ST

System for testing SWIR imagers

Fig. 1. Photo of the ST200 test system

1 Introduction

SWIR imagers are imaging systems sensitive mainly in SWIR range: 1000nm to 3000nm. There are three main types of SWIR imagers:

1. standard SWIR imagers sensitive in approximate spectral band 900-1650nm (typically built using non cooled InGaAs imaging sensors),
2. shortwave extended SWIR imagers sensitive in approximate spectral band 500-1650nm (typically built using shortwave extended InGaAs imaging sensors),
3. long-wave extended SWIR imagers sensitive in approximate spectral band 1000-2400nm (typically built using cooled extended InGaAs imaging sensors).

In all three spectral bands (including long-wave extended imagers) light emitted by Sun/Moon/sky dominates over thermal radiation emitted by targets of interest. However, thermal radiation becomes noticeable in case of long-wave extended 1000-2500nm band and such SWIR imagers can detect medium temperature targets (aircraft engines, high speed missiles, helicopters, IR flares) using thermal radiation emitted by such targets.

Testing SWIR imagers is carried out using systems similar to systems for testing VIS-NIR cameras (collimator, light source, rotary wheel, set of targets). In case first two types of SWIR imagers it is enough to modify light source to expand to SWIR band up to about 1700nm. In case of third types of SWIR imagers light source of spectral band up to about 2200nm is needed. Further on, if thermal tests are to be done then additional medium temperature blackbody is needed. However, the blackbody is needed only in rare case of long-wave extended SWIR imagers.

ST is a system offered by Inframet for testing high end surveillance SWIR imagers used for medium/long range surveillance at both day and night conditions. In detail, ST is a variable intensity image projector that projects images of some standard targets into direction of tested SWIR camera. The tested camera generates copies of the projected images. Quality of the images generated by the camera is evaluated and its important characteristics are measured.

The ST system enable simulation of both ultra dark nights (moonless clouded nights) and ultra bright days (bright sand desert at noon) and accurate testing performance of surveillance SWIR imagers working at any illumination conditions. Testing surveillance SWIR cameras with ST test station generate a series of parameters that give vital information about potential camera surveillance capabilities for camera users.

2 What E-O systems can be tested?

ST system is basically universal test system that can be used to test virtually all of high end SWIR imagers. However, in detail ST system is optimized for testing three main groups of such imagers:

1. Multi purpose SWIR imagers,
2. Long/medium range surveillance imagers,
3. SWIR imagers for multi-sensor imaging/laser system.

Photos of exemplary SWIR cameras from these groups are presented in Figs.2-6. It should be noted that ST system is to test SWIR imagers of multi sensor imaging/laser systems and is not designed to test all parts of that system.

Fig. 2. Owl 640 VIS-SWIR Camera Raptor Photonics

Fig. 3. FLIR A6260 SWIR Camera with InGaAs Detector

Fig. 4. RHT SWIR CAMERAS from Silent Sentinel

Fig. 5. Long Range SWIR camera from Shandong Sheenrun Optics & Electronics Co., Ltd.

Fig. 6. FLIR multi sensor ULTRAFORCE® 380-HDc system (including SWIR imager)

3 Test capabilities

ST system in the most advanced versions can enable measurement of a long list of parameters of SWIR cameras. These parameters are listed below using criterion of their popularity:

1. Resolution,
2. MTF (Modulation Transfer Function),
3. MRC (Minimal Resolvable Contrast),
4. FOV (Field of View),
5. Noise Equivalent Input: NEL (Noise Equivalent Luminance), NEI (Noise Equivalent Illuminance), NEIR (Noise Equivalent Irradiance), NER (Noise Equivalent Radiance),
6. FPN (Fixed Pattern Noise),
7. Distortion,
8. 3D Noise,
9. Sensitivity,
10. SNR (Signal to Noise Ratio),
11. Resposivity function (Responsivity, Linearity, Dynamic, Light Range),
12. Bad pixels,
13. GRD (Ground Resolved Distance),
14. EMVA1288 tests – option for testing camera cores,
15. MRT – minimal resolvable temperature,
16. MDT – minimum detectable temperature.

