Product Document

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Application Note

AN000718

EGA2000-850-UW

Design Guidelines

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Content Guide

1 Introduction

This application note gives a design guideline of the EGA2000-850-UW, a product variant of the EGA2000 product family.

A typical behavior of the product is described in this document, focusing on parameters that are relevant for the end application. The data provided come from measurements performed on a limited number of samples.

The user can get the optimum performances out of the product by selecting the proper operating conditions as well as having a good thermal management.

It is the user's responsibility to take care of the eye safety compliance at system level.

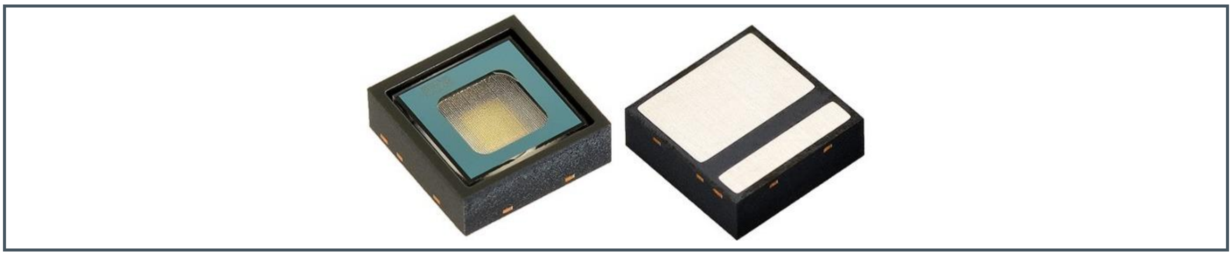
1.1 Product Overview

The EGA2000-850-UW product is a VCSEL (Vertical-Cavity Surface-Emitting Laser) based high power flood illuminator enabling 2D near infrared (NIR) imaging and 3D time-of-flight (ToF) systems for industrial mass market applications.

Figure 1:
Added Value Overview

Benefits	Features
Small package size	4.1 mm x 4.1 mm x 1.38 mm ± 0.100 mm
Power efficient	High power conversion efficiency
Easy component mounting	Standard lead-free solder reflow compatible
Uniform power distribution	100% tested for uniformity in the far field
Full traceability	Unit level track with 2D barcode

Figure 2:
Top and Bottom View of EGA2000-850-UW



1.2 Ordering Information

Ordering Code	Description
ASDX-00	EGA2000-850-UW

2 Electro-Optical Typical Performance

The electro-optical properties of the EGA2000-850-UW modules are characterized using an electro-optical test bench through well-identified tests under varying environmental and electrical conditions.

2.1 LIV Curve over Temperature

In order to determine the proper operating characteristics, the LIV (Light intensity = Optical power (L) / Current (I) / Voltage (V)) is performed on the products at different temperature.

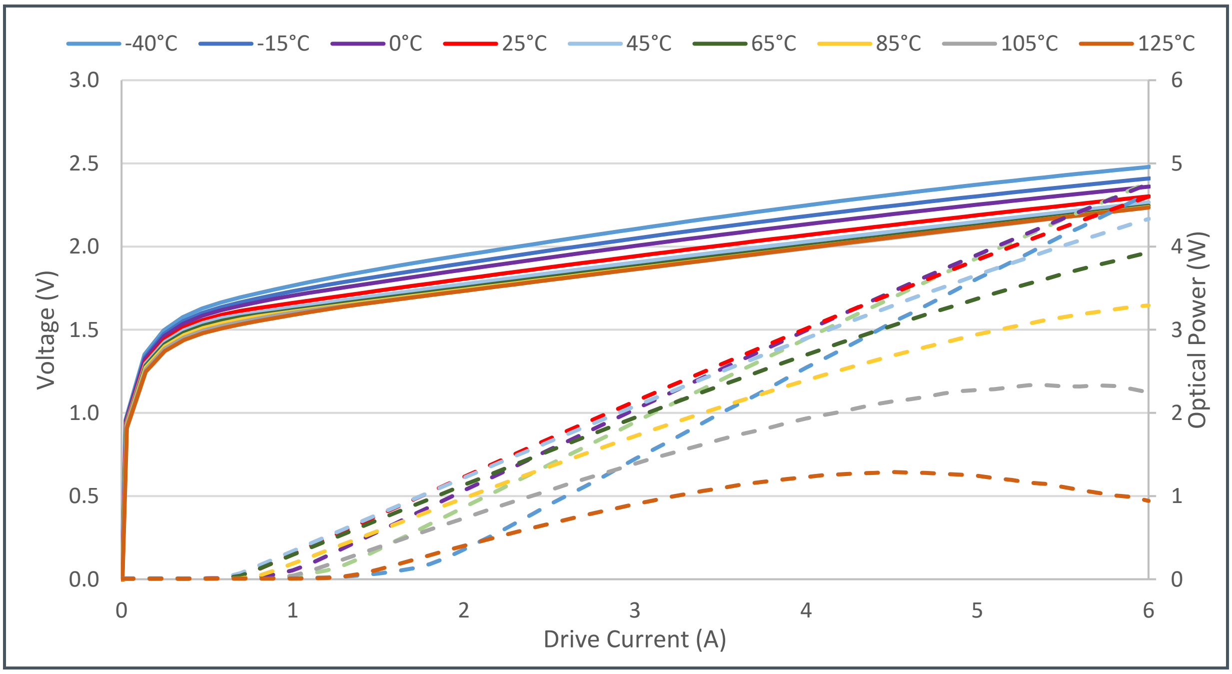
2.1.1 At Long Driving Pulse and High Duty Cycle

The measurements were performed on 5 modules at the following conditions:

- Pulse width: 4 ms
- Duty cycle: 10%
- Current cycle: 0 A to 6 A
- Soldered temperature cycle: -40 ºC to 125 ºC

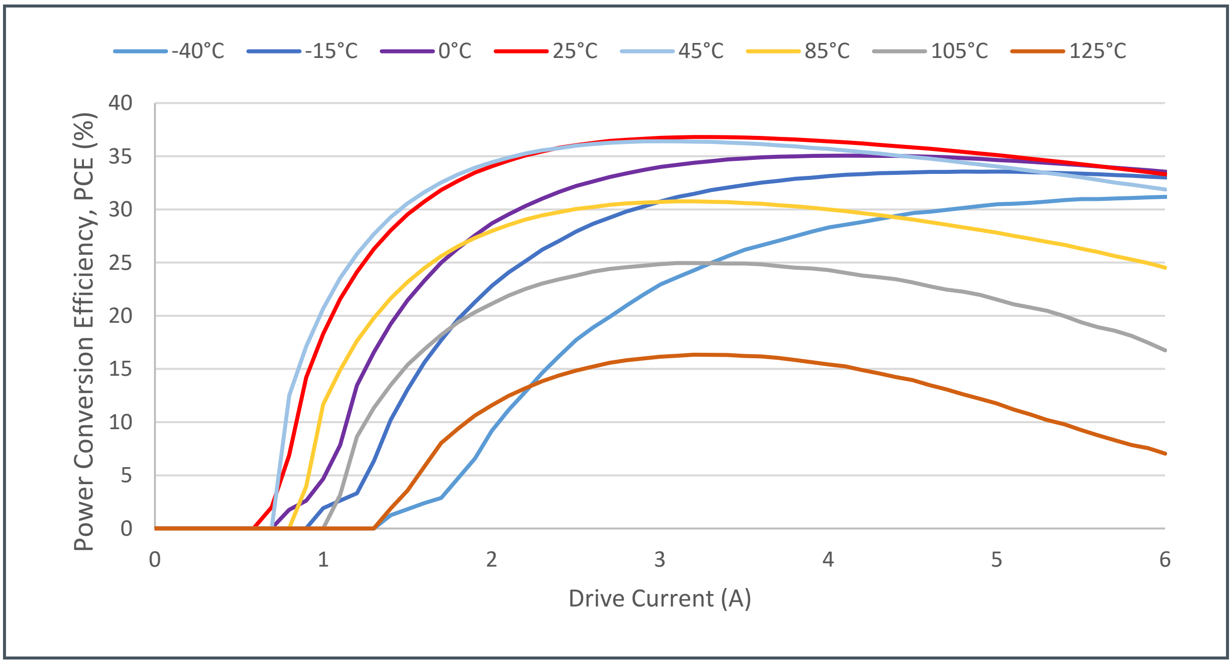
The data shown on the plots below are the average of the 5 tested modules.

