



The Optical Engineering Experts®

POWERED BY *OPTEST*® 7 SOFTWARE

Thermal Module* Series for Lens Temperature Testing



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

*THE THERMAL MODULE PRODUCT LINE IS PATENT PENDING

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.

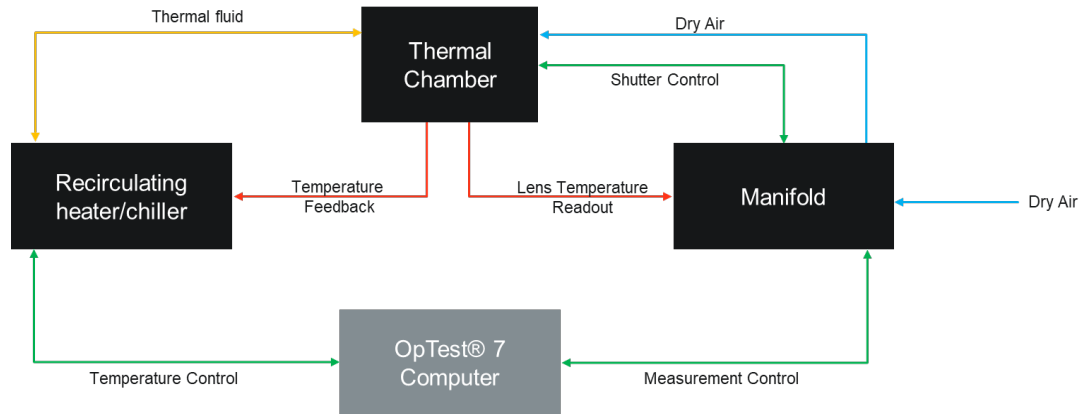
Optikos Thermal Modules Provide Measurements for a Range of Temperatures and Lens Shapes and Sizes

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 two models, the TM-1150 with a temperature chamber internal diameter of 150mm, and the TM-1050 with an internal diameter of 50mm. The TM-1050 is intended for testing relatively small imaging automotive camera lenses on a LensCheck test bench, while the TM-1150 is used for measuring larger LIDAR type lenses and imaging lenses mounted in large housings or with large windows attached.

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.