Following boresight tests can be carried out using ST system:

1. Zoom-through boresight: angular shift of target marked by imager line of sight (indicated by aiming mark) when zooming,
2. Focus-through boresight: angular shift of target marked by imager line of sight (indicated by aiming mark) when focusing (at different range of focusing depending on version).
3. Boresight of UUT to collimator: checking if tested UUT is properly positioned relative to collimator output of test system

4 How ST systems are built?

ST test system is a modular system built in most expaned version using over twenty blocks:

1. CDT off axis reflective collimator (collimators of different aperture, focal length and optical quality are available for different applications),
2. Device to exchange active target (MRW motorized rotary wheel (version of rotary wheel is determined by version of collimator, its FOV and number of targets) or FRW focusing rotary wheel (optional replacement of MRW wheel) - alternative of MRW wheel,
3. Computerized LS-SAL light source in different versions,
4. Set of VIS targets,
5. Medium temperature MTB-2D blackbody,
6. Set of IR targets,
7. Set of frame grabber cards to capture electronic video image,
8. PC – typical PC working under Windows operating system (laptop or desktop PC are delivered),
9. Set of control programs: Light source control, Target control,
10. Set of measurement support programs: SUB-V, TAS-V, BOR,
11. IL illuminator to help to position of UUT relative to collimator,
12. BOFOC boresight focuser block that enables to regulate position of pinhole of SWIR source along collimator optical axix (regulation of distance to simulated pinhole target).

It should be noted that ST is a system for testing high end SWIR cameras and testing small, cheap cameras of very short range (majority of security cameras) is excluded.

The first six blocks (collimator, rotary wheel, light source, blackbody, set of targets) form a system that can be called variable target projector. It projects optical images of different reference targets into direction of a tested SWIR camera. The fifth block (set of frame grabbers) enables capturing video image generated by typical electronic output thermal imager in a long series of video standards. The block 6–8 (PC, monitor, software) form a system that can be called computing/display center that control light source/wheel, and carries image acquisition, image analysis and calculates measured parameters of tested camera. The blocks 1–10 form a system that can be considered as basic ST system used for basic testing typical electronic output thermal imagers.

Higher number blocks expand test capabilities of ST system. Block no 11 (IL illuminator) enables easy positioning of UUT relative to output of collimator of test system, Block 12 enables expanded boresgith of tested VIS NIR camera.

Attention: It is assumed that customer is to deliver mechanical platform/angular stages for tested UUT. Inframet can offer some optional platform /stages. However, they are not on list of basic modules because customers often use need customized platform /angular stages for regulation of position of their imagers.

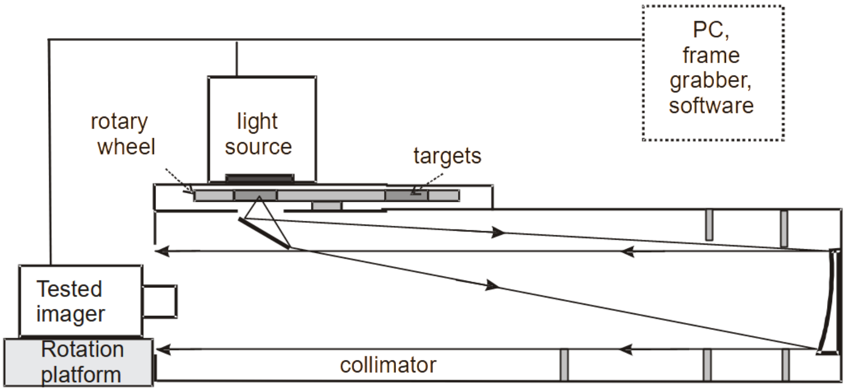

Fig. 7. Block diagram of the ST series test system (basic version)

Fig. 8. Image of a USAF target generated by the tested imager.

5 Versions of ST system

ST test systems are modular systems that can be configured into a long series of versions of different test capabilities and price optimized for testing slightly different groups of imagers.

