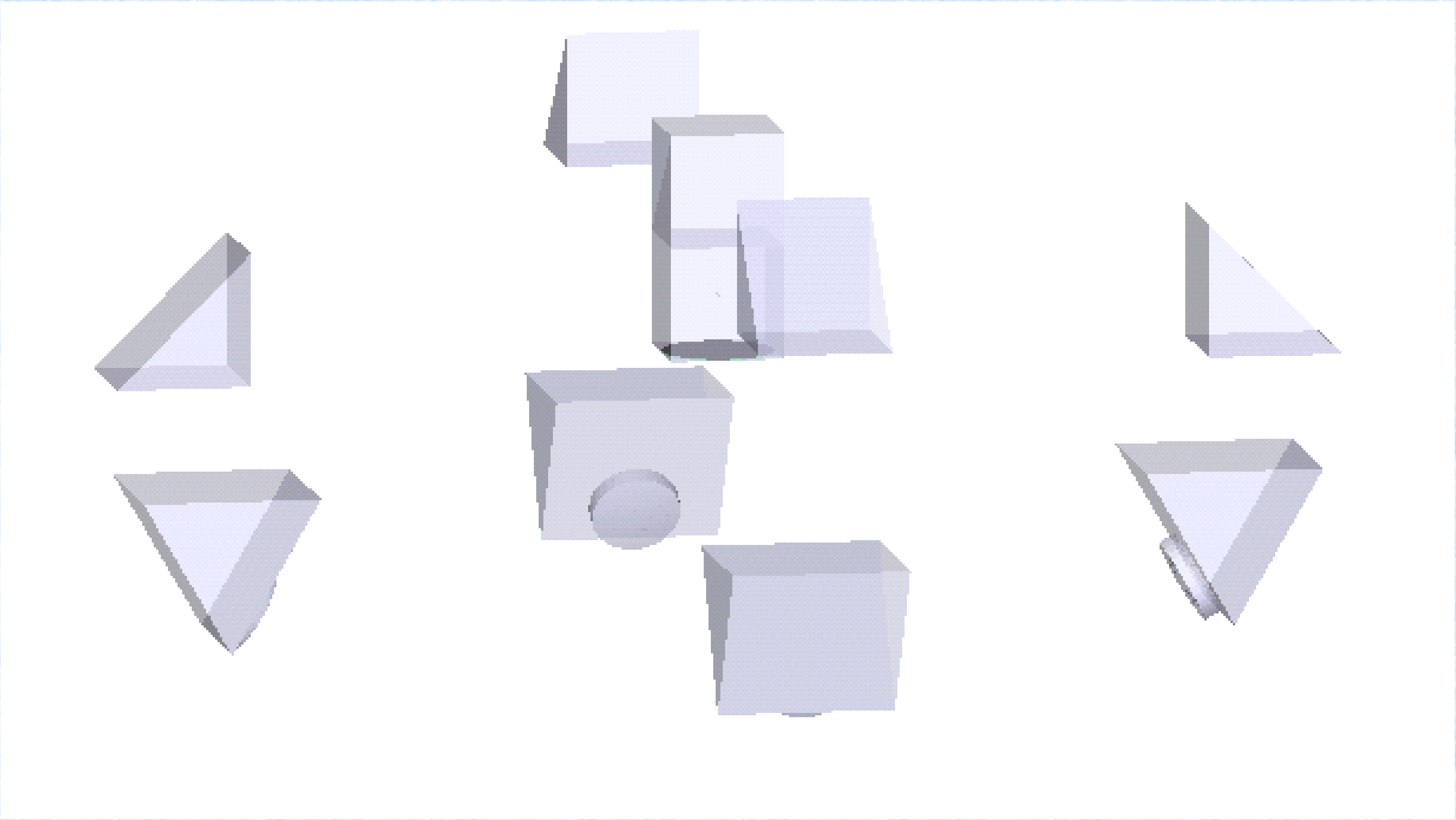
To eliminate image inhomogeneity,the laser beam propagates in two incidence planes that are orthogonal to each other



