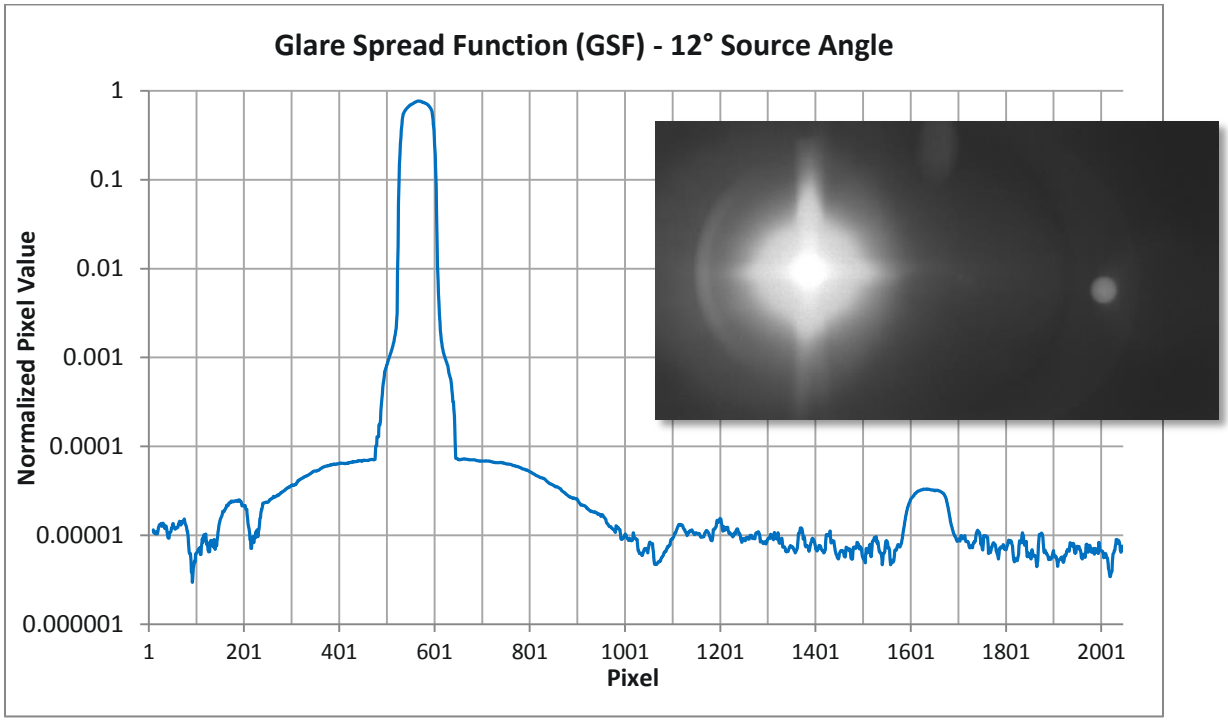
Optikos®

The Optical Engineering Experts™

POWERED BY *OPTEST*® SOFTWARE

Stray Light Measurement on *LensCheck*™ Lens Measurement Systems



Introduction

Manufacturers are asking vision systems to take on more and more challenging imaging tasks across non-ideal imaging environments. Many applications require imaging scenes with extraordinarily high dynamic range content. For example, automotive cameras must be able to identify a pedestrian or traffic light at night while also imaging an on-coming car's headlights. This performance must be determined while viewing through protective windows that may be scratched or covered with debris. Windows, debris, optical elements, and even the sensor can result in unintended radiation striking the detector. This light can potentially overwhelm the desired signal and introduce computational errors.

The designers, manufacturers and consumers of these lens and camera systems require a quantitative measurement of stray light. Optikos® products are designed to accurately perform these measurements.

What is Stray Light?

Different terminology is used in different industries to describe stray light. Common terms are *stray light*, *lens flare, veiling glare, ghost image, image glare*, and many more. Most of these terms are not rigorously defined and will be interpreted differently by different readers. A useful introduction to stray light is provided in ISO 9358 – "Optics and optical instruments – Veiling glare of image-forming systems – Definitions and methods of measurement." This standard is actively maintained (2014) and describes how to measure stray light in a lens assembly. ISO 18844 is a new standard under development (expected release 2017) that covers Image Flare Measurement in a Camera System. This standard is directed at digital cameras and photography markets and is not as relevant for rigorous lens testing.