Choosing proper version of ST system is not an easy task. It can be done in two ways.

1. **Filling questionnaire document on thermal imagers to be tested and sending it to Inframet. Inframet will choose optimal test system.**
2. Careful reading this section and determination code of ST system.

This section talks about the second way. Concept of code that could precisely describe design / test capabilities of ST system is based on the idea to use two part code:

Part 1: describe basic design parameters of collimator used by ST system (collimator code);

Part 2: describe test capabilities of ST system (system code).

5.1 Collimator code

Collimator code (example CDT30200-44-8) is determined by choosing one of collimators from list in Table 1. While combining full ST system, collimator letters "CDT" are exchanged by system letters "ST" to get system code ST 30200-44-8.

Collimator code delivers information about a series of useful parameters

1. Collimator aperture;
2. Collimator focal length;
3. Target diameter;
4. Number of targets;
5. Effective FOV;
6. Minimal frequency of USAF 1951 target.

Table 1. List of models of collimators that can be used to build ST system.

CDT collimator model	Aperture [cm]	Focal length [cm]	Max target size [mm]	Number of targets	FOV [º]	Collimator F-number	Minimal frequency: USAF1951 [lp/mrad]
660-44-8	6	600	44	8	4.19	10	0.3
11100-44-8	11	100	44	8	2.47	9.09	0.5
15150-44-8	15	150	44	8	1.65	10	0.75
20200-75-8	20	200	75	8	2.11	10	0.50
25200-44-12	25	200	44	12	1.24	8	1.00
30200-44-12	30	200	44	12	1.24	6.67	1.00
30200-75-8	30	200	75	8	2.11	6.67	0.50
30300-44-12	30	300	44	12	0.82	10	1.50
30300-75-8	30	300	75	8	1.40	10	1.50
35350-75-8	35	350	75	12	1.20	10	0.88
40400-75-12	40	400	75	12	1.05	10	1.00
45500-107-8	45	500	107	8	1.20	11.11	1.25
50500-75-12	50	500	75	12	0.84	10	1.25
50500-107-8	50	500	107	8	1.20	10	1.25
60600-107-12	60	600	107	12	1.00	10	1.50

Collimator aperture

Collimator aperture gives information on diameter of maximal multi imaging/laser system that can be seen by the collimator (diameter of circle that overlaps optics of all imaging/laser sensor of the tested system).

Focal length

Information on focal length is needed to calculate angular size/spatial frequency of targets located at collimator focal plane. It gives also information on approximate length of the collimator.

Target diameter

Target diameter delivers information how big can be test targets to be projected by the collimator into direction of tested EO system.

Number of targets

Number of targets delivers information on maximal number of target plates that can be inserted into rotary wheel. Higher number of targets enables to carry out in shorter time expanded test that need many targets. Please remember that in case of small patterns multi-pattern targets can be used to increase number of patterns. See details in targets data sheet https://www.inframet.com/Data_sheets/Targets_IR.pdf

Collimator FOV

Real collimator FOV is angular size of maximal hypothetical target located at collimator focal plane that can be projected by the collimator. It depends mainly on diameter of the secondary flat mirror. This parameter is rarely published because from user point of view more important is effective collimator FOV. It is angular size of target plane that can be inserted to rotary wheel located at collimator focal plane. This parameter determined also indirectly size of radiation sources (blackbody, light source) that must be sufficiently big to fill collimator FOV.

Collimator F-number

Collimator F-number gives information of relative uniformity of image quality within collimator FOV. All off axis parabolic reflective collimators can project near perfect image of target located in center of collimator FOV (focus point). However, quality of projected image always deteriorate for non-center targets. The level of this deterioration is much higher for collimators of low F-number. Therefore if non center resolution patterns are to be used then collimators high F-number (over about 8) are preferable.

Frequency of targets

Frequency of minimal USAF1951 target that can be projected is calculated as minimal frequency (biggest bars) USAF1951 target that can be inserted into angular circle equal to collimator FOV. It delivers direct information what is minimal frequency the resolution/MRC tests can be carried out.

