Addressing High Precision Automated Optical Inspection Challenges with Unique 3D Technology Solution

John Hoffman
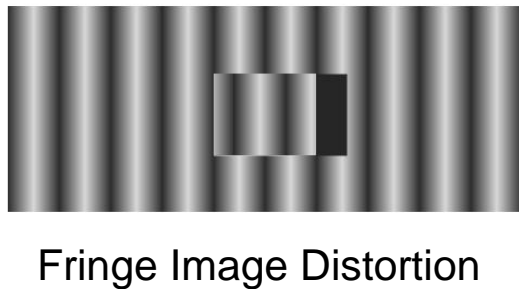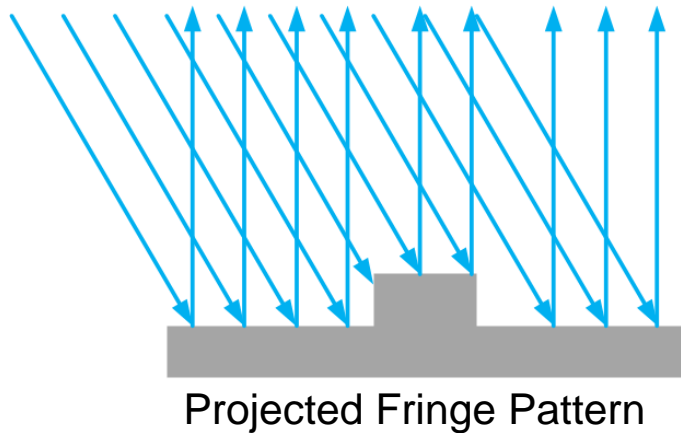## CyberOptics Corporation
jhoffman@cyberoptics.com

CYBEROPTICS

Outline/Agenda

- **Phase Profilometry**
- **SMT Assembly Imaging Challenges**
- **3D Technology Solution**
- **Results**
- **Conclusions**
- **Q & A**

Phase Profilometry

Projected Fringe Pattern

Fringe Image Distortion

$$I = I_0 R(1 + m \sin(2\pi f_x + \phi_0))$$

Advantages

- Combination of speed and accuracy when properly architected
- Micron level accuracy

Challenges

- Tall components
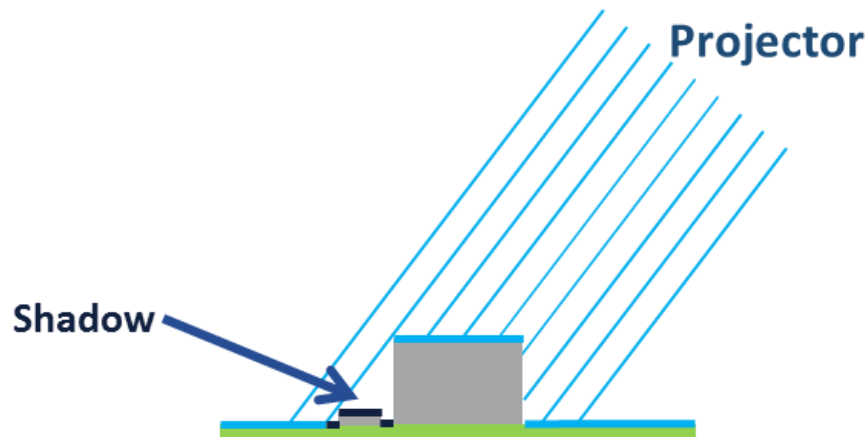- Highly reflective surfaces
- Odd shapes
- Inspection speed

SMT Assembly Imaging Challenges

- Tall Components

- Highly Reflective Surfaces

- Odd Shapes

- Inspection Speeds

Tall Component Challenges

Projector

Shadow

Small components and features are shadowed

- Small passives next to taller RF shields
- SMT assemblies with THT components
- SMT connector leads shadowed by other components and connector body

Sufficient range to measure above 10mm
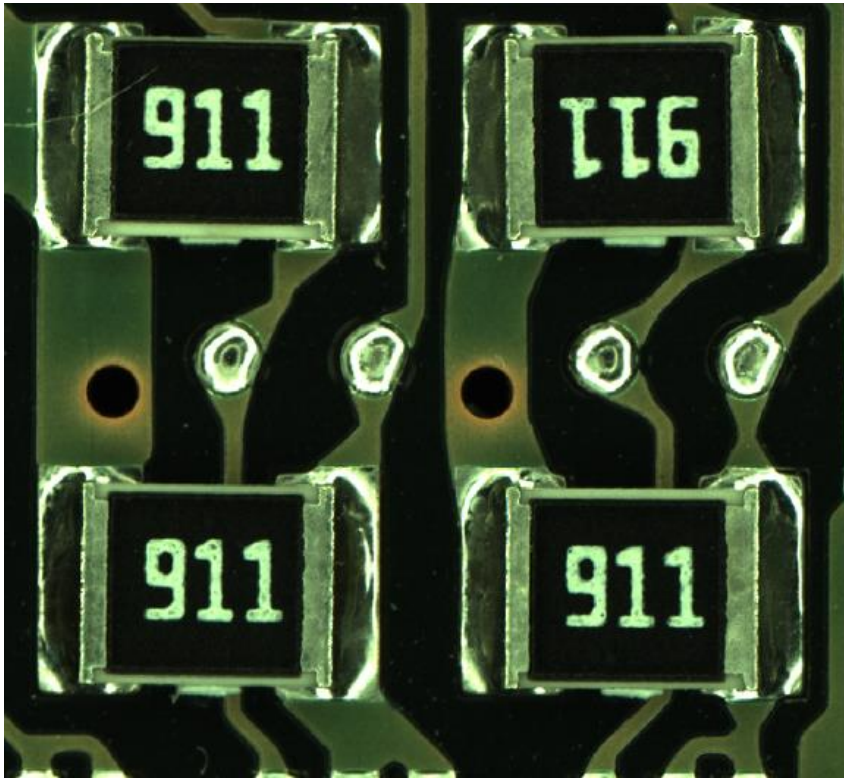
Challenges Imaging SMT Assemblies

- Tall Components
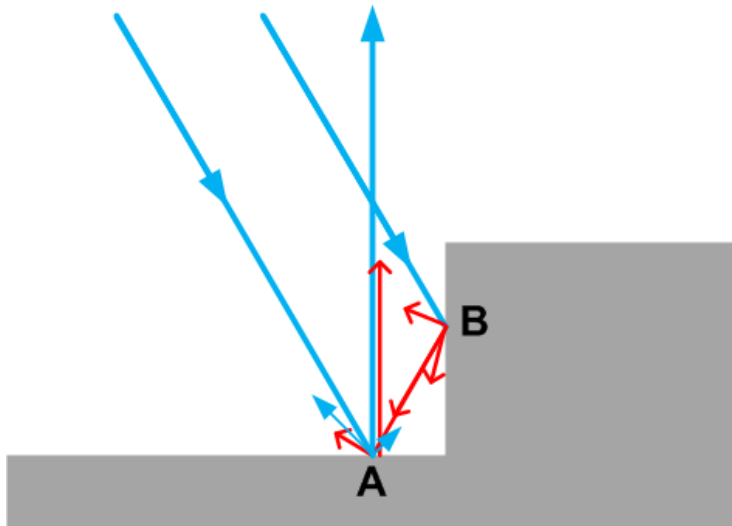
- Highly Reflective Surfaces

