● INFRAMET

Normalization, methods and equipment for testing cameras for imaging scintillation screens

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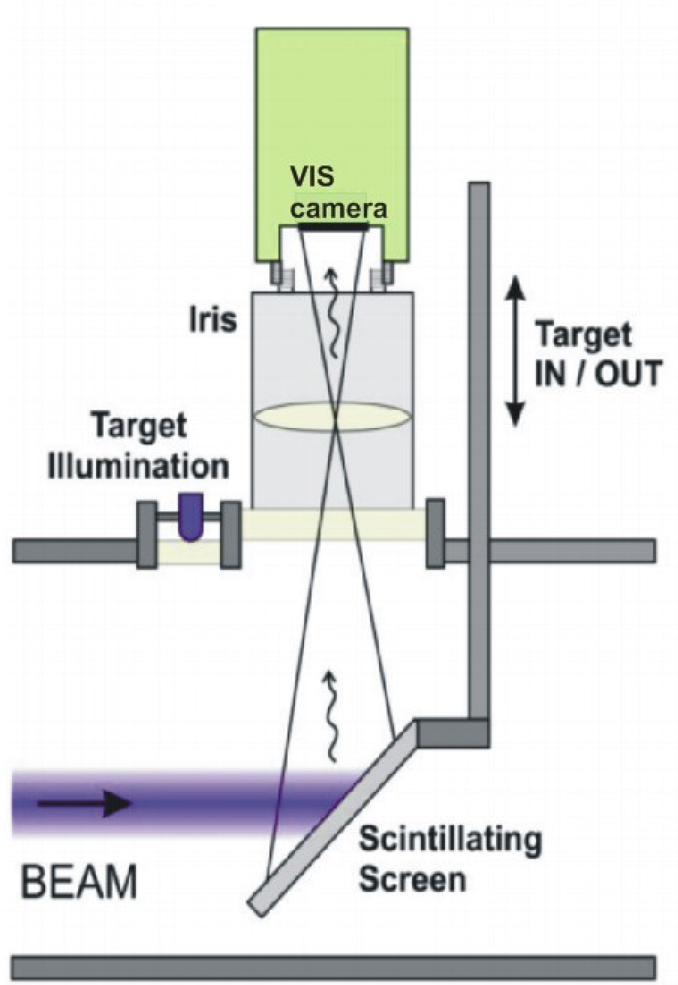
Concept of beam testing

The most easy and direct way to determine the beam profile is to use an imaging system built by combining a scintillation screen with an imaging camera sensitive in UV-VIS range.

Requirements on imaging cameras:

1. *radiation resistance*
2. high sensitivity, low temporal and spatial noise
3. high dynamic
4. very good linearity
5. high frame rate and short integration time
6. ability to create high contrast image of small details.



Standards on testing cameras for imaging scintillation screens

There is not standards on testing cameras for imaging scintillation screens. However, it is possible to use recommendations from standards for cameras for similar applications.

There six main International standards groups working in area of imaging cameras sensitive in visible range: International Standard Organization (ISO), Institute of Electrical and Electronics Engineers Standards Association (IEEE), International Electrotechnical Commission (IEC), International Color Consortium (ICC), European Broadcasting Union (EBU), European Machine Vision Association (EMVA).

ISO TC42 WG 18: Digital Still Photography

•ISO 12233 for photography and electronic still picture imaging, resolution and spatial frequency
•ISO 12232 for ISO, speed rating, standard output sensitivity, and recommended exposure index
•ISO 15739: Noise and dynamic range
•ISO 14524: Tone curve OECF standard
•ISO 17850: Geometric distortion
•ISO 17957: Uniformity/shading measurements
•ISO 18844: Flare
•ISO 19084: Chromatic displacement
•ISO 19567: Texture reproduction – partial support

IEEE-SA Working group P1858

CPIQ: Camera Phone Image Quality

Standards on testing imaging cameras – part 2

IEC: International Electrotechnical Commission
IEC-62676 – Video surveillance systems for use in security applications

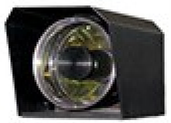
ICC/CIE: International Color Consortium
ICC and CIE focus on the standardization of color characterization and calculation. Standardized cross-platform device profile format, ICC profiles, the CIELAB color space.
European Broadcasting Union (EBU)
EBU Tech 3335: Measurement of imaging performance of TV cameras

EMVA: European Machine Vision Association

1. EMVA-1288: Standard for Measurement and Presentation of Specifications for Machine Vision Sensors and Cameras.
2. GeniCam: Standard Image acquisition interface

EMVA-1288 standards is the most important as requirements for machine vision cameras are similar to requirements on cameras for imaging scintillation screens.