Figure 3:
LIV Characteristics up to 6 A(1)



(1) Dashed line: Optical power, Continuous line: Operating voltage.

Figure 4:
Power Conversion Efficiency (PCE) Characteristics up to 6 A[(1)](#)



(1) The power conversion efficiency is calculated as follow: $PCE = \frac{Popt}{V*I}$.

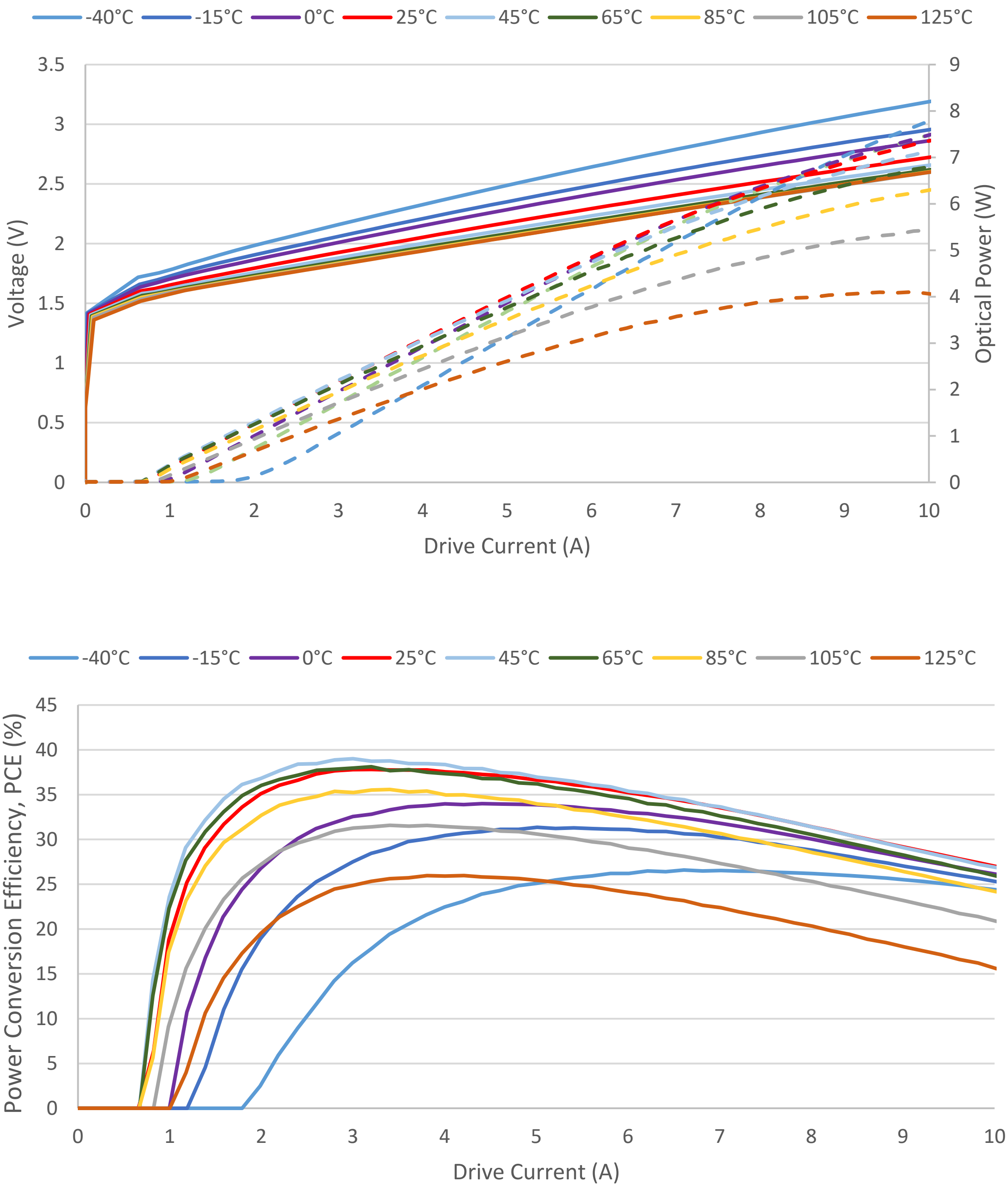
2.1.2 At Driving Current Up to 10 A and Low Duty Cycle

The measurements were performed on a limited number of samples at the following conditions:

- Pulse width: 100 µs and 1 ms
- Duty cycle: 2% and 2.5%
- Current cycle: 0 A to 10 A
- Solder temperature cycle: -40 ºC to 125 ºC

The data shown on the plots below are the average of maximum 5 tested modules.