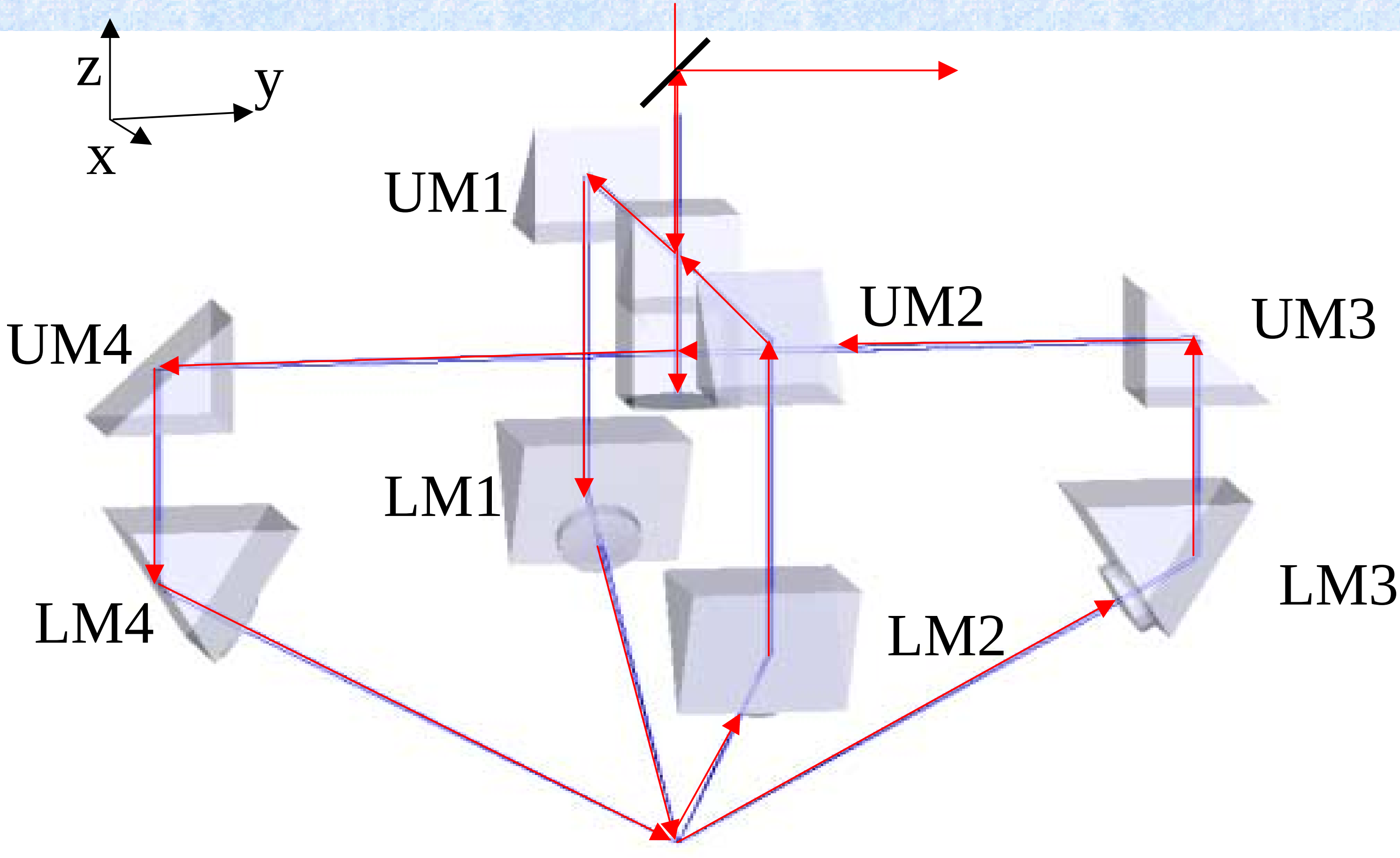


Simulated reflectance map from the embodiment on the left. Image uniformity ~97% @ 60^0 incidence

