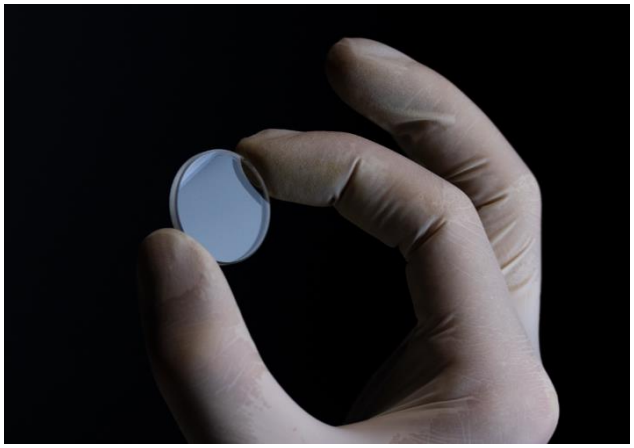
AUTOMATED SCRATCH-DIG INSPECTION



Executive summary: Optical surface inspection is critical for quality assurance during the manufacturing of optical components. While manual-visual inspection is widely used in the industry, the subjectivity of manual inspection, shortage of skilled optical technicians, and the drive towards automating manufacturing procedures has prompted increased demand for automated defect inspection. Automated scratch-dig inspection improves accuracy with less hands-on technician time, reducing waste and costs for optical manufacturers.

Challenges for manual-visual inspection

- **Shortage of optical technicians:** As the optics industry continues to grow, it is facing a shortage of skilled optical technicians who are trained in tasks like manual-visual inspection[1].
- **Subjective inspection results:** While inspection standards attempt to provide objective criteria for analyzing optical surface quality, results can vary widely between inspectors or with fatigue levels. Erroneously discarded parts cause waste, and incorrectly passed parts cause even more expensive problems further down the manufacturing line.
- **Increased salary costs:** Manual inspection requires paying employees to spend time dedicated to surface quality inspection.

[1] E. Moore et al, *Applied Optics* **62**(31), 2023.

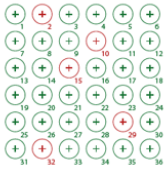
Advantages of computer-based inspection

- **Automated batch inspection:** Machine vision inspection allows for automated inspection of trays of optical elements, reducing the hands-on time needed, and therefore reducing costs in the long term.
- **Increased objectivity:** ISO inspection requirements include measuring the cumulative area of defects, concentrations of defects per area, and scratch width. Such metrics are well-suited to computer vision and image processing algorithms. Accurate, objective inspection results reduce waste and cost.
- **Detailed inspection reports:** Computer-based inspection can automatically provide an overview of which parts in a tray have passed / failed and detailed inspection reports for each element with defect size statistics, images, and maps of defect locations.

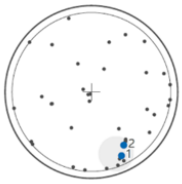
Inspection Reports

Detailed inspection reports are useful for:

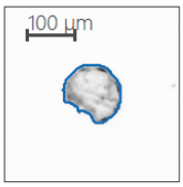
- Quality documentation
- External conversations with customers and suppliers regarding part quality
- Root-cause analysis from defect size statistics and high-resolution images
- Easy-to-read overview of tray inspection



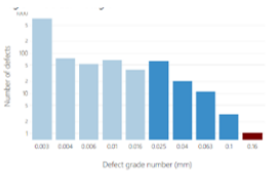
Tray overview



Lens overview



Defect image



Size statistics

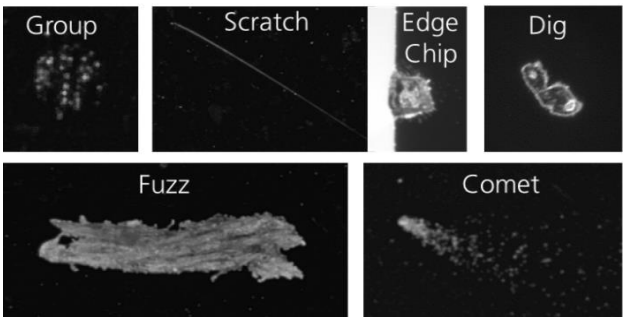
AI for automated defect classification

Artificial intelligence (AI) can be used for automated defect classification. Although basic classification of scratches, digs, and edge chips can be performed according to dimensional and positional criteria (e.g. aspect ratio, length, and proximity to edge), it is sometimes useful to customize defect classification to distinguish additional defect classes. Images and statistical analysis of custom defect classes can aid root-cause analysis in manufacturing.

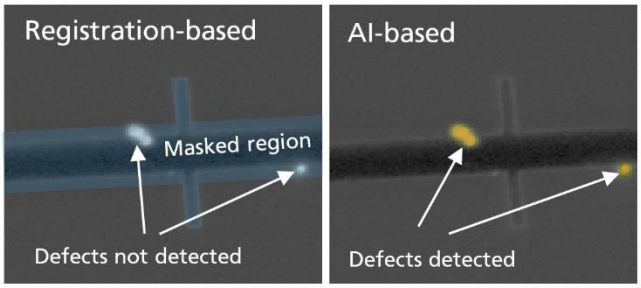
AI for inspection of structured surfaces

Surfaces with features that scatter light, such as embedded electronics, diffractive structures, or reticles, can still be inspected but require a way to avoid reporting the structures as defects. The structure can be identified with image registration and masked out, but this leaves a blind region around the structure where defects will not be detected. Alternatively, AI algorithms can be trained to detect defects directly on top of structures.

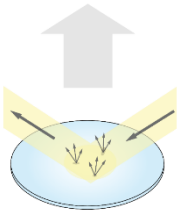
Images of different defect classes



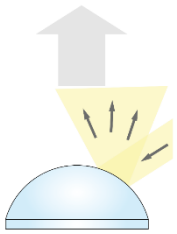
Registration and masking vs. AI detection



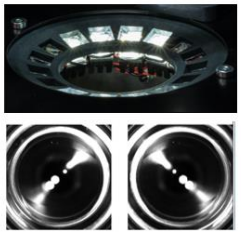
Dark field imaging



For flat optics, only scattered light reaches the detector, creating images of bright defects on a dark background.



For lenses, the curved surface's specular reflections may also reach the detector.



To avoid this, groups of LEDs in the LED dome are turned on sequentially, creating images where different parts of the image have reflections.

The images are then combined to create a single dark-field image where the bright parts are only from defects.

Dark field imaging for curved surfaces

Like visual inspectors look at optical surfaces under oblique illumination, the principle of dark field illumination can be used to enable computer vision-based analysis of defects. This requires oblique illumination (e.g. from an LED dome) so that light only reaches the detector if a defect scatters light, resulting in bright defects on a dark background. For curved surfaces like lenses, illumination multiplexing is used to create synthetic dark field images.

Considerations in automated defect inspection

The following capabilities and requirements should be considered when integrating automated defect inspection.

- **Part cleanliness** is critical since dust will be detected as defects. Parts should be cleaned before inspecting, and should be inspected in a clean room or flow hood.
- **Stray light** from reflections internal to the optic can increase background signal and make it difficult to find defects on certain parts.
- **Measurement speed** is important for high volume applications, and is determined by the part's surface sag, inspection area, and the imaging system's resolution.

Optics manufacturers have much to gain from automating surface defect inspection, including objective inspection results, quantitative reports to aid external discussions, and reduced waste and costs.

Want to learn more? Contact our experts or visit dioptic.de/en

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