- Odd Shapes

- Inspection Speeds

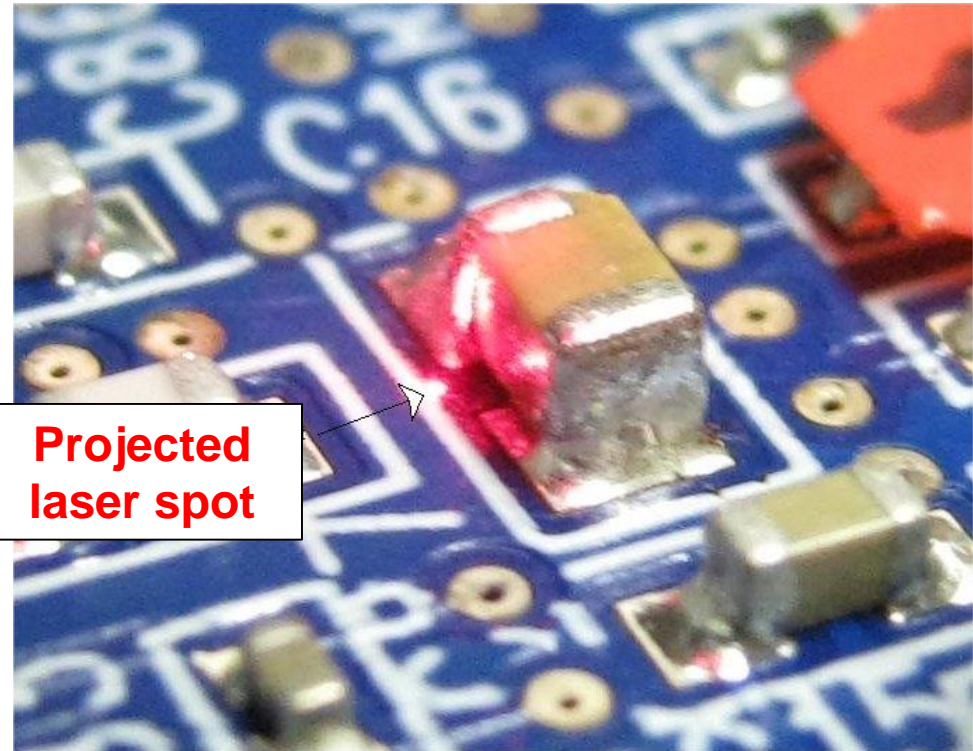# Typical PCB with Highly Reflective Solder Joints

- Some mirror-like surfaces will cause camera saturation
- Other mirror-like surfaces will reflect light completely away from camera
- Severity of multiple reflections increase with highly reflective surfaces

