



ACCURATE METROLOGY

with TeleStar® Zoom Lens

The TeleStar zoom lens was developed by Optical Gaging Products (OGP®) for precision, three-dimensional metrology. The design provides the benefits of a large zoom range with the superior optical performance of a fixed lens system.

Other companies improperly claim to have telecentric zoom lenses when, in fact, the lenses are only telecentric over a small part of their magnification ranges.

The TeleStar zoom lens provides the benefits of continuously selectable magnifications and telecentricity throughout its entire 10:1 zoom range ensuring accurate metrology at any magnification required for measurement of three-dimensional parts.

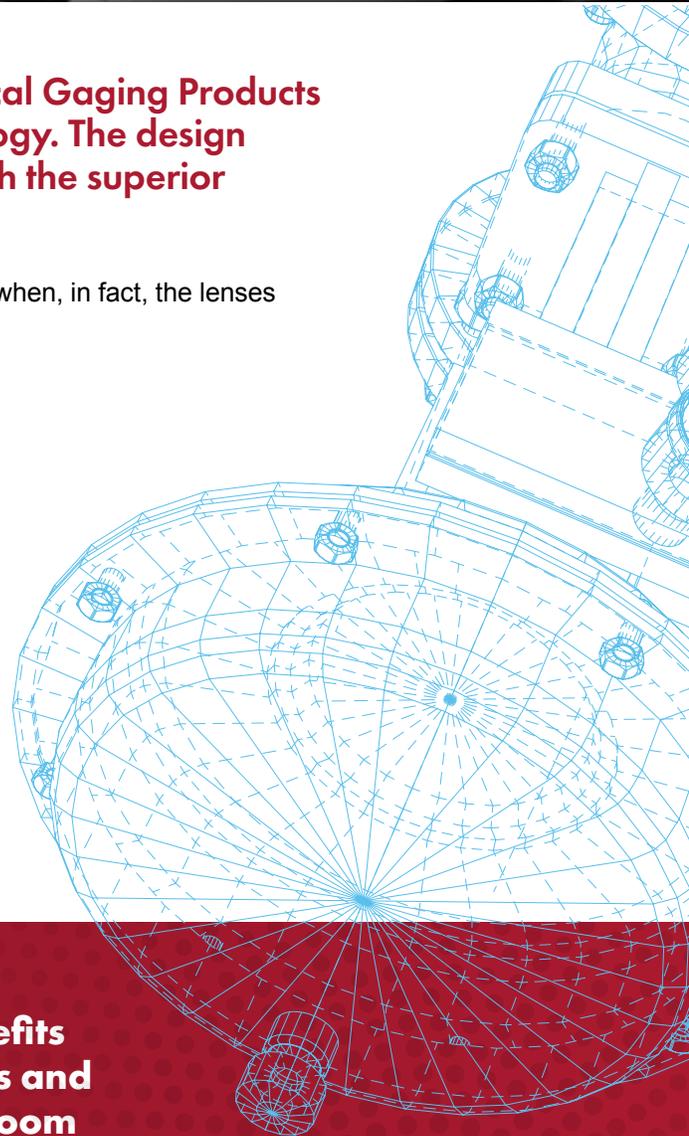
At the lowest magnification the lens has the largest depth of field to keep three-dimensional parts in focus.

At the highest magnification the lens has the smallest depth of field for excellent autofocus accuracy.

The light level needed on the part is constant over the entire magnification range because the light received by the camera is the same at all zoom positions.

Telecentricity is automatically maintained throughout the full zoom range by a motorized iris that removes light that is not parallel to the optical axis.