It is commonly accepted that Nyquist frequency of tested imager should be at least two times higher than frequency of the biggest bar target. Therefore frequency of maximal 3-bar pattern in USAF1951 target determines also minimal Nyquist frequency of the tested imagers. The latter Nyquist frequency is simply two times higher comparing to frequency of maximal 3-bar patterns of USAF1951 target.

Attention:

1. If two collimator models of the same aperture and different FOV listed in Table 1 can be used for testing VIS-NIR cameras then collimator with smaller FOV but having more targets is recommended.
2. If none of interesting collimators (proper aperture) cannot fulfill condition then Inframet can deliver optional refractive collimators of wider FOV.

5.2 System code

System design/test capabilities are described using ten digit code that delivers precision information on ten following criterion:

A) Maximal Nyquist frequency of imager to be tested (collimator grade),
B) Supported video interfaces,
C) Measured parameters of SWIR imagers
D) Simulated light conditions,
E) Broadband spectrum light source
F) Monochromatic source
G) Calibration
H) Optical boresight
I) Tests of camera cores
J) Variable focus colllimator.

Precise definitions of ten digit code are shown in Table .2 The columns A–J show what digits are to be chosen to precisely define required version of ST test system.

Table 2. Ten digit code of basic versions of ST system

	A	B	C	D	E
No	**Maximal Nyquist frequency of tested cameras [lp/mrad]**	**Supported video interfaces**	**Measured parameters**	**Simulated light conditions**	**Dual mode light source**
1	5	No video output	Infinity focus, resolution	Day	No. Only halogen approximately 2856K spectrum
2	25	One (1)	+Typical imaging tests (resolution, MTF, FOV)	Day/Night	Yes. Additional multi SWIR LED
3	100	Two (2)	+Noise equivalent parameters, FPN, SNR		
4	400	Three (3)	+MRC		
5		Four (4)	+Thermal imaging tests (MRT, MDT)		
6			Customized tests		

	F	G	H	I	J
No	**Monochromatic mode tests**	**Calibration of light source**	**Boresight to reference optical axis**	**Tests of camera cores**	**Variable focus collimator**
1	Only broadband spectrum	Only photometric quantities	No	**No**	Fixed Infinity
2	Up to four manually regulated narrow spectral bands	+Radiometric units	Zoom through boresight	Noise parameters	Continuous regulation
3		+SWIR specific quantities (SWUX)	Focus through boresight	EMVA1288 parameters	
4			Both tests		
5					

The ten digit coding looks complicated and difficult to be used. However, the code is necessary to show precisely what configuration of ST is truly needed. Next, details of design of test system are not needed to determine the code. The user is expected mostly to present basic requirements on system test capabilities (what thermal imager to be tested, Nyquist frequencies of tested imagers, and number of parameters/boresight errors to be measured.

A Maximal Nyquist frequency

Requirements on quality of image projected by collimator (collimator grade) are determined by maximal Nyquist spatial frequency of tested imagers. In detail, Nyquist spatial frequency determines maximal spatial frequency (smallest sinusoidal bar patterns) that imager can reproduce perfectly. Nyquist spatial frequency of tested imagers can be easily calculated in two ways:

1. ratio of imager focal length to (in mm) to dimension of pair pixels of image sensor used by the imager (in µm),
2. half of ratio of pixel number (unitless) of image sensor to imager FOV (in mrad unit).

Maximal Nyquist spatial frequency of tested imagers is a near perfect criterion to estimate real requirements on quality of image projected by the collimator. Nyquist spatial frequency of imagers tested using DT systems often vary a lot: from about 0.5lp/mrad (short range imagers) up to about 100lp/mrad (space imagers). Therefore, the conclusion is that requirements image projected by the collimator vary a lot and there is little sense to deliver perfectly aligned collimator built using perfectly manufactured mirrors for testing short/medium range imagers (low Nyquist spatial frequency). Therefore, Inframet offers for ST systems four grades of off axis collimators depending on mirror manufacturing accuracy:

A1. SR (standard resolution) - manufacturing accuracy P-V not worse than about λ/2 at λ = 630 nm;
A2. HR (high resolution) - manufacturing accuracy P-V not worse than about λ/4 at λ = 630 nm;
A3. UR (ultra high resolution) - manufacturing accuracy P-V not worse than λ/8 at λ = 630 nm;
A4. XR (extreme resolution) - manufacturing accuracy P-V not worse than λ/12 at λ = 630 nm.

