ORIFA

Station for testing folded optical objectives

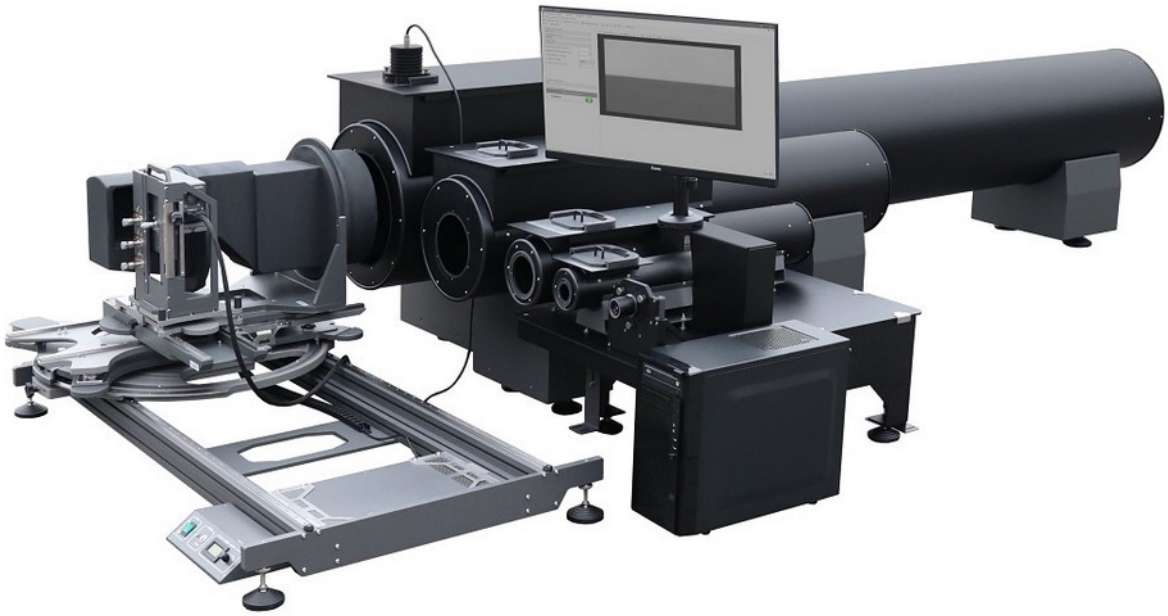

Fig. 1. Photo of ORIFA test station (MWIR/LWIR configuration)

1 Types of optical objectives

Great majority of optical objectives are objectives having straight optical axis and manufactured in form of simple cylinders. Manufacturing simplicity is a great advantage of such objectives but they are also characterized by an important drawback: long length, especially in case of objectives of long focal length. This drawback can be eliminated or reduced in case of folded objectives having bent optical axis in a way to make the optical path much longer than the size of the system. The highest reduction of size can be achieved in case of special class of folded objectives: the U–turn objectives. These are folded objectives having optical axis bent at least two times in a way that input optical axis is parallel to output optical axis (Fig. 2). Nowadays, folded objectives are becoming a popular solution for high–end infrared zoom objectives used in long range thermal imagers.

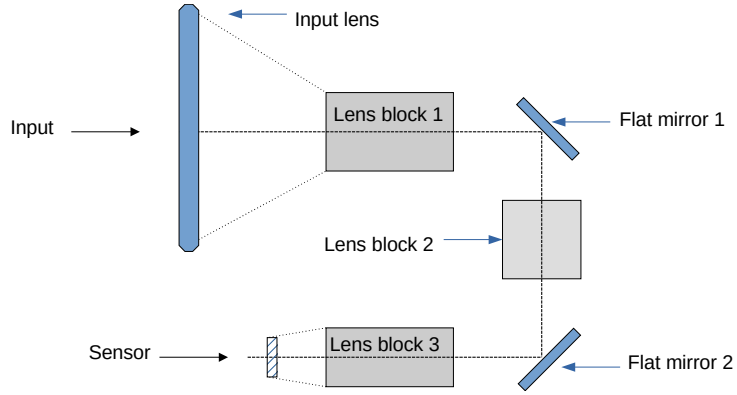

Fig. 2. Diagram of exemplary folded objective (U–turn version)

There are also other 3 significant differences between straight axis objectives and folded objectives. The first objectives are independent mechanical blocks having optical elements in their housing. Such objectives are to be attached to an imager core having its own housing. The second objectives are not independent blocks. Optical elements of the folded objectives are typically mounted to a special big housing that mounts both the optical elements and electronics/imaging sensor of the imager core ((Fig. 2). Therefore testing folded objectives requires special test stations.

2 Inframet situation

For over a decade, Inframet manufactures ORI station (see details at for testing optical objectives. ORI is a quasi universal station capable to test optical objective of any focal length/aperture, any number of parameters, and any spectral band. The ORI stations are reliable, accurate, easy to operate. The station have very good opinion among their users, especially for customers who need quasi universal station for testing MWIR/LWIR objectives. However, there is one limitation: the station can be used for typical objectives with straight optical axis built in form of a cylinder; it cannot be used for testing folded objectives.