Optics Arrangement for Bow-tie Suppression

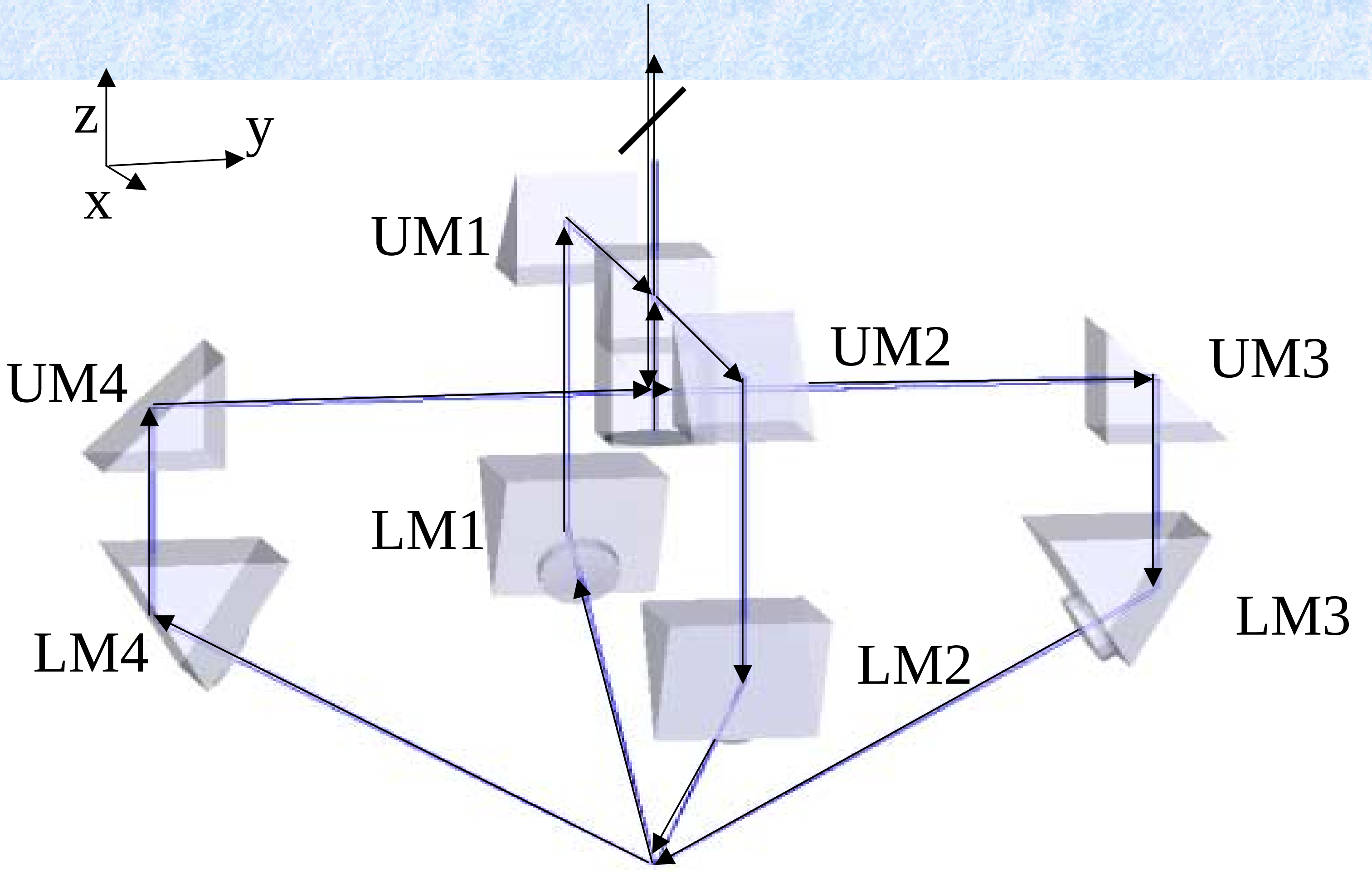


Beam Path for s-pol. Light



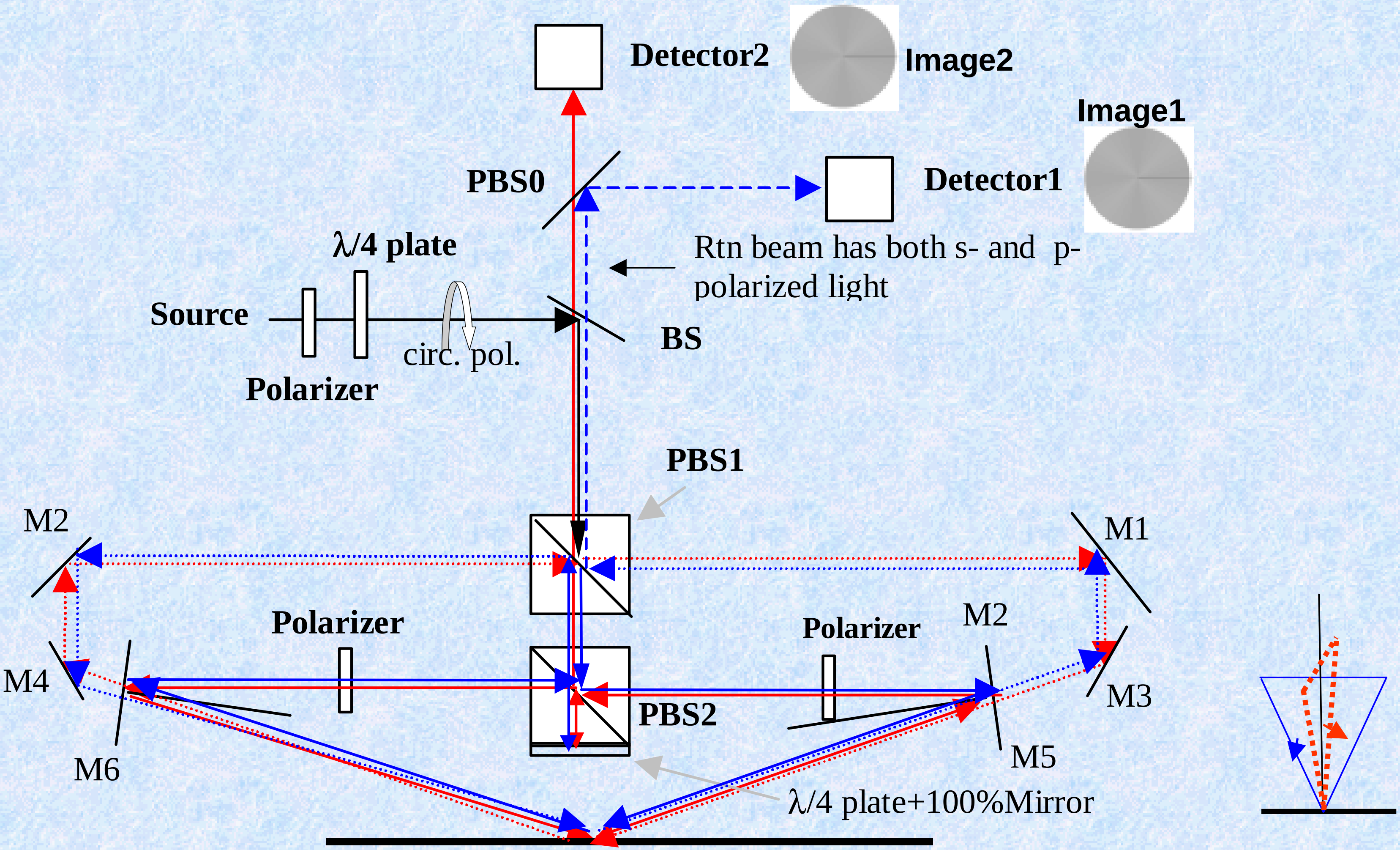
TE polarization in both planes of incidence