SR mirrors are of lowest quality and can be used to built collimators only for testing short range imagers. HR mirrors are used in collimators for testing medium/long range imagers. UR class mirrors are used in collimators for testing ultra long range imagers of ultra narrow FOV. XR collimators are used for special space imagers o big aperture and long focal lenght.

Mirrors of higher manufacturing accuracy can potentially generate high quality images only if used in properly aligned collimators. Therefore, SR/HR/UR/XR symbols determine not only mirror manufacturing accuracy but also class of aligning of the collimator. Recommendations on collimator grade depending on maximal Nyquist spatial frequency of tested imager is presented in table 3. The user is expected to calculate maximal Nyquist spatial frequency of imagers to be tested and later to choose proper grade of the collimator.

Table 3. Recommended collimator grade depending on maximal Nyquist spatial frequency of tested imagers

Column a (row number)	1	2	3	4
Nyquist frequency of tested imagers [lp/mrad]	<5	<25	<100	<400
Recommended collimator grade	SR	HR	UR	XR

Attention:
Nyquist frequency in Table above is imager frequency in lp/mrad (line pair per mrad unit). It is not image sensor Nyquist frequency in lp/mm unit.

B Supported video interfaces

Tested multi-sensor imaging systems typically generate output image to be analyzed by humans or by software in electronic forms using different video interfaces. This video image must be captured and analyzed to measure parameters of thermal imagers.

Long series of video interfaces can be used: analog video, Camera Link, GigE, LVDS, HD-SDI, DVI, HDMI, CoaXPress, USB2.0/3.0, Ethernet and so on. Capturing video image is carried out using specialized frame grabber cards inserted to PC and image acquisition software optimized for specific video interface. Inframet can deliver frame grabbers/software that support approximately up to four video interfaces. If more interfaces are needed then additional PC with frame grabbers is delivered.

C Measured parameters

This column describes list of measurable parameters of typical electronic output thermal imagers. As can be seen in Table 2 the code vary from C1 to C5. Below are presented blocks that are delivered or modified to change test capability:

- **C1.** Basic version of LS-SAL-X-11-11. One negative 100% contrast USAF1951 target (groups 0 to 7). No special software.
- **C2.** Additional: Slanted edge target, positive 100% contrast USAF1951 target (groups -1 to 7). MTF module of TAS-V program to support MTF measurement.
- **C3.** Additional noise module of TAS-V program to support measurement of noise equivalent parameters, FPN, SNR.
- **C4.** Additional: set of five USAF1951 target (groups -1 to 7) of different positive contrasts needed for MRC measurement. SUB-V program to support measurement of MRC.
- **C5.** Additional MTB blackbody and set of IR targets.

D Simulated light conditions

Cameras are used at illuminations conditions that vary a lot. Illumination at night at Afghanistan mountain can be below 0. 03 mlx when at bright days at Arabian desert can be up to 30 000lx (dynamic over 10^9). LS-SAL source enable simulation of both extreme light conditions. However, majority of cameras works only at day conditions and some customers wants only simulation of day conditions. Therefore ST stations offers regulation of simulated light conditions:

- **D1.** Only day condition
- **D2.** Both day and night conditions.

The difference is in design of delivered LS-SAL source.

E Dual mode light source

Calibrated light sources used in systems for testing SWIR imagers are typically light sources built using halogen bulb. However there are three main drawbacks of such light sources. First, spectrum of such halogen source does not ideally in SWIR band to typical 2856K spectrum used when testing night vision devices. Second, halogen light sources are characterized by relatively short life time of halogen light sources (typically below 1000 hours). In detail, performance deterioration starts several times earlier. Third, mechanically regulated halogen sources are relatively slow to stabilize (up to a minute or more).