Sample VIS-NIR cameras that can be tested

EMVA Standard 1288

EMVA 1288 presents parameters, measurement methods and characterization data for cameras and image sensors used for machine vision applications.

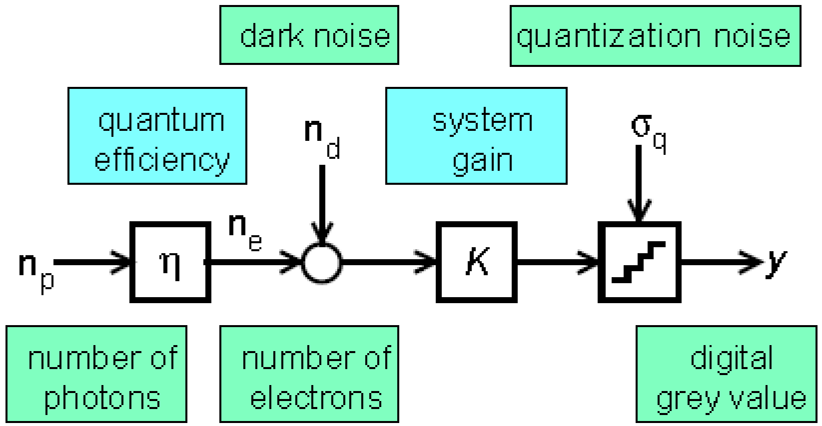
EMVA1288 set of parameters:
Quantum efficiency,
Gain,
Temporal Dark Noise,
DSNU1288,
SNRmax,
PRNU1288,
LE nonlinearity,
Absolute Sensitivity Threshold,
Saturation capacity,
Dynamic Range,
Dark current,
relative spectral sensitivity

Table 2: List of all EMVA 1288 parameters with classification into mandatory and optional.

Type of measurement	Mandatory	Reference
Quantum efficiency η	Y	Specify center and FWHM wavelengths of the light source used
Gain $1/K$	Y	units e^-/DN
Dark noise	Y	in units DN and e^-
$DSNU_{1288}$	Y	in units DN and e^-
Signal to noise ratio SNR_{max}	Y	as ratio and in units dB and bits
SNR_{max}^{-1}	Y	in %
$PRNU_{1288}$	Y	in %
Non-whiteness factor F(dark)	Y	
Non-whiteness factor F(50%)	Y	
Non-linearity error LE	Y	%
Absolute sensitivity threshold	Y	in number of electrons and photons, specify center wavelength
Saturation capacity	Y	in number of electrons and photons, specify center wavelength
Dynamic range (DR)	Y	as ratio and in units dB and bits
Dark current	Y	in units DN/s and e^-/s
Doubling temperature T_d (K)	N	see Section 7.2

EMVA Standard 1288- part II

The standard assumes graphical model of the camera as below



Other assumptions

1. linear relation between the mean gray value y and the number of photons irradiated during the exposure time onto the pixel:

$$\mu_y = \mu_{y.\text{dark}} + K\eta\,\mu_p = \mu_{y.\text{dark}} + K\eta\frac{\lambda A}{hc}\,E\,t_{\text{exp}}$$

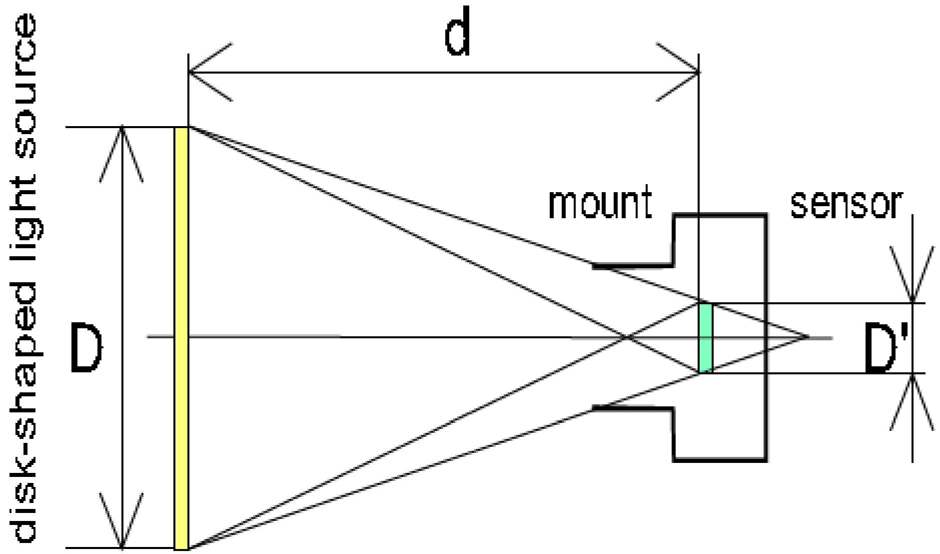
2. the noise can be related to the measured mean digital signal:

$$\sigma_y^2 = \underbrace{K^2\sigma_d^2 + \sigma_q^2}_{\text{offset}} + \underbrace{K}_{\text{slope}}\,(\mu_y - \mu_{y.\text{dark}})$$

EMVA 1288 measurement setup and methods

The EMVA standards does not describe in detail system that is to be used for testing cameras but presents a series of recommendations that can be divided into three groups:

1. A setup for the measurement of sensitivity, linearity and nonuniformity using a homogeneous monochromatic light source
2. The measurement of the temperature dependency of the dark current
3. A setup for spectral measurements of the quantum efficiency over the whole range of wavelength to which the sensor is sensitive (relative spectral sensitivity)



Optical setup for the irradiation of the image sensor

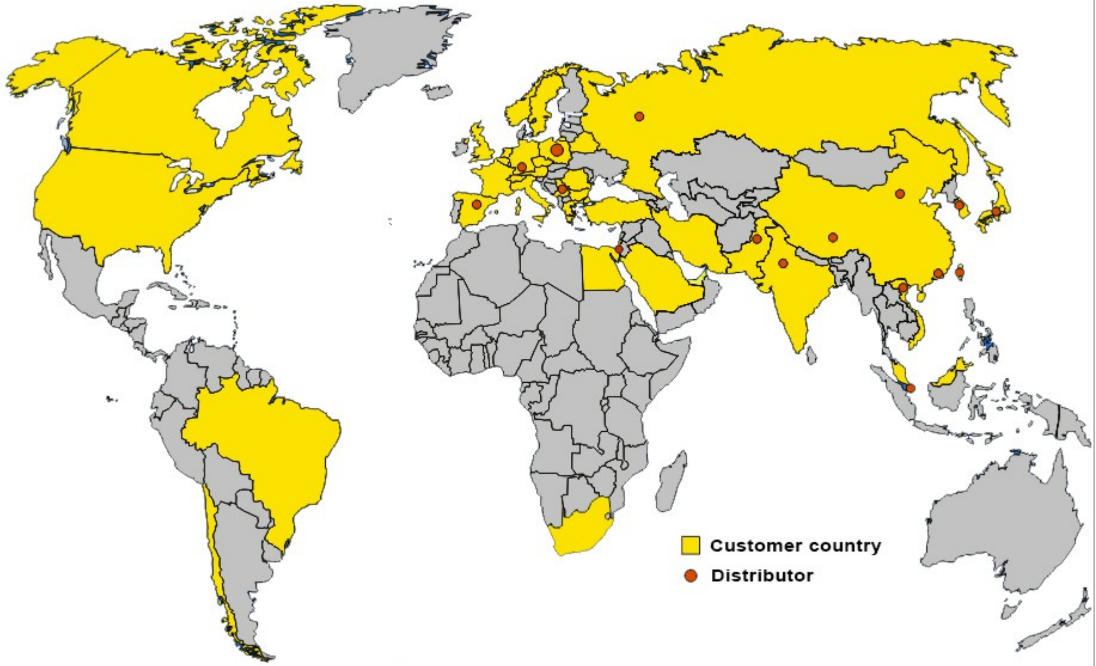
Methods to regulate Irradiation: I. Constant illumination with variable exposure time, II. Variable continuous illumination with constant exposure time, III. Pulsed illumination with constant exposure time.

Conclusion: EMVA accepts different detail technical solutions of a system for testing cameras as long as generate the same measurement results

What is Inframet?