ORI works on using a concept of a simple but very effective concept of inverse imaging (Fig. 3) where image of reference edge target must be created at focal plane of the tested objective. This situation is achieved in case of testing typical objectives with straight optical axis by placing both TG target generator block and the tested objective on common mechanical platform (AEH platform) and regulation of distance between these two blocks. It should be noted that imaging plane of typical straight axis objective is located outside mechanical case of such objective. However, such a solution cannot be used in case of folded objectives due to mechanical constraints: the imaging plane of the folded objective is typically deep inside its mechanical case.

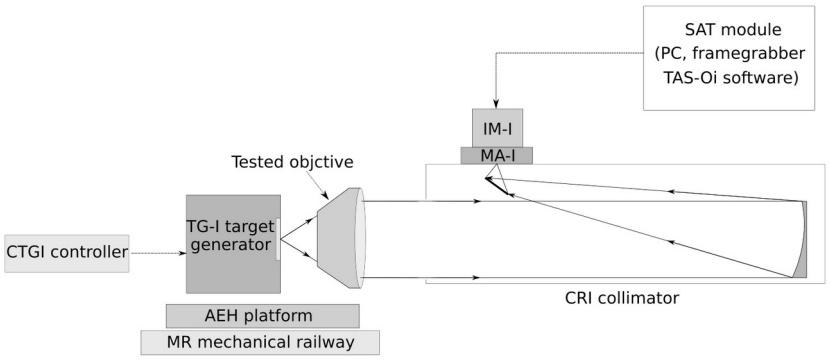

Fig. 3.Diagram of typical ORI station

3 What is ORIFA?

ORIFA is a special modified version of ORI station that enables testing folded objectives in addition to testing typical straight axis objectives. This expanded test capability has been achieved by design of a special new block: TG–U miniaturized target generator. This miniaturized block in contrast to typical large TG target generator can be inserted to compartment intended for electronics/sensor of the imager. After precision positioning of TG–U block the reference edge target generated by this block is exactly at position intended for the imaging sensor of the imager. At such situation the inverse imaging method can be used to measure MTF and other important parameters of tested folded objective in the same way as used for typical mature ORI stations. Other blocks of ORIFA are the same as in classical ORI station.

4 Version of ORIFA

ORIFA stations can be delivered in many different versions depending on type of tested objectives (straight axis/ folded), max/min focal length, max/min aperture, number of measured parameters, spectral band of tested objective.

The version is described using code composed from one digit and three letters (example ORIFA–1ABC) presented in the tables below.

Table. 1. Definition of digit code used to describe versions of ORIFA test system

Code	Type of tested objectives
1	only folded optical objectives
2	both folded optical objectives and straight axis optical objectives

Table. 2. Definition of letter codes used to describe versions of ORIFA test system

	1	2	3
Code	**Aperture range/ focal length range**	**Test capabilities**	**Spectral range**
A	20–70mm 20–200mm	MTF (on – axis)	VIS/NIR
B	20–100mm 20–400 mm	MTF (on – axis, off – axis, sagittal, tangential), effective focal length and optionally resolution (only for VIS–SWIR range)	LWIR
C	20–150mm 20–600 mm	As in point B but additionally: distortion, vignetting, relative transmission	MWIR/ LWIR
D	20–200 mm 20–800 mm	As in point C but additionally: absolute transmission	MWIR/LWIR/ VIS/NIR
E	20–250 mm 20–1000 mm	As in point D but additionally: depth of focus, field curvature	SWIR/VIS/NIR
F	20–300 mm 20–1500 mm	As in point E but additionally: chromatic aberration (for VIS/NIR optics)	MWIR/LWIR/ SWIR
G	20–400 mm 20–2500 mm		MWIR/LWIR/ SWIR/VIS/NIR

Example code:
ORIFA–2BBC means ORIFA station of following performance:

1. ability to test both both folded optical objectives and straight axis optical objectives
2. max/min aperture: 20/100mm
3. max/min focal length: 20/400mm
4. measured parameters: MTF (on – axis, off – axis, sagittal, tangential), effective focal length
5. spectral bands: MWIR/ LWIR.

ORIFA is not fully universal when testing folded objectives. Therefore the potential customer is expected to deliver detail information on his folded objective/objectives to be tested (including drawings). After analysis of delivered data Inframet can confirm final capabilities when testing the folded objectives.
It should be also noted that test capabilities of ORIFA can differ slightly depending on type of tested objective: folded objectives or straight axis objectives.

5 Options

ORIFA can be delivered in a series of additional options to expand test capabilities:

1. Optional versions of ORIFA can be delivered for testing standard cylindrical objectives of focal length as short as 7mm and FOV as big as 90º can be delivered. Please add OC to typical code of chosen ORIFA station.
2. Optional versions of ORIFA can be delivered for testing standard cylindrical objectives of aperture as high as 700mm and focal length as 6000 mm. Please add BIG to typical code of chosen ORIFA station.
3. If different combination of spectral range of tested optics (or additional UV band) is needed please contact Inframet.