Beam Path for p-pol. Light



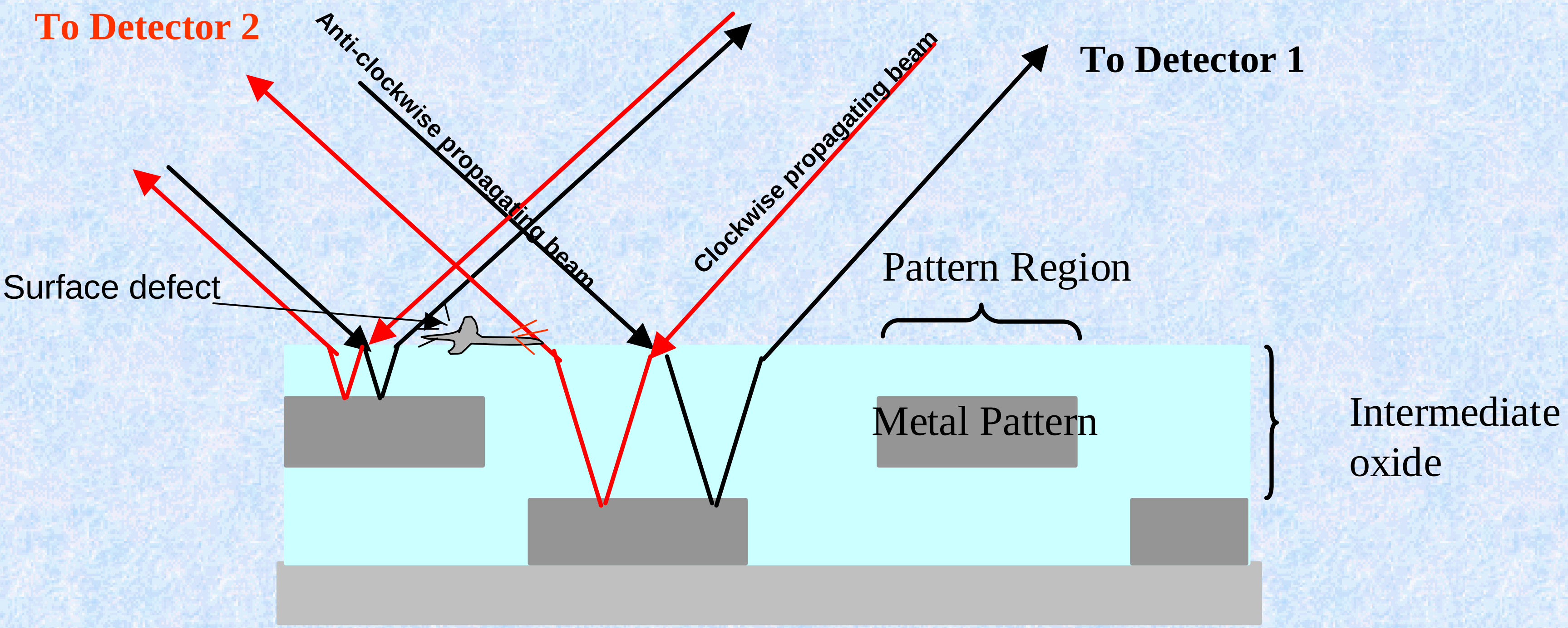
TE polarization in both planes of incidence

Simultaneous Acquisition of Two Wafer Images



S- and P- components of the input beam travel through both planes of incidence as s- polarized beam

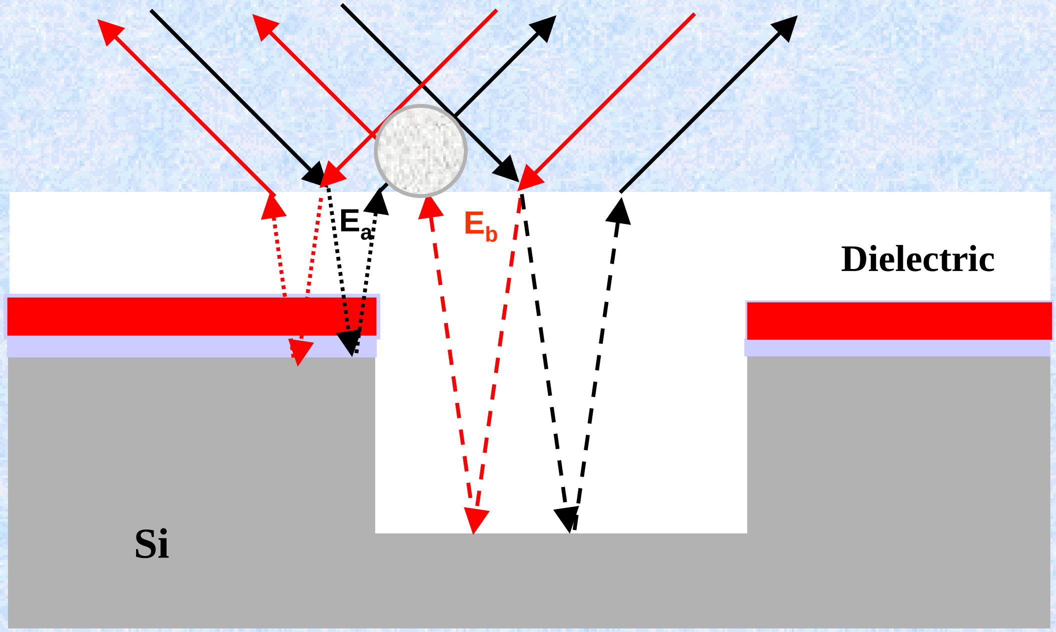
Origin of Difference Image



Because of difference in scattering cross section and difference in local electric field, the two counter propagating beams should experience different amount of scattering at the defect site. Therefore the difference signal should have no or minimal:

1. Die misalignment noise, Color Noise and Pattern noise
2. Impact from under layer in recipe preparation

Role of Field Asymmetry in Defect Detection



Region A **Region B**

Region A

$$\begin{pmatrix} p & q \\ r & s \end{pmatrix} = \begin{pmatrix} 1 & r_{Diel} \\ r_{Diel} & 1 \end{pmatrix} \begin{pmatrix} e^{i\delta_{DielA}} & r_{SiN} e^{i\delta_{DielA}} \\ r_{SiN} e^{-i\delta_{DielA}} & e^{-i\delta_{DielA}} \end{pmatrix} \begin{pmatrix} e^{i\delta_{SiN}} & r_{Ox} e^{i\delta_{SiN}} \\ r_{Ox} e^{-i\delta_{SiN}} & e^{-i\delta_{SiN}} \end{pmatrix} \begin{pmatrix} e^{i\delta_{Ox}} & r_{Si} e^{i\delta_{Ox}} \\ r_{Si} e^{-i\delta_{Ox}} & e^{-i\delta_{Ox}} \end{pmatrix}$$

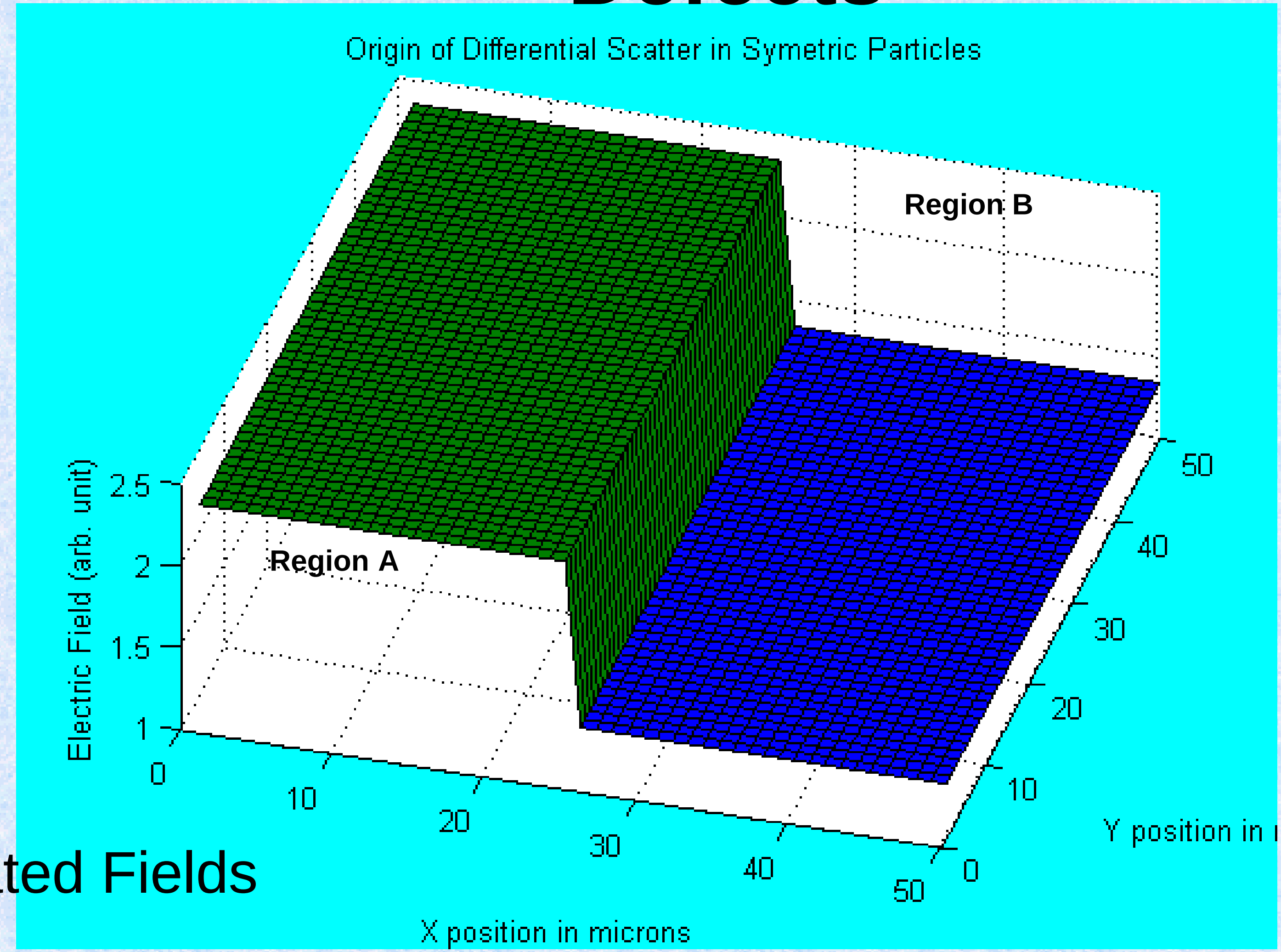
$E_a = r/p$

Region B

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} = \begin{pmatrix} 1 & r_{Diel} \\ r_{Diel} & 1 \end{pmatrix} \begin{pmatrix} e^{i\delta_{DielB}} & r_{Si} e^{i\delta_{DielB}} \\ r_{Si} e^{-i\delta_{DielB}} & e^{-i\delta_{DielB}} \end{pmatrix}$$