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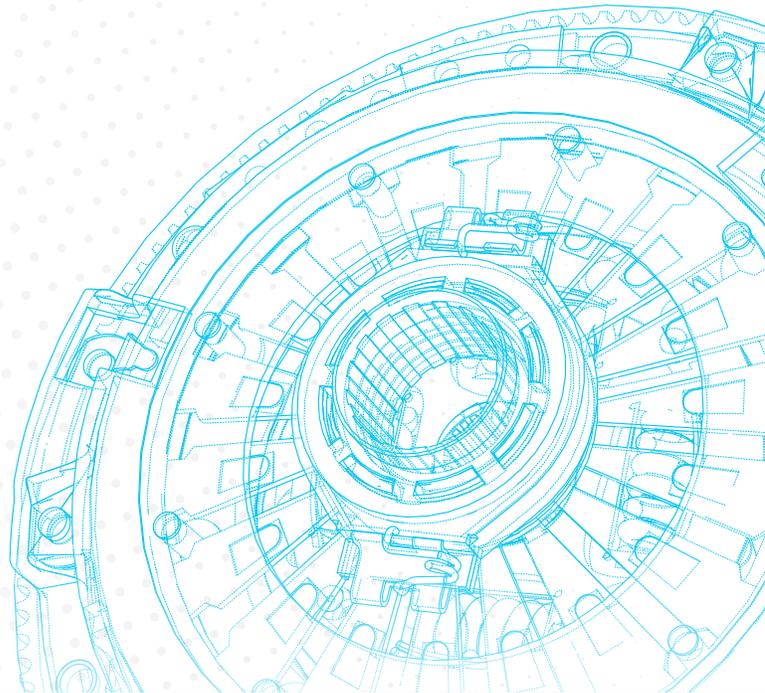


2 VIDEO MEASUREMENT BASICS

Video measurement is the analysis of optical images in order to determine dimensional or spatial relationships between features on the part under test. In order to most accurately determine edge or surface points, the feature of interest is magnified by the zoom lens system and imaged on a camera.

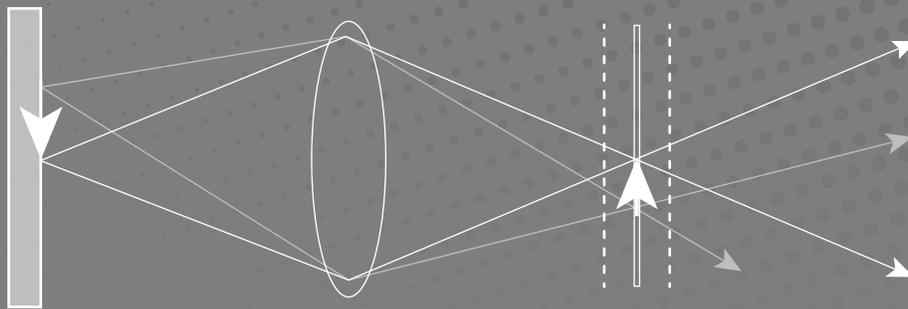
Camera signals are inputs to system electronics for processing by specialized software algorithms in order to accurately identify edge locations and surface points from image intensity and contrast variations.

The precision of these measurements depends on the quality of the image relayed to the camera by the imaging optics.



2 OPTICS LIMITATIONS

In a simple imaging system illustration, when properly focused, the surface of the part at the object plane of the lens (left) is magnified and reversed at the image plane (right) – where the surface of the camera detector is located. If the lens was perfectly aberration-free and the object and image planes exactly orthogonal (perpendicular) to the optical axis through the lens, the image plane would show a faithful image of the part. With variations in lens design the image can be magnified, but the principle is the same. Unfortunately simple lenses are insufficient for metrology-grade imaging. Compound lenses are made up of several lens elements. With increased complexity comes increased potential for imaging errors.



The principal limitation with simple imaging optics is the fact that rays from the object focus only within a narrow depth of field at the image plane, continuing to diverge or converge on either side of that image plane, as shown in the illustration. In this situation, the image size is accurate only at an optimal focus position. Imaging at either side of optimal causes the image size to vary. This effect is of most concern at low magnifications where a large depth of field can make the image appear to be in focus when it is not, with the result that the image size is either too large or too small.

Fixed magnification lenses, traditionally the choice for high-accuracy imaging, do not offer the necessary versatility of rapid magnification changes needed for real-world measurement applications. Fixed magnification creates a fixed field size. Although that size may be optimal for a particular situation, some objects overfill the image field while others fill too little of it for reliable image analysis.

For example, finding points along an edge may be inaccurate if the edge covers too little of the image area, and thus, too few pixels at the detector. Magnifying that edge allows for better determination of a greater number of edge points.

A zoom lens can change magnification as required to cover more of the field of view as features of different sizes are encountered. Unfortunately, conventional zoom lenses can also change the position of the image or object planes.