ISO 9358 includes the following definitions:

> **Veiling Glare** – Unwanted irradiation in the image plane of an optical or electro-optical system, caused by a proportion of the radiation which enters the system through its normal entrance aperture. The radiation may be from inside or outside the field of view.
>
> *Veiling Glare Index* is a useful single-number summary of a Veiling Glare measurement. This will be discussed below.
>
> **Glare Spread Function** – Irradiance distribution in the image plane, produced by a small source object, normalized to unit total flux, in the on-axis image of the small source.
>
> For the purposes of this discussion Optikos will primarily use the terms Veiling Glare and Veiling Glare Index (VGI), and Glare Spread Function (GSF). These measurements encompass all mechanisms of stray light.

How OpTest® Measures Stray Light

Many customers are interested in testing smaller optics for which the LensCheck™ test instrument is an appropriate choice. The LensCheck supports either the *VGI* or the *GSF* stray light measurements using OpTest® 7 software. Both methods comply with ISO 9358 with a few exceptions.

Veiling Glare Index

Veiling Glare Index (VGI) is a measurement of stray light reported as a single percentage value. VGI tests are performed without a camera or sensor in place. The *lens under test* views a uniformly illuminated field that extends beyond the lens field. In practice this is usually an integrating sphere placed around the lens entrance pupil. A small, perfectly black object (light trap) is placed in the center of the field. A camera views the image plane, and the software measures the unwanted energy collected in the black area. This dark area signal is then compared to the bright signal. Small values of VGI are desirable.

