ORI

Station for testing optical systems

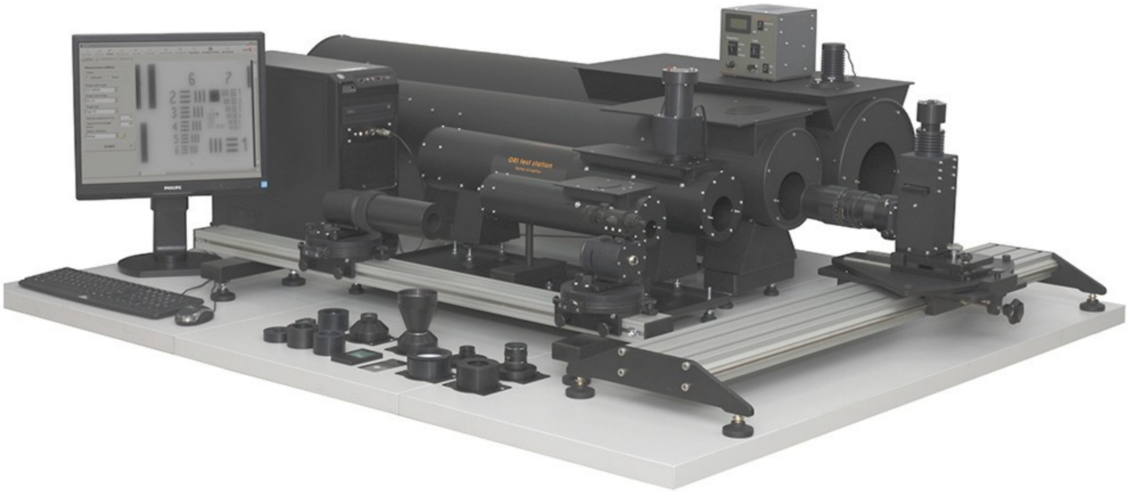

Fig. 1. Photo of ORI test station

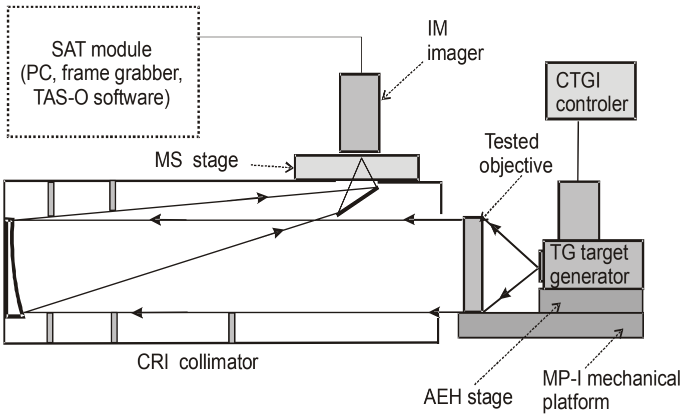

Fig. 2. Simplified block diagram of the ORI test station

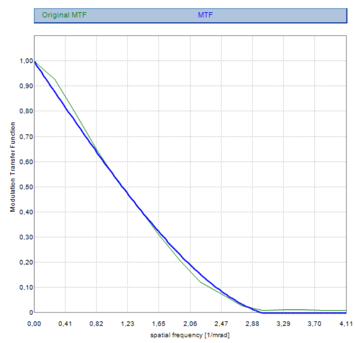

Fig. 3. MTF curve of an exemplary diffraction limited LWIR objective

Basic information:

ORI test station is an universal station for testing of optical systems. This station enables measurement of all important parameters of optical objectives, oculars or afocal systems (MTF, resolution, effective focal length, distortion, vignetting, transmission, back focal length, working focal length, depth of focus, field curvature) of optical systems working in all typical spectral bands: VIS , VIS-NIR, SWIR, MWIR, and LWIR.

How is built?

ORI test station uses a concept of inverse imaging for testing optical objectives. This means that the tested objective projects image of a reference target located at its focal plane instead of creating an image at its focal plane. In detail, a target generator module (high intensity radiation source combined with a reference target) is located at the focal plane of the tested objective that projects target image into direction of a reflective collimator combined with an imaging camera. The collimator creates image of the reference target at its focal plane where imaging camera captures and digitizes this image. Quality of this output image of reference target is evaluated using specialized software that calculates parameters of tested objective.

ORI is a modular universal station that can be configured for testing optical systems working in different spectral bands (1-VIS-NIR, 2-SWIR, 3- MWIR-LWIR) using a series of exchangeable blocks: set of CRI off axis reflective collimators, a series of TG target generators, set CTG controllers, set of mechanical adapters, AEH optical stage, MP mechanical platform , set of spectral filters, set of optical attenuators, set of targets, set of IM electronic imagers (versions optimized for different spectral bands), PC set, frame grabber, TAS-O computer program, and optional set of reference optical objectives. By exchange of these blocks ORI station can be easily converted from version for testing VIS-NIR objectives to a version optimized for testing LWIR/MWIR objectives or SWIR objectives.

