LS-SAL

High-end calibrated NIR-SWIR light source

Fig. 1. Photo of three LS-SAL standard SWIR light sources: 1) LS-SAL50, 2) LS-SAL100, 3) LS-SAL150

1 What is LS-SAL?

LS-SAL is a standard light source developed for simulation of illumination conditions from dark, moonless nights to ultra bright days in SWIR spectral band. This light source is used as a critical block in Inframet systems (ST systems https://www.inframet.com/swir_imagers.htm) for testing SWIR imagers. In detail, the light source simulates background of targets of interest in images projected by the test system. LS-SAL can be also optionally used as a stand alone reference light sources in other applications.

2 How does LS-SAL work?

LS-SAL source works as a light emitter of regulated light intensity and light spectrum. Design of LS-SAL is based on an idea to use a system combined from five main blocks: integrating block, halogen bulb, opto-mechanical attenuator, set of LEDs, set of 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.

In other words, LS-SAL light source is a dual mode light source capable of working in two modes: 1) halogen mode of resembling 2856K spectrum in SWIR band, 2) SWIR LEDs mode of 2856K spectrum in SWIR band. In addition, spectral filters allow to modify light spectrum and work in monochromatic mode.

3 LAS-SAL 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 standard light sources are built using integrating sphere method and the term integrating sphere is commonly used as the name for many standard light sources (including mechanical and electronic systems). However, it is technically possible to design near perfect uniform light sources using different methods to improve uniformity. Therefore, Inframet use the term standard light source and not the term integrating sphere. However, practically LS-SAL 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 compared to typical paints used in typical integrating spheres.

4 Why LS-SAL is special?

There are many light sources that emit light in VIS-SWIR spectral band offered on the market that can be potentially used for testing/calibration of SWIR imagers. However, LS-SAL is designed in a way that offers a series of advantages (at least in advanced versions):

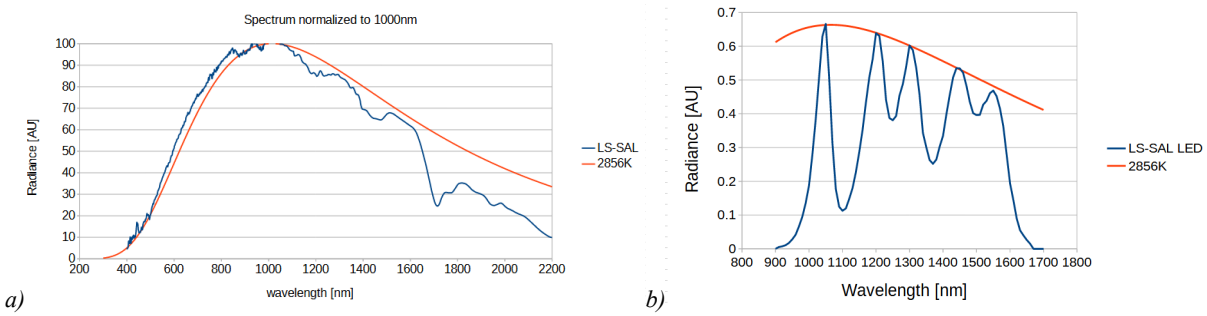
1. Light emitter of size as high as 150mm (optional 250mm) is offered in spite of compact design when all mechanical modules are integrated in one metal case.
2. LS-SAL can work in two broadband modes: 1) typical halogen lamp of broadband spectrum 400-2200nm, 2) multi-LED emitting at 1000-1600nm band (critical band of SWIR imagers).
3. Light intensity of LS-SAL working in both broadband modes can be calibrated in three ways: 1) luminance/illuminance, 2) broadband exitance, 3) SWIR radiance/irradiance (in swux related units).
4. LS-SAL can work in monochromatic mode by changing active LED. Additional regulation of spectrum of LS-SAL light sources is possible using manually exchangeable spectral filters. This is near perfect solution for measurements that verify theoretical models.

5. Use of LEDs enable to improve reliability of light source (even if halogen bulb does not work, then LS SAL in LED mode can still be used).

Due to these new features LS-SAL is a perfect solution for systems for testing SWIR cameras.

