LS-DAL

High-end calibrated VIS-NIR light source

Fig. 1. Photo of three LS-DAL calibrated light sources: 1) LS-DAL50, 2) LS-DAL100, 3) LS-DAL150.

1 What is LS-DAL?

LS-DAL is a high end calibrated light source developed for realistic simulation of light conditions from dark, moonless nights to ultra bright days at different geographical regions in VIS-NIR spectral band. This light source is used as a critical block in Inframet systems (TVT systems https://www.inframet.com/tv_cameras.htm) for testing VIS-NIR cameras (color/monochrome CMOS/ICCD/EBCCD cameras) working in 400-1000nm spectral band and used for long/medium range surveillance in defense/security applications. In detail, the light source simulates background of targets of interest in images projected by the test system. LS-DAL can be also optionally used as a stand alone reference light sources in other applications.

2 How does LS-DAL work?

LS-DAL source works as light emitter of regulated light intensity and light spectrum. Design of LS-DAL is based on an idea to use a system combined from five main blocks: integrating block, halogen bulb, opto-mechanical attenuator, set of monochromatic LEDs, set of optical spectral filters. Halogen bulb illuminates the integrating block through opto-mechanical attenuator of regulated attenuation. Electronically regulated LEDs illuminate the integrating block directly. Intensity of the LED sources is regulated electronically using advanced electronic regulation/stabilization system. Manual change of spectral filters allows modification of light spectrum to required form.

In other words, LS-DAL light source is a dual mode light source capable to work in two modes: 1) halogen mode of 2856K spectrum in 400-1000nm band, 2) multi-LED of 5000K in the same band. In addition, spectral filters allows changing light spectrum and working in monochromatic mode.

3 LAS-DAL versus integrating spheres

Integrating sphere is an old technique (invented in XIX century) to improve uniformity of light sources. In detail, the concept is to paint interior of a sphere using a white paint. This technique is still popular. In fact, majority of calibrated light sources are built using integrating sphere method and the term integrating sphere is commonly used as the name for total light source, including mechanical and electronic systems. However, it is technically possible to design near perfect methods using different methods to improve light uniformity. Therefore, Inframet use the term calibrated light source and not the term integrating sphere. However, practically LS-DAL is built using a concept similar to integrating sphere: integrating block in form of empty cylinder is used. This change enables to use coating of higher reflectivity and durability comparing to paints used in typical integrating spheres.

4 Why is LS-DAL special?

There are many calibrated light sources that emit light in VIS-SWIR spectral band offered on the market that can be potentially used for testing/calibration of VIS-NIR cameras. They are typically built by combining halogen bulb with special mechanical attenuator in order to enable regulation of light intensity. These typical sources are characterized using photometric quantities (luminance, illuminace).

There are five main drawbacks of such typical light sources:

1. In spite of relatively small diameter of light emitter (typically below 5-10 cm) these light sources are bulky due to being designed as a loose collection of integrating sphere, attenuator, and electronic controller.
2. Dynamic of regulation of light intensity does not allow to simulate both very dark nights and very bright days.

3. Typical halogen light source emits light of 2856K color temperature that is poor fit to day time illumination conditions. In addition, halogen light sources are characterized by relatively short life time (typically below 1000 hours). These mechanically regulated sources are also slow.
4. Typical light sources can work only as broadband light emitters when in some applications (verification of theoretical models) monochromatic light is needed.
5. Typical light sources are calibrated using photometric quantities when sensitivity of VIS-NIR cameras is outside visible band.

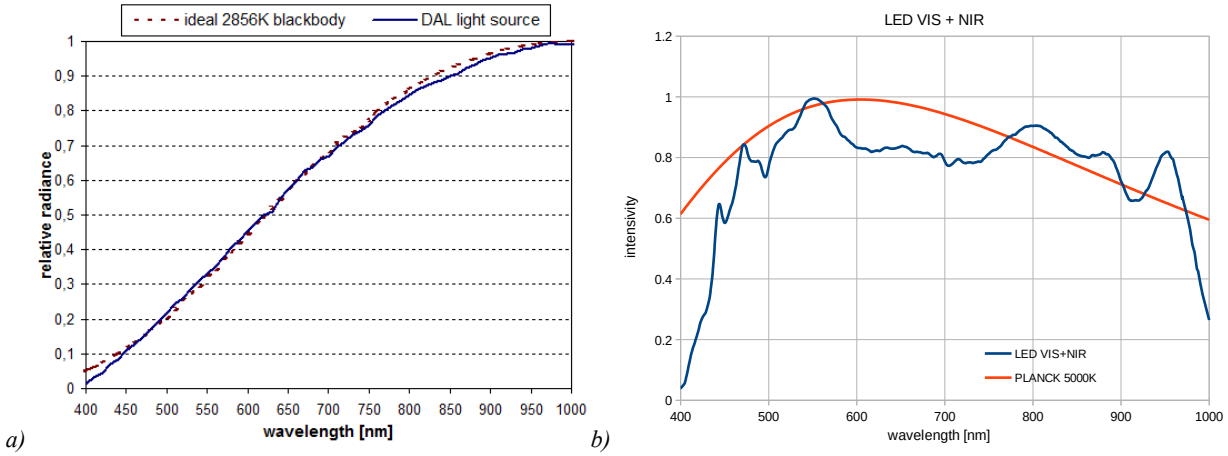
LS-DAL designed has eliminated all these drawbacks (at least in advanced versions):