3 OPTICAL ABERRATIONS AND METROLOGY

Lenses used for video metrology must exhibit minimal distortion.

Distortion is a variation in the magnification across the image plane where the magnification varies with distance from the optical axis through the lens. The metrological impact of lens distortion is that the apparent size of the object will vary across the image plane. In other words, a lens with distortion will show an object to be of different size depending upon where it is located within the field of view. It is important to note that a lens that exhibits distortion can provide a sharp, crisp, focused image but return erroneous measurements across its field. This can be an issue in the performance of a video system with data capture throughout the field of view.

Curvature of the field means the image does not focus in a plane. Field curvature is not always symmetric. It can vary in magnitude and orientation in a lens with astigmatism.

Astigmatic lenses focus in shallow cylinders – perpendicular fields through the lens focus as different curves near the image plane. When those curves are of opposite signs, the wavefront resembles a potato chip shape.

Since uniformity of the image at the plane of the detector is required for highest accuracy measurement, field curvature and astigmatism should be minimal in a metrology lens.

Other lens errors such as spherical aberration, where axial rays across a lens focus at different points, and coma, where off-axis rays

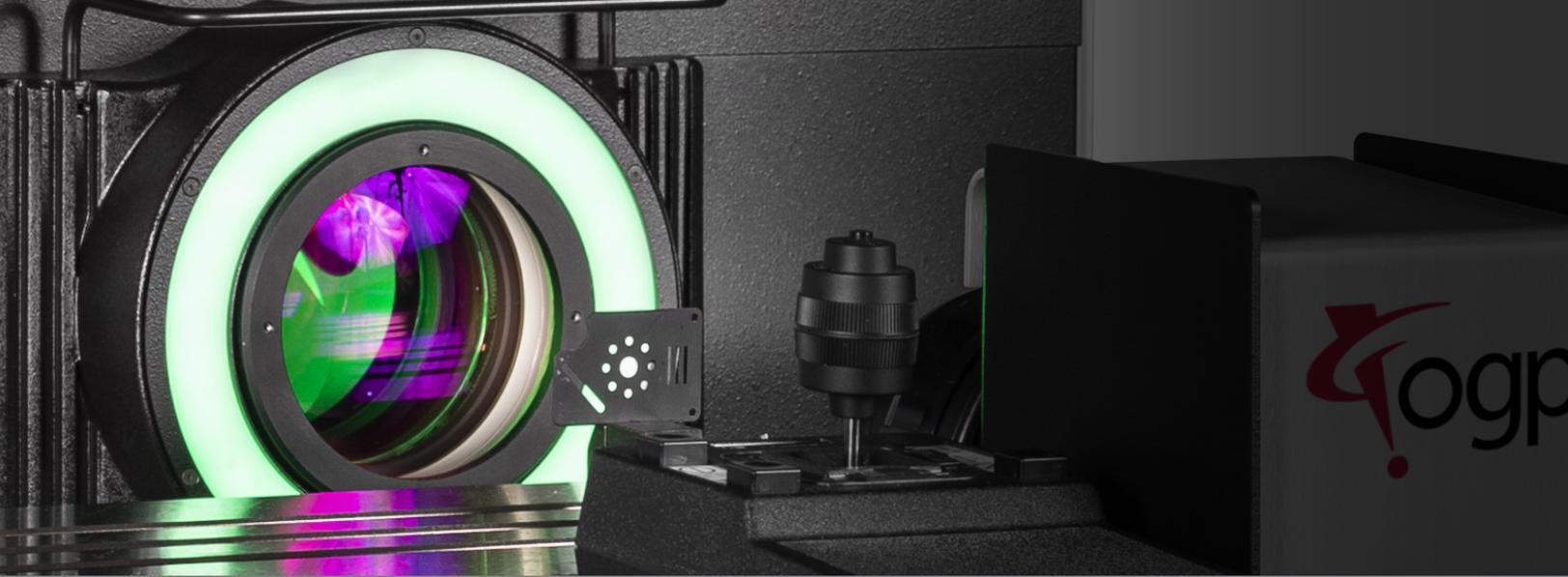
focus at different points, should be minimized in a lens selected for high-accuracy video measurement.

Since video measurement systems use various illumination techniques to optimize image contrast, chromatic aberration can affect measurement accuracy. With chromatic aberration, light of different colors focuses either at different points on the optical axis, or at different points within the image plane, or both.

