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OpTest® System Thermal Module* for Lens Temperature Testing

***The TM Line of Thermal Modules is Patent Pending. The TM-1150 Thermal Module is shown mounted on the LP-1000 lens platform in a typical OpTest® Lens Testing System.**

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Lens Performance is Sensitive to Temperature Changes

Temperature testing is particularly important for automotive lens manufacturers and integrators, whose applications have stringent performance and athermalization requirements to meet safety standards for camera image quality. The proliferation of these cameras brings with it the demand for lens testing over a wide range of temperatures. Optikos has refined techniques used to make these measurements for several years in our IQ-Lab as part of our ever expanding menu of measurement services. We are now pleased to offer the TM line of Thermal Modules for Lens Measurements as accessories to our flagship OpTest® lens testing systems. As a newly introduced product line, all specifications in this data sheet should be considered preliminary and subject to change.

OpTest® Thermal Modules Provide Measurements for a Range of Temperatures and Lens Shapes and Sizes

Typically, there are two lens parameters that are of interest when making temperature dependent measurements: image quality, and flange focal length (FFL), the distance from the mounting flange of the lens to the image plane. The question of image quality is answered by finding the plane of best focus and then measuring the Modulation Transfer Function (MTF) of the lens in this plane. The flange focal length is the distance measured from this plane of best focus to the mounting flange of the lens. As discussed in more detail later, the approach taken here is to measure the temperature variation in FFL, not necessarily the FFL itself.

Designers of lenses to be used in automotive applications, in general, will design the camera system to be athermal, meaning that the image will remain focused on the sensor as the temperature of the lens changes. This does *not* necessarily mean that the distance from the mounting flange to the image plane of the lens measured in isolation is invariant with temperature! If the lens flange is mounted to the sensor with a non-negligible thickness of aluminum, for example, then an athermal lens design for this camera would require the FFL variation to actually track the thickness change in aluminum over the prescribed temperature range.

The OpTest® TM Thermal Module is used in place of the usual lens mount on the LP-1000 lens platform of an OpTest bench equipped with a visible image analyzer, such as the VI-1000, and enables an operator to measure both image quality and flange focal length.

SYSTEM COMPONENTS

There are three main components to the TM system: the recirculating chiller/heater, the manifold, and the thermal chamber in which the lens is mounted. Insulated hoses are provided to connect the three subsystems. The recirculating chiller/heater serves to control the temperature of the working fluid and to pump it through the walls of the heat exchanger in the thermal chamber. The manifold regulates the flow of dry air or nitrogen into the chamber, and the thermal chamber itself mounts to the LP-1000 lens platform and regulates the temperature of the lens under test. The design of the thermal chamber features an integrated tip-tilt mount to facilitate the alignment of the lens to the optical bench.

TM THERMAL CHAMBER USE AND DESIGN CONSIDERATIONS

In order to make measurements across the field of view of the lens, it is generally preferable to place the front of the lens under test close to the chamber window. This mitigates the effect of the chamber aperture vignetting the incident beam at steep off-axis angles. The problem of achieving this condition for lenses of different lengths is solved through the innovative design of an expandable heat exchanger.

Segments may be added to, or removed from the cell in order to match the chamber length to that of the lens under test. Each added segment includes an outer ring of rigid insulation and an inner heat exchanger section that incorporates sectors of spiral channels for the working fluid, thereby ensuring thermal uniformity as the fluid circulates through the entire length of the cell along a double helix path. The light input end of the heat exchanger stack is enclosed by a double glazed window section consisting of a pair of air-spaced precision fused silica windows for improved thermal insulation, and at the other end of the stack is the lens mount, discussed in more detail below.

Dry air or nitrogen passes through the heat sink and is introduced into the thermal chamber at the window end. It then flows over the lens under test and exits at the image side of the chamber. No window is present on the image side of the lens because including one would introduce spherical aberration into the image. The exception to this rule is the case in which a window of appropriate thickness is required in order to simulate the effects of cover glass over the sensor.

When the lens is cooled below the ambient dew point, exposing it to the room air will result in condensation or frosting on the last optical surface. During measurements, a low flow of dry nitrogen or air over the lens maintains positive pressure in the cell and prevents this effect. Between measurements, an increased flow rate of dry gas over the lens helps accelerate temperature changes by providing a forced convection heat transfer path in addition to conduction through the lens mount.

A motorized thermal shutter is incorporated at the image side of the chamber. The shutter serves to close off the end of the chamber until the lens has reached thermal equilibrium, at which point it automatically opens only for the time required to make a measurement. The shutter blades are magnetically attached and can be easily removed to provide full access to the interior when inserting or removing the lens.

The temperature of the lens is monitored continuously using one or more platinum resistance thermometer probes affixed directly to the lens housing.

LENS MOUNTS

The lens mount serves two important roles: it is the primary thermal conduction path from the heat exchanger to the lens under test; and it provides the reference surface for flange focal length measurements. It consists of two parts—the carrier and the insert. The carrier is provided with the Thermal Module and interfaces directly to the end of the heat exchanger. The insert, often designed and provided by the customer, mounts the lens under test and interfaces to the carrier. When the flange focal length variation of the lens needs to be measured, it is typical to fabricate the insert from a low expansion alloy (such as Invar) so that the side nearest the image analyzer may be used as a proxy reference for the flange itself.

At each temperature point the image analyzer microscope is focused on the near surface of the insert and then again at the image plane of the lens, and the distance between the two is recorded. Since this dimension includes the thickness of the insert, this is not the flange focal length, but has the same thermal variation since we assume changes in the Invar thickness to be negligibly small. The insert may also be designed to carry the actual structure or housing used for mounting the lens to the sensor in the camera, in which case the rear surface of the mount may be used as a reference by the image analyzer.

MODELS

The Thermal Module line currently consists of two models, the TM-1150 with a heat exchanger internal diameter of 150mm, and the TM-1100 with an internal diameter of 100mm. The TM-1100 is intended for testing relatively small imaging automotive camera lenses, while the TM-1150 is used for measuring larger LIDAR type lenses and imaging lenses mounted in large housings or with large windows attached.

Both models use the same recirculating chiller/heater and manifold, and both models are designed to be compatible with the OpTest LP-1000 lens platform. Although very small lenses can be measured in the larger chamber, it is generally true that, because of its lower thermal mass, the TM-1100 will heat and cool more rapidly than the TM-1150. Also, because of its smaller surface area, heat losses are somewhat less in the smaller chamber enabling it to reach lower temperatures.

Currently under development is the TM-1050, a small fixed-length chamber specifically intended for testing small automotive type lenses. This model is being developed with the intention that it be compatible with the LensCheck product line.

OPTEST® THERMAL CHAMBER SPECIFICATIONS*			
PARAMETER	TM-1050†	TM-1100	TM-1150
Compatible Test Bench	OpTest® Lens Testing Bench ‡ and LensCheck	OpTest® Lens Testing Bench	OpTest® Lens Testing Bench
Compatible Wavelength Range	Visible-NIR. Compatible with VI-1000 image analyzers and LensCheck Image Analyzer	Visible-NIR. Compatible with VI-1000 image analyzers	Visible-NIR. Compatible with VI-1000 image analyzers
Internal Diameter	50mm	100mm	150mm
Window clear aperture	40mm	60mm	100mm
Heat Exchanger Segment Width	N/A (Fixed Chamber Depth of 40mm)	15mm	15mm
External chiller/heater	Julabo Presto A40	Julabo Presto A40	Julabo Presto A40
Ambient Temperature	10°C to 30°C	10°C to 30°C	10°C to 30°C
Working fluid	PDMS (Silicone Oil) or Galden HT-170 thermal fluid	PDMS (Silicone Oil) or Galden HT-170 thermal fluid	PDMS (Silicone Oil) or Galden HT-170 thermal fluid
Power Requirements	208V/60Hz/15A (US) (International options available)	208V/60Hz/15A (US) (International options available)	208V/60Hz/15A (US) (International options available)
Maximum Attainable Lens Under Test Temperature	105°C (limited for safety)	105°C (limited for safety)	105°C (limited for safety)
Minimum Attainable Lens Under Test Temperature	Specification Pending. Dependent on heat exchanger configuration and hose lengths (-30°C expected)	Specification Pending. Dependent on heat exchanger configuration and hose length (-30°C expected)	Specification Pending. Dependent on heat exchanger configuration and hose length (-25°C expected)

* Preliminary Specification

† In Development

‡ Adapter required

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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 standard products are suitable for any industry or application, and we will design a custom product for your specific needs. Learn more at optikos.com.

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