UVICOR

System for testing solar blind UV cameras

Fig. 1. UVICOR system in three work configurations: a)radiometric tests configuration, b)solar tests configuration, c)image quality test configuration

1 BASIC INFORMATION

Solar blind UV cameras are imaging devices optimized to detect ultraviolet light at wavelengths below about 280nm. Such cameras are almost insensitive against sunlight due to very low sensitivity to visible and long wave UV light. Testing performance of SBUV cameras is important because parameters of cameras offered on market vary noticeably and additionally sensitivity of these cameras significantly deteriorate with time.

From design point of view SBUV cameras are actually bispectral imaging systems built by combining true UV camera with typical visible camera. These bispectral imaging system generate output image as overlay of typical visible image with image of analyzed UV source.

In 2016 year Inframet has developed the first commercial station for testing SBUV cameras coded as UVIC. Now Inframet offers UVICOR that is modular test system built by significant upgrading of the UVIC station.

Feature/parameter	UVIC	UVICOR
Targeted application	Maintenance tests	R/D, acceptance/maintenance tests
Solar sensitivity tests	No	Yes
Inframet software for image analysis	No. Only camera software is used.	Specialized Inframet software
Design concept	Single block that communicate with laptop	Modular test systems that can be reconfigured to work in 3 configurations and cooperate with PC set
Work configurations	Single configuration	Three work configuration optimized to measure different parameters
Number of measured parameters	6	14

UVICOR is the first commercially available test system that enable comprehensive testing of SBUV cameras including solar tests.

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2 WHY TO TEST?

Performance of SBUV cameras offered on market vary significantly. Two cameras having almost the same data sheet can perform in much different way in real applications. Next, performance of SBUV cameras vary with time due to deterioration of the crucial block: solar blind UV image intensifier. Due to these reasons testing SBUV cameras is critically important at after warranty stage of life of SBUV cameras.

3 WHAT CAN BE MEASURED?

UVCOR enables measurement of of parameters listed in table below:

Table 1. List of measured parameters and measurement range

Parameter	Measurement range
Sensitivity (Noise Equivalent Radiant Exitance)	At least 10^{-18} to 10^{-6} W/cm^2 at 260nm
Response function	At least10^6 dL cm^2/W to 256 10^{18} dL cm^2/W
Event count response function	Depends on camera event count calculation algorithm
Variable target detectivity	At least from 0.1mrad to 100mrad
UV resolution	At least 0.2 – 10 lp/mrad at 2-10m distance
UV glare	Qualitative evaluation
UV FOV	At least 1º to 10º
Visible sensitivity	At least 0.1cd/m^2 to 10cd/m^2
Visible resolution	2 – 100 lp/mrad at 2 m distance
Visible FOV	At least 1º to 10º
Center boresight error	0.1-20mrad
Peripheral boresight error	0.1-40mrad
Noise Equivalent Blackbody Temperature	600ºC to 1100ºC
Long-wave sensitivity limit	260nm to 340nm

Sensitivity of SBUV cameras is defined as noise equivalent radiant exitance (NERE). In detail, NERE is equal to radiant exitance of a large target at peak sensitivity wavelength (typically 260nm) that can generate the same output signal as signal generated by dark noise of the tested camera. It should be noted that NERE depends on camera gain and integration time. NERE unit is W/cm^2.

Response function RF is a ratio between camera output signal (average grey level of analysed image area) and input radiant exitance of a large target. It should be noted that RF depends on camera gain and integration time. RF unit is DL W^{-1} cm^2 where DL is digital level.

Event Count Response function ECRF is a ratio between spatio-temporal density of event counts in analysed image area and input radiant exitance of a large target. In detail, ECRF is calculated as ratio of average number of event counts recorded in time unit and input radiant exitance of a large target. EFRF unit is s^{-1} W^{-1} cm^2. Attention: ECRF depends on size of analyzed area.

Variable target detectivity (VTD) is function of minimal detectable exitance of target of interest versus angular size of this target. Measurement is to be done in UV only mode by visual observation of the image generated by tested camera by a human observer.

UV resolution is a maximal angular spatial frequency of 3-bar 100% contrast target irradiated by SBUV light that can be resolved by human observer looking on image of this target generated by UV channel of SBUV camera on its display.

UV glare is an effect when UV source being outside camera generates ghost images that can be interpreted as false corona targets. This parameter is to be evaluated only qualitively due to lack of precision guidelines on measurement of this effect for similar imaging systems: VIS-NIR cameras.

There are standards that presents precision definitions and measurement methods of glare effect for optical systems for VIS-NIR range. However, there is not standards that regulate measurement of glare effect of VIS-NIR cameras.

UV FOV is a set of two angle (horizontal and vertical) that determine field of view of the UV channel of SBUV camera.

Visible sensitivity is minimal luminance of a large target that can be detected from background by a human observer.

Visible resolution is a maximal angular spatial frequency of 3-bar target 100% contrast irradiated by visible light that can be resolved by human observer looking on image of this target generated by visible channel of SBUV camera on its display.