When using illuminators of discrete wavelengths with a lens exhibiting chromatic aberration, each source might image differently. In the case of white light illuminators, chromatic aberration can cause the image to show false colors and poor focus, a problem for systems with color cameras.

Minimizing all these aberrations is important in a lens used for video metrology since it is the image of the object that is measured, not the object itself. Errors in image quality can result in errors in coordinate and dimensional measurements.





4 TELECENTRIC LENS DESIGN

Telecentric lenses overcome many of the limitations of simple zoom lenses. In a telecentric lens, all rays are parallel to the optical axis and orthogonal to the object and image planes. Commonly referred to as “infinity corrected,” a telecentric lens system has its pupil at infinity. This means that the object size anywhere within the field of view will be the same, and therefore, measure correctly.

The TeleStar zoom lens available in OGP SmartScope® Quest™ measuring systems is a constant f-22 at the image plane (at the camera). In the object plane (at the part), it offers a large depth of field at low magnification, which decreases as magnification increases. The fact that image size stays constant at all magnifications from the fully telecentric TeleStar lens means that measurements can be performed at any magnification.

Less capable lenses are typically telecentric at only one point, or over a very narrow part of their magnification range. Typically manufacturers that use such lenses make claims about avoiding measurements at lower magnifications for this reason.

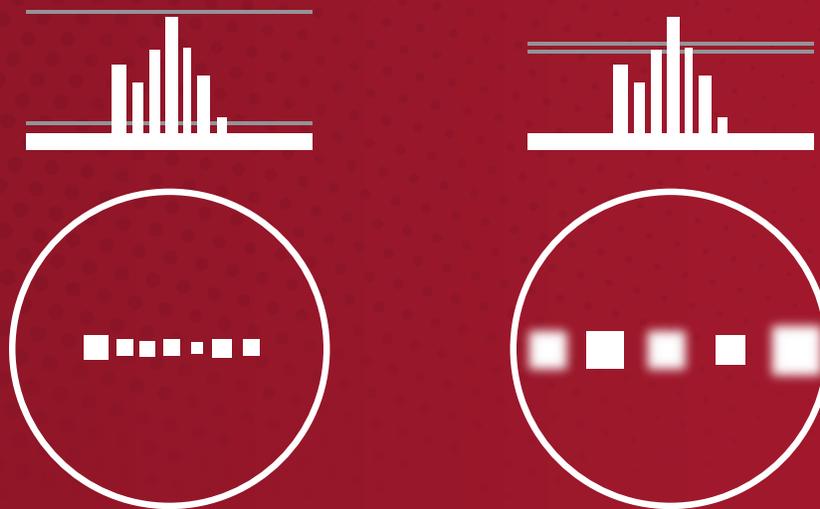
Or, they may limit their claims to measurements of flat parts.

TeleStar incorporates a patented roller mechanical system that maintains superior optical performance by keeping the lens sub-assemblies properly aligned across the magnification range, in both directions.

Non-metrology zoom lenses may suffer from hysteresis of sub-assemblies that can cause them to return to slightly different positions when magnification is changed. Non-repeatability of zoom lens element positions can introduce distortion and affect measurement repeatability.

