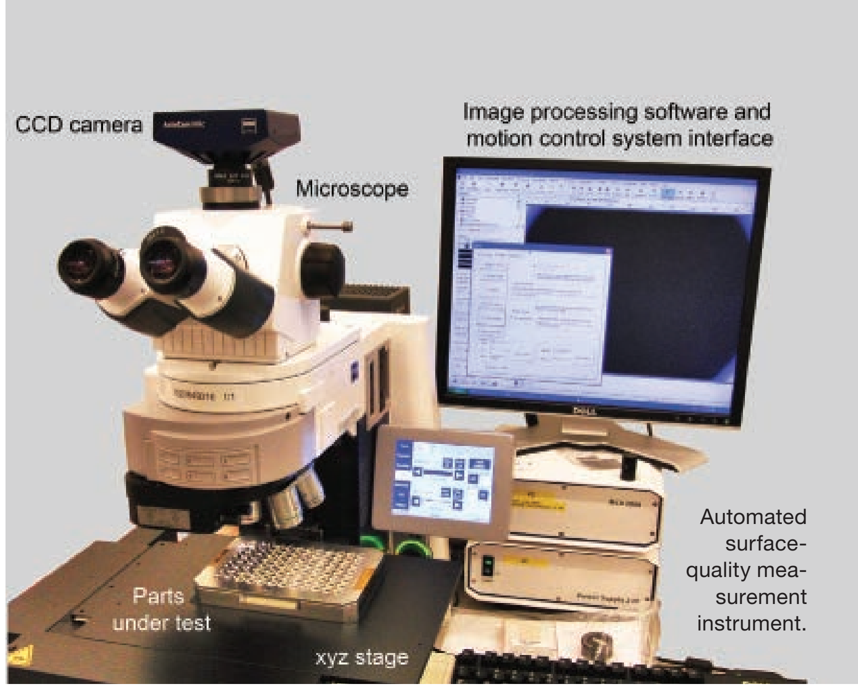

REO

Automated Inspection of **Optics** using ISO Specifications

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Representatives from Research Electro-Optics Inc., a precision optics manufacturer, explain how to quickly and accurately identify surface defects using an automated microscope-based system that follows the ISO 10110-7 specification.

It is difficult for manufacturers of precision optical components to quickly and accurately detect µm-scale surface defects. This is often because it's time-consuming for an operator to examine each piece; the resolution needed to measure these defects limits the area that can be examined at one time; and, of course, there is the potential for human error during data translation. A possible solution for high-volume facilities such as ours is to implement an automated microscope-based system for surface quality inspection using ISO 10110-7 specification.

Automated inspection using ISO 10110-7

ISO 10110-7 defines allowable defect sizes and the total area that they can cover, but it does not specify how measurements are to be performed. Since the smallest defect can be on the order of micrometers, manufacturers cannot rely on visual inspection. A calibrated, high-magnification microscope can be used to detect size defects on this scale. However, an operator-based microscope system has a small field of view, making it time consuming to examine the entire surface of an optical component.

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An automated microscope-based system can speed up inspection and eliminate operator-dependent biases. Our system uses dark field microscopy with a charge-coupled device (CCD) detector, image-processing software and a motorized stage that can test multiple sites on a single optic. The CCD only images the light scattered from optical defects: It appears as bright spots against a dark background. A computer controls the camera and microscope stage motion, while simultaneously receiving and processing data.

The system's image processing software measures the size of each defect by finding the location of its edge. This is an uncomplicated process for defects that are substantially larger than the resolving power of the microscope because the intensity profiles typically have wide, flat distributions with a small transition region at the edge. Therefore, the exact location of the edge does not significantly change the measured size.

The method for measuring small defects is quite different. Scratches that are smaller than the resolving power of the scope create intensity profiles that span only a few pixels. Microscope resolution limit and CCD detector pixilation make the edge hard to locate. At Research Electro-Optics Inc., we use a conservative image-processing approach that provides an upper-limit estimate of defect size. This method works well on both large and small defects, and it is easy to implement.