Multiple Reflections

Observed Intensity at Point A is Altered by Scattered Reflection at Point B

Laser Experiment to Visualize Multiple Reflections

Challenges Imaging SMT Assemblies

- Tall Components

- Reflective Surfaces

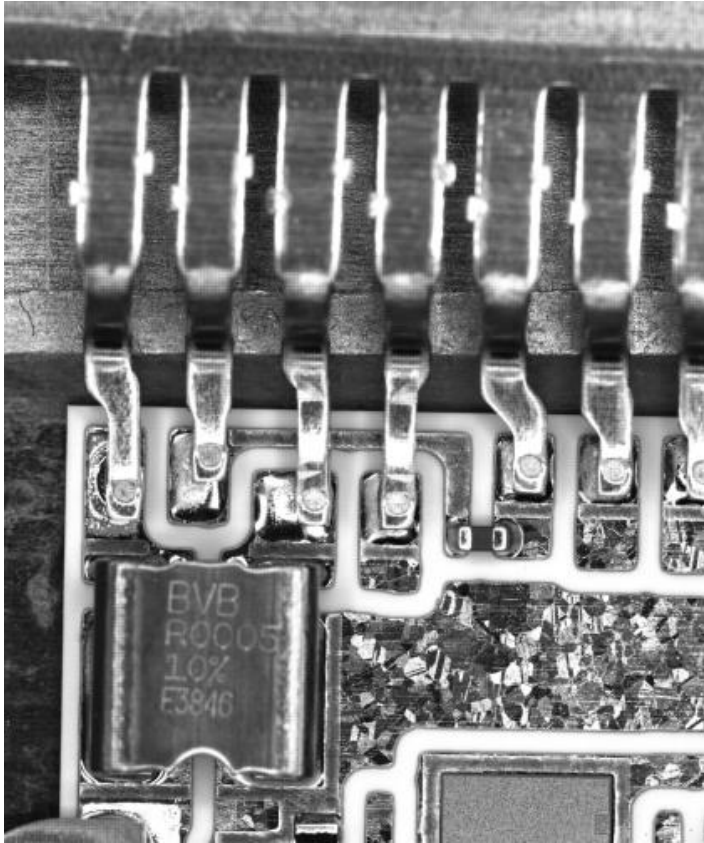- Odd Shapes

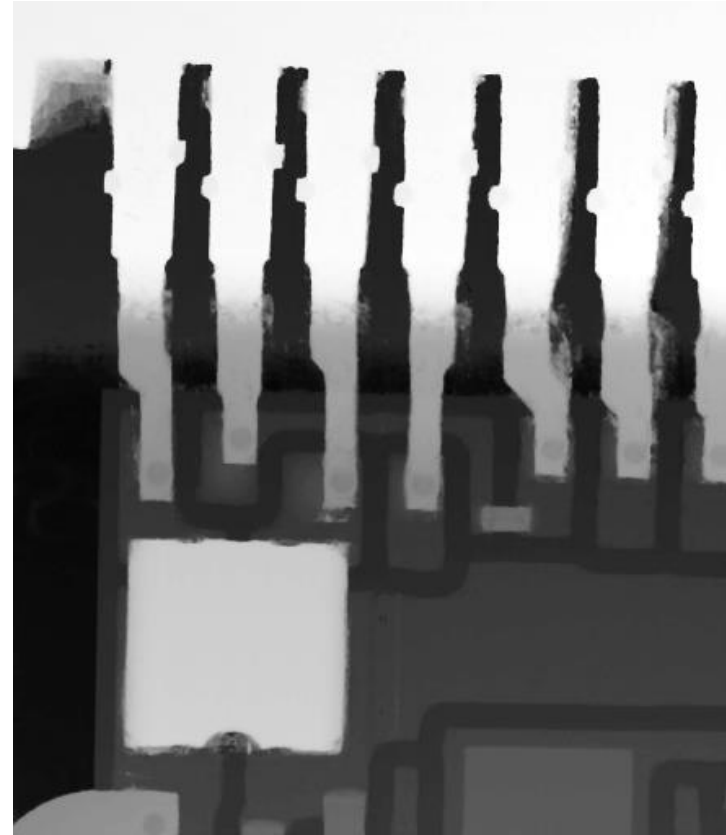- Inspection Speeds

Odd Shapes

Image data in 2D

Image data in 3D

Challenges Imaging SMT Assemblies

- Tall Components

- Reflective Surfaces

- Odd Shapes

- Inspection Speeds

Inspection Speed

- Image acquisition – 10X more images
  - Traditional 2D Image technology - up to 2-3 images with different illumination at each FOV
  - 3D systems require all of the 2D imagery plus
    - At least 6, and likely more, images from each projector (4x)
   - RGB images if using monochrome imaging detector for each illumination type (+3x)

Inspection Speed

- **Image Processing**
  - All existing 2D inspection
  - Plus processing to obtain 3D height information
  - Plus additional 3D task processing

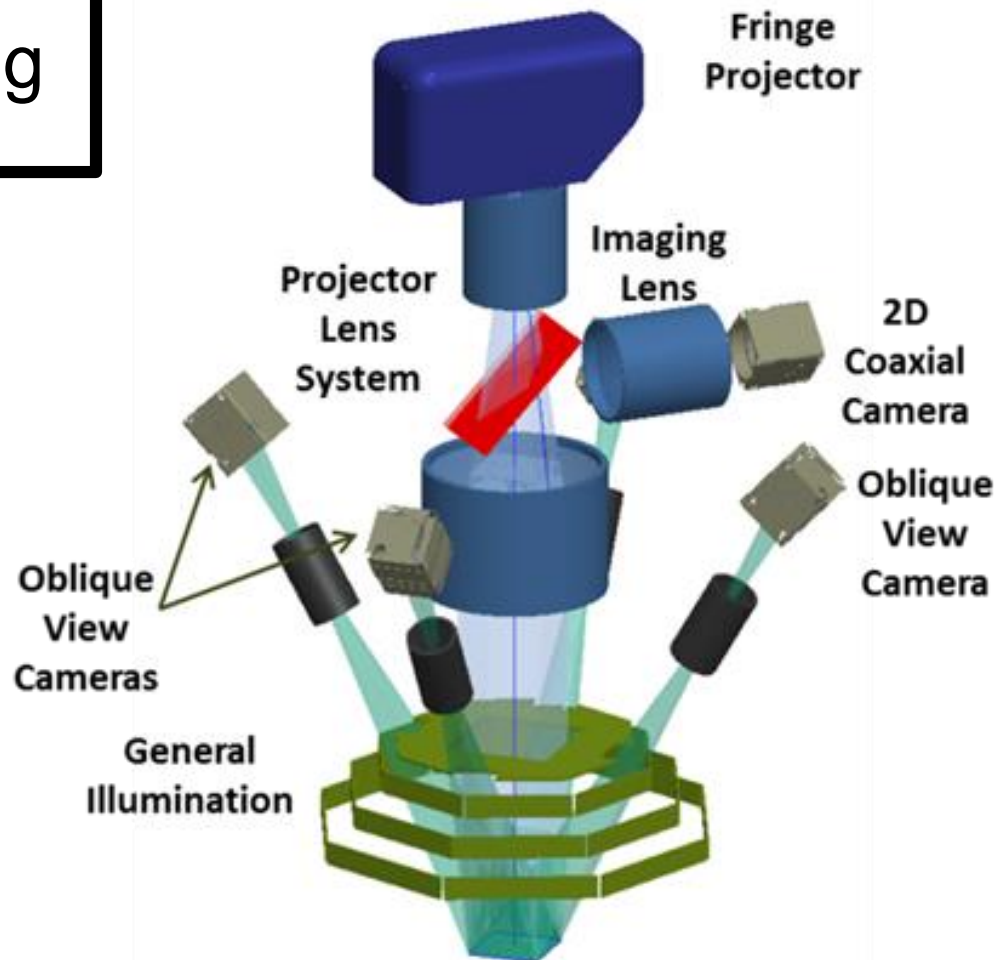# Sensing Architecture to Overcome Inspection Challenges

- Parallel 3D Sensing

- Flexible fringe projector

- Model accurate height information
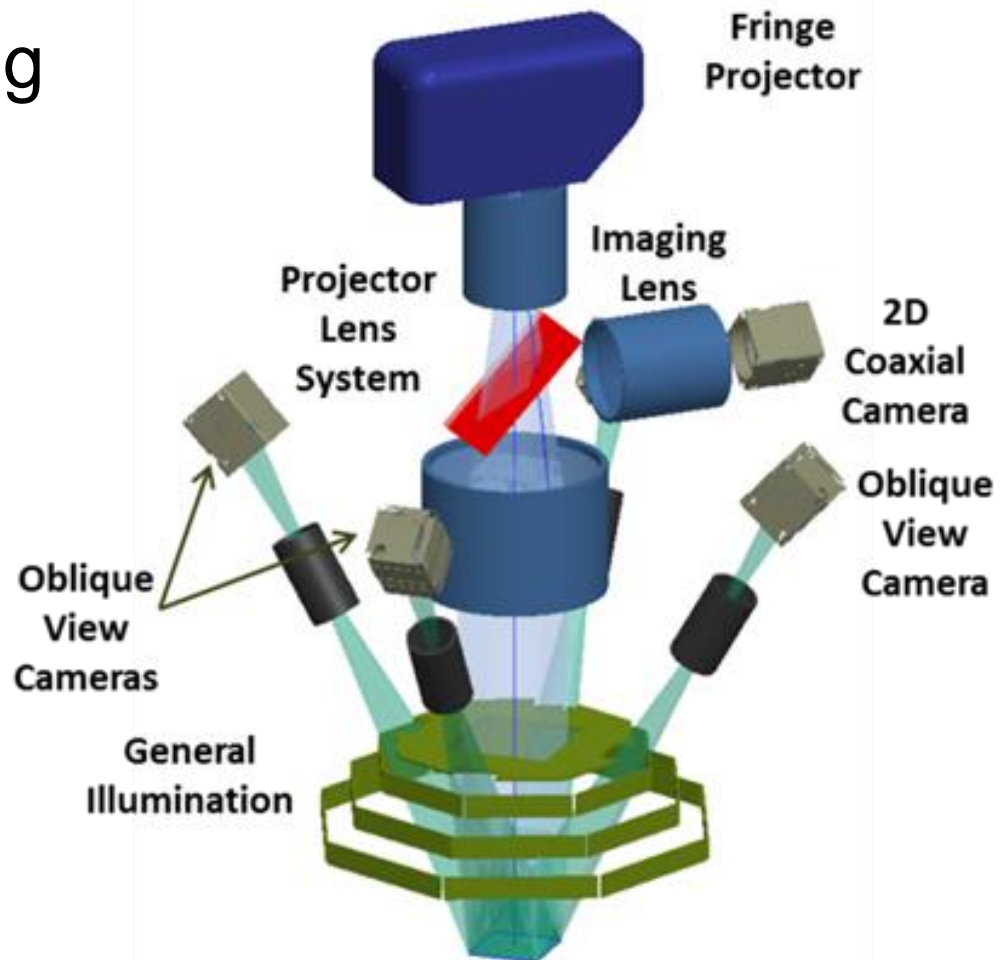
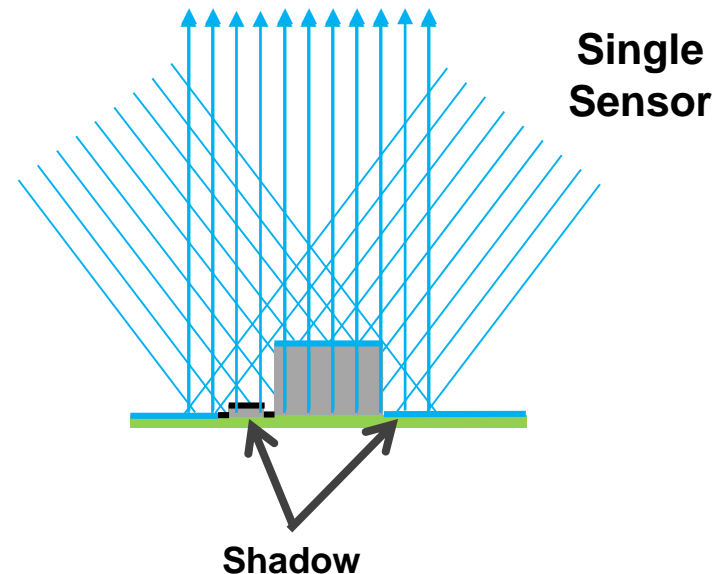# Sensing Architecture to Overcome Inspection Challenges