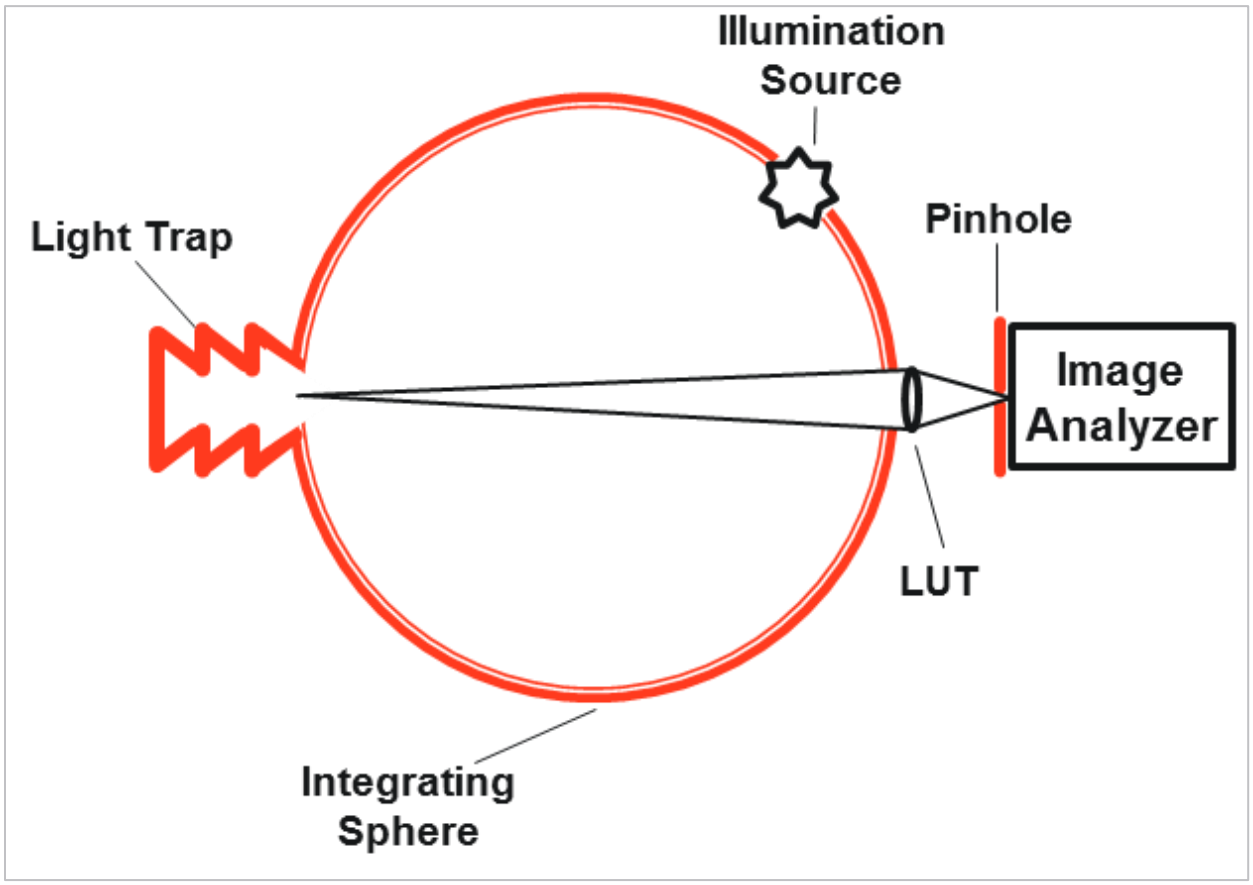


Figure 1 - Instrumentation schematic. The Lens Under Test (LUT) is placed at the entrance port of the integrating sphere.

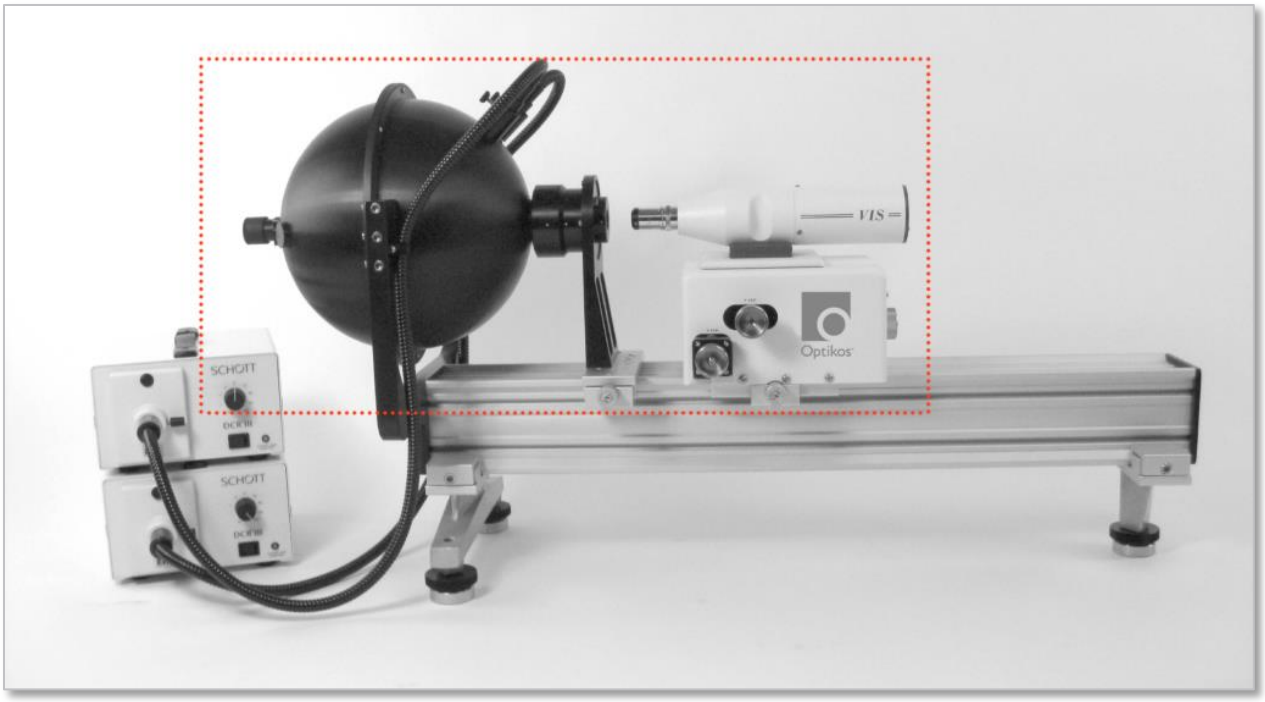


Figure 2 - The LensCheck *Stray Light Kit* is an add-on option for the LensCheck VIS. Optikos offers models with a 4", 6", and 10" integrating sphere, the large (10") sphere is shown here.

How does the VGI measurement work with LensCheck and OpTest® 7?