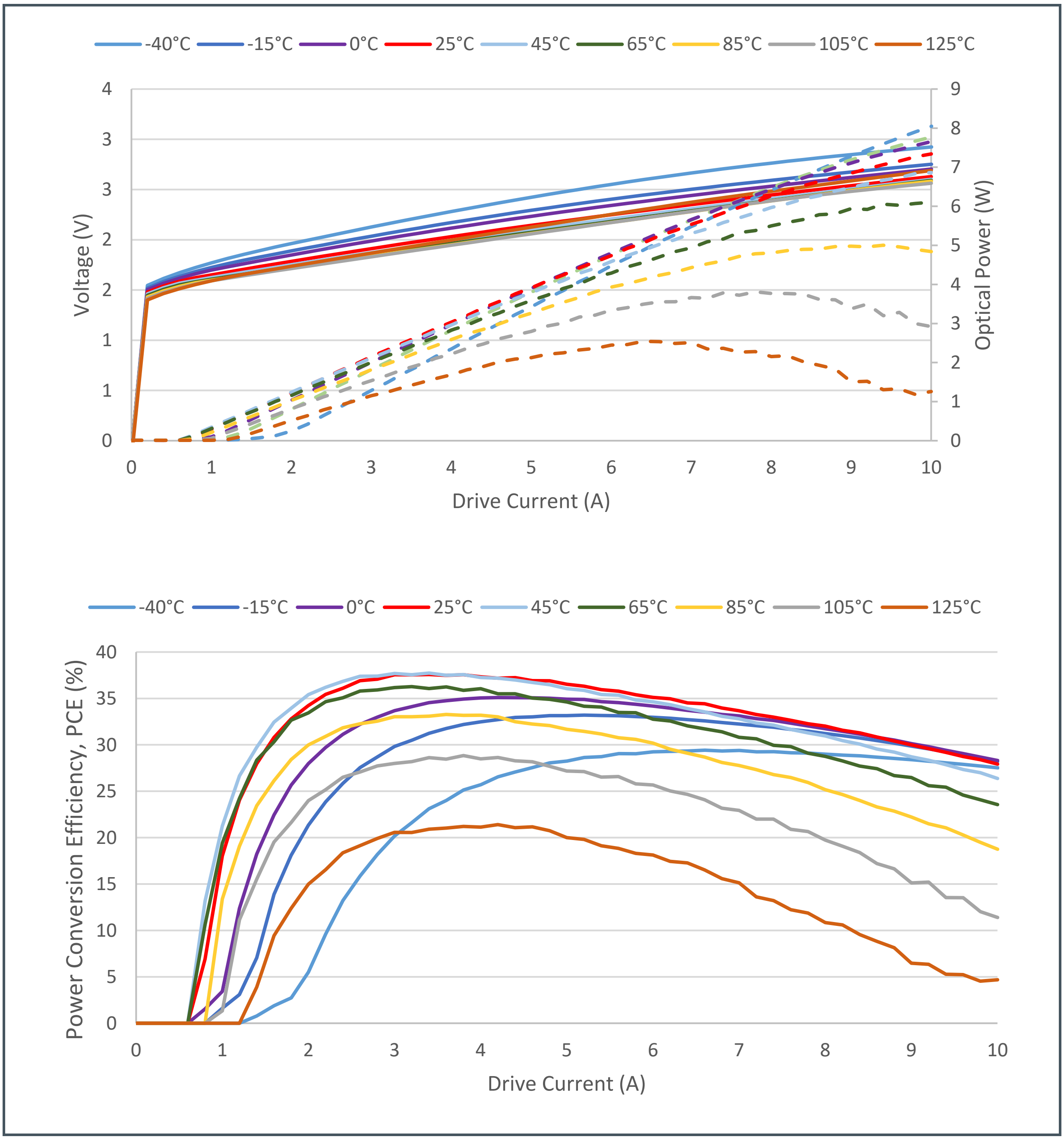
Figure 5:
LIV Characteristics(1) and PCE(2) @100 µs / 2% Duty Cycle



(1) Dashed line: Optical power, Continuous line: Operating voltage.

(2) The power conversion efficiency is calculated as follow: $PCE = \frac{Popt}{V*I}$.

Figure 6:
LIV Characteristics[(1)] and PCE[(2)] @1 ms / 2.5% Duty Cycle



(1) Dashed line: Optical power, Continuous line: Operating voltage.

(2) The power conversion efficiency is calculated as follow: $PCE = \frac{Popt}{V*I}$.

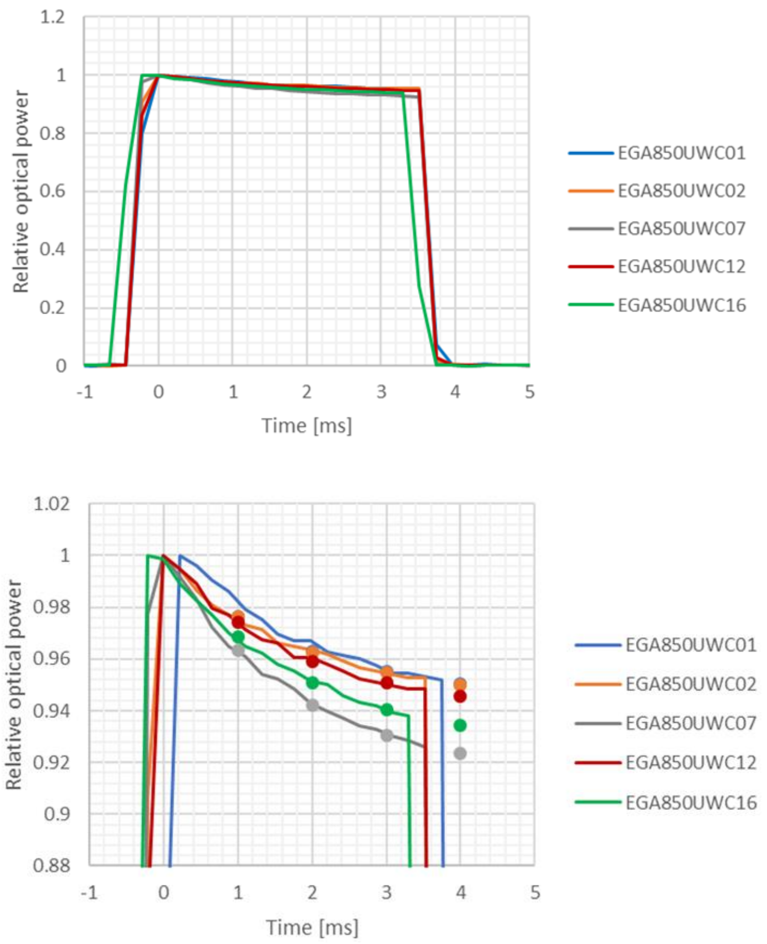
2.2 Optical Power Stability

The optical power stability has been evaluated on five modules with the optical power stability being defined as the variation of the nominal power over the pulse. The tests conditions used are as following:

- Pulse width:4 ms
- Duty cycle: 10%
- Current: 6 A
- Solder temperature: 25 ºC

The figure below shows the outcome of the measurements. It is shown on this measurement that optical power within a pulse width of 4ms is less than 8% for the worse module.

Figure 7:
Optical Power Drop at 6 A / 4 ms Pulse Width / 10% Duty Cycle(1)



(1) Plot from measurements done on 5 modules.

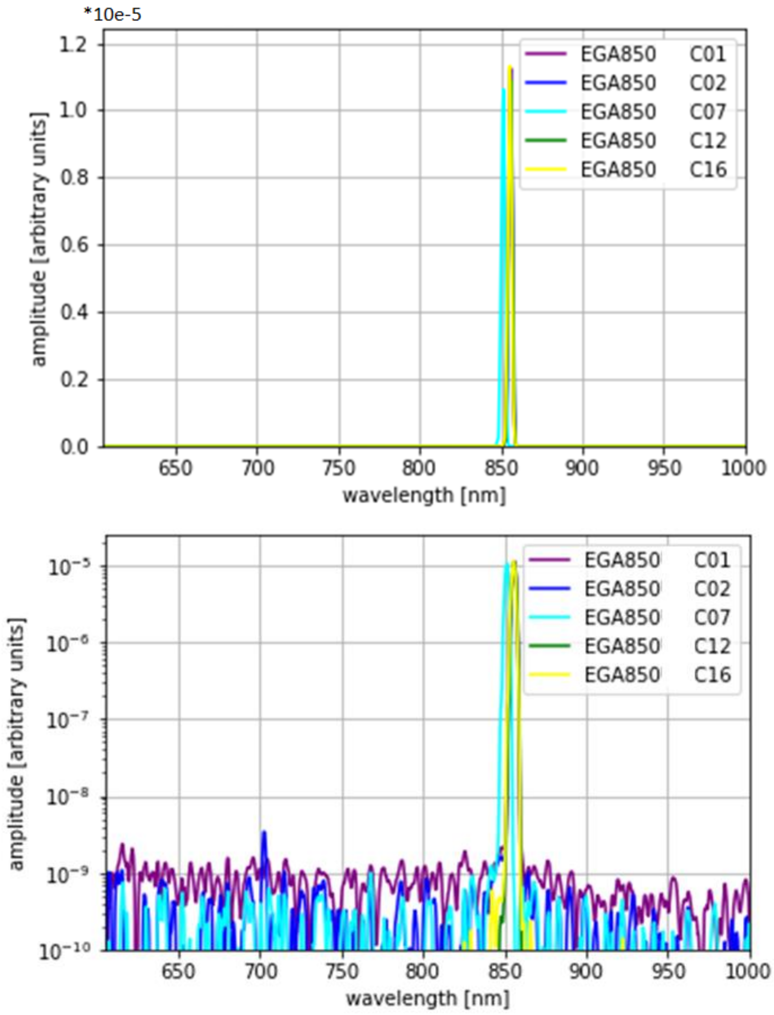
3 Optical Performance

Optical measurements were performed on the module in order to evaluate the spectrum of the module over a wide spectral range as well as to show a typical irradiance map and illumination profile.