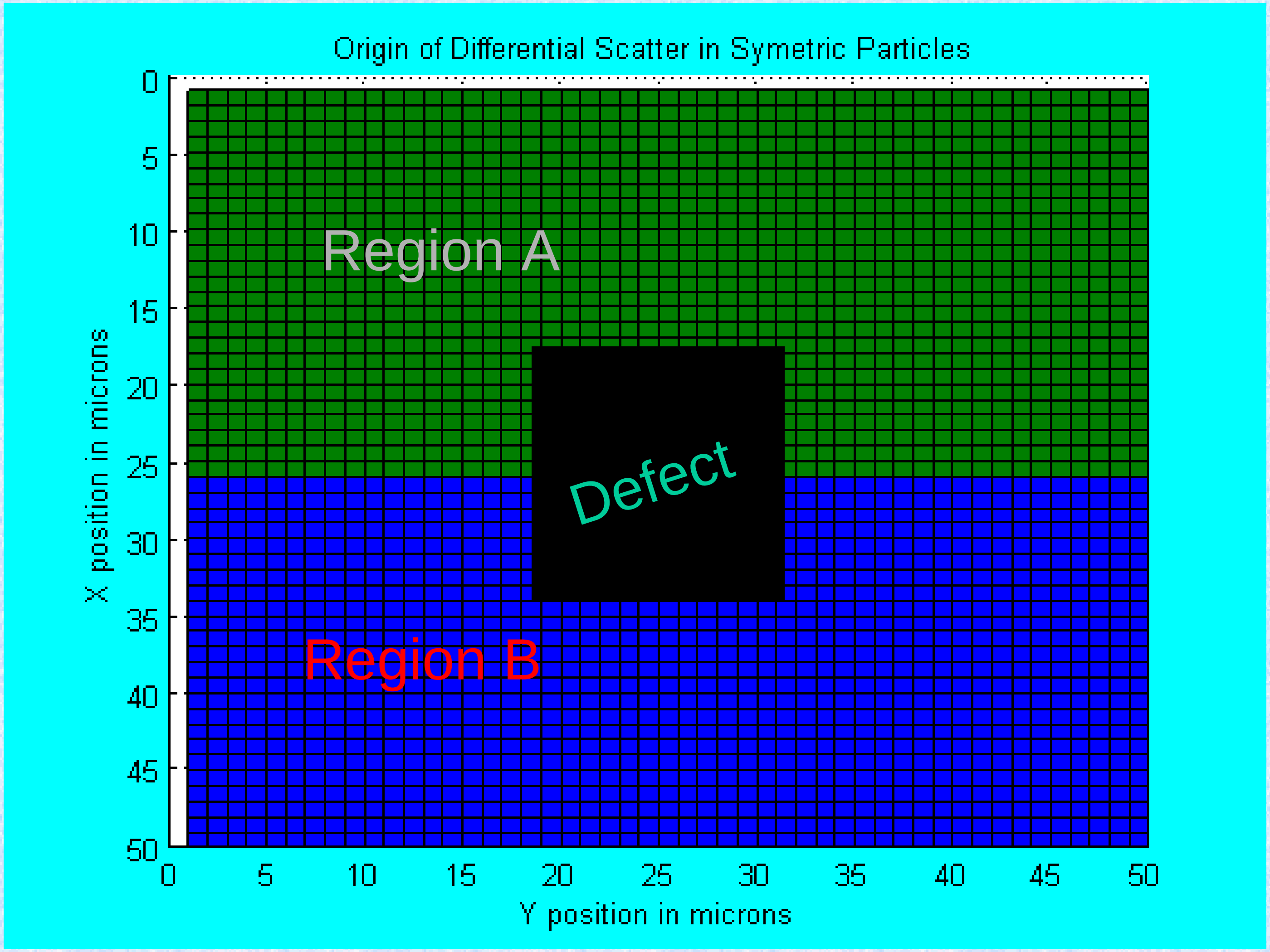
$E_b = c/a$

Electric Field Difference Experienced by Symmetric Defects

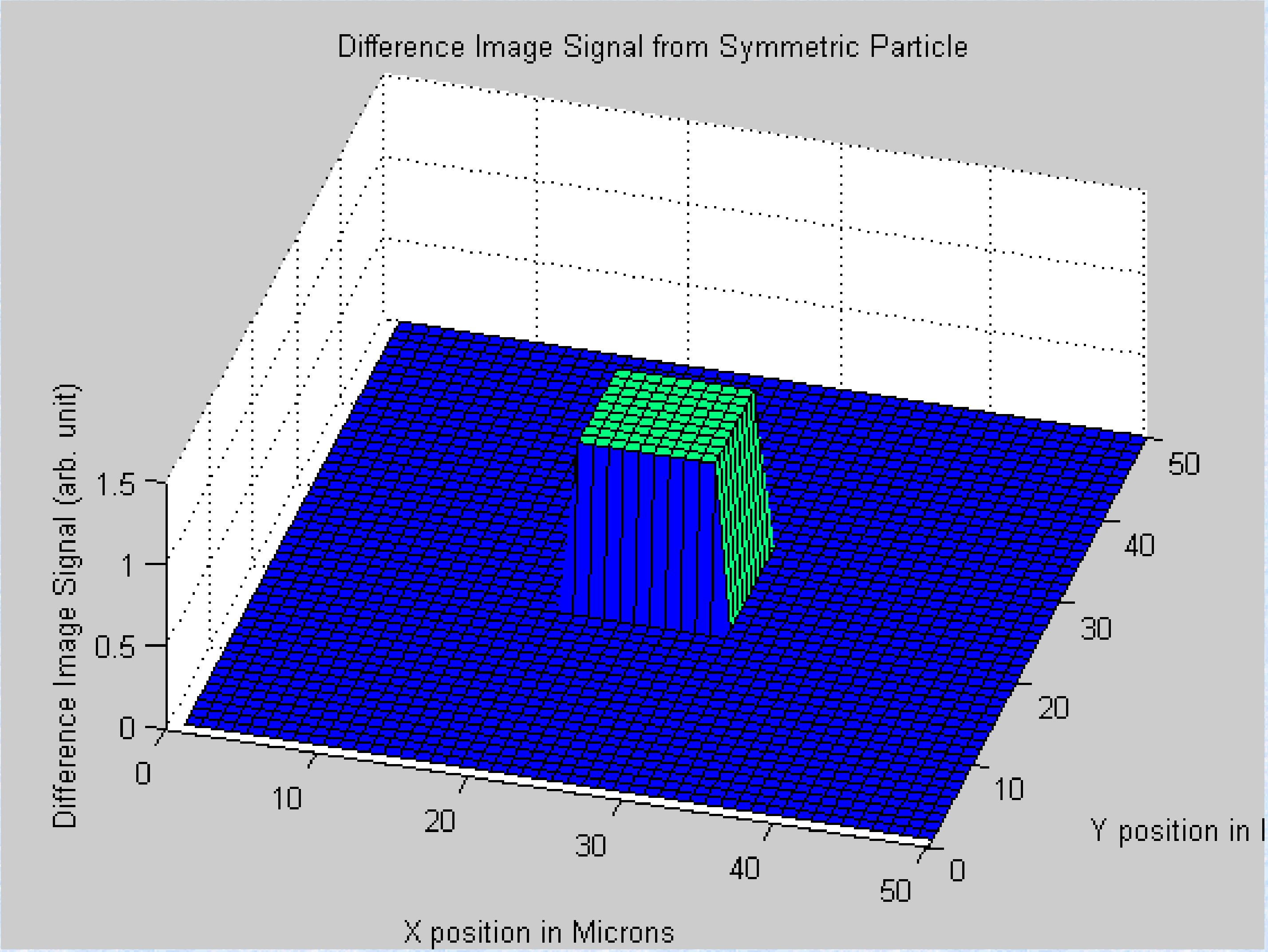


Simulated Fields

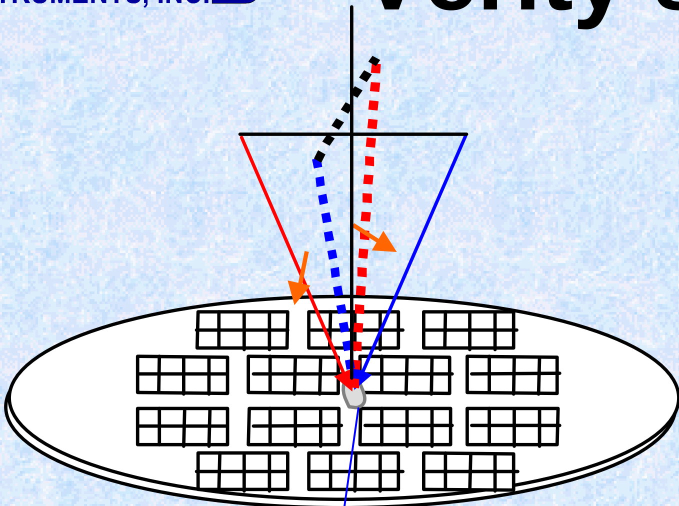
Asymmetric Field Experienced by Symmetric Defects



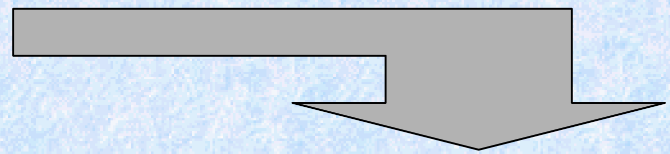
Difference Image Signal due to Symmetric Defect



Verity's Die By Die Subtraction Approach



Symmetric Illumination of Wafer



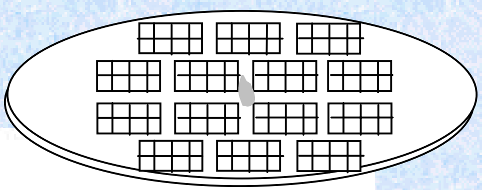


Image from Detector1 (say)