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Why ORI station?

There are several design differences and differences in overall performance that make ORI unique on international market. From design point of view there are two main differences of ORI stations comparing to typical test stations offered on the market : special measurement method , and exclusive use 2D imaging cameras to capture image generated by tested optical system (typically an optical objective).

ORI test station uses inverse imaging method for testing optical objectives. This method requires to use a series of off axis reflective collimators of different apertures and focal length to achieve proper magnification and sufficient light intensity of images of the reference targets created at collimator focal plane.   Next, output image of magnified blurred image of reference target is always captured using 2D imaging cameras working in different spectral bands.

Inverse imaging test method based on 2D imaging cameras creates several challenges for the manufacturer. First, high manufacturing costs because a set of off axis collimators and a set of imaging cameras for different spectral bands are needed. Second, advanced algorithms for calibration and image processing are needed to convert typical imaging cameras into imaging radiometers capable to capture precision spatial intensity distribution in images generated by tested objective.

Typical test stations for testing optical objectives are practically typical reflective image projectors used for testing thermal imagers/VIS-NIR cameras/SWIR imagers with an additional module: a video microscope that captures magnified image of a reference target at focal plane of the tested optical objective. Analysis of quality of captured images gives data that can be used to calculate parameters of tested optical objective.

The video microscope method reduces requirements on the collimators as a single off axis reflective collimator can be used to built a test station capable to test optical objectives of different apertures and focal lengths. This change means lower manufacturing costs and potential possiblity to create automatic test stations. The video microscope method can also enable fast and accurate tests of optical objectives if the video microscope can capture image from the tested objective without any degradation and in short time.

It is a technical challenge to fulfill these two conditions on the video microscope (not noticeable image degradation and short capturing time) used in stations for testing optical objectives.

It is relatively easy to fulfill the conditions when designing video microscopes for VIS-NIR spectral band. There are commercially available both ultra bright near perfect microscope objectives and high-res CCD/CMOS camerass. However, it is extremely difficult to design near perfect ultra bright optical objectives for video microscopes for SWIR/MWIR/LWIR bands that would not degrade quality of magnified image. It is possible to correct this degradation but any correction limits also measurement accuracy.

Next, SWIR/MWIR/LWIR imaging cameras are costly and additionally typical commercial cameras do not offer proper accuracy of capturing spatial distribution of light intensity. Therefore the test stations based on video microscope method often use a scanning imager built cooled discrete MWIR/LWIR detector. This technology is cheaper and reliable but is also much slower comparing to use of 2D imaging cameras employed in ORI station. Some of competitors try to use 2D imaging cameras but so far succeded only for LWIR band.

Further on, accuracy data of test stations based on video microscope method often refers to specifications of version for testing VIS-NIR objecives.

Because of these reasons impressive automatic test stations based on video microscope method are typically less universal, less accurate and much slower comparing to manual but software supported ORI test station.

Recommendations

Honest recommendation of Inframet for potential customers in form of four basic rules are presented below.

1. If station for testing mass manufactured   small VIS-NIR objectives (aperture below 40 mm) is needed then buy a competitor test station based on video microscope method.
2. If universal station for testing small/medium quantities of objectives of different apertures and for different spectral bands (VIS/NIR SWIR/MWIR/LWIR) then buy a typical version of ORI optimal for size of tested optics and required test capabilities.
3. If station for testing mass manufactured   SWIR/MWIR/LWIR objectives is needed then contact Inframet for modified ORI station optimal for your application.
4. If station for testing space quality of large VIS-NIR objectives is needed then please consider ORI test station.

To justify these claims we state that some of best in the world optical objectives for SWIR/MWIR/LWIR spectral bands have been developed with help of ORI test station and that the conclusion on superiority of ORI stations is based on an analysis of current market situation. Inframet can optionally deliver both reference list and detail market review for potential customers of ORI station.

MEASUREMENT RANGE AND ACCURACY

Measurement range and measurement accuracy depend on version of ORI station. Precision data is delivered when ORI version is determined. Below is presented general data.