- Parallel 3D Sensing

- Flexible fringe projector
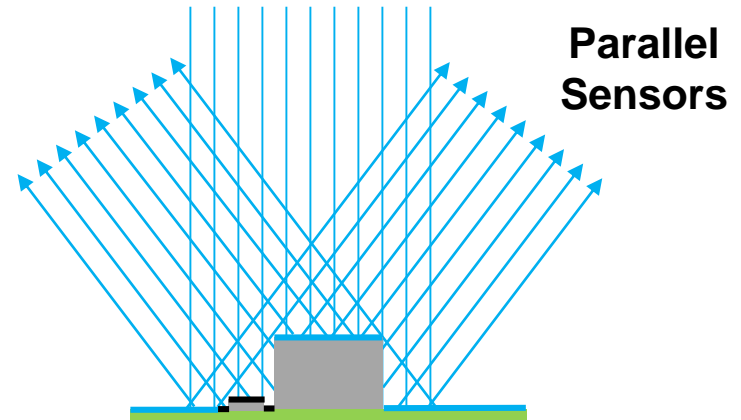
- Model accurate height information

Single 3D Sensing

- With AOI a shadow effect is inevitable

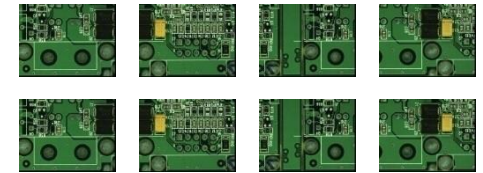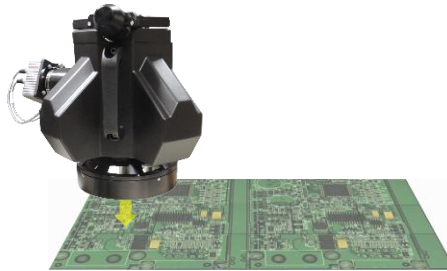- Single sensor system uses multiple sources to obtain necessary information

Single Sensor

Shadow

Parallel 3D Sensing

- Multiple sensor can simultaneously obtain all necessary information in parallel
- Increases potential speed

Parallel Sensors
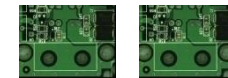
Advantage of Parallel Architecture is Acquisition Speed
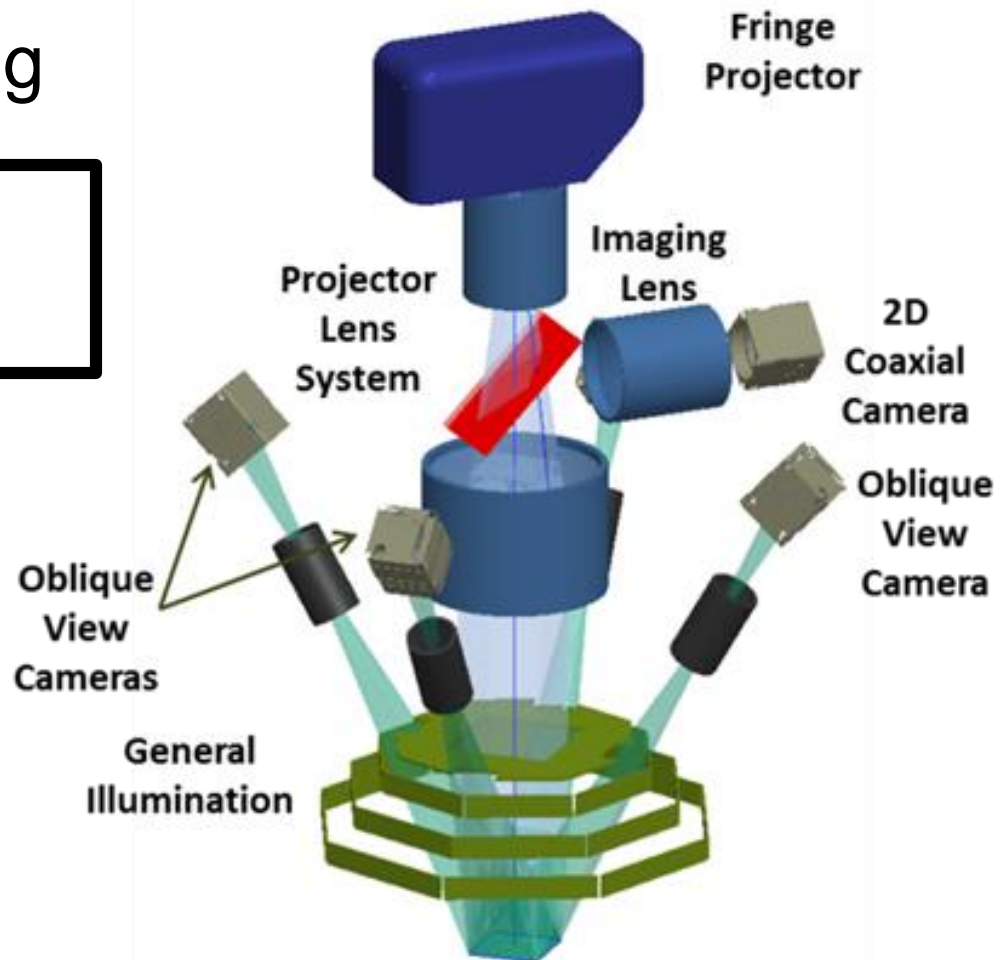
- **Parallel 3D Sensing**