3.1 Spectrum Measurement

Measurements were performed on 5 samples over a wide spectral range from 400 nm to 1000 nm.

Figure 8:
Spectrum(1)



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(1) Spectrum measured at 4 ms pulse width, 10% duty cycle, 6 A, at 25 ºC.

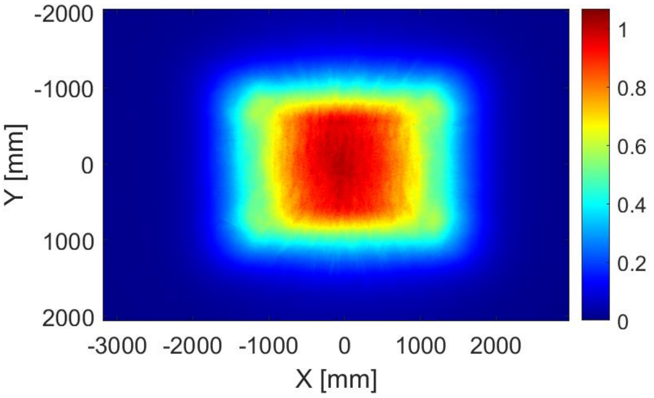
The spectrum (wavelength, spectral bandwidth) of the module depends strongly on the driving conditions.

3.2 Irradiance Measurement

3.2.1 Example of Typical Irradiance Map and Illumination Profile

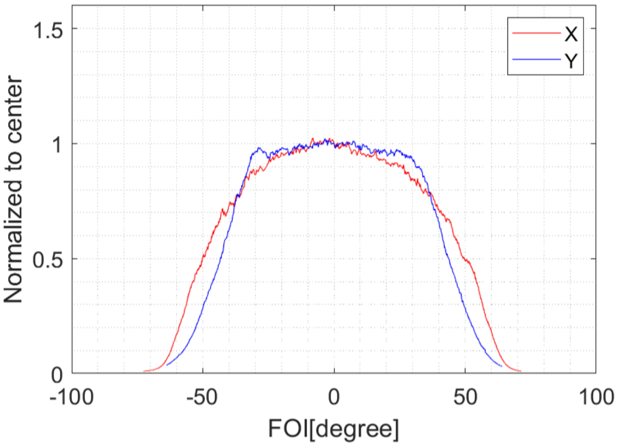
The irradiance map is acquired in transmission mode through a translucent flat screen.

Figure 9:
Typical Irradiance Map(1)



(1) Measurement done at 100 µs pulse width, 2% duty cycle, 4 A, at 25 ºC.

Figure 10:
Typical Illumination Profile(1)



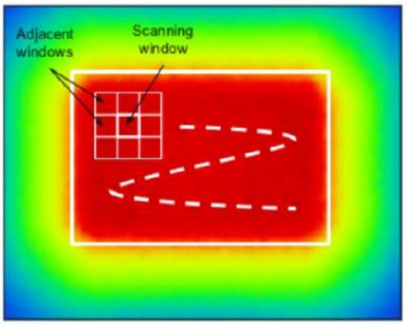
(1) Based on irradiance measurement done at 100 µs pulse width, 2% duty cycle, 4 A, at 25 ºC.

3.2.2 Field of Illumination and Global Uniformity

The field of illumination is the angle determined from the irradiance at 50% level normalized to the centroid (Full Width at Half Maximum).

The global uniformity is calculated from the average intensity (at 80% FWHM) from a 3ºx3º scanning window with 1º increment throughout a box.

Figure 11:
Global Uniformity Definition



$$Global\ Uniformity = P_i - P_{ave80}$$

If (P_i – P_{ave80}) = negative value, then the largest value of this is GlobalUni_Min

If (P_i – P_{ave80}) = positive value, then the largest value of this is GlobalUni_Max

Figure 12:
Field of Illumination and Global Uniformity Data @6 A / 4 ms Pulse Width / 10% Duty Cycle(1)

Parameter	Mean Value	Unit
Horizontal FOI	100.34	deg
Vertical FOI	85.16	deg
Global uniformity max	13	%
Global uniformity min	-18	%

(1) Average value from 5 modules measured.

4 Thermal Parameters

To help the user to predict the proper PCB that will be used with the product as well as the thermal behavior of the product, three parameters are necessary to know: the temperature wavelength coefficient, thermal resistance and maximum junction temperature.

Hereunder is shown how is defined, the temperature.

Figure 13:
Solder Temperature

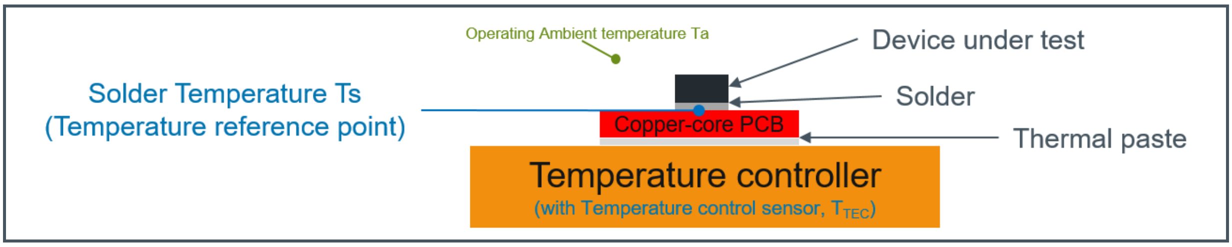
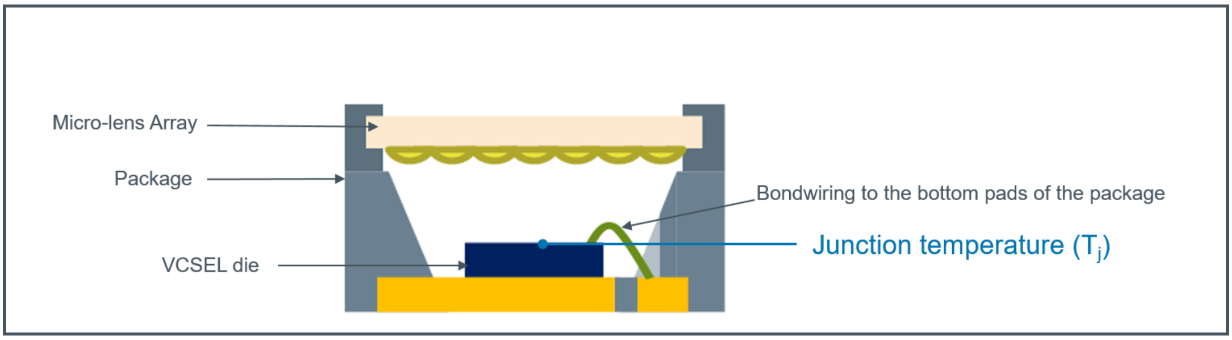


Figure 14:
Junction Temperature



In order to do the measurements over the temperature, the ambient temperature meaning the air temperature is not controlled only the solder temperature.