Table. 1. Acceptable parameters of tested objectives

Parameter	VIS and VIS/NIR objectives	SWIR objectives	MWIR objectives	LWIR objectives
Range of acceptable focal length	10 – 800 mm	10 – 800 mm	10 – 800 mm	10 – 800 mm
Range of acceptable back focal length	10 – 700 mm	10 – 700 mm	10 – 700 mm	10 – 700 mm
Acceptable Optics length	5-300 mm	5-300 mm	5-300 mm	5-300 mm
Range of acceptable aperture of tested objectives	From about 2 mm to 200 mm	From about 4 mm to 200 mm	From about 3 mm to 200 mm	From about 5 mm to 200 mm
Range of acceptable F-number	From 0.8 to 10	From 1 to 5	from 1 to 5	from 1 to 3
Maximal simulated sensor	18 mm image intensifier tube or 1” sensor (12.8x9.6 mm)	Max 15x15 mm	IR FPA of dimension: 17.4x13.1 mm	IR FPA of dimension: 17.4x13.1 mm

Table. 2. Measurement range and measurement accuracy

Parameter	Visible/NIR objectives	SWIR objectives	MWIR objectives	LWIR objectives
Spatial frequency range for MTF measurement	0- 400 lp/mm	0- 200 lp/mm	0-150 lp/mm	0-100 lp/mm
Maximal spatial frequency of resolution target	456 lp/mm	228 lp/mm	-	-
Off-axis angle range	from 0^0 to 30^0	from 0^0 to 30^0	from 0^0 to 30^0	from 0^0 to 30^0
MTF measurement uncertainty	+/-0.02 (at MTF >0.2)	+/-0.02 (MTF>0.2)	+/-0.02 (MTF >0.2)	+/-0.02 (MTF >0.2)
MTF measurement repeatability	+/-0.01 (when MTF >0.2)	+/-0.01 (MTF >0.2)	+/-0.01 (MTF >0.2)	+/-0.01 (MTF >0.2)
Focal length measurement relative uncertainty	≤1%	≤1%	≤2%	≤ 2%
Distortion measurement relative uncertainty	≤ 4% but measurement resolution 1%	≤ 4% but measurement resolution 1%	≤ 9% but measurement resolution 1%	≤ 9% but measurement resolution 1%
Vignetting measurement relative uncertainty	≤ 3%	≤ 3%	≤ 5%	≤ 5%
Relative uncertainty of relative transmittance measurement	≤ 3%	≤ 3%	≤ 8%	≤ 8%
Relative uncertainty of absolute transmission mea-	≤ 7%	≤ 7%	≤ 10%	≤ 10%

surement				
Relative uncertainty of back focal length	≤ 1%	≤ 1%	≤ 1.5%	≤ 2%
Relative uncertainty of working focal length	≤ 1%	≤ 1%	≤ 1.5%	≤ 2%
Relative uncertainty of depth of focus	≤ 7%	≤ 7%	≤ 10%	≤ 10%
Relative uncertainty of field curvature	≤ 10%	≤ 10%	≤ 14%	≤ 14%

VERSIONS

ORI stations can be delivered in many different versions. The version is described using five letter code (abcd) presented in the table below.

Table. 3. Definition of codes used to describe versions of ORI test system

	1	2	3	4	5
Code	**Aperture/ range/ focal length range**	**Test capabilities**	**Type of tested optical system**	**Spectral range of tested optical system**	**Simulated distance**
A	3-70mm 3-240mm	MTF (on axis), resolution (for VIS optics)	Converging objectives	VIS/NIR	Fixed - optical infinity
B	3-100mm 3-400 mm	MTF (on-axis, off-axis- sagital, tangential), effective focal length, resolution (for VIS/NIR optics)	Afocal systems only	MWIR/ LWIR (option: LWIR)	Regulated: from 3 up to 20 focal length
C	3-150mm 3-600 mm	As in point B but additionally distortion, vignetting, relative transmission of converging objectives	Converging objectives and Afocal systems	MWIR/LWIR/ VIS/NIR	Test to be done at both distances
D	3-200 mm 3-800 mm	As in point C but additionally absolute transmission		SWIR/VIS/NIR	
E	3-250 mm 3-1000 mm	As in point C but additionally back focal length, working focal length, depth of focus, field curvature		MWIR/LWIR/ SWIR	
F	3-300 mm 3-1200 mm	As in point E but additionally absolute transmission		MWIR/LWIR/ SWIR/VIS/NIR	

Attention:

1. Special versions of ORI can be delivered for testing bigger optical systems.
2. Version optimized for testing optical objectives for NVDs (simulation of glass input image intensifier tubes) can be deliuvered.
3. If different combination of spectral range of tested optics (or additional UV band) is needed please contact Inframet.

Example: ORI -CAACA means the following ORI test system: 1C) maximal aperture of tested optical objective equals 150mm, maximal focal length equals 600mm, 2A) test system capable to measure MTF(on axis), resolution(visible objectives); 3A) the test system capable to test only Converging optical objectives; 4C) MWIR / LWIR/VIS/NIR objectives can be tested, 5A) objective is to be tested at infinity simulated distance.

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