- **Single Sensor**

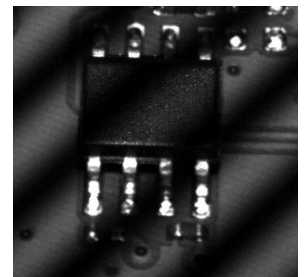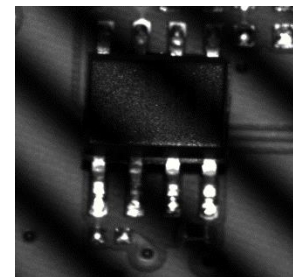# Sensing Architecture to Overcome Inspection Challenges

- Parallel 3D Sensing

- Flexible fringe projector

- Model accurate height information

Fringe Projector

Projector Lens System

Imaging Lens

2D Coaxial Camera

Oblique View Camera

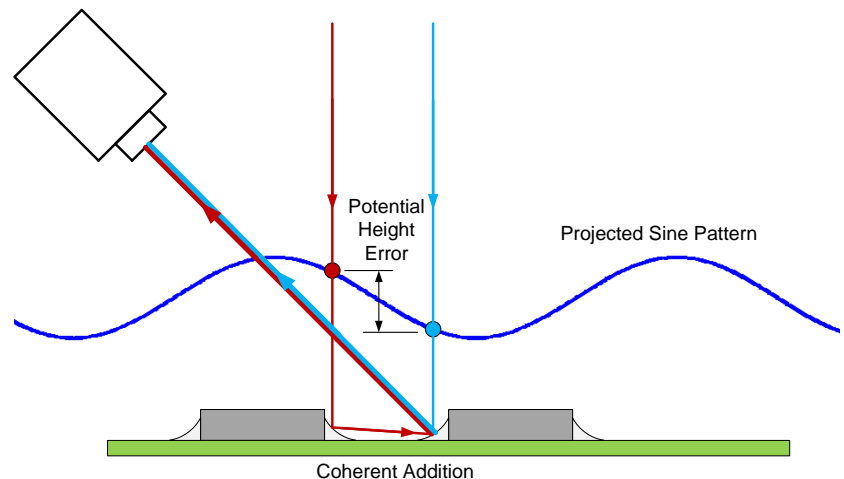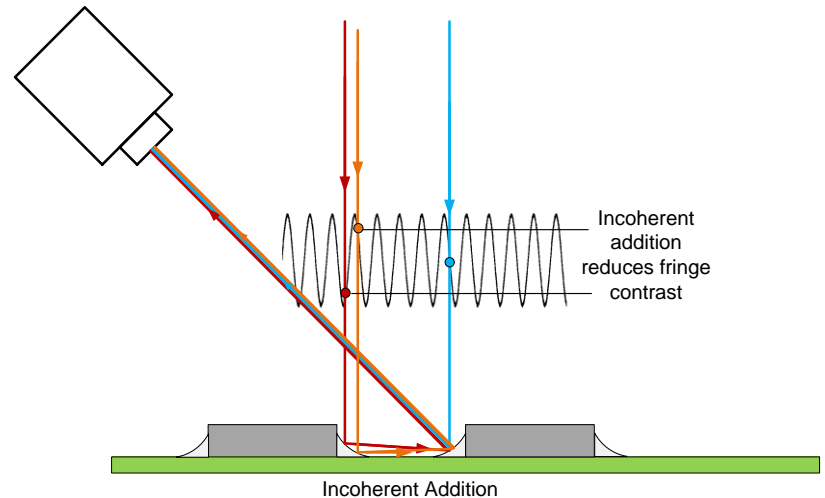Oblique View Cameras

General Illumination

Flexible Illumination

- **Programmable 3D illumination projector using DLP or LCoS technology**
  - ☐ Any pattern in any direction
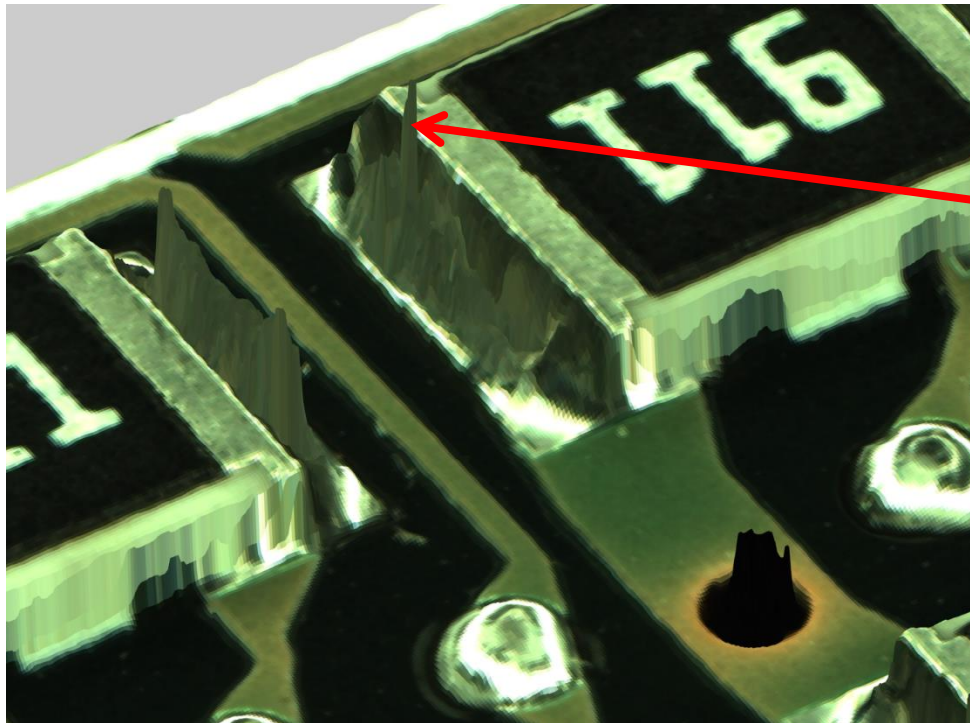 - ☐ Wide and varying height range suited to application
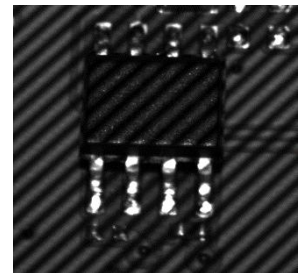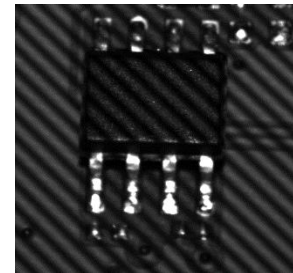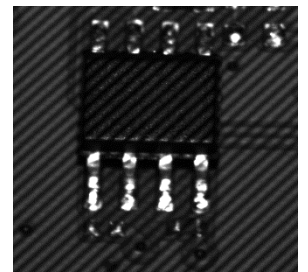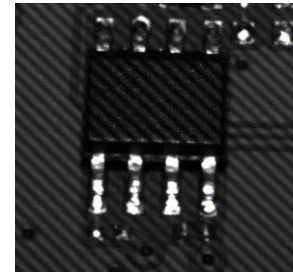
Detecting and Suppressing Multiple Reflections