4.1 Wavelength Shift over Temperature

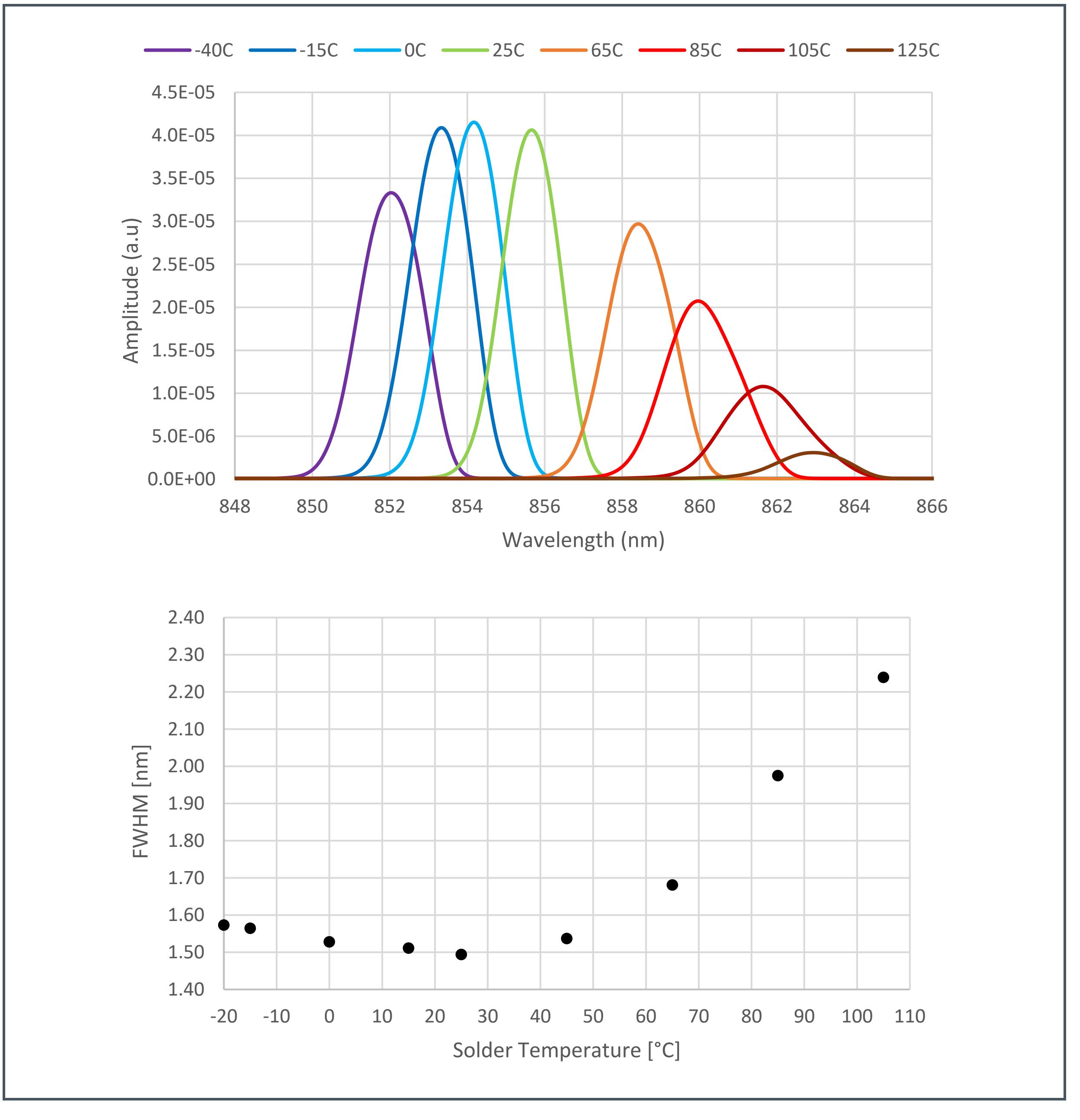
In order to determine the temperature wavelength coefficient, the wavelength of the module was measured at different temperatures on several samples. The calculated value for this product is (average value over data coming from limited number of modules):

- dλ/dT = 0.0687 nm/ºC @ 6 A / 4 ms pulse width / 10% duty cycle.
- dλ/dT = 0.0617 nm/ºC @ 6 A / 100 µs pulse width / 2% duty cycle.

As mentioned in the previous chapter, the spectrum is changing with the driving conditions at room temperature. On top of this variation, it is also observed that the spectrum is changing with the temperature as well.

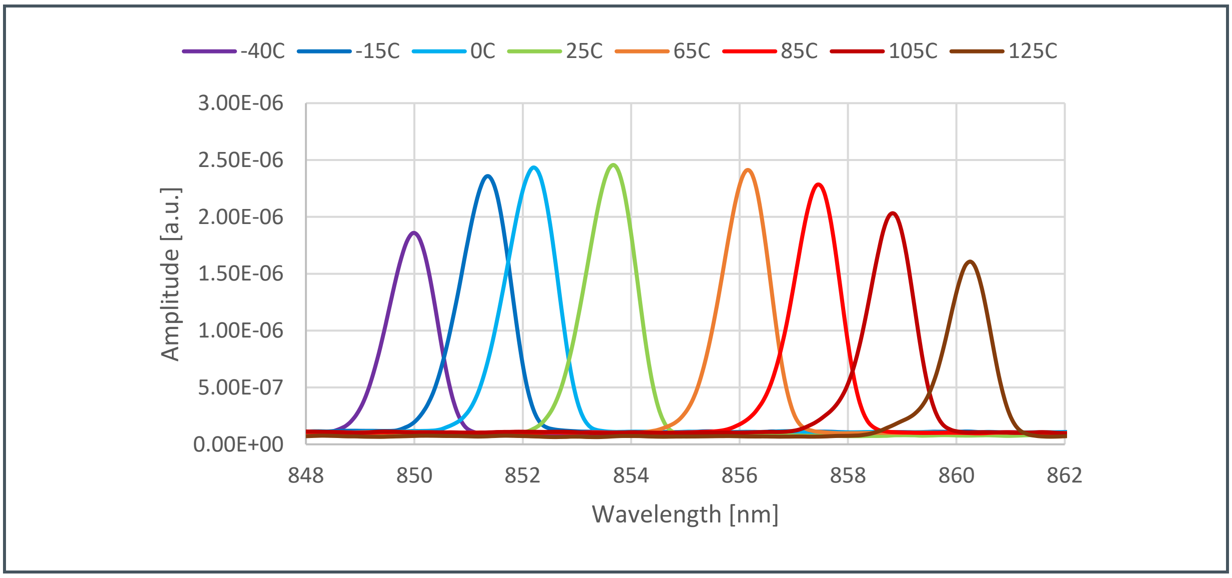
The measurements show that the spectral bandwidth varies and increases much more with the temperature for long pulses and high duty cycle. On the other hand, the amplitude of the spectrum decreases at long pulses and high duty cycle. When the pulse width is low and the duty cycle as well, the spectral bandwidth is more constant over the temperature.