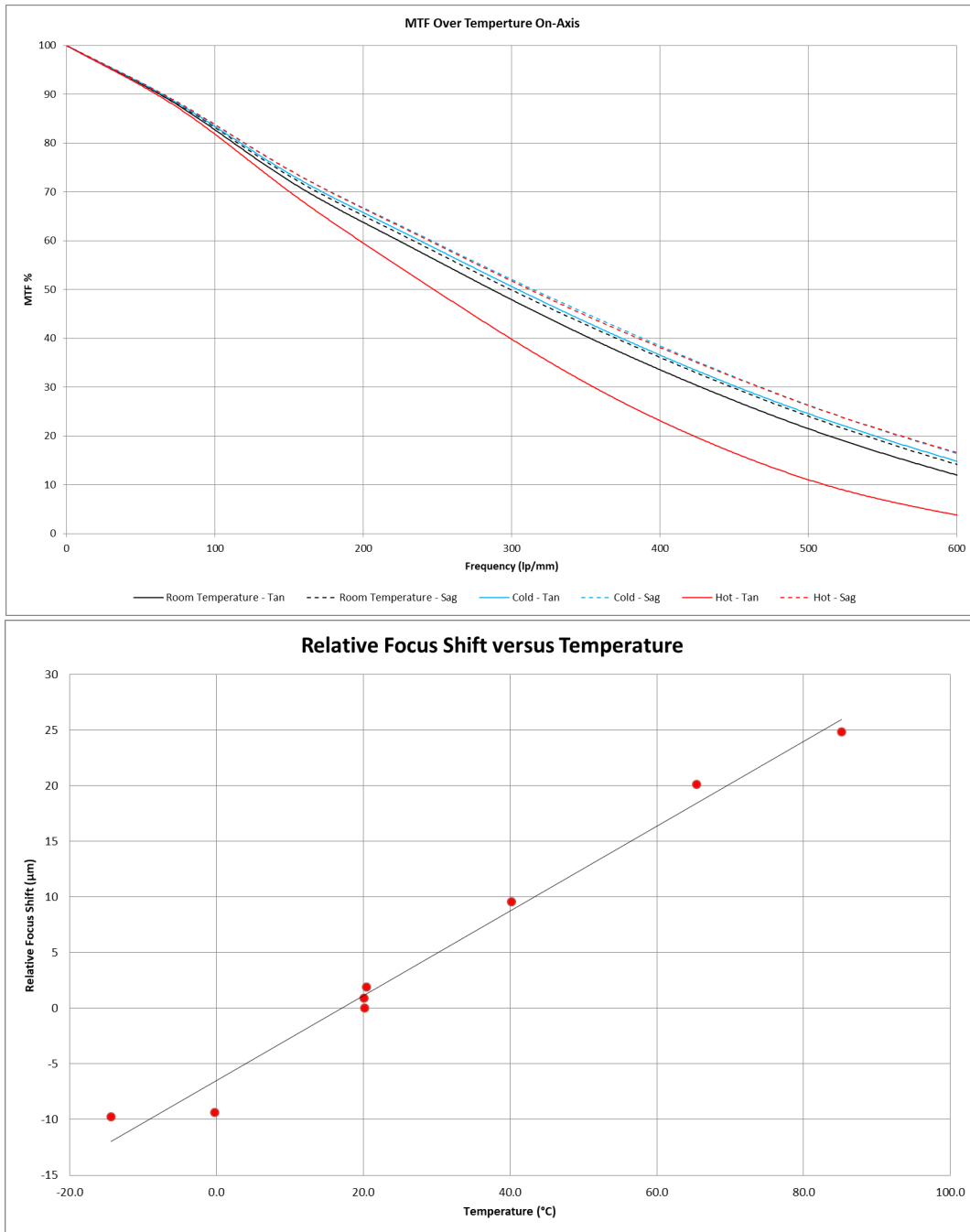


Three main components interface with each other and with OpTest 7 to run testing routines over temperature

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 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. An example plot of MTF versus temperature is shown below, in which the performance of the lens under test clearly degrades at hot temperatures.

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. An example plot of focus shift versus temperature is shown below, and for this test lens the image plane moves 35 microns over the full operating temperature range. 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.



Examples of common measurements of interest over temperature – image quality (MTF) and flange focal length variation

TM Thermal Chamber 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. 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. 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.

The TM-1050 chamber has a fixed length of 30mm, which was chosen to accommodate the typical size of an automotive lens.

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.

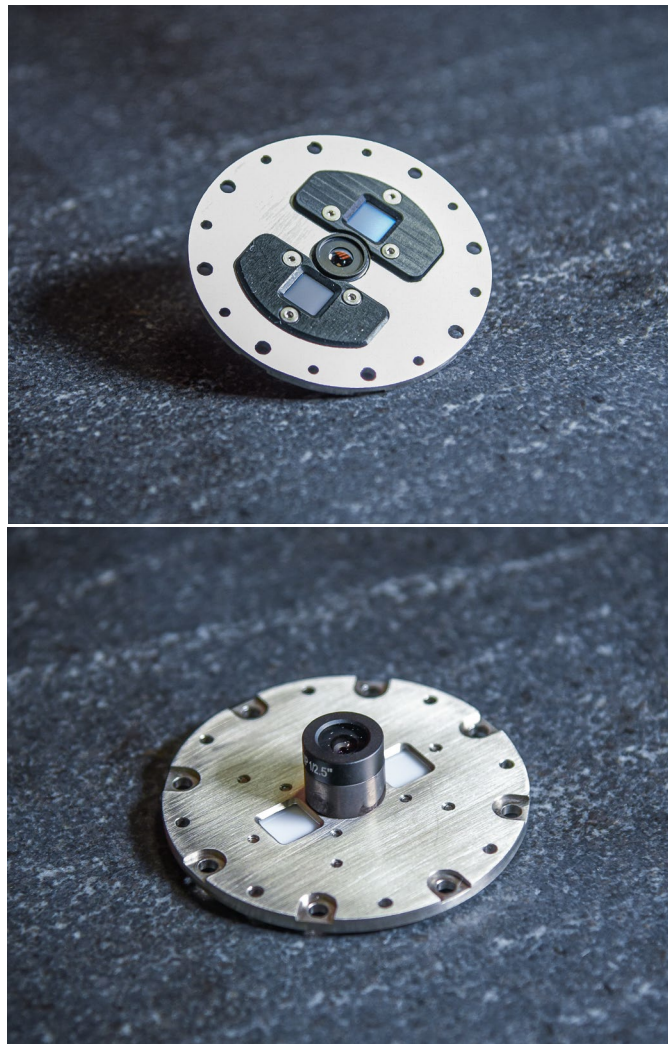
A motorized thermal shutter is incorporated at the image side of the chamber. The shutter serves to close off the end of the chamber until the lens has reached thermal equilibrium, at which point it automatically opens only for the time required to make a measurement.

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.

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.

A new feature in the TM-1050 design is the integration of a back-illuminated, chrome on glass reticle into the external surface of the insert. 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-1050 lens inserts enable automated FFL variation measurements.

THERMAL CHAMBER SPECIFICATIONS

PARAMETER	TM-1050	TM-1150
Compatible Test Bench	OpTest® Lens Testing Bench [‡] LensCheck VIS	OpTest® Lens Testing Bench
Compatible Wavelength Range	Visible-NIR. Compatible with VI-1000 series and LensCheck VIS image analyzers	Visible-NIR. Compatible with VI-1000 series image analyzers
Internal Diameter	50mm	150mm
Window Clear Aperture	47mm	100mm
Heat Exchanger Segment Width	N/A Fixed Chamber Depth of 30mm	15mm
External Chiller/Heater	Julabo Presto A40	Julabo Presto A40
Ambient Temperature	10C to 30C	10C to 30C
Working Fluid	Galden HT-160 Thermal Fluid	Galden HT-160 Thermal Fluid
Power Requirements	208V/60HZ/15Z (US) (International options available)	208V/60HZ/15Z (US) (International options available)
Maximum Attainable Lens Under Test Temperature	105C	105C
Minimum Attainable Lens Under Test Temperature	-25C	-20C

[‡] Adapter required



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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 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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