- **Multiple reflections do occur, but provide different return at**
  - ☐ Different projection frequencies
  - ☐ Different camera angles
- **Used to separate the primary reflections from the secondary**

Incoherent addition reduces fringe contrast

Incoherent Addition

Potential Height Error
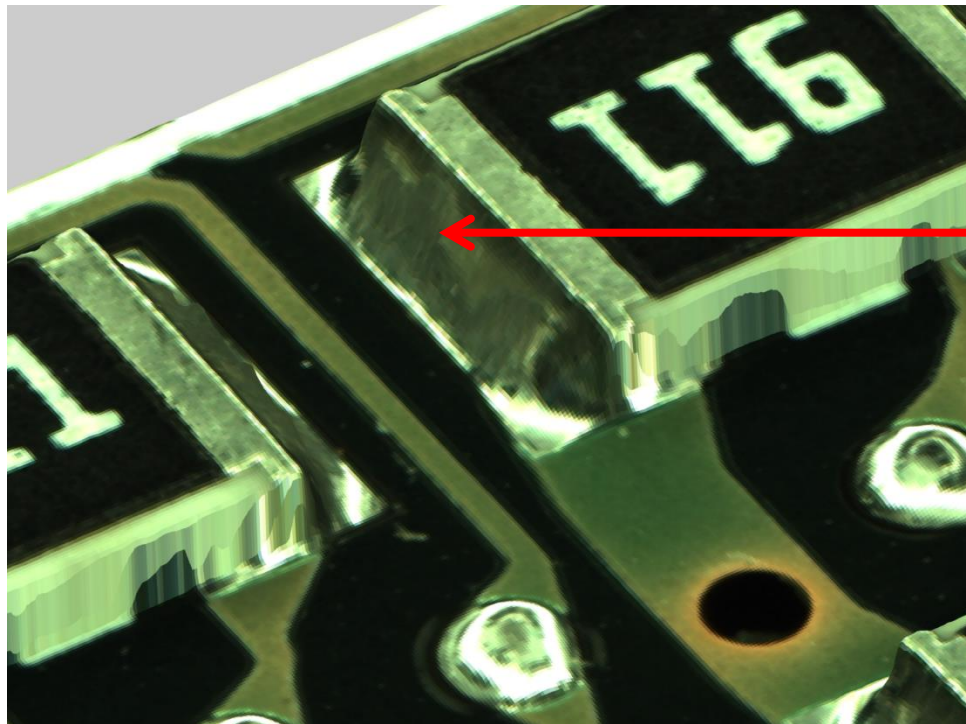
Projected Sine Pattern

Coherent Addition

Without Multiple Reflection Suppression Techniques
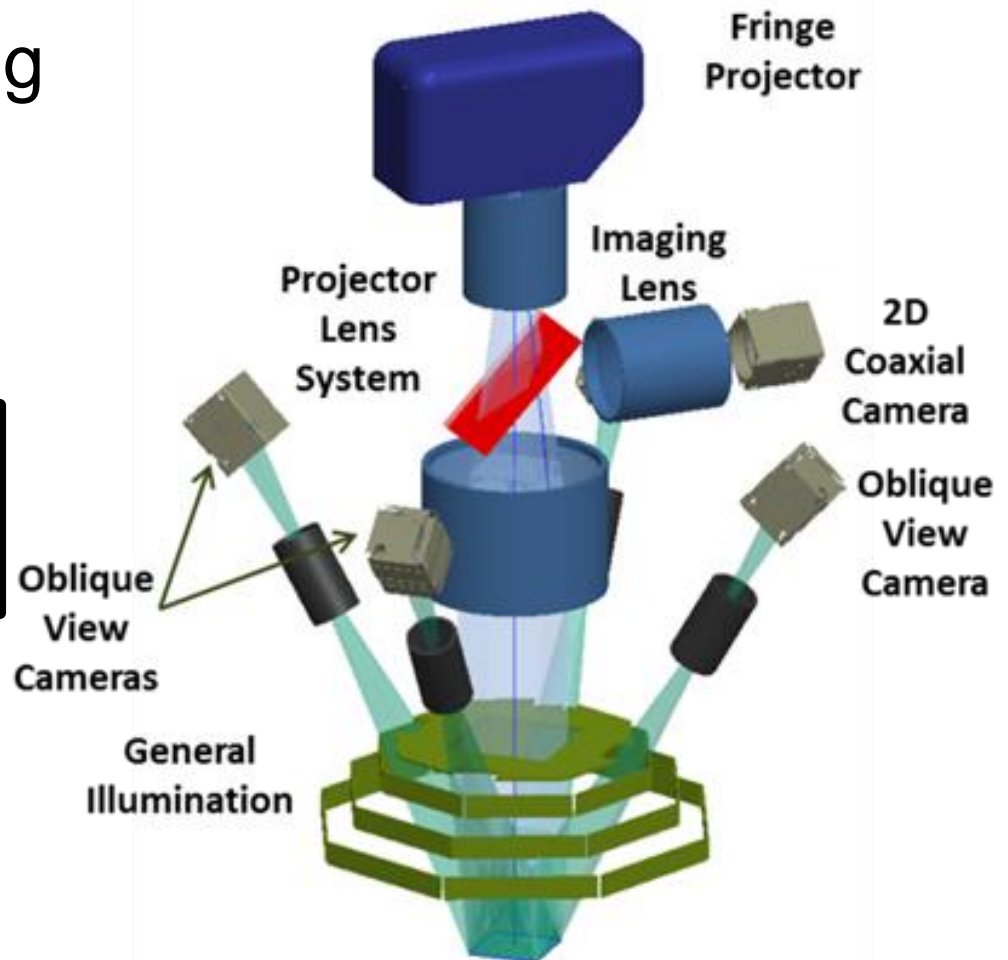