Figure 15:
Spectrum Variation over Temperature @ 6 A / 4 ms Pulse Width / 10% Duty Cycle(1)



(1) Average data from measurements on 5 modules.

Figure 16:
Spectrum Variation over Temperature @ 6 A / 100 µs Pulse Width / 2% Duty Cycle(1)



(1) Average data from measurements on 3 modules.

4.2 Junction Temperature

VCSELs lifetime depends on the junction temperature. To have an optimum lifetime, the device has to operate always under the maximum junction temperature of the product being T_{j_max} = 150 ºC.

The following parameters drive the junction temperature:

- Pulse width: A distinction needs to be done between a pulse width in the nano-second range versus the hundreds of micro-second range or higher.
- Duty cycle: A distinction needs to be done between a duty cycle ≤1% and >1%.
- Driving current: The higher the worse for the junction temperature.
- Operating temperature range.

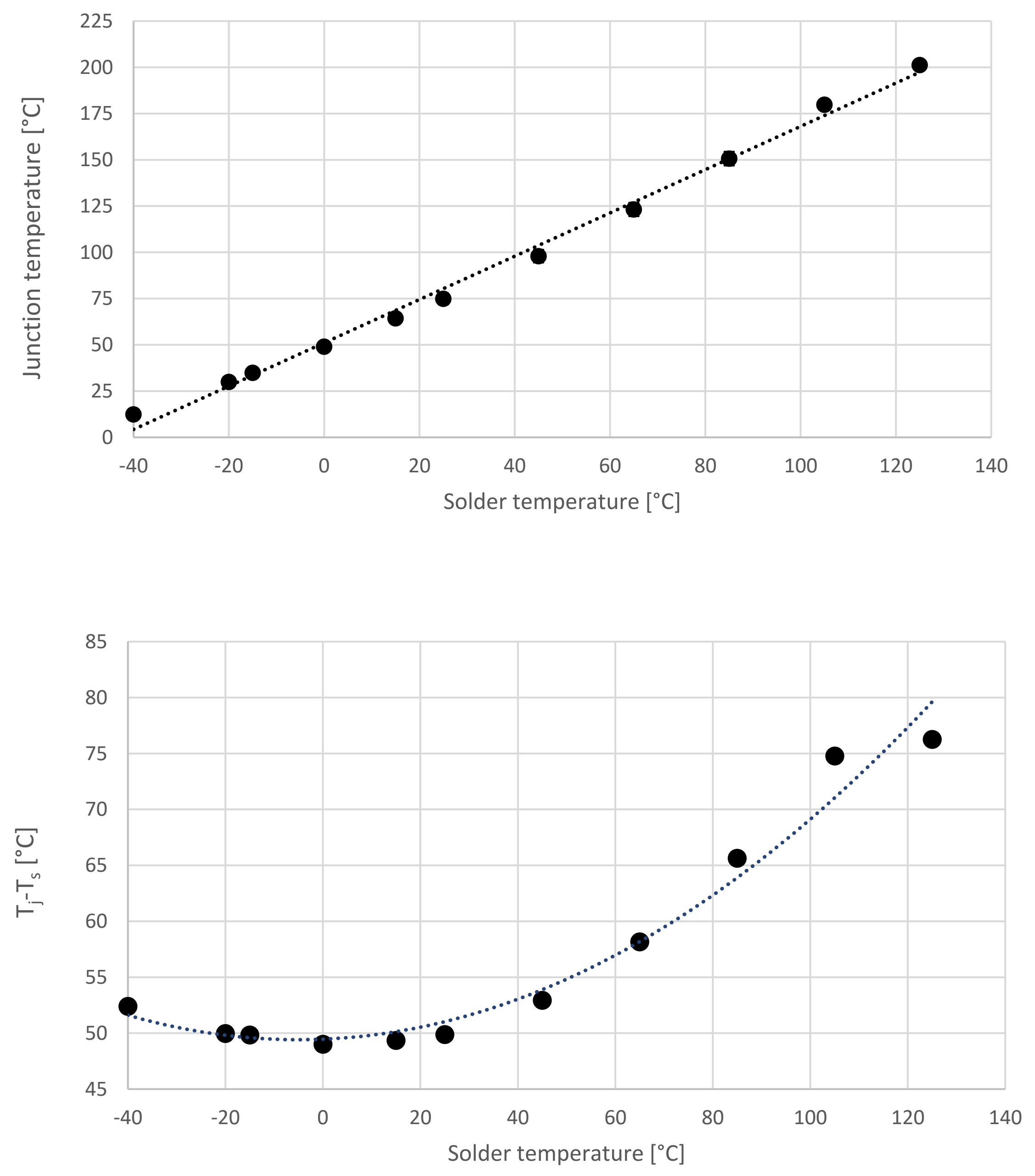
A good thermal management is important to reduce the junction temperature.

4.2.1 Junction Temperature vs Solder Temperature

However, this parameter cannot be measured easily and is also dependent on the operating condition and thermal management. Therefore, in order to ensure that one operates at a junction temperature lower than the maximum value allowed for EGA2000-850-UW, it is important to have a temperature reference point which is the solder temperature.

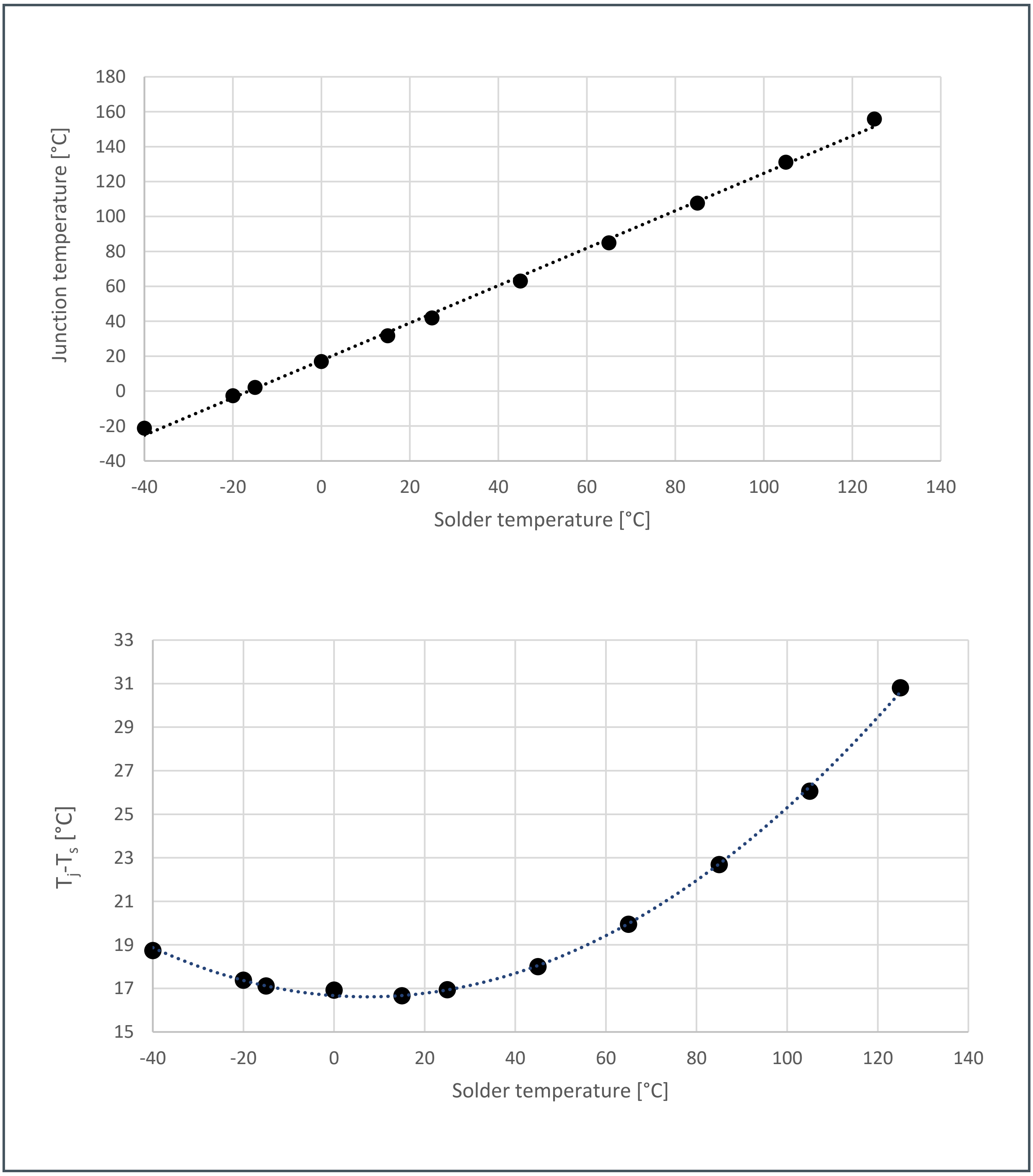
This correlation between the junction temperature and the solder temperature depends also a lot on the driving conditions (pulse width, duty cycle and current).