In such a situation Inframet LS-SAL light source (models since 2025 year) has been designed to work in two modes:

1. broadband halogen source 400-2200nm,
2. multi-LED source of 2856K color temperature in 900-1650nm band.

Code interpretation:

- **E1.** LS-SAL source is delivered in basic version when can work only in halogen bulb
- **E2.** LS-SAL source is delivered in expanded version when can work in two switchable work modes: halogen bulb or multi SWIR LED of 2856K spectrum at basic SWIR band.

F Monochromatic mode tests

Virtually all SWIR cameras are imagers sensitive in broadband spectral bands. However, for a series of different reasons it is sometimes useful to carry out tests of SWIR imagers at a specified wavelengths (narrow spectral bands). One of such reasons is to verify performance of theoretical optical models.

Typical light sources does not enable work at monochromatic mode or require to use large cumbersome filters. In such a situation Inframet offers LS-SAL light source in advanced version when it can work in monochromatic mode of wavelength regulated by manual exchange of monochromatic filters in optical system of this source.

Code interpretation:

- **F1.** LS-SAL source is delivered in basic version that cannot work in monochromatic mode. Only broadband spectrum.
- **F2.** LS-SAL source is delivered in advanced version that cant work in monochromatic mode (up to 4 wavelengths). Manual exchange of monochromatic filters.

G Calibration of light source

Light intensity of light sources used in systems for testing SWIR cameras is typically characterized by two alternative photometric quantities: luminance in cd/m^2 unit or in illuminance in lx unit. However, these photometric quantities actually describe light intensity only in visible band, when these cameras are typically sensitive in SWIR band or in total VIS-SWIR band from about 400nm to about 1700nm. Therefore, light intensity of light sources used in systems for testing VIS-SWIR cameras can be also characterized by radiometric quantities (exitance/irradiance) measured over total VIS-SWIR band in W/m^2 unit.

Another more optimal solution is to characterize light intensity using a concept of so called SWUX unit. It is a modern solution proposed in recent specialized literature:

Richards, A., and M. Hübner. "A new radiometric unit of measure to characterize SWIR illumination." Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XXVIII. Vol. 10178. SPIE, 2017.

Code interpretation:

- **G1.** LS-SAL source is delivered calibrated in photometric quantities:1)luminance in cd/m^2 unit, 2) illuminance in lx unit.
- **G2.** In addition to photometric calibration LS-SAL source characterized by broadband exitance/irradiance in total VIS-SWIR spectral band.
- **G3.** In addition to previous calibrations LS-SAL source is characterized by SWIR exitance/ irradiance in SWUX unit.

H Boresight to reference optical axis

This column describes ability to measure two boresight errors:

1. Zoom-through boresight: angular shift of target marked by imager line of sight (indicated by aiming mark) when zooming,
2. Focus-through boresight: angular shift of target marked by imager line of sight (indicated by aiming mark) when focusing (at different range of focusing depending on version).

Below are presented blocks that are delivered or modified to change test capability of ST system:

- **I1.** No boresight to reference optical axis
- **I2.** BOR software,
- **I3.** Additional BOFOC boresight focuser.
  Attention: Minimal distance that can be simulated by BOFOC can be estimated as 20x FL^2 (where FL is focal length in meters).

I Tests of camera cores

This column describes ability to test thermal camera cores. They are basically SWIR cameras without optics, but capable to generate output electronic image.

Inframet typically offers specialized set system for testing SWIR camera cores coded SIWIR https://www.inframet.com/Data_sheets/SIWIR.pdf that offers ultra extended characterization of such camera cores.

Here only a solution for basic noise/sensitivity tests of SWUR camera cores is proposed. In detail, it is proposed measurement of some radiometric parameters: noise equivalent parameters (detail names depends on source calibration in column G), FPN, 3D Noise, sensitivity.

Below are presented blocks that are delivered or modified to change test capability of ST system:

- **I1.** No tests of camera cores,

I2. Basic tests of camera cores (modified design of image projector blocks, special software).