Height Spikes

With Multiple Reflection Suppression Techniques

Height Spikes Eliminated

Sensing Architecture to Overcome Inspection Challenges

- Parallel 3D Sensing

- Flexible fringe projector

- Model accurate height information
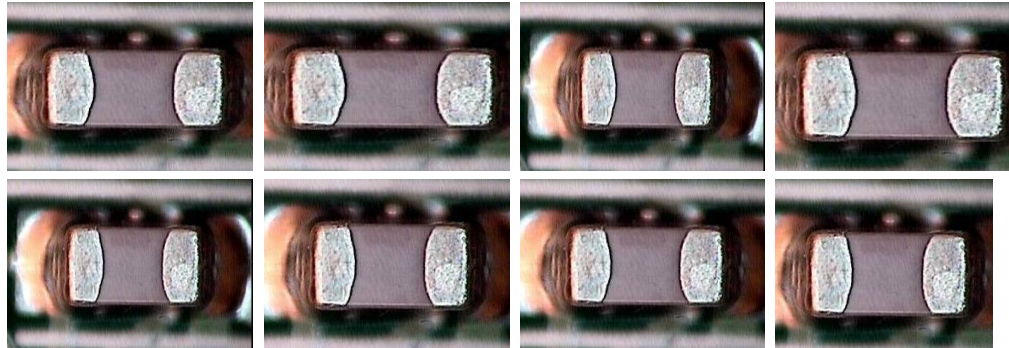
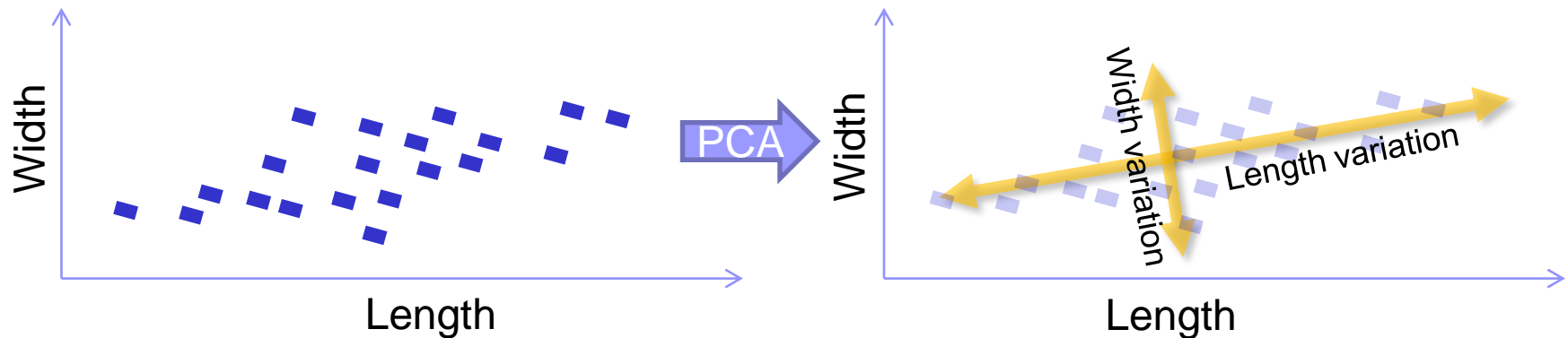# PCA Learns Normal to Detect Abnormal

Original

5% Larger

5% Larger Eye Only

Principal Component Analysis (PCA) Basic Concept

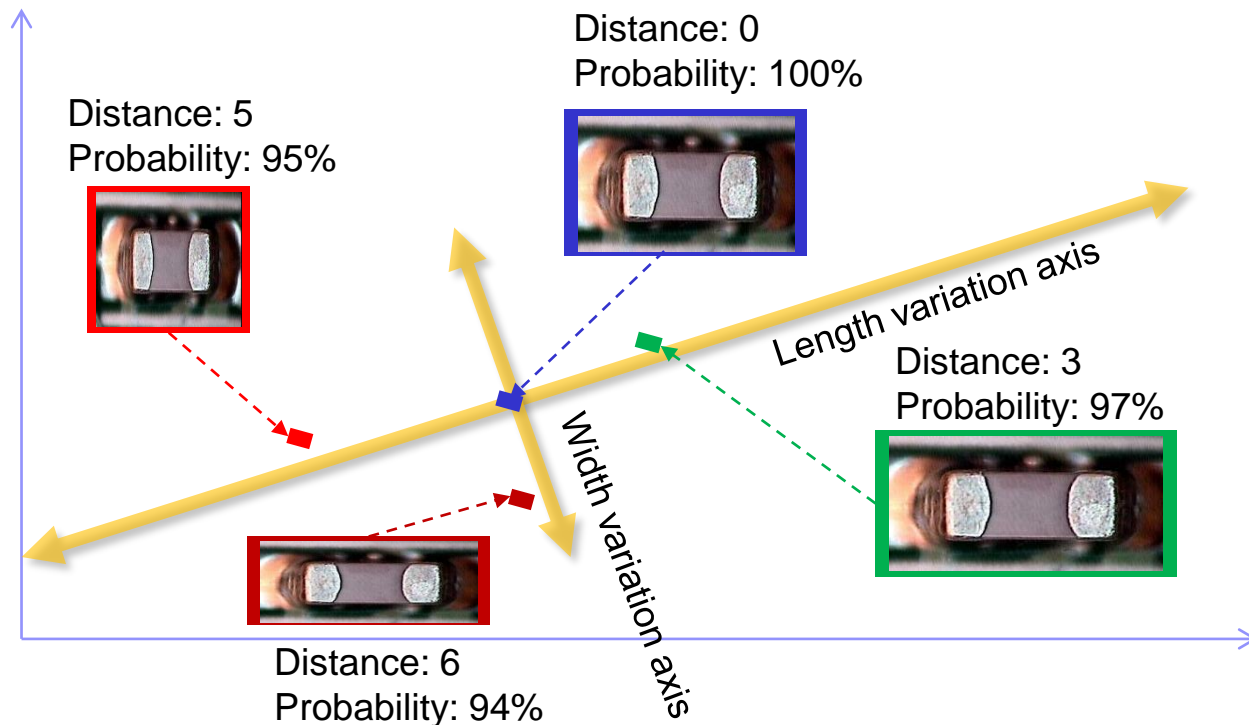For example, resistors with only differences in width and length
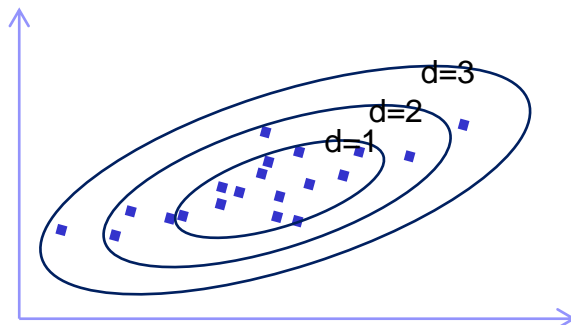