Visible FOV is a set of two angles (horizontal and vertical) that determine field of view of the visible channel of SBUV camera.

Center boresight error (CBE) is an angular image shift between UV image and visible image of the same target located in approximate center of FOV of both channels. Unit of CBE is mrad.
Peripheral boresight error is an average angular image shift between UV image and visible image of the same targets located in approximate corners of FOV of both channels. Unit of PBE is mrad.

Noise Equivalent Blackbody Temperature (NEBT) is minimal temperature of a large blackbody target that generates the same output signal as the signal generated by dark noise of the tested camera. It should be noted that NEBT depends on camera gain and integration time. NEBT unit is ºC.

Longwave sensitivity limit (LSL) of SBUV camera is a wavelength that represent theoretical longwave limit of spectral sensitivity of SBUV camera calculated on basis measured NERE and NEBT. LSL is calculated using this formula

$$\int_0^{LSL} M_{bb}(\lambda, NEBT)\, d\lambda = NERE \qquad (1)$$

LSB of value below 280nm means SBUV camera that is truly non sensitive to standard ASTM solar light. LSB of value over about 320nm means fully solar sensitive camera.

4 HOW IS BUILT?

UVICOR is modular system built from following blocks:

1. UVIC source/projector
2. SOT set of targets
3. UVRCOL-U refractive collimator
4. YNAS10 platform for angular positioning of tested cameras
5. PC set
6. set of frame grabbers
7. UVIC Control program
8. TAS-UV program
9. BOR program
10. HTB-25D-1000-COL
11. UVRCOL-B refractive collimator
12. HTB Control program

UVIC source/projector is practically typical UVIC station without laptop as in data sheet https://www.inframet.com/Data%20sheets/UVIC.pdf .
SOT is set of targets used to change shape of pattern simulated by UVIC source/projector when measuring image quality parameters. In detail following targets are offered: Set of six 3-bar targets for resolution tests, set of six circular targets for measurement of Variable target detectivity (VTD), UV glare, boresight error, FOV and USAF1951 target for measurement of resolution of visible channel.
UVRCOL-U is a refractive (lens) collimator optimized to cooperate with UVIC station. The collimator simulates light emitter of UVIC station in optical infinity and what is more important simulates large size UV target due to short focal length of the collimator (about 200mm).

YNAS10 is a platform for angular positioning of tested cameras.
PC is a a typical desktop PC set.
Set of frame grabbers is a set of two frame grabbers: 1)analog video grabber, 2)digital frame grabber. HDMI frame grabber is typically used as digital frame grabber. However, Inframet can optionally deliver other types of frame grabbers:
UVIC Control is program to control light intensity of UVIC source/projector.
TAS-UV is computer program optimized to capture, analyse images and calculate parameters of SBUV cameras.
BOR is computer program to calculate boresight errors.
HTB-25D-1000-COL is a special version of HTB-25D-1000 blackbody of emission angle optimal for UVRCOL-B refractive collimator (focal lenght 500mm, aperture 48mm). Typical cavity blackbodies have very narrow emission angle and cannot cooperate with collimators.
UVRCOL-B is a refractive collimator optimized to cooperate with HTB blackbody. The collimator simulates blackbody emitter in optical infinity and what is more important simulates large size UV target due to short focal length of the collimator (about 500mm).

5 Specifications of the modules

Table 2. Technical specifications of modules of UVICOR system

Parameter	**Value**
UVIC source/projector	
Solar box aperture	160x120 mm
Non-solar source aperture	36 mm
Spectral band of non solar source	From 250nm to 270nm
Spectral band of solar source	360nm to 730nm
Exitance range of non-solar UV source	10^{-18} to 10^{-6} W/cm^2
Luminance range of solar box	0.1 -300 cd/m^2 (simulated approximate illumination 0.3-1000 lx)
PC Control	RS 232/USB 2.0
Mass	12 kg
Dimensions	390x380x310mm
Operating temperature range	5°C to 40°C
Storage temperature range	-5°C to 55°C
Humidity	Up to 95% (non-condensing)
Power	AC230/110 V (option DC12V)
Set of targets	
UV targets	set of six circular targets (diameter: 1.6; 3.2; 6.4; 12.8; 25.6; 34 mm), set of five 3-bar resolution targets of bar width: 5; 3; 2; 1.41; 1mm
Visible targets	USAF 1951 resolution target (spatial frequency from 1 lp/mm to 7.13 lp/mm)
UVRCOL-U refractive collimator	
Spectral band	At least 240-800nm
aperture	At least 48 mm
Focal lenght	200mm
YNAS10 platform	
Application	for angular positioning of tested cameras
Load Capacity	5, 10, 15 kg
Azimut range	± 3°
Elevation range	± 3°
Vertical regular	100 mm
PC set	
PC set components	PC main unit, computer monitor, keyboard, mouse, Windows 10 program, video monitor
Parameters	At least: IBM compatible PC with Intel Core i5-3330 or better processor with 17'' color monitor, 2GB RAM, >500GB hard disk, DVD writer (basically modern PC)
Set of frame grabbers	
Number of frame grabbers	2