Attention: two point NUC tests cannot be done.

J Variable focus colllimator

VIS-NIR cameras are typically tested at lab conditions using test systems that project images of target located at optical infinity. It means that rotary wheel with targets is located at focal plane of the collimator. Such situation is typically totally acceptable because typical work distance to targets of interest is at least several hundreds of times higher that focal length of optics of the imager. Such distance can be considered as near infinity because image quality of target generated by imager does not changes when distance is changed from work distance to infinity. Therefore, there is typically no need for tests exactly at work distance. However, there are two exception from this rules.

First, faulty mechanical focusing mechanism can generate noticeable image shift even for minor focusing. Second, precision simulation of targets located at variable work distance becomes important for long range imagers built using optics of very long focal length (say over 1m). Sometimes customers need also simulation of non infinity distance for other reasons (correction of non vacuum condition, correction of different ambient temperature).

Due to the first reason Inframet offers BOFOC focuser capable to regulate distance to simulated pinhole target (see column E3).

Due to the second reason Inframet special version of ST system where after collimator modification typical MWR rotary wheel is replaced by FRW focusing-rotary wheel (movement range about 20mm). This version enables continuous regulation of distance to simulated target. In contrast to BOFOC focuser this case enables regulation of distance not to a single pinhole target but to all targets in total FOV of the collimator. Minimal simulated distance depends on focal length of the collimator and is presented in Table 4.

Table 4. Minimal simulated distance for collimators of different focal lengths

Collimator focal length [m]	1	1.20	1.5	1.6	2	2.4	3	3.5	4	5	6
Minimal distance [m]	50	75	100	125	200	300	400	600	800	1200	1800

Below are presented blocks that are delivered or modified to enable regulation to simulated targets:

J1. Fixed: Optical infinity

J2. Continuous regulation: CDT collimator is modified and typical MRW rotary wheel is replaced by FRW focusing-rotary wheel

6 Exemplary versions

ST can be configured into myriads of versions. Here codes for three popular versions are shown:

1. ST660-44-8-V12-11-11-11-11 – version for basic testing medium range VIS-NIR cameras;
2. ST15150-44-8-V22-22-21-34-11 – version for expanded testing long range VISNIR cameras
3. ST30300-44-8- V32-42-22-32-12 – version for testing ultra long range SWIR imagers

7 Optional solutions

Inframet can deliver also a series of optional support blocks that can significantly increase test capabilities of ST systems:

1. AT optical table as plaform for test system and UUT,
2. Angular stages for tested UUT,
3. YVAP variable angle projector
4. Additional refractive collimators.
5. BORIM autocollimator
6. IL collimator illuminator

7.1 AT optical table

AT optical table is used as a platform for both tested system and test system. It can be delivered in many versions depending on its size and anti-vibration properties (rubber attenuators, air pressure attenuators, QZS attenuators). It should be emphasized that optical table is of crucial importance when testing imager of high Nyquist frequency (over about 50lp/mrad). Details about at tables: https://www.inframet.com/optical_tables.htm

7.2 Angular stages

Customers typicall use customized angular stages for regulation of angular position of their imagers. However, Inframet can optionally deliver both manual and motorized rotary wheels as listed in website to support this task. https://www.inframet.com/positioning_stages.htm

7.3 YAVAP variable angle projector

ST system measures typically FOV of tested imagers using software that compares maximal size of output image with size of image of a reference target of known angular size. The methods works perfectly for imagers of FOV comparable to collimator FOV (typically below 3º). This method enables also relatively accurarate measurement of imager FOV in cases when imager FOV is several times higher over collimator FOV. Practically it means that software of ST system enables relatively accurate measurement of FOV for imagers of FOV up to about 12º-15º. This range is sufficient in majority of applications of ST system. In addition, Inframet can deliver optional YAVAP variable angle projector that enables accurate FOV measurement up to at least 30º.

YAVAP is a computerized module that mounted at collimator output project image of a pinhole target at regulated angle comparing to collimator axis. Analysis of location of pinhole target at image generated by tested imager enables accurate measurement of imager FOV.