To make a veiling glare measurement with the LensCheck Instrument, one needs to purchase the Stray Light Kit option. The 10" version includes an integrating sphere, additional light sources, and a support rail. The integrating sphere is necessary to produce 180° of uniform illumination as illustrated in Figure 1.

The Image Analyzer is moved from the LensCheck to the Stray Light Kit support rail. The LensCheck computer is still used to run OpTest 7. The VGI measurement routine exists as a core part of OpTest 7 and directs the user in how to proceed with the measurement. The VGI measurement fully conforms to ISO 9358. Optikos has validated the stray light kit accuracy to 0.1%.

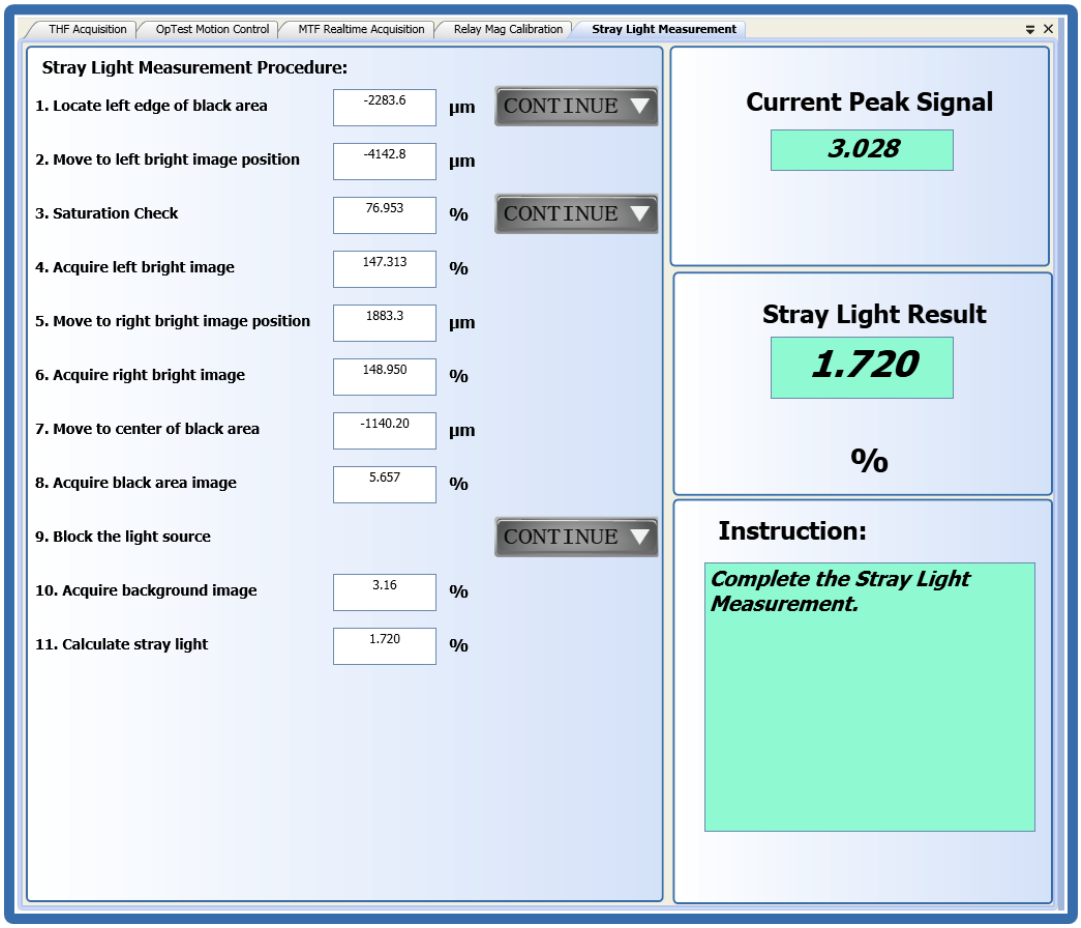


Figure 3 - The OpTest® 7 Interface for Performing Veiling Glare Index (Stray Light) Measurements

What lenses can I test with the Stray Light Kit?

The lens focal length is limited by the diameter of the integrating sphere. Optikos offers three sizes of stray light kits – a 4" (100mm), 6" (150mm), and 10" (250mm) diameter sphere. The ISO standard recommends that the integrating sphere diameter be greater than 10 times the focal length of the lens under test. **The *Stray Light Kit* with 10" integrating sphere is therefore suitable for testing lenses of focal lengths up to 25mm.** For lenses with longer focal lengths, Optikos can provide custom solutions.