Analog standard	Analog Video standard (CVBS)
Resolution of analog video grabber	720x576 (PAL) 720x480 (NTSC)
Type of digital frame grabber	HDMI (option Ethernet, USB3.0)
UVIC Control program	
Function	to control light intensity of UVIC source/projector
TAS-UV computer program	
Function	to capture, analyse images and calculate parameters of SBUV cameras: UV Sensitivity, Response function, UV FOV, visible FOV, Long-wave sensitivity limit
BOR computer program	
Function	to calculate boresight errors.
HTB-25D-1000-COL blackbody	
Temperature range	100-1100ºC
Aperture	25mm
Optimization	blackbody of emission angle optimal for UVRCOL-B refractive collimator (focal length 500mm, aperture 48mm)
Control	USB
Angular size when seen through collimator	50mrad (approximately 2.8º)
UVRCOL-B refractive collimator	
Spectral band	At least 240-800nm
aperture	At least 48 mm
Focal length	500mm
HTB Control program	
Function	To regulate temperature of HTB-25D-1000-COL blackbody from PC

6 HOW IT WORKS

UVICOR is a modular system that can be used to create three configurations:

1. Radiometric tests configuration,
2. Solar tests configuration,
3. Image quality test configuration.

6.1 Radiometric test configuration

Radiometric test configuration is built using following blocks

1. UVIC source/projector
2. SOT set of targets
3. UVRCOL-U refractive collimator
4. YNAS10 platform
5. PC set
6. set of frame grabbers
7. UVIC Control program
8. TAS-UV program

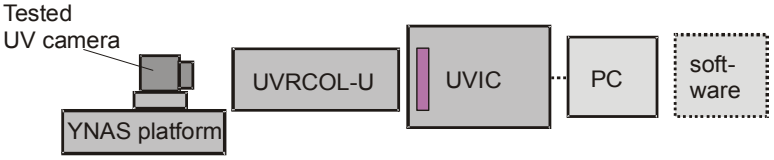

Fig. 1. Block diagram of UVICOR in radiometric configuration

UVICOR in radiometric configuration works as image projector of s large UV/visible target of regulated light intensity.

1 Following parameters are measured: Sensitivity (Noise Equivalent Radiant Exitance at 260nm), Response function, Event count response function, Visible sensitivity.

6.2 Solar test configuration

Solar test configuration is built using following blocks

1. HTB-25D-1000-COL
2. UVRCOL-B refractive collimator
3. YNAS10 platform
4. PC set
5. set of frame grabbers
6. TAS-UV program
7. HTB Control program

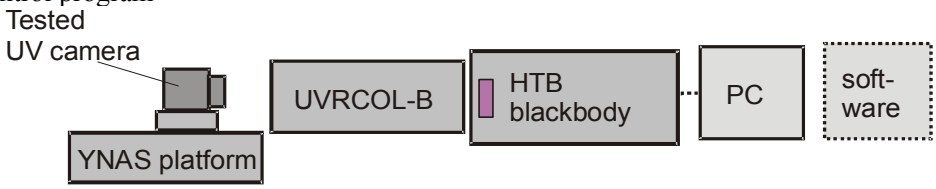

Fig. 2. Block diagram of UVICOR in solar configuration

UVICOR in solar configuration works as image projector of a large UV target (blackbody emitter) of regulated light intensity. Following parameters are measured: Noise Equivalent Blackbody Temperature, Longwave sensitivity limit LSF.

6.3 Image quality configuration

Image quality test configuration is built using following blocks

1. UVIC source/projector
2. SOT set of targets
3. YNAS10 platform
4. PC set
5. set of frame grabbers
6. UVIC Control program
7. TAS-UV program

From design point of view UVICOR in image quality configuration is practically typical UVIC station that works as direct view image projector without collimator.

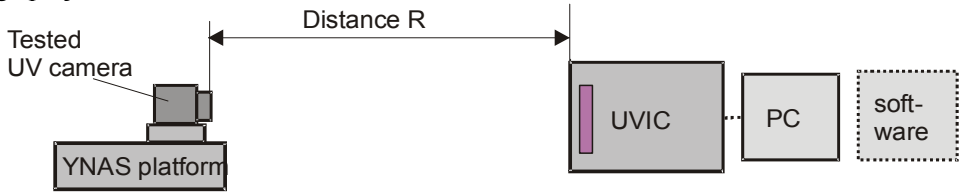

Fig. 3. Block diagram of UVICOR in image quality configuration

UVICOR in image quality configuration works as direct view image projector of variable size, variable type targets of regulated light intensity.

Following parameters are measured: Variable target detectivity, UV resolution, UV glare, UV FOV, Visible resolution, Visible FOV, Center boregight error, Peripheral boresight error.

SUMMARY

UVICOR is the first commercially available test system that enable comprehensive testing of SBUV cameras including solar tests. The station can be a very valuable tool to evaluate true performance of these expensive cameras available on the market and to monitor performance deterioration during their life time.

CONTACT: Tel: +48 604061817 Fax: +48 22 3987244 Email: info@inframet.com

• INFRAMET