Principal **C**omponent **A**nalysis to discover key variation axes

Principle Component Analysis Basic Concept
Inspection

✓ Calculate how far the new sample is from the model based on **Mahalanobis distance**

Distance: 5
Probability: 95%

Distance: 0
Probability: 100%

Length variation axis

Distance: 3
Probability: 97%

Width variation axis

Distance: 6
Probability: 94%

3D Image Information

- Modeling using height information instead of intensity information
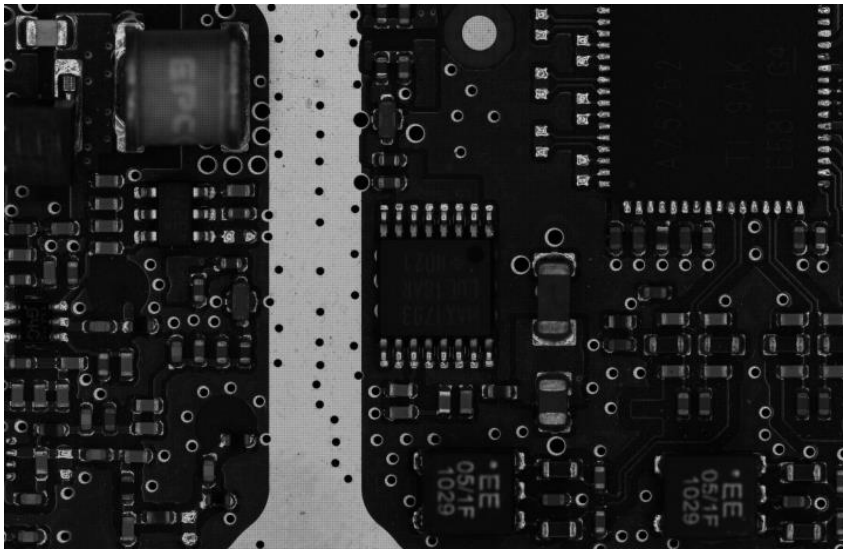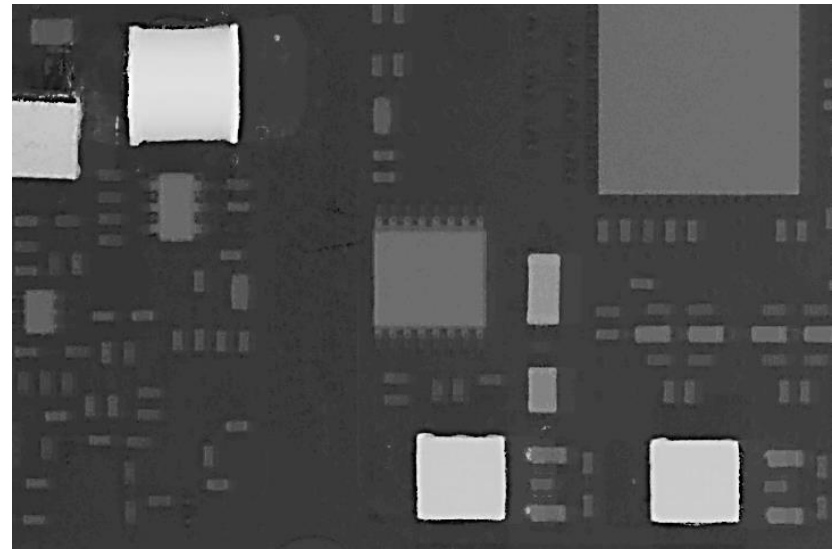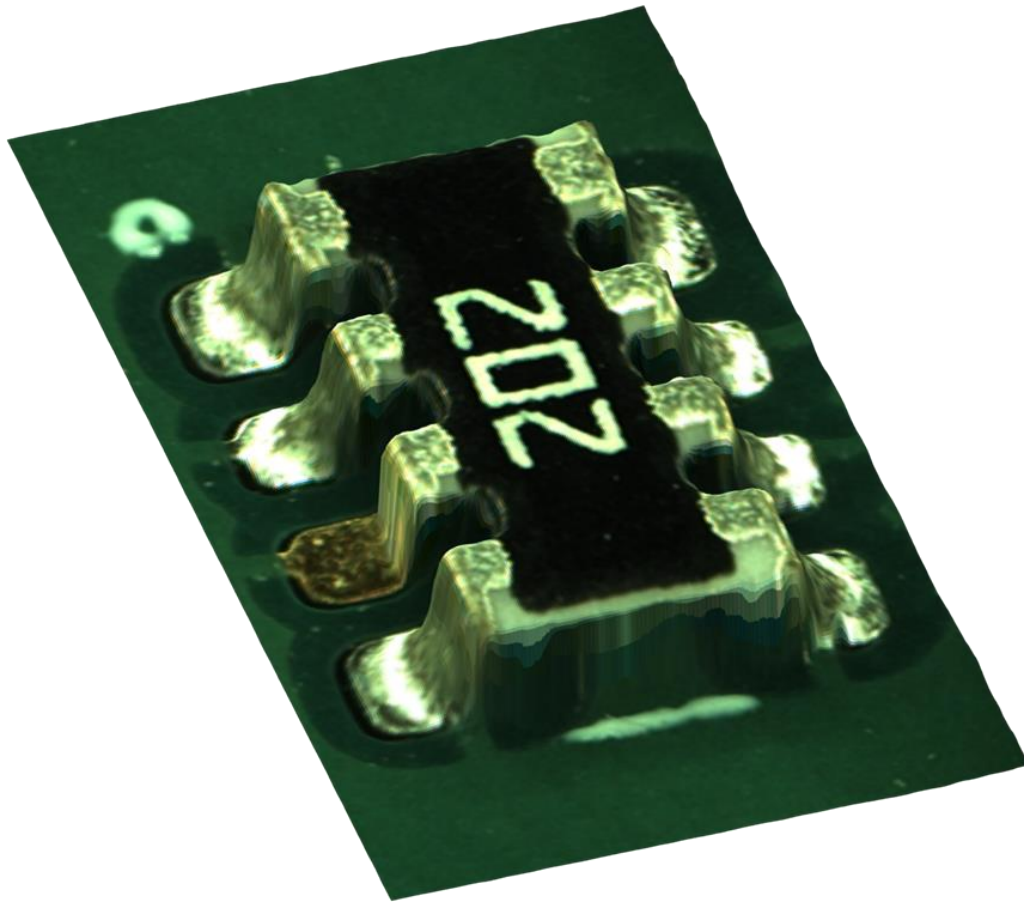

Image data in 2D

Image data in 3D

Results

Conclusion

- There are many inspection challenges for 3D AOI systems to overcome

- Technological architecture enables the best solutions to these challenges

- Understanding how an inspection system accomplishes inspection is key to choosing the right system for your needs