Figure 17:
Junction Temperature Measurement vs Solder Temperature at 6 A / 4 ms / 10% Duty Cycle(1)



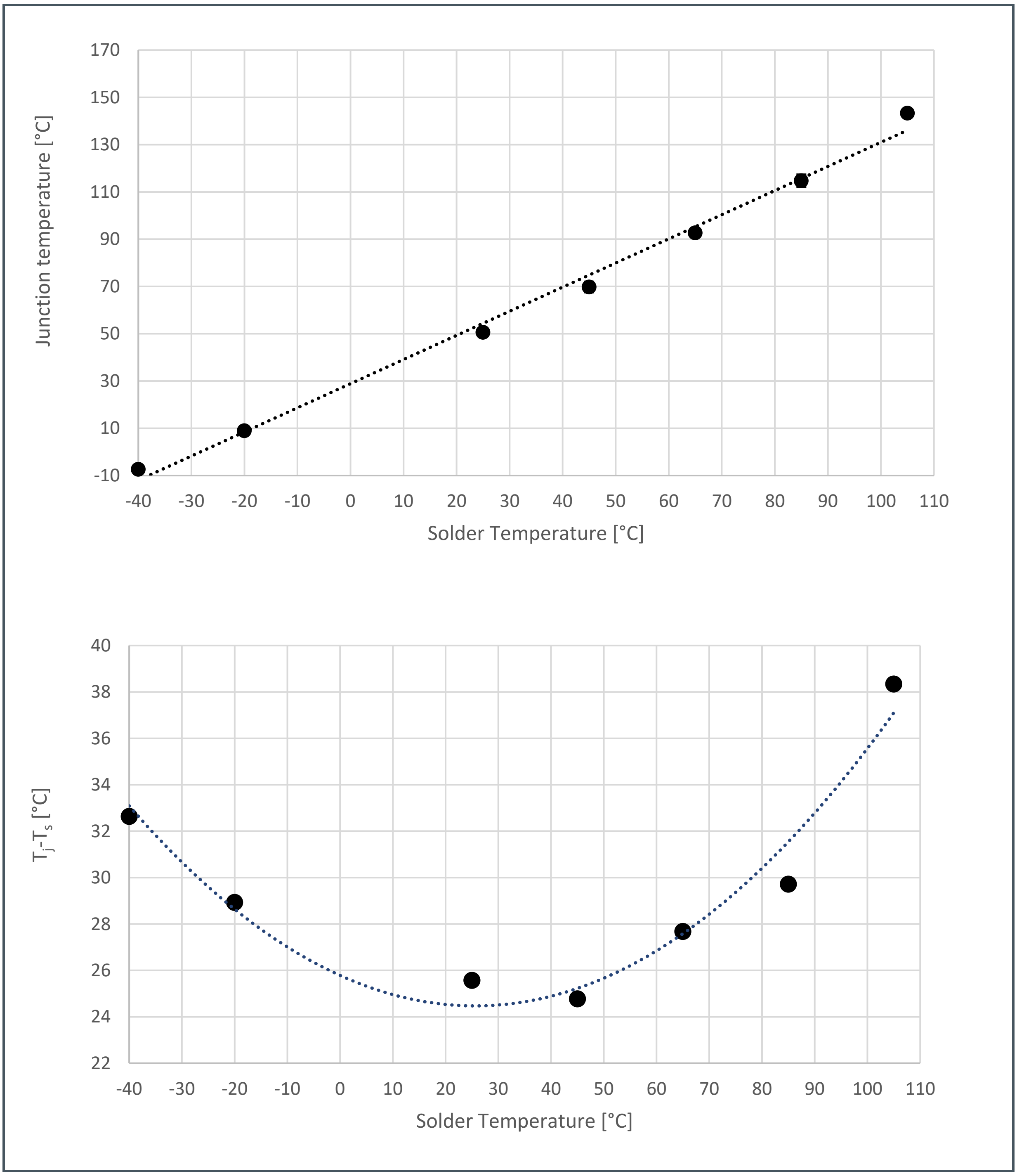
(1) Average plot from measurements done on 5 modules.

Figure 18:
Junction Temperature Measurement over Solder Temperature at 6 A / 100 µs / 2.5% Duty Cycle(1)



(1) Average plot from measurements done on 5 modules.

Figure 19:
Junction Temperature Measurement over Solder Temperature at 3 A / 100% Duty Cycle (CW)(1)