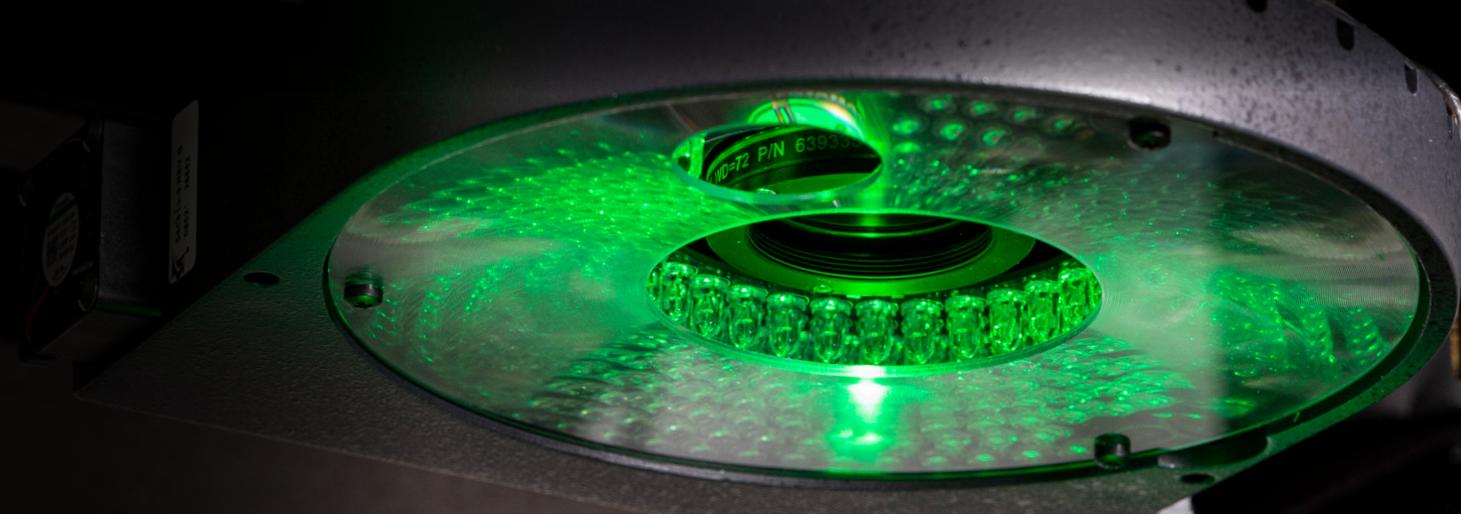
5 TELESTAR APPLICATIONS

Consider a part with seven equally spaced square posts imaged in a single field of view. When imaged at lowest magnification, as shown in the image to the left below, the depth of focus is the greatest (the area between the two parallel horizontal gray lines), and the surfaces of all the posts are in focus. Most importantly, the corresponding image is of the proper dimensions and spacings for coordinate measurement.



On the right are similar parts imaged at the highest magnification. The focus depth is much narrower (horizontal parallel gray lines). In this example it is possible to accurately focus on the two posts of the same height while the other posts on either side of the focus range are not as crisply focused. Despite the minor out-of-focus condition of the other posts, telecentricity ensures that sizes and positions are accurately retained.

The telecentric advantage is not as significant at high magnifications with their shallow depths of field. However, a telecentric lens yields other advantages at higher magnifications. There are two optical phenomena that occur when light entering the lens system is not parallel - "wall-effect" and "wrap around effect." On prismatic 3D parts, wall-effect occurs because non-parallel rays actually image from the sides of the part that are perpendicular to the imaging system. This causes image contrast to degrade, or a faint shadow to appear on the image of the edge. Wrap around effect is similar but affects cylinders and spheres where the light tends to effectively "wrap around" the curved surfaces. These effects have often been hurdles for video measurement systems, causing ambiguity in edge definition, thus affecting measurement repeatability. A telecentric lens system minimizes these effects, improving image quality, and therefore measurement accuracy and repeatability.



6 THE TELESTAR SOLUTION FROM OGP

The patented TeleStar zoom lens from OGP overcomes the limitations of both simple zoom lenses and partially telecentric lenses. First of all, it is telecentric across its entire (10X) magnification range from f-2.5 to f-25. The lens provides a range of magnifications to accommodate a variety of real-world industrial applications – parts with increasing complexity and tighter tolerances. The capability to measure a part over a range of magnifications in a single setup speeds workflow. In addition, the capability to change magnifications under program control allows system operators to do other productive work while the system is measuring.

