PRECISION IN FOCUS
Innovative Inspection and Measurement Solutions
Why use In-line Inspection?

Return on Investment through:

- Improve Processes
- Increase Quality
- Faster Cycle Time
- Higher Yield
- Increase Delivery Reliability
- Avoid Recalls and Claims
- Improve Quality Rating
- Faster Time to Market
- Increase End-Customer Satisfaction

 ✓ Reduce Waste
 ✓ Reduce Disposal Cost
 ✓ Reduce Energy Cost

Environment | Production | End-Customer
How to Specify an Inspection Solution

The recommended inspection solution is a result of:

- Detection capability combined with additional monitoring and measurement features.
- Classification capability.
- Qualification features and functionalities.
The detection capability of Automated Optical Inspection is determined by three main factors:

- The camera properties.
- The illumination properties.
- The optical setup.
The AOI detection capability is determined by the camera:

- Camera chip sensor area of the 2k-, 4k-, or 8k sensors
  
<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Sensor Area</th>
<th>Signal to Noise Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>2k Sensor</td>
<td>14 µm x 14 µm</td>
<td>1.00</td>
</tr>
<tr>
<td>4k Sensor</td>
<td>10 µm x 10 µm</td>
<td>0.51</td>
</tr>
<tr>
<td>8k Sensor</td>
<td>7 µm x 7 µm</td>
<td>0.25</td>
</tr>
</tbody>
</table>

- Camera chip sensor technology, single line vs. dual line.
- Camera chip sensor quality, e.g. blooming.
- Camera resolution in machine- and cross direction.

Precise selection of camera technology (high sensitivity) is essential for best signal-to-noise ratio.
Newest High Performance
CMOS-Line Camera Technology

Key Features:

• CMOS yield to more sensitive sensors with an increased dynamic range (does not saturate as fast as CCD)
• Extreme high sensitivity due to innovative dual-line sensor technology
• Robust industrial camera for rough environments
• High Speed: up to 320 MHz pixel frequency
• Digital camera with high dynamic range (12 bit res.)
• Anti-blooming
• Video pre-processing and monitoring functions
• Cooling free - Low power consumption
**Line Scan Camera Technology**

- The image is acquired one line at a time as the material moves through the “scan line”.
- Typical Cameras are 2048 (2k) 4096 (4k) and 8192 (8k) pixels
- If higher resolution is desired, multiple cameras are lined up across the web
- The number of pixels and the number of cameras determines the resolution of the image in cross-web direction, with consideration of a camera overlap (typically 2-5%)

\[
rcw = \frac{W_{Web}}{N_{cameras} \times N_{Pixel} \times (1 - R_{Overlap})}
\]

![Graph showing cross-web resolution in micron vs. web width in inch for different camera configurations](image)

- 1x2k
- 2x2k, 1x4k
- 4x2k, 2x4k, 1x8k
- 8x2k, 4x4k, 2x8k
- 10x2k, 5x4k
- 12x2k, 6x4k, 3x8k
- 16x2k, 8x4k, 4x8k
- 20x2k, 10x4k, 5x8k
Pixel rate … what does that actually mean?

- Pixel rate is the number of pixel a camera delivers every second
- 320 MHz pixel Rate is 320 million pixel/second
- Double the resolution at a given speed means a camera needs four times the pixel rate

Achievable down-web resolution at different line speed:
Influencing the Detection Capability

The AOI detection capability is determined by the illumination:

- Illumination technique e.g. focused/diffuse light. Example shows a bubble in glass.
- Illumination light power.
- Optical properties of illumination lenses and camera lenses.
- Light wavelength in relation to the defect visibility. Example shows dirt on a glass surface.
- Light wavelength in relation to the camera chip sensitivity.

Precise selection of illumination technology (high sensitivity) is essential for best signal-to-noise ratio.
LED-Illumination Unit

Key Features:
- Different wave lengths for different purpose: red, blue, white, UV, and many more
- Modules of 140 mm length adaptable to each customer web width (6 meters)
- Extreme high on/off switching speed
- Resistance to high ambient temperature
- Long LED life time > 50,000 h (~ 5 years)
Influencing the Detection Capability

**Bright-Field:** CCD-Camera looks directly into the light source
- High sensitivity for **contrast defects** (e.g. inclusions, gels, color drops, coating voids, ...)

**Dark-Field:** CCD-Camera looks past the light source
- High sensitivity for **scattering defects**
Influencing the Detection Capability

The AOI detection capability is determined by the optical setup:

• Bright-field – Near dark-field – Dark-field.
  Example shows deformation defect on coated surface.