6 List of blocks

Detail list of blocks of ORIFA depends on version. Here only simplified list is presented:

1. Set of CRI reflective off axis parabolic collimators
2. Series of TG–U miniaturized target generators – for testing folded objectives
3. AEH–U optical stage – for angular aligning of the folded objectives
4. Series of TG target generators – for testing straight axis objectives
5. AEH optical stage – for angular aligning of the straight axis objectives
6. MP mechanical platform – horizontal positioning of tested objectives
7. Set of spectral filters
8. Set of optical attenuators
9. Set of IM electronic imagers (versions optimized for different spectral bands)
10. PC set
11. Frame grabber

12. TAS–O computer program
13. Optional set of reference optical objectives

By exchange of these blocks ORIFA station can be easily converted from version for testing VIS–NIR objectives to a version optimized for testing SWIR objectives or MWIR/LWIR objectives; or from version capable to test only folded objectives to version capable to test both folded objectives and straight axis objectives.

7 Measurement range and accuracy

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

Table. 3. Acceptable parameters of tested objectives

Parameter	VIS and VIS/NIR optical objectives	SWIR optical objectives	MWIR optical objectives	LWIR optical objectives
Range of acceptable focal length[1]	20 – 1500 mm	20 – 1500 mm	20 – 1500 mm	20 – 1500 mm
Minimal space for target generator[2]	35x60mm	35x60mm	35x60mm	35x60mm
Acceptable Optics length	20 – 500 mm	20 – 500 mm	20 – 500 mm	20 – 500 mm
Maximal load of AEH platform	<35kg	<35kg	<35kg	<35kg
Range of acceptable aperture of tested objectives	20 – 300 mm	20 – 300 mm	20 – 300 mm	20 – 300 mm
Range of acceptable F–number	From 0.7 to 10	From 0.7 to 5	From 0.7 to 6	From 0.7 to 3
Maximal simulated sensor (can be extended)	18 mm image intensifier tube or 1” sensor (12.8x9.6 mm)	SWIR FPA of dimension: 15x15 mm	IR FPA of dimension: 17.4x13.1 mm	IR FPA of dimension:17.4x13.1 mm
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[3] (can be extended)	from -30^0 to 30^0	from -30^0 to 30	from -30^0 to 30^0	from -30^0 to 30^0

Table. 4. Measurement range and measurement relative uncertainty

Parameter	Visible/NIR optical objectives	SWIR optical objectives	MWIR optical objectives	LWIR optical objectives
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[4]	≤1%	≤1%	≤1.5%	≤ 2%

[1]Minimal focal length can be extended – special version for small optics
[2]Minimal space for target generator – space where target generator is inserted inside tested optical objective
[3]Maximal FOV of tested objective is equal to two times of off–axis angle range
[4]Uncertainty of measurement of focal length is typically better than 1%. Value in data sheet is conservative value for a case of poor quality objective when image is blurred.

Distortion measurement relative uncertainty[5]	≤ 4%	≤ 4%	≤ 6%	≤ 6%
Distortion measurement sensitivity	≤ 0.6%	≤ 0.6%	≤ 0.8%	≤ 0.8%
Vignetting measurement relative uncertainty	≤ 3%	≤ 3%	≤ 4%	≤ 4%
Relative transmission measurement relative uncertainty	≤ 3%	≤ 3%	≤ 5%	≤ 5%
Absolute transmission measurement relative uncertainty	≤ 4%	≤ 4%	≤ 6%	≤ 6%
Depth of focus measurement relative uncertainty	≤ 4%	≤ 5%	≤ 6%	≤ 6%
Field curvature measurement relative uncertainty	≤ 6%	≤ 8%	≤ 9%	≤ 10%
Chromatic aberration measurement relative uncertainty	≤ 5%	–	–	–

Attention: Measurement uncertainties presented in table above should be treated as approximate values. Uncertainties of some of parameters (focal length, back focal length, distortion, depth of focus, field curvature) do depend not only on quality of ORIFA test station but even more on quality of image projected by tested objective. Better image quality better measurement. This relationship occurs because measurement of these parameters requires to mark edges of image of reference target. More blurred edges means that measurement errors are higher.

8 Why ORIFA station?

There are several reasons to choose ORIFA station:

1. At present ORIFA is the only station offered on the market capable to test folded objectives,
2. ORIFA has been successfully used by a series of manufacturers of folded objective,
3. ORIFA is based on well checked design of ORI station having very good opinion due to reliability, simplicity of operation and high measurement accuracy,
4. Advantages of ORI station are valid also for ORIFA station (see ORI data sheet https://www.inframet.com/Data_sheets/ORI.pdf)

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[5]But not better than indicated by sensitivity value