INFRAMET is a high-tech company founded in Poland in 2002 that specializes in high-tech equipment for testing electro-optical imaging&laser systems (thermal imagers, night vision devices, VIS-NIR cameras, SWIR cameras, UV cameras, laser range finders, laser designators, multi-sensor surveillance systems, fused imagers).

•Inframet is a global high-tech company operating in over 40 countries all over the world (orange color - the countries where Inframet delivered equipment or test services).



•Equipment for testing VIS-NIR imaging sensors/cameras is one of important products

•Main customers: manufacturers of VIS-NIR imaging sensors/cameras and R/D centers

Inframet offer for testing VIS-NIR cameras

Image sensors sensitive in VIS-NIR range are almost exclusively silicon chips manufactured using a series of technologies: CCD, CMOS. ICCD, EMCCD, EBAPS, sCMOS in color or monochromatic versions. Spectral band of these sensors is from about 350nm to 1000nm.

From point of test equipment **the type of imaging sensor does not matter**, only spectral band is important and interface of output electronic signal
Typical interfaces: analog video, Camera Link, GigE , LVDS, HD-SDI/DVI/HDMI, AHD/HD-TVI/HD-CVI, CoaXPress, USB2.0, USB3.0, Ethernet

1. Inframet uses a series of frame grabbers and specialized software that makes possible to capture video sequences from any of these imaging cameras
2. Inframet supports also recommended by EMVA GENeric programming Interface for CAMeras.

Inframet offer for testing sensors/camera cores and VIS-NIR complete cameras (camera core and optics) two test stations:

1. VIT stations – for testing camera cores or imaging sensors
2. TVT stations – for testing complete cameras.

VIT test station

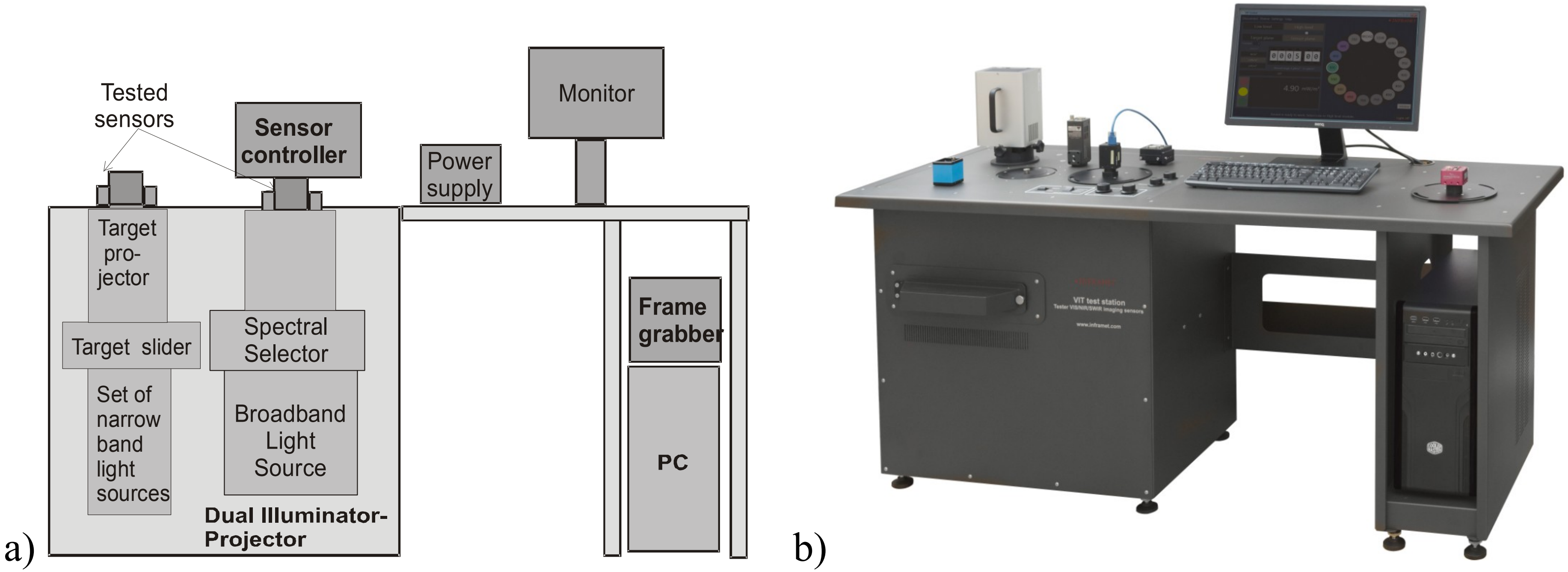


Fig. 1. VIT test station a)block diagram, b)photo

VIT is a dual channel test station that enables measurement of all important parameters of virtually all VIS-NIR camera cores/image sensors available on international market. The station is used by a series of top world manufacturers of VIS-SWIR camera cores/ image sensors.