• Reflection – Transmission.
  Example shows bubble in PET film.

Precise selection of optical set-up (high sensitivity) is essential for best signal-to-noise ratio.
Camera Synchronized Switched Illumination

- LED can be switched on and off at the same frequency as the cameras scan
- If properly synchronized, alternating line scans can be used to create multiple images with different illumination, revealing different aspects of defects
- Defects is being detected with different lighting condition at exactly the same spot without the need to calibrate and precision align multiple banks of cameras against each other

Bright-field

Near Dark-field
Bright-Field Illumination: Detected Defects

Typical **Contrast Defects** in Web Material

- **Dents**
- **Inclusion**
- **Insects**

- **Coating Void**
- **Coating Bubbles**
- **Coating Defect**
- **Pinhole in TCO Coating**
- **Scratch in coating layer**
Dark-Field Illumination: Detected Defects

Typical Scattering Defects in Web Material

Scratches in down-web direction

Particles and Scratches

Scratches
Improving the Classification Capability

The AOI classification capability is determined by:

- The quality of the defect detection (Signal-to-Noise ratio).
- The image depth: The images of a camera at 12 bit (4096 gray values) show 16-times higher dynamic range and are thus by far superior to 8 bit (256 gray values) images.
- The number of optical channels and the applied set-up technique. Example: combined usage of 1. reflection BF and 2. transmission BF and 3. transmission DF channel + 4. switched transmission Multiple Darkfield.
- The availability of tools for continuous classification improvement, e.g. defect libraries and easy to use classifier setting.
Defect Inspection as Gauging Systems?

Gauging Systems do provide:

- Single spot, well calibrated measurement.
- Move across web in meandering fashion.
- Actual measurement density far less than 1%.
Defect Inspection as Gauging Systems?

Classical Role of Defect Inspection Systems:

• 100% surface coverage
• Localized imperfections
• Not calibrated for gauging
Individual Pixel Calibration

• Every pixel of the line scan is calibrated individually
• The calibration comprises of an Offset ($C_O$) and a multiplicative Gain ($C_G$) calibration, not just the usual offset.

\[ M_{Cal,n} = C_{G,n} \cdot M_{Raw,n} + C_O \]
Meta Pixels

The web is divided in a number of “tiles” or meta-pixels consisting of many individual measurements pixels
Meta Pixel Properties

For each meta-pixel the measurements of the individual points are summarized in real-time with statistical properties, representing the meta-pixel’s set of measurements.

- Average
- Standard Deviation
- Min /Max
- Median
- Binned Measurement histogram
- Other advanced properties
Meta Pixel Average
Data Interpretation

Pass/Fail Map

False Color Map
Data Interpretation

Down-Web Diagram

Cross-Web Diagram

+ Digital outputs for control- and specification limits
Light Transmission vs. Basis Weight

Typical Basis Weight Calibration Curve

Overall Precision achieved using:

- Full roll weight comparison
- Dynamic-recalibration against scanning gauge measurements
- A scanning gauge combined with defect detection can deliver both accuracy and 100% surface coverage
Defect Inspection as Gauging Systems?

Gauging and defect detection in one system

Running Defect Map

Cross Web Diagram

Down Web Diagram

Density Map
## Plastic Film Inspection & Measurement

<table>
<thead>
<tr>
<th>Problem of</th>
<th>Caused by</th>
<th>Effect in</th>
<th>Detection of</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Local defects</td>
<td>• Poor production process</td>
<td>• Performance in end product</td>
<td>Local Defects</td>
</tr>
<tr>
<td>(inclusions, contaminations, bubbles, scratches)</td>
<td>• Poor material quality</td>
<td>• Problems at converting</td>
<td></td>
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<tr>
<td>• Surface issues:</td>
<td></td>
<td></td>
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<tr>
<td>unevenness, deformations</td>
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<tr>
<td>• Coating layer inhomogeneity, Thickness</td>
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<tr>
<td>• Poor material deposition</td>
<td>• Poor material quality</td>
<td>• Performance in end product</td>
<td>Area Deviations</td>
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<tr>
<td>• Poor material quality</td>
<td></td>
<td>• Waste of coating material</td>
<td></td>
</tr>
<tr>
<td>• Film inhomogeneity</td>
<td>• Material deposition</td>
<td>• Performance in end product</td>
<td>Area Deviations</td>
</tr>
<tr>
<td>Thickness, Porosity, Haze, Reflectivity</td>
<td>• Material quality</td>
<td>• Problems at converting</td>
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<tr>
<td>• Calander Process</td>
<td>• Stretching Process</td>
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*EasyMeasure*
Schenk Worldwide

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