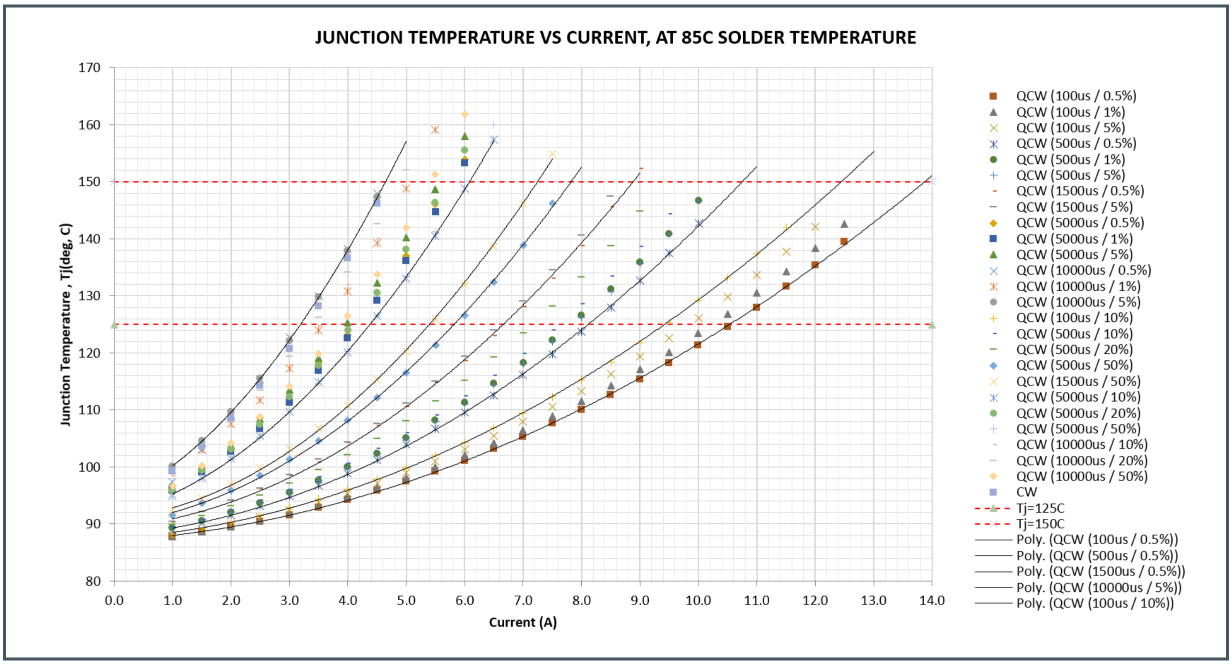


(1) Average plot from measurements done on 5 modules.

4.2.2 Junction Temperature vs Current at Fixed Temperature

As mentioned and shown previously, the junction temperature of the VCSEL also depends on driving current. The graph below shows a typical behavior of the junction temperature vs the driving conditions at 85 ºC.

Figure 20:
Junction Temperature (T_j) Variation over the Driving Conditions



4.3 Thermal Resistance

The thermal resistance $R_{th,JS}$ is determined between the soldered pad and the junction of the device. It reflects the heat transfer inside the module package.

This parameter is derived from the junction temperature as a function of the dissipated power.

Figure 21:
Maximum Thermal Resistance(1)

Conditions	Max	Unit
At -40 ºC	6.1	K/W
At 25 ºC	7.3	K/W
At 105 ºC	9.3	K/W

(1) Maximum value from the measurements done on 5 modules.

4.4 Thermal Degradation

The section above shows that the junction temperature is increasing with the solder temperature and there is a delta between both reference temperatures depending on the driving conditions. These temperatures also play a role on the optical performance of the module.

4.4.1 Two Types of Thermal Degradation Root Causes

Thermal effects affect the module performance, both intra-pulse and long-term use:

- For a long enough pulse length, the emitted optical intensity decreases along the pulse.
- For a long enough burst of pulses, the last pulses have a lower intensity than the first ones.
- Partially related to laser threshold dependence on temperature, the laser has to be kept as cool as possible.

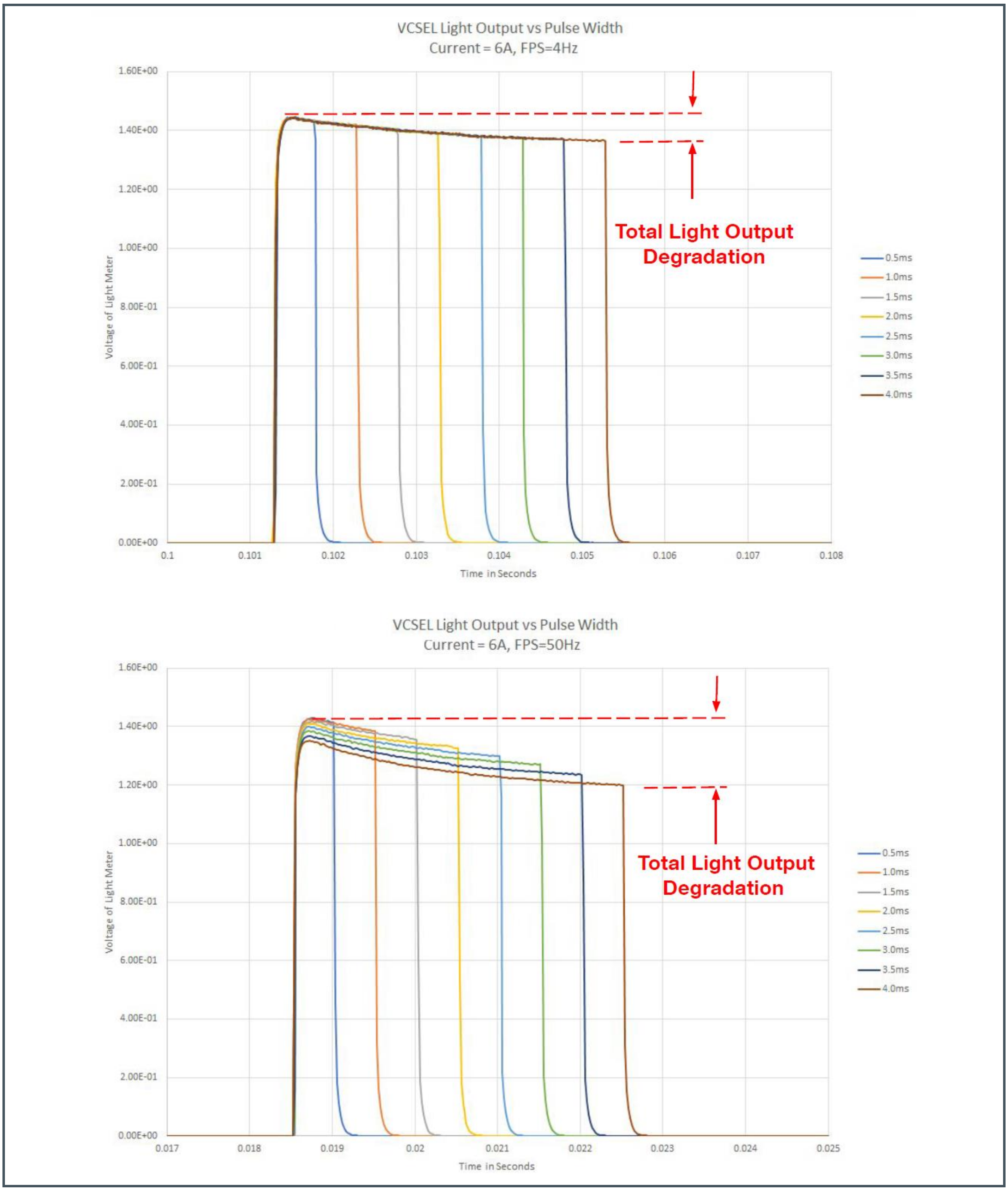
There are two types of thermal degradation of light output (as highlighted and illustrated by SeeingMachines):

- Type 1: Thermal degradation inside single pulse, which will not accumulate with the time, such degradation happens for the driving condition with very low duty cycle.
- Type 2: Thermal degradation due to heat capacitance, which reduces the peak optical power at high duty cycle.

The peak value of light output inside a single pulse will not change much with the increase of pulse width for very low duty cycle (e.g. a frame rate of 4 Hz). However, with a higher frame rate e.g. of 50 Hz, the peak value of light output inside a single pulse decreases with increasing of pulse width.

On top of the thermal degradation of the light output, the thermal management as shown in the previous sections also affects the spectrum (especially the spectral bandwidth and spectrum amplitude).

Figure 22:
Light Output Degradations vs Pulse Width and Frame Rate(1)