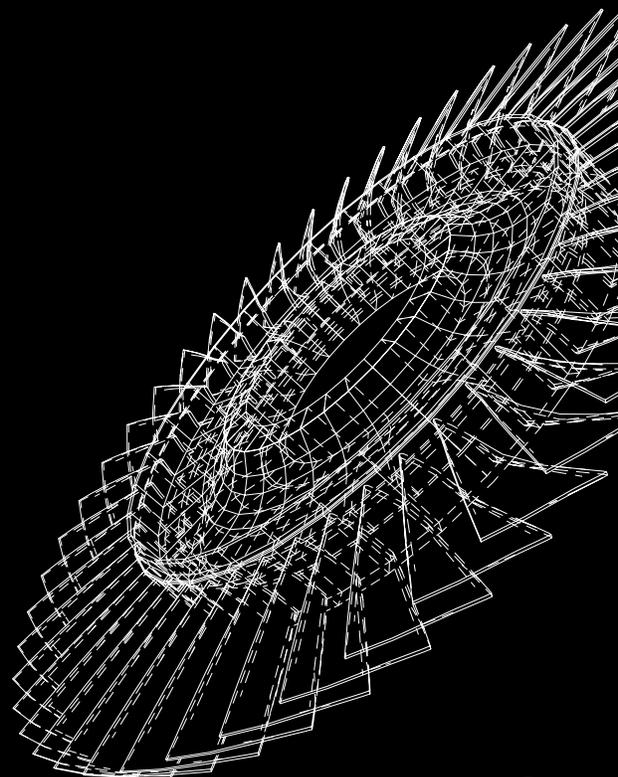
The TeleStar zoom has minimal optical distortion across its magnification range (less than 0.5 percent distortion). This means that, unlike uncorrected zoom lenses, features are a constant size at any position within the field of view.

The TeleStar lens has a large depth of field at its lower magnifications where the advantages of telecentricity ensure that height variations across the part are both in focus and of accurate size and position.

The TeleStar lens has a small depth of field at high magnification for accurate measurement of surface height. At the highest magnification

the optical resolution is the highest and the depth of field the shallowest. This allows the system to find the precise point where the contrast in the image is the sharpest as the lens moves through the depth of field during autofocus. The system can more precisely subdivide the depth of field because the image is not blurred because it does not grow or shrink while focusing.

The TeleStar zoom lens is color-corrected to minimize chromatic aberrations, so it works throughout its range with white and colored LED illuminators.



As an integral part of OGP SmartScope Quest measurement systems, the lens presents a constant f-number to the camera (f-22). On the object side, it uses a computer-controlled motorized iris to match the source size of the illuminators to the numerical aperture (NA) of the optics across its range of magnifications. This feature eliminates stray light through the lens system. Since only collimated light enters the system across its range of magnifications, wall-effect and wrap around effect on prismatic parts of any size are minimized.

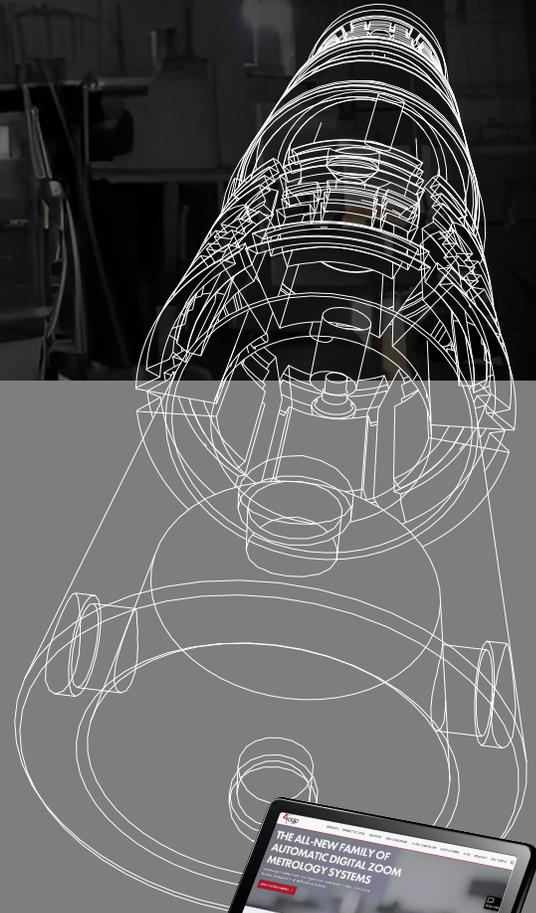
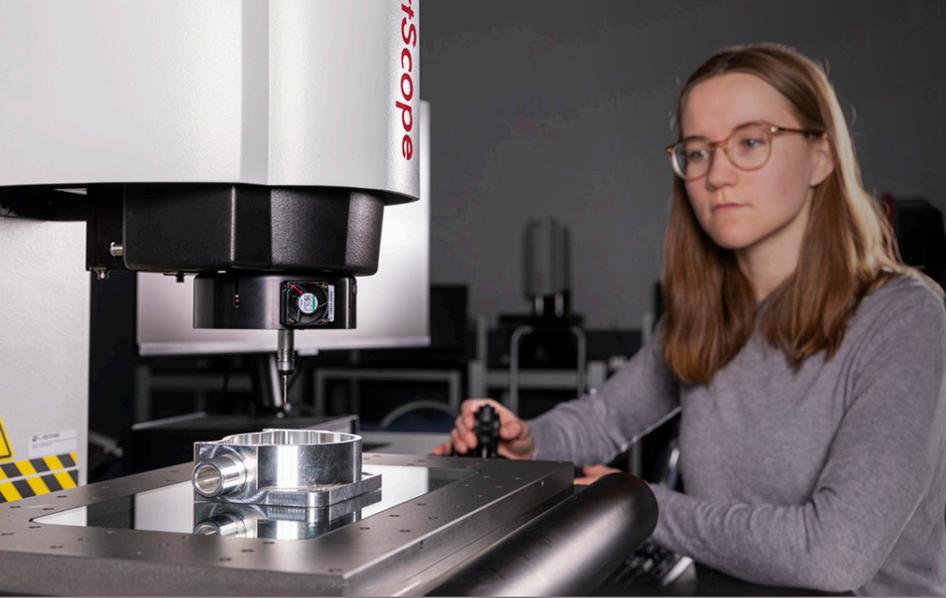
As an OGP product, the TeleStar lens benefits from other OGP innovations in optics. The lens is AccuCentric®. This patented technique automatically calibrates the field of view every time the zoom lens magnification is changed. This ensures that measurements performed on images are scaled properly for consistent accuracy. Full field-of-view calibration fine tunes the system to minimize any remaining non-linear optical errors. Parfocal calibration ensures that Z-measurements across magnifications are consistent.