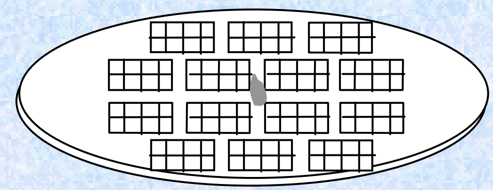
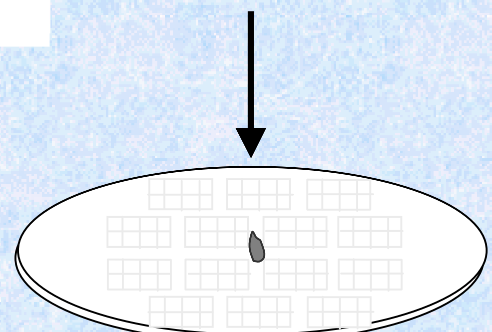


Image from Detector2 (say)

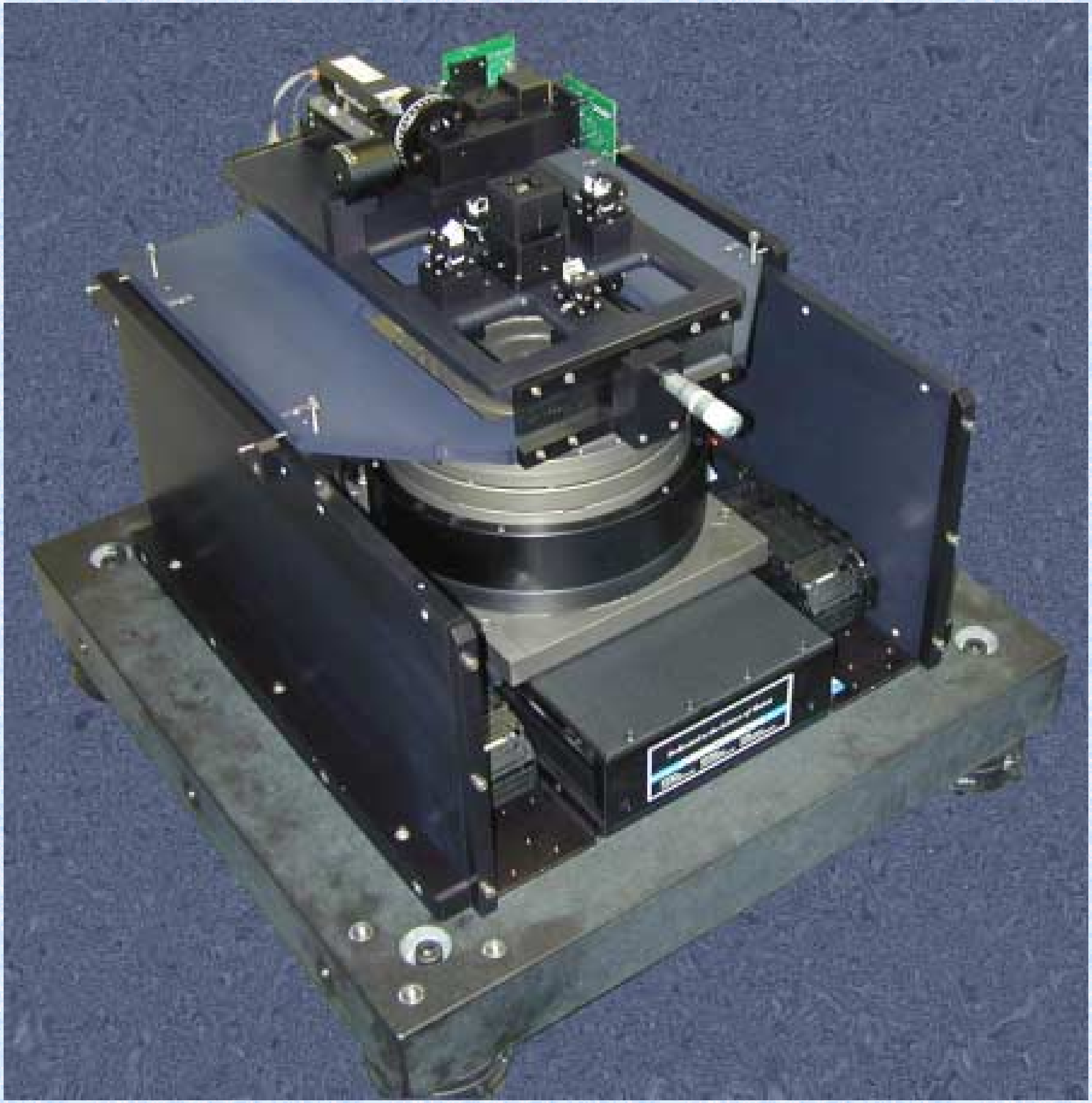
Img1 – Img2



Difference Image Enhances Defect and suppresses Background Noise

- Die misalignment Elimination
- Color Noise mitigation
- Pattern noise reduction
- Minimal Impact from Under layer in recipe preparation

Macro Inspector System



Envelope: 24x24x18 in^3