5 Spectrum of LS-SAL light source

Spectrum of LS-SAL is presented in figure below.



a) b)

Fig. 2. Spectrum of light emitted by LS-SAL source working in two different modes: a)Halogen mode, b)multi SWIR LEDs of 2856K spectrum

As can be see LS SAL works as 2856K color temperature source. It is an important spectrum. First, it is used as a standard iluminant (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 SWUX unit 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-SAL light source

Inframet offers three ways of calibration of LS-SAL: 1)photometric, 2)band radiometric, 3)SWIR specific.

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 SWIR specific quantities (unit: SWIR cd/m^2 or SWUX).

Details on the latter way can be fount at paper: 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.

7 Versions of LS-SAL light source

Requirements on test capabilities of systems for testing SWIR 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 the most advanced source from the list is needed. Therefore, Inframet offers LS-SAL 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-SAL 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 mane	**LS-SAL 50**	**LS-SAL 100**	**LS-SAL 150**
Diameter of emitter of light source typical version	48mm	80mm	120mm
Max diameter of emitter of light source optional version	50 mm	100 mm	150 mm

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

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

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

	A	B	C	D
No	**Dynamic of light intensity**	**Broadband spectrum modes**	**Monochromatic modes**	**Radiometric calibration**
1	Day	Halogen light source	Only broadband modes as defined in column 2	Luminance (halogen mode)
2	Nigh/Day	Additional mode: multi SWIR LEDs of near 2856K spectrum	up to four manually switched optical filters	Radiant exitance at user regulated spectral band
3			Custom	SWIR specific radiance /irradiance
4				

In this way both tables present precise way to define coding. For example code LS-SAL 50-12-23 means SAL 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 SWIR LED;
4. monochromatic mode: individually controlled SWIR LEDs
5. calibration: photometric and radiometric (including SWIR specific quantities).

8 Technical specifications

Table 3. Technical parameter of SAL light sources

Parameter	Value
Performance parameters	
Light source diameter	SAL 50: 48 mm; SAL 100: 80 mm (option: 95mm) SAL 150:120 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 2) broadband multi SWIR LEDs of 2856K spectrum in 1000-1700nm spectral band
Emission angle	Lambertian source at least 7° (collimators of F number over 6)
Broadband halogen mode	
Light emitter	halogen bulb as a polychromatic source of light in 400 nm to 1000nm spectral band
Spectrum of emitted light	Greybody of color temperature 2856K in VIS-NIR range (see Fig. 2a)
Uncertainty of color temperature	50K
Regulation type	Continuous
Regulation method	Opto-mechanical attenuator
Light intensity range	Day/night version: 1)Luminance: 10µcd/m^2 – 3000 cd/m^2 (day/night mode) 2)Radiance at 400-2200nm: ~0.36µW/m^2 sr – 108 W/m^2 sr

	3)SWIR specific radiance ~2.8 10^{-2} – 8.4 10^{6} SWIR-candela/m^2 Day version: minimal level higher 100x times
Stabilization time	<90 sec
Temporal stability	<1%
Broadband multi-SWIR LED mode	
Light emitter	LEDs as a source of polychromatic light at spectral range 950-1650 μm.
Spectrum of emitted light	Resemble greybody of color temperature 2850K in main part of SWIR band (see Fig. 2b)
Regulation method	Electronic regulation
Light intensity range	Equivalent luminance 0.05 cd/m^2 – 500 cd/m^2 Band radiance: 0.0012 – 12 W/m^2 sr SWIR specific radiance ~ $2 \cdot 10^2$ – $2 \cdot 10^6$ SWIR-candela
Stabilization time	<60 sec
Temporal stability	<1%
Monochromatic mode	
Light emitter	halogen bulb combined with monochromatic filter
Number of spectral bands	up to 4
Typical wavelengths	980, 1064, 1300, 1550,
Exchange of filters	manual
Calibration	radiometric in W/m^2 units
Light intensity	depends on intensity halogen 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-SAL light source due to extremely wide range of regulated light intensity, spectrum that resemble standard 2856K color temperature blackbody, ability to work at both broadband and monochromatic modes, 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 SWIR imagers.

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