The lens includes an OGP Grid Projector to optimize focus accuracy on parts with no discernible surface detail. By illuminating a contrast grid with an LED, the autofocus system optimizes the image contrast of the grid (the position of which coincides with the object plane of the part). The process is accurate, repeatable and automatic.



OGP Quest 300
3D Multisensor
Measurement System



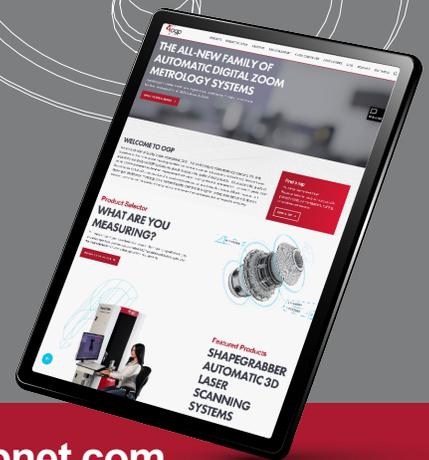


SUMMARY

In precision metrology based on optical imaging, the best optics for a particular task are object dependent. Telecentric zoom optics offer significant advantages over simple zoom lenses when consistent measurements anywhere within the field of view are important, especially when imaging curved surfaces without distinct edges.

The TeleStar zoom lens from OGP was developed specifically for precision metrology and incorporates several innovations that are patented. The fact that it is telecentric across its entire magnification range means it can be used to perform measurements at any magnification.

Integrated into SmartScope Quest measurement systems, the lens offers unique imaging capabilities, automatic optimization of illuminator source size, and automatic calibration each time a zoom setting is changed. TeleStar Zoom from OGP is the high-accuracy imaging solution for user-friendly, high-accuracy video metrology.



Learn more about OGP Measurement Systems at ogpnet.com

OGP (Optical Gaging Products) is a division of Quality Vision International Inc (QVI®), a world leading manufacturer of precision multisensor metrology systems for industrial Quality Control. Our metrology systems focus on measurement technologies that help manufacturers monitor dimensional compliance to design specifications. First introduced in 1992, the famous OGP SmartScope® product family has become one of the world's most popular and versatile dimensional measurement systems. SmartScope systems are designed and produced at QVI corporate headquarters in Rochester, NY, USA. Flash branded systems are sold in North America while Flash CNC and CNC systems are found outside North America.



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