What are the limitations of the Stray Light Kit?

Longer focal length lenses can be difficult to test with the stray light kit. Also it is critical that the test environment (laboratory, factory, etc.) be completely dark for accurate measurements. If necessary, a light-shield may be constructed to block ambient light from the test setup.

The ISO specification defines VGI as an on-axis measurement. The black object is placed in the center of the field. For interested customers, Optikos can customize the Stray Light Kit to include off-axis measurement points as well.

Glare Spread Function

Glare Spread Function (GSF) is a measure of the irradiance distribution across the image plane given collimated light at a specific angle of incidence. This requires a source and collimator, as well as a rotary platform to set the incident angle (see Figure 4). The LensCheck has all of these capabilities and no further add-ons are required. The test conditions for GSF are determined by the user, and GSF can be recorded for a range of incident angles or a single angle.

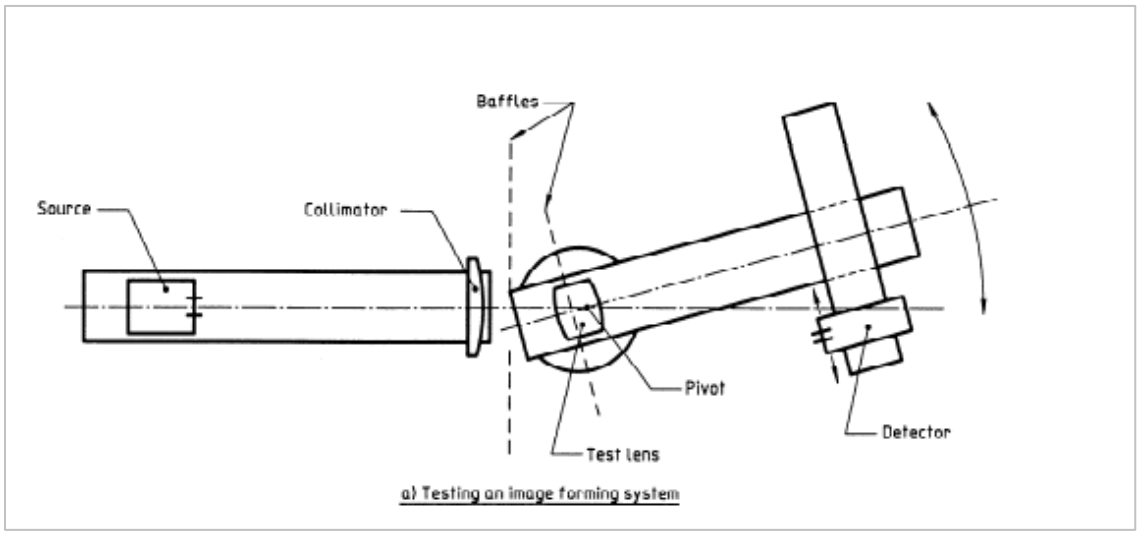


Figure 4 – ISO 9598 Illustration of GSF Measurement

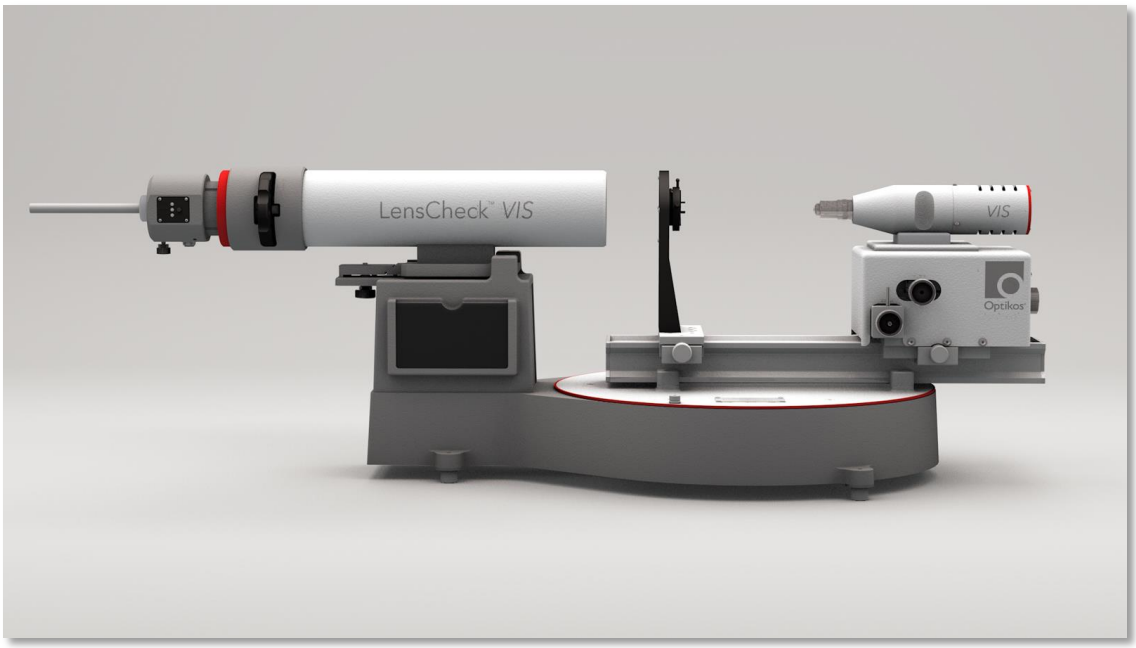


Figure 5 - GSF can be measured on the LensCheck without modification

Is it best to measure GSF of the lens or camera (lens & sensor)?

An important distinction arises when measuring the GSF of the lens or the camera. These two tests can produce very different results because the camera itself can contribute significantly to stray light. Reflections off of the cover glass, sensor, mount and mechanics produce unwanted irradiation. Furthermore, the sensor itself can contribute random and fixed pattern pixel noise, readout errors such as blooming, residual images, electron drift and crosstalk, and other phenomena that play a significant role in perceived stray light. For this reason Optikos recommends testing with the camera in place.

The ISO 9598 standard only specifies testing a lens assembly and not a camera. This is the primary area where the Optikos GSF measurement method differs from the ISO standard.

How does the GSF measurement work with LensCheck and OpTest 7?

The critical requirement for a successful GSF measurement is very high dynamic range for the sensor, on the order of 10^5 or 10^6. When the intense light source is within the lens field of view, it will overwhelm other regions of interest. Optikos uses High-Dynamic Range (HDR) imaging to achieve the required dynamic range. Multiple images are exposed with increasing exposure times and then merged to create one composite image. That composite image is then analyzed to generate the GSF.

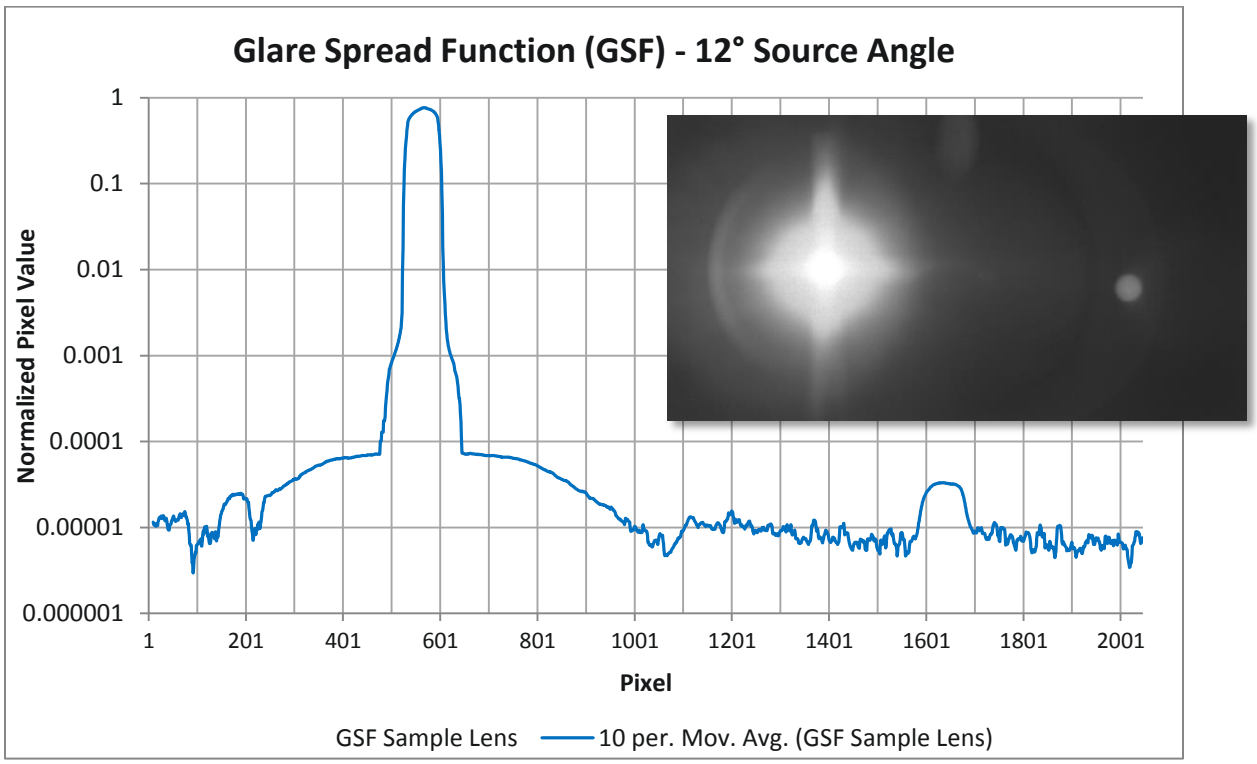


Figure 6 - Horizontal GSF with a lens 12° off-axis. The dynamic range is greater than 10^6. The inset image shows a very long exposure image. Five images with varying exposure times were combined to create the GSF plot.

It is important to note that if the user is testing a camera system, OpTest 7 will not collect images from the video stream! OpTest 7 only reads the video input from the LensCheck. In this case, the user manually sets exposure times and saves images. Optikos can advise on how to set exposure times and post-process images to generate a GSF plot as shown in Figure 6. Optikos provides the software to generate HDR composite images. This is the primary reason why GSF tests are more time-consuming than VGI.

Are add-ons required for GSF measurements?

The Glare Spread Function does not require any customization of the LensCheck hardware.

On what lenses can I measure GSF?

The Glare Spread Measurement may be performed on any lens that can be tested by LensCheck—clear apertures up to 50mm, focal lengths between 1mm and 200mm.

What are the limitations of the GSF measurement?

As noted above the GSF is a more manual measurement. It is important for the user to decide which angles are of interest for a GSF measurement. This is usually determined by viewing the video stream while varying the input angle. When a problem is observed (such as the ghost image in Figure 6) that is an appropriate location for GSF measurement.

Veiling Glare Index or Glare Spread Function?

Both VGI and GSF can be valuable tests. VGI is useful as a measure of diffuse irradiance on the image plane. Poor VGI is commonly seen from poor coatings or insufficient baffling and produces a general loss of contrast. The VGI is easily specified by a single percentage value and is a quick and easy measurement. It is very effective for comparing lens performance across suppliers and for use in lens specifications. Many MIL specifications, such as for image-intensifier tubes, require VGI testing.

GSF is particularly useful to evaluate severity of ghost reflections or other prominent stray light artifacts that form concentrated irradiation patterns. The GSF test is more time consuming but also provides more insight into the origin of stray light issues. This is particularly valuable to the optical and opto-mechanical designer. Because of the very high sensitivity of GSF measurements they are also useful for challenging imaging environments that are sensitive to stray light such as evaluating the impact of windows on automotive cameras, airborne cameras, or LIDAR systems.

Summary

Optikos is seeing continued interest in measuring stray light from our customer's products and anticipates substantial growth in suppliers and end-users specifying and testing stray light performance. This is encouraging as it shows an increasing appreciation for the significance of stray light in optical imaging systems. The LensCheck is an ideal and affordable instrument for enabling measurement of both Veiling Glare Index and Glare Spread Function.

Get Started with Optikos

Optikos offers metrology products and services for measuring lenses and camera systems, as well as engineering design and manufacturing for optically-based product development. Our full-line of standard products for testing optical, imager and camera systems are appropriate for any industry and we will design a custom product for your specific application. Visit our website at optikos.com, email us at sales@optikos.com or give us a call at +1 617.354.7557 to learn more.

Optikos Corporation
107 Audubon Road, Bldg. 3
Wakefield, MA 01880 USA

+1 617.354.7557
sales@optikos.com
www.optikos.com