7.4 Additional refractive collimators

ST systems based on reflective collimator are characterized by relatively narrow FOV. Due to this feature they are optimal for testing medium/long range VIS-NIR cameras (max FOV can be estimated at about 15 degrees). It is enough for testing high end cameras but low cost short range security cameras cannot be tested. Therefore Inframet can deliver optional set of two refractive collimators that enable such tests.

7.5 BORIM autocollimator

BORIM boresight autocollimator enables aligning of optical axis (LOS) of imager (thermal imager or VIS-NIR camera) with reference front wall of the imager (axis is perpendicular to the front wall). It is achieved using special ABT target located inside the collimator that emits laser beam to be reflected by small mirror attached to imager reference flat wall. It should be noted that such boresight of LOS of imager to a reference mechanical plane is needed only in case of special thermal sights having such reference wall (example Catherine from Thales).

7.6 IL collimator illuminator

IL collimator illuminator enables to check if tested system is properly positioned relative to collimator of test system. in detail, collimator aperture should overlap optics of all imaging/laser systems. The aim is achieved by emission of visible optical beam by the IL illuminator that that illuminates tested multi-sensor system. It is easy to check if all optics of test system is illuminated to assure that tested system is properly positioned relative to collimator.

8 Special test conditions

Typical ST systems are optimized to work at typical laboratory conditions: ambient temperature in range from about 10°C to about 30°C, typical air pressure conditions. However, ST systems can be optionally delivered in versions capable to work at:

1. Temperature chamber;
2. Clean room;
3. Vacuum chamber.

Please add following abbreviations to system code: TC, CR, VC. However, please note that these are customized test systems and detail information on work conditions is expected before order is accepted.

9 Comparison to previous coding of ST system

New coding of ST systems presented in previous section has been introduced to be valid since 2025 year to replace previous one used for last decade. New code is more detail and present additional information: collimator focal length; collimator FOV; size of target plates; maximal imager Nyquist frequency (collimator grade). There are also significant changes in form of description of test capabilities, especially boresight errors.

10 Summary

There are on market other systems for testing SWIR cameras. However, there is a series of reasons to consider ST station as the best solution for testing long range SWIR cameras.

1. Universal modular test system that enable extended tests of all commercially available surveillance VIS-

NIR cameras

2. Ultra expanded measurement capabilities. The system enables measurement of following parameters: Resolution, Minimal Resolvable Contrast, MTF, Distortion, FOV, Sensitivity, SNR, Noise Equivalent Parameters, Input, Fixed Pattern Noise, 3D Noise, Number of bad pixels and bad pixel localisation, *Typical test systems offer typically measurement of lower number of parameters.*
3. ST system offer for testing SWIR cameras (MRC tests) using a set of at least six USAF 1951 targets of contrast from about 3% to 100%. This test is extremely important because most of targets of interest are low contrast targets. It is easy to manufacture high contrast targets but very difficult to manufacture low contrast targets. Inframet mastered technology to produce targets of contrast as low at 3%. *Typical competitor test stations offer usually only one USAF 1951 target of fixed 100% contrast.*
4. Ability to simulate both day conditions and night conditions due to extremely wide range of illumination regulation. In other words it can be said that ST system can simulates both ultra dark nights in Afghanistan mountains and very bright day conditions on Arabia desert. *There is on the market no test system that could simulate illumination condition in so wide range.*
5. Unique light source with two work modes: halogen source and multi SWIR LED of 2856K color temperature. Typical light sources can work only at halogen mode of 2856K color temperature.
6. Optional set of exchangeable refractive collimators (enable regulation of angular size of the simulated scenery depending on FOV of the tested imager).
7. Advanced software for image capturing and analysis that enable measurement of all important parameters of all types of surveillance SWIR cameras.
8. ST system offers measurement of aligning errors of zoom/step FOV objective.
9. ST test system has been experimentally verified by a long series of manufacturers of SWIR imagers, test centers or scientific institutes that do research in field of SWIR imaging who have purchased this test system.

Version 7.1

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