The process begins with flat-fielding the image by removing brightness variations inherent in the optical system—in other words, zeroing out the field of view. Next, a fixed threshold value is set to define "defect pixels." This threshold is comfortably above the background light and image noise. It is used to find the edge of defects, allowing the computer to calculate the maximum and minimum dimensions of the defect, as well as their total area. For inspection to the ISO 10110-7 standard, the computer program counts all the pixels inside the defects and calculates their combined actual area.

Size vs. appearance: Comparing apples to oranges

The International Organization for Standardization (ISO) 10110-7 specification for the surface quality of optical elements is a tremendous improvement from the older military specification (MIL-O-13830) because it quantifies allowable defect sizes.

A key issue with using MIL-O-13830 for modern optical applications is that it cannot be used to specify defects that fall below the smallest comparison standards—size 10 for scratches and size 5 (diameter of 50 µm) for digs.

MIL-O-13830

- Published in 1954, years before the advent of the laser.
- Defines the visual and cosmetic appearance of optical components. It is not intended to relate to optics performance or to the actual dimensions of scratches.
- Limits for scratches are based on a visual comparison to a standard.

ISO 10110-7

- Published in 1996
- Defines precise sizes and frequency of occurrence for acceptable defects over a given area. This allows for the specification of smaller defect levels and makes the surface inspection process more quantitative and less prone to operator error.
- Does not indicate how measurements should be performed.

Implementation tips

Two key parameters must be considered when selecting components for an automated surface-quality inspection system: spatial resolution and field of view. Unfortunately, as resolution increases, field of view decreases. To determine the optimal resolution parameter for an optical component, we calculate the minimum sizeable imperfection *S*. The following formula is based on the assumption that, for proper sizing, the object should be larger than the resolving limit of the microscope's objective lens and span at least five camera pixels:

$$S = 5 \times \frac{D_p}{M} \quad .$$

D_p is the camera pixel spacing and M is the overall magnification from the optical component to the camera. The optimal imaging system field of view *FOV* is calculated using the formula:

$$FOV = \frac{D_s}{M} \quad ,$$

where D_s is the camera sensor size.

The table gives a few typical values for spatial resolution and field of view parameters, assuming a sensor size of 9.2 mm (the horizontal width of a standard sensor), with pixel spacing at 6.45 µm (typical for a 1.2-megapixel CCD).

Two key parameters must be considered when selecting components for an automated surface-quality inspection system: spatial resolution and field of view.

What parameters would you need to detect ISO 10110-7 grade number 0.005 scratches (5/L NX-.005) over a 25-mm clear aperture? The largest allowable scratch width is 5 µm. This can be resolved with a 10X objective lens, and the clear aperture can be covered with 200 images. However, the subdivision clause of ISO 10110-7 (section 4.1.2) requires that scratches as narrow as 1.5 µm must also be sized and counted, which demands a 50X objective and an unreasonable 7,000 images.

This example demonstrates the challenges of inspection to the full ISO 10110-7 standard. Similar issues hold for digs and their subdivision requirements. In practice, the problem is lessened somewhat, since the typical high-quality optical component usually has few defects, making it unnecessary to examine the entire surface at high resolution. A more practical approach is an initial survey of the aperture under low magnification. Minute defects will be apparent, especially with dark field illumination. Areas of concern can then be inspected at higher magnification.

[Microscope optics parameters]

Objective Lens Magnification	2.5X	5X	10X	20X	50X
Objective NA	0.06	0.13	0.2	0.4	0.7
Field of View (mm)	5.84	2.92	1.46	0.73	0.29
Objective Resolution (µm)	5.59	2.58	1.68	0.84	0.48
Minimum Sizeable Imperfection (µm)	20.48	10.24	5.12	2.56	1.02
Camera Adapter Magnification (M)	0.63X				
Pixel Spacing (µm)	6.45				
Sensor Size (mm)	9.2				
Center Wavelength of Illumination (nm)	550				

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