It enables to measure all parameters recommended by EMVA1288 standard and also several important parameters that characterize image quality like MTF, MRC, blooming, FOV.

VIT special features

1. Blocks: DIP dual image projector, set of frame grabbers, PC set, test software, CON sensor controller
2. Two channels: 1) variable intensity and wavelength uniform light source, 2) variable intensity image projector
3. Ultra high dynamic (ability to simulate both ultra dark night and ultra bright day: 1 μlx to 10 000lx (10^{10} dynamic)
4. Light in up to 16 wavelengths can be generated

Measured parameters:

EMVA 1288: Quantum efficiency, Gain, Temporal Dark Noise, DSNU1288, SNRmax, PRNU1288, LE nonlinearity, Absolute Sensitivity Threshold, Saturation capacity, Dynamic Range, Dark current, relative spectral sensitivity

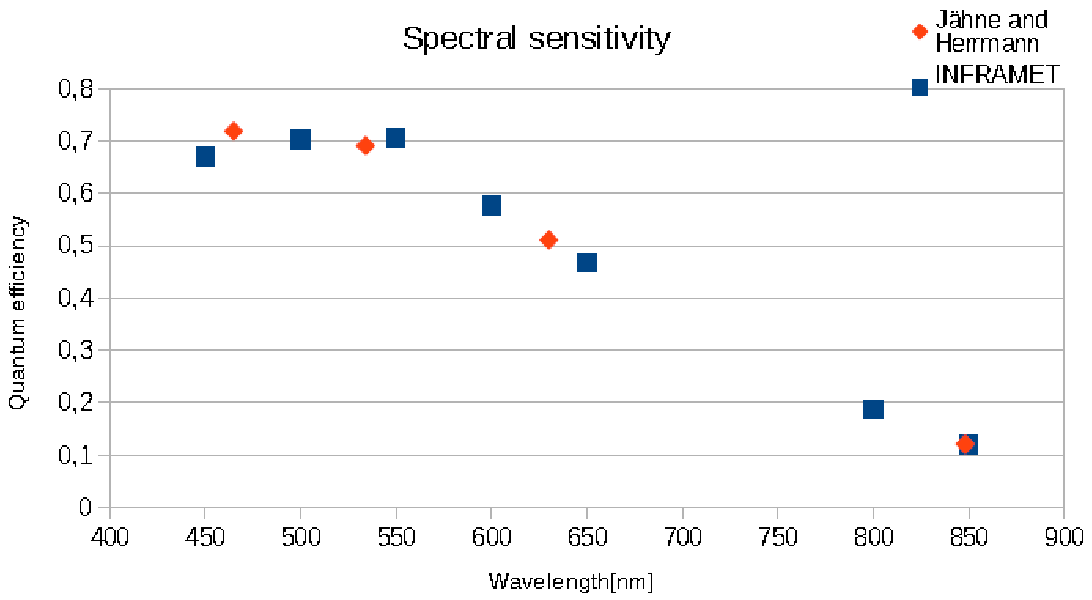
Other parameters:

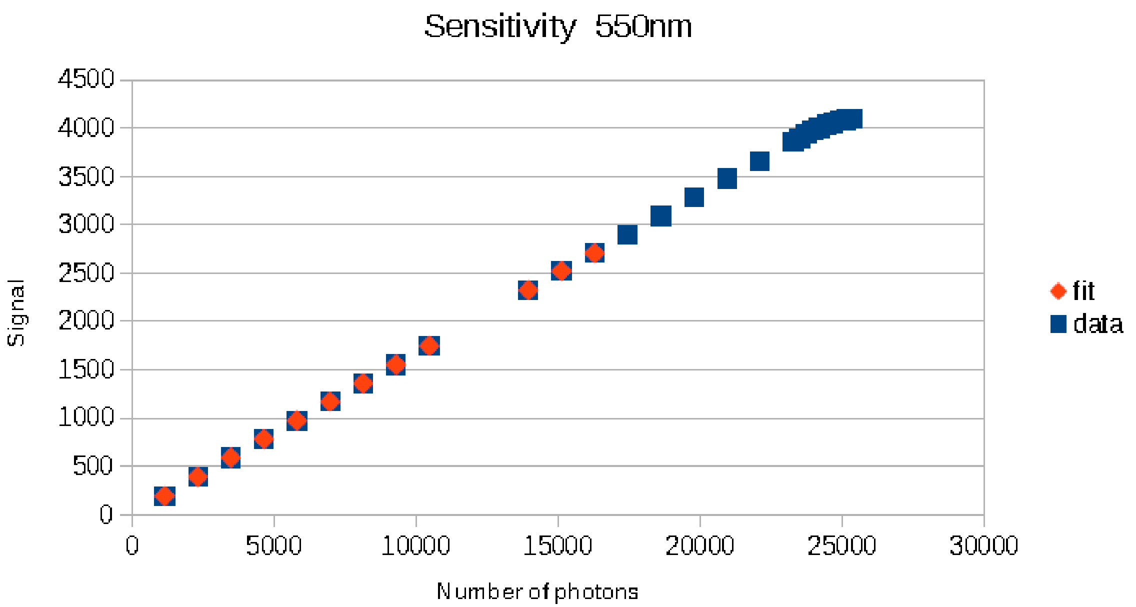
Radiometric parameters: relative spectral sensitivity, normalized detectivity D*, quantum efficiency QE, sensitivity, dynamic range, linearity, Noise Equivalent Illuminance/Irradiance, Fixed Pattern Noise, Non Uniformity, Signal to Noise Ratio, dead pixels, 3D Noise.

Imaging parameters: MTF, resolution, Minimal Resolvable Contrast, crosstalk, blooming, FOV

Measurements can be done at 16 wavelengths including emission wavelengths of typical scintillation screens.

Comparison tests of Basler, acA1920 camera





Comparison tests - conclusions

Parameter	Inframet (550nm, FWHW 10nm)			Jähne and Herrmann (534nm, FWHM 31,3nm)		
Dark frame standard deviation [DN]	0,79			0,80		
Saturation [fot]	Single point: 47502			48951		
	Averaged: 47036					
Overal system gain K [DN/e$^-$]	0,119			0,120		
Responsivity R [DN/fot]	0,084			0,083		
Quantum efficiency QE	70,6%			69,1%		
Saturation capacity [e$^-$]	Single point: 33547			33836		
	Averaged: 33218					
Absolute sensitivity threshold AST	10,14			10,45		
Dynamic range DR	4683	73,4dB	12,2 Bit	4686	73,4dB	12,2Bit
SNR	183	45,3dB	7,5 Bit	184	45,3dB	7,5Bit

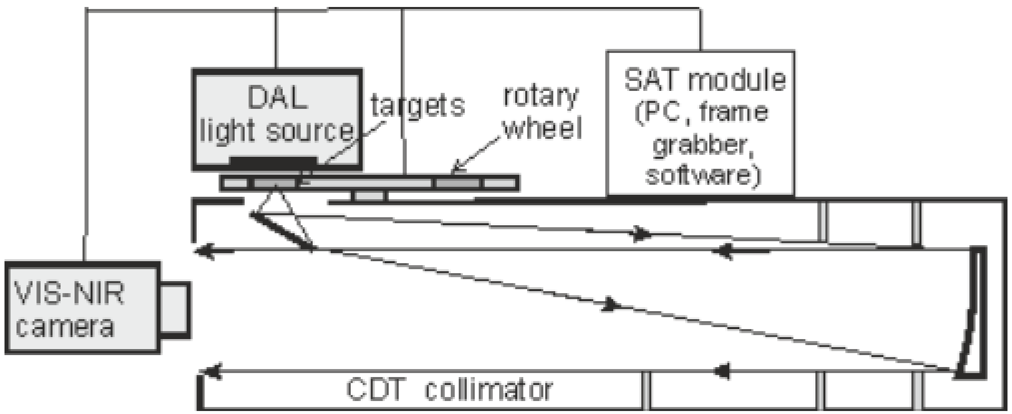
Conclusion: Results from VIT station agree well to results from a reference scientific institute

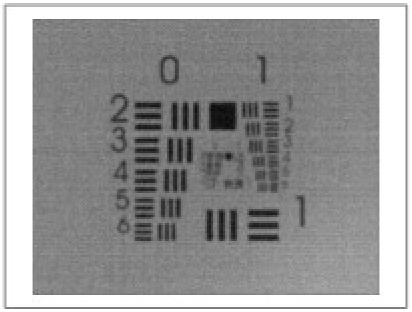
VIS/NIR cameras - test concept

	Testing thermal imagers	Testing VIS/NIR cameras
Source of radiation	low temperature blackbody	high temperature bulb
Radiation spectrum	Variable, depending on blackbody temperature	Constant, typically 2856K or 3000K
Units of radiation	standard temperature units [K]	photometric units [cd/m^2 or lx]
Method of radiation measurement	measurement of radiator temperature	measurement of light luminance/illuminance
Type of projector optics	Reflective off axis collimator	Reflective off axis collimator and additional refractive collimators
Targets	transparent patterns (holes) in opaque metal sheets	non transparent patterns on transparent glass sheets
Typical resolution target	4-bar target	USAF 1951 target
Technical crux	Temporal stability of blackbody (< 3 mK)	Dynamic of light source (> 10^{10}) to simulate both day and night conditions

Conclusion: it is possible to modify systems for testing thermal imagers by replacing blackbody and metal targets to a calibrated light source and glass targets and do testing of VIS-NIR cameras.

TVT station for testing VIS-NIR cameras





TVT special features

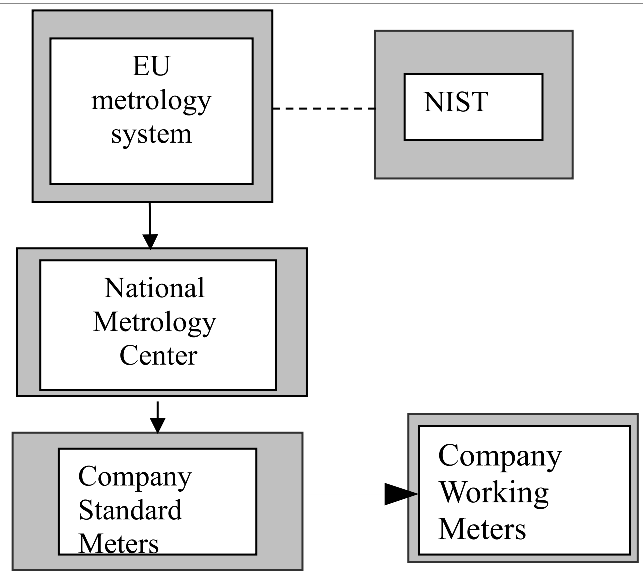
1. High quality image projector based on aberration free off axis parabolic collimator
2. High performance DAL calibrated light source of ultra high dynamic (at least 10^{10})
3. Ability to vary spectrum of the light source
4. Software support semi automatic testing of VIS-NIR cameras
5. Ability to test cameras generating image in any of standard of electronic imaging: Additional grabber: CL, GigE, LVDS, CVBS, YpbPr, Coa-XPress, HDSDI, HD-CVI, HD-TVI, AHD, DVI, HDMI, Fire
6. Ability to measure all important parameters of VIS-NIR cameras: MRC, MTF, distortion, FOV, sensitivity, SNR, NEI, FPN, non uniformity, responsivity function, linearity, 3D Noise model, PVF, NPSD

Calibration of VIT/TVT test stations

Typical national metrology centers like NIST in USA, PTB in Germany, NPL in UK, LNE in France cannot certify complete stations for testing VIS-NIR cameras.

In absence of certification bodies of world wide range capable to certify E-O testers Inframet in order to achieve high accuracy of measurements has been to implement following metrology policy:

1. Calibrate critical measuring modules of test systems using meters traceable to world metrological system
2. Carry out uncertainty of measurements according to JCGM 100:2008Evaluation of measurement data — Guide to the expression of uncertainty in measurement



Comparison tests have confirmed high accuracy of Inframet stations for testing VIS-NIR cameras

Conclusions

1. There is not standards on testing cameras for imaging scintillation screens. However, it is possible to use recommendations from standards for cameras for similar applications.
2. EMVA1288 is the recommended standard to be used to test and evaluate VIS-NIR cameras for imaging scintillation screens.
3. Inframet test stations (VIT and TVT) can be used for for testing any VIS-NIR camera potentially useful for imaging scintillation screens.

Thank you for attention !!