1. Light emitter of size as high as 150mm (optional: 250mm) is offered in spite of compact design when all mechanical modules are integrated in one metal case.
2. Ultra expanded regulation of light intensity enables to simulate both very dark nights (Afghanistan mountains) and very bright days (Arabian desert). In detail, LS-DAL dynamic range of light intensity is at least 10^9.
3. LS-DAL can work in two broadband spectral modes: 1) typical halogen 2856K color temperature in 400-1000nm, 2) multi-LED of 5000K color temperature spectrum in the same band. This solution increases realism of simulated light conditions. Both day/night and ground/naval/air conditions can be simulated.
4. LS-DAL can work in monochromatic mode. Wavelength is regulated by manual/motorized exchange of monochromatic filters.
5. In addition to photometric quantities, LS-DAL can be calibrated using radiometric quantities (exitance/irradiance) measured over total VIS-NIR band in W/m^2 unit. Another, solution is to characterize light intensity using a concept of so called silux unit.

Due to these features LS-DAL is a perfect solution in systems for testing VIS-NIR cameras.

5 Spectrum of LS-DAL light source

Spectrum of LS-DAL light source is presented in figure below.



a) *b)*

Fig. 2. Spectrum of light emitted by LS-DAL source working in two different modes: a) Halogen, b) White broadband LED

As can be seen DAL offers 2856K color temperature spectrum that useful for several reasons. First, it is used as a standard illuminant (CIE standard illuminant A). Secondly, it is used as a standard source in night vision device and image intensifier testing as per MIL and STANAG standards. Thirdly, it is a reference source from which SILUX unit (new way of radiometric calibration) is derived. As such having access to 2856K light spectrum is immensely useful and greatly simplifies cross checking measurement results and verifying theoretical models.

6 Calibration of LS-DAL

Inframet offers three ways of calibration of LS-DAL light source: 1)photometric (units: cd/m^2 or lx), 2)band radiometric (unit: W/m^2), 3)silicon specific (unit: SILUX).

In the first way light intensity is characterized using typical photometric quantities: luminance (unit: cd/m^2) or equivalent illuminance. (unit: lx).

In the second way light intensity is characterized using typical radiometric quantities: exitance (unit: W/m^2) or radiance (unit:W/m2 sr) over a specified spectral band.

In the third way light intensity is characterized using recently proposed silicon specific quantities (unit: SILUX). Details on the latter way can be fount at paper: Richards, A., and M. Hübner. "Silux: a unit of silicon detector-weighted irradiance." Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XXXIV. Vol. 12533. SPIE, 2023.

7 Versions of LS-DAL light source

Requirements on test capabilities of systems for testing VIS-NIR cameras vary a lot depending on tested imager, tender requirements or preferences of test team. Due to such situation it natural that requirements on test system including the light source vary a lot. In some cases, simple light source can be accepted, when in other case, most advanced list source is needed. Therefore, Inframet offers LS-DAL light sources in dozen of versions of different design, performance and price.

Version is precisely determined using a code composed from one main number, describing the diameter of the source, and four additional digits for source capabilities. The main criterion of division of LS-DAL sources is diameter of emitter of light source. It is divided into three main types (Table 1).

Table 1. Diameter of emitter of light source

Model	**LS-DAL50**	**LS-DAL100**	**LS-DAL150**
Diameter of emitter of light source typical version	48mm	80mm	120mm
Max diameter of emitter of light source (optional version)	50mm	95mm	145mm

LS-DAL light source can be further divided using four criterion:

1. Simulated illumination conditions (regulation of light intensity),
2. Broadband spectrum source modes,
3. Monochromatic mode,
4. Radiometric calibration.

Table 2. Four letter code to describe performance of LS-DAL source

	A	**B**	**C**	**D**
No	**Simulated light conditions**	**Broadband spectrum source modes**	**Monochromatic mode**	**Radiometric calibration**
1	Day	Only halogen 2856K color temperature spectrum	Only broadband modes as defined in column 2	Only photometric quantities (luminance/illuminance)
2	Day/Night	Additional mode: multi LED 5000K color temperature spectrum	Up to four manually switched calibrated narrow spectral bands	+Radiometric quantities (radiance/irradiance at user regulated bandwidth)
3			Custom	+Silux related quantities

In this way, both tables present precise way to define coding. For example code LS-DAL50-12-23 means DAL light source of following features:

1. emitter diameter: 48mm,
2. simulated illumination conditions: day,
3. broadband spectrum: two exchangeable modes: 1) halogen 2856K, b) multi LED 5000K,
4. monochromatic mode: up to four manually switched calibrated narrow spectral bands,
5. calibration: photometric and radiometric (including silux).

8 Technical specifications

Table 3. Technical parameter of DAL light sources

Parameter	Value
Performance parameters	
Light source diameter	DAL50: 48 mm; DAL100: 80 mm (option: 95mm) DAL150:120 mm (option: up to 145mm); *Typical diameters are optimized to fill holes on Inframet MRW rotary wheels*
Light spectrum	as in Fig. 2
Broadband modes of work:	**1)** halogen bulb of 2856K color temperature in 400 –1000nm spectral band **2)** broadband white LED of color temperature about 5000K in 400–1000nm spectral band
Total luminance range	10 mcd/m^2 – 10 kcd/m^2 – day version 10 µcd/m^2 – 10 kcd/m^2 – day/night version (option: luminance range can be expanded)
Simulated illuminance ranges (approximate values for targets of 100% reflectance)	day version: 30 mlx – 30 klx (0.003 fc-3000 fc) day/night version: 30 µlx – 30 klx (0.000003 fc-3000 fc)
Total dynamic of light source	at least 10^6 – day version at least 10^9 – day/nigh version
Spectral band	LS-DAL in halogen mode emits in wide band from about 350nm to about 2000nm but the source is calibrated in 400-1000nm (optimized for testing VIS or VIS/NIR imaging sensors)
Emission angle	Lambertian source in at least 7° (collimators of F number over 6)
Broadband halogen mode	
Light emitter	halogen bulb as a polychromatic source of light in 400nm to 1000nm spectral band
Spectrum of emitted light	Greybody of color temperature 2856K (see Fig. 2)
Uncertainty of color temperature	50K
Regulation type	Continuous
Regulation method	Opto-mechanical attenuator
Luminance range	10µcd/m^2 – 3000 cd/m^2 additional calibration in radiometric and silicon specific units
Regulation resolution	10µcd/m^2 (at low intensity range)
Stabilization time	<90 sec
Temporal stability	<1%
Broadband multi-LED mode	
Light emitter	white LED as a source of polychromatic light at spectral range 400nm to 1000nm
Spectrum of emitted light	Resemble greybody of color temperature over 5000K in VIS-NIR band (see Fig. 2b)
Regulation method	Electronic regulation
Luminance range	1cd/m^2 – 10 000 cd/m^2
Regulation resolution	1 cd/m^2
Stabilization time	<60 sec
Temporal stability	<1%
Monochromatic mode	
Light emitter	halogen bulb or multi LED (whatever higher power) combined with monochromatic filter

Number of spectral bands	up to 4 (up to 7 in case of LS-DAL150)
Typical wavelengths [nm]	500; 600; 750, 900
Exchange of filters	manual
Calibration	radiometric in W/m^2 units
Light intensity	depends on intensity halogen/multiLED source at specific wavelength
Other parameters	
Work temperature	+5°C to +35°C
Storage temperature	-5°C to +55°C
Humidity	Up to 90% (non condensing)
Dimensions	380x260x250
Mass	12 kg

*specifications are subject to change without prior notice

9 Comparison of LS-DAL light source with LS-SAL light source

Inframet offers two high end specialized light sources: LS-DAL and LS-SAL light source. They look externally very similar due to similar design, but there are differences.
Similarities:

1. Near identical external view,
2. Similar two mode design: 1) halogen source, 2) multi-LED source,
3. Halogen lamp used in both sources emits light in wide spectral band from about 400nm to about 2200nm,
4. Optional use of set of filters to enable monochromatic work mode.

Differences:

1. LS-DAL is optimized for spectral band 400 –1000nm (testing VIS-NIR cameras) when LS-SAL is optimized for spectral band 500 –2200nm for testing SWIR cameras (crucial band 900 –1700nm),
2. Spectrum of of halogen lamp in LS-DAL at wavelengths over 1100nm is much below spectrum of 2856K greybody when in case of LS-SAL this difference is much smaller,
3. MultiLED source used in LS-DAL emits in VIS-NIR spectral band when the same source used in LS-SAL emits in SWIR band.

10 Summary

LS-DAL light source due to extremely wide range of regulated luminance, ability to vary light spectrum of simulated scenery, PC control, and compact design significantly exceeds simpler, single channel halogen light sources offered at international market. It is a near perfect solution for systems for testing VIS-NIR cameras.

Version 7.1

CONTACT:
Tel: +48 22 6668780 Fax: +48 22 3987244 Email: info@inframet.com