Optikos®

The Optical Engineering Experts®

Thermal Module

for Lens Temperature Testing

General Information

Lens Performance is Sensitive to Temperature Changes

When a camera system is exposed to a range of temperatures, the imaging performance can suffer drastically if the design was not properly athermalized. The need for cameras that can perform over temperature 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 as part of our ever-expanding menu of measurement services offered by the Optikos IQ Lab™. We are now pleased to offer the TM-1000 line of Thermal Modules for lens measurements as accessories to our flagship OpTest® and LensCheck™ lens testing systems.

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

The Optikos Thermal Module temperature chamber is used in place of the usual lens mount on the rotary platform of an OpTest bench or LensCheck system equipped with a visible image analyzer. By building off of our established product lines, the TM-1000 series enables an operator to measure a broad range of image quality metrics over temperature for lenses operating in the visible spectrum.

The Thermal Module line currently consists of four models: TM-1010, TM-1050 and TM-1065 for use on a LensCheck and the TM-1150 with a temperature chamber internal diameter of 150mm for testing larger lens assemblies on an OpTest bench All four models can be included with a LensCheck or OpTest system, or added to an existing system.

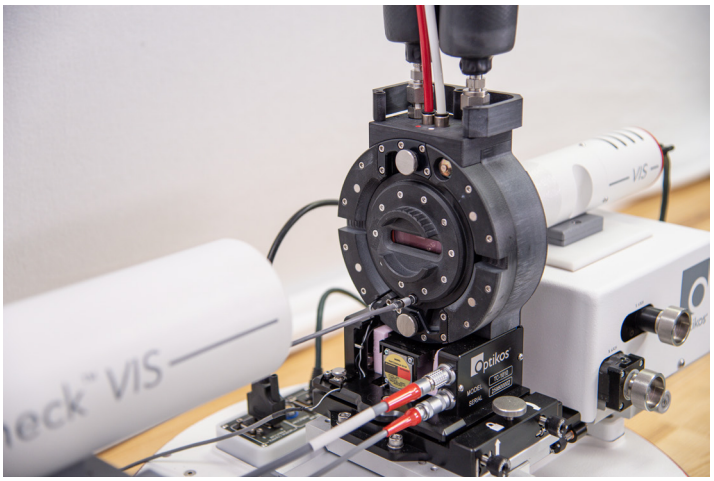
System Components

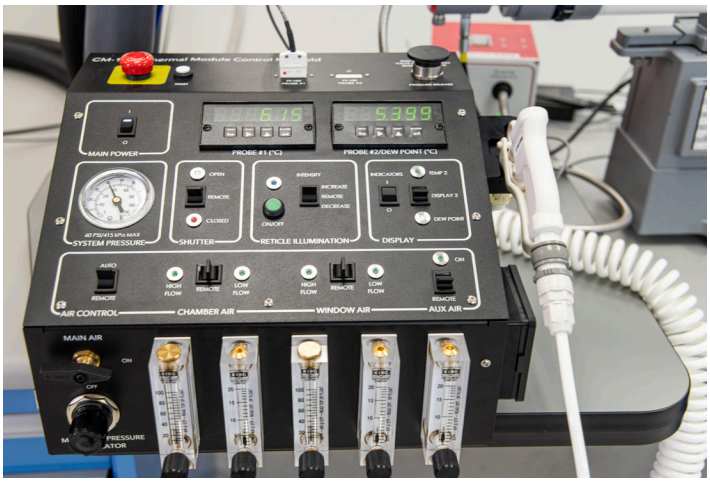
There are three main components to the TM system: the recirculating chiller/heater, the manifold, and the thermal chamber in which the lens is mounted. Insulated hoses are provided to connect the three subsystems. The recirculating chiller/heater serves to control the temperature of the working fluid 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 controls the shutter during the measurement routine. The manifold also continuously monitors the temperature of the lens under test via one or more platinum resistance thermometer probes affixed directly to the lens housing. The thermal chamber itself mounts to the rotary platform and provides temperature feedback to the recirculating chiller/heater and manifold. The three components also interface with the OpTest 7 software application, provided with each LensCheck or OpTest test bench.

Typical Measurements

There are two lens parameters that are usually 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 standard image quality measurements in our OpTest 7 software like MTF, distortion, and field curvature are also available when running temperature testing routines with the Thermal Module. Typically, the plane of the on-axis best focus is found at each temperature point and then used for collecting on- and off-axis image quality data at temperature.

The flange focal length is the distance measured from this plane of best focus to the mounting flange of the lens. As discussed in the Lens Mount section, the approach taken here is to measure the temperature variation in FFL, or relative shift of the best focus plane, not necessarily the FFL itself. We should note here that lenses are often designed to have a specific (and non-zero) focus shift with temperature to counteract thermal movements of the camera housing and produce an athermal camera system, so large focus shifts with temperature are not atypical.





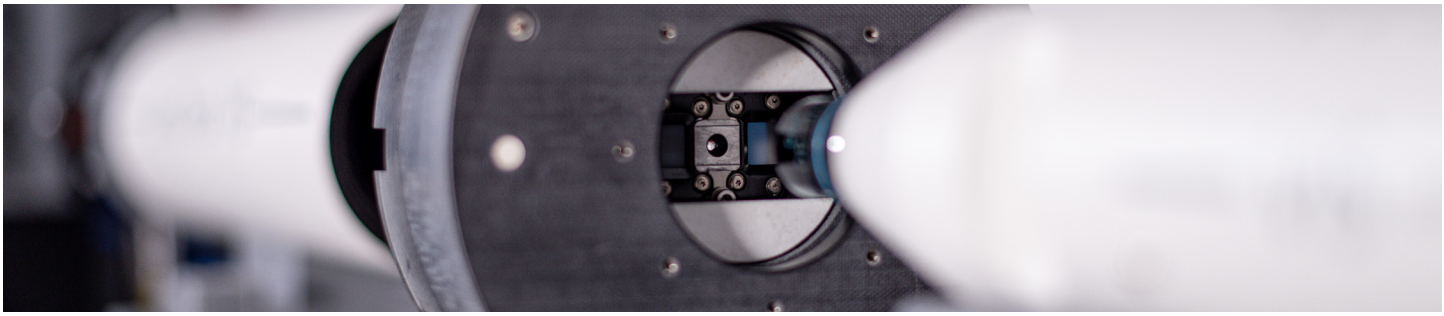
Use and Design Considerations

Accommodations for Off-Axis Testing

In order to make measurements across the full 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. This is important to consider when using the TM-1050 and TM-1065 thermal chambers, which have a fixed length and front window diameter.

The TM-1010 thermal chamber is intended for small pupil (~1mm), wide field of view lenses, and therefore has a double paned, segmented window assembly that allows for image quality testing over a very large field of view.

For larger lenses of varying lengths, the problem of achieving this condition is solved through the innovative design of an expandable heat exchanger for the TM-1150. Segments may be added to, or removed from the cell in order to match the chamber length to that of the lens under test. 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.



Condensation Mitigation

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. The dry air or nitrogen passes through the heat exchanger sections 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. 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.

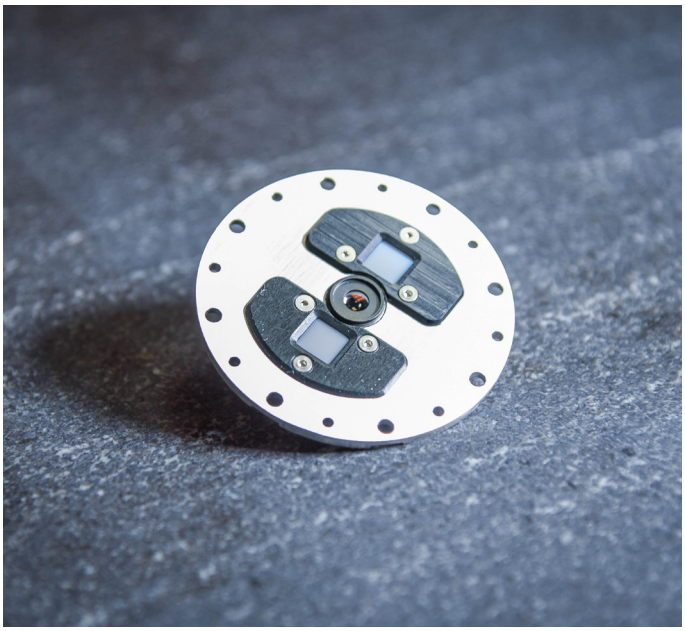
A motorized thermal shutter is incorporated at the image side of the chamber. The shutter serves to close off the end of the chamber until the lens has reached thermal equilibrium, at which point it automatically opens only for the time required to make a measurement.

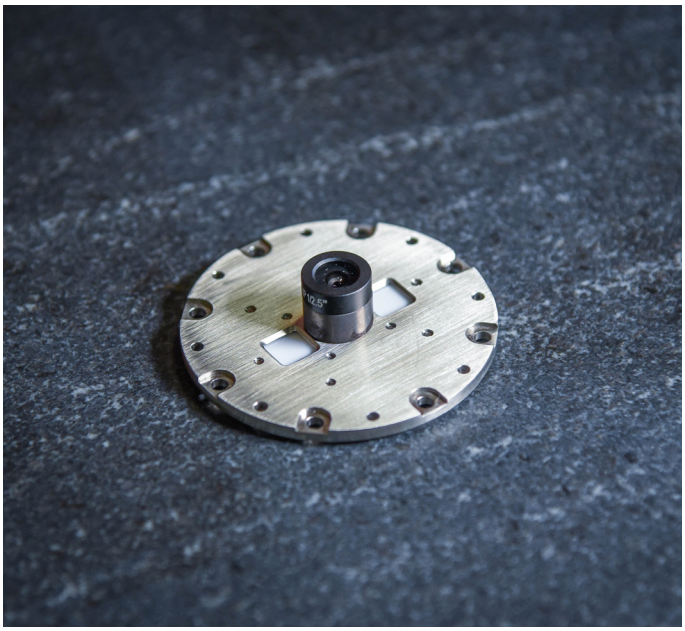
Use and Design Considerations

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 custom designed for a specific lens, 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.

A unique feature in the TM chamber design is the integration of a back-illuminated, chrome on glass reticle into the external surface of the insert. The image analyzer can focus on the reticle and then move to focus on the image, and the distance moved along the focus axis is recorded and used to monitor the relative FFL change over temperature. This feature allows the user to make automated FFL variation measurements over temperature through the OpTest 7 software application. The reticle is spring loaded against a retaining plate that places the reticle surface in the same plane as the external surface of the Invar insert. The illumination is provided by LEDs installed in the thermal chamber that can be turned on only when needed for making FFL variation measurements.





Back illuminated, chrome on glass reticles installed into the TM lens inserts enable automated FFL variation measurements.

Specifications

Thermal Module Specifications				
Parameter	**TM-1010**	**TM-1050**	**TM-1065**	**TM-1150**
Compatible Test Bench	LensCheck OpTest Bench (with additional riser)			OpTest Bench
Compatible Wavelength Range	VIS-NIR (400-1000nm)			
Maximum Allowable Lens Diameter (mm)	10	50	70*	150
Window Clear Aperture (mm)	N/A	47	71	100
Maximum Allowable Entrance Pupil Diameter (mm)	Contact Optikos for more details	45	65	95
Chamber Depth (mm)	10 (fixed)	30 (fixed)	40 (fixed)	Variable with 15mm thick segments
Maximum Allowable Lens Length (mm)	10	30	40	Contact Optikos for more details
External Chiller/Heater	Julabo Presto A80 (standard) Julabo Presto A40 (option)			
Ambient Temperature	10°C to 30°C			
Working Fluid	Galden HT-135 Thermal Fluid (not provided with system)			
Power Requirements	208V/60Hz/15Z (US) (International options available)			
Maximum Attainable Lens Under Test Temperature (°C)	105			
Minimum Attainable Lens Under Test Temperature (°C) **	-40	-40	-40	-20

*FFL variation measurements may not be possible with lenses larger than 35mm in diameter
**With Julabo Presto A80

The Optical Engineering Experts®

Anywhere Light Goes®

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

phone: +1.617.354.7557
email: sales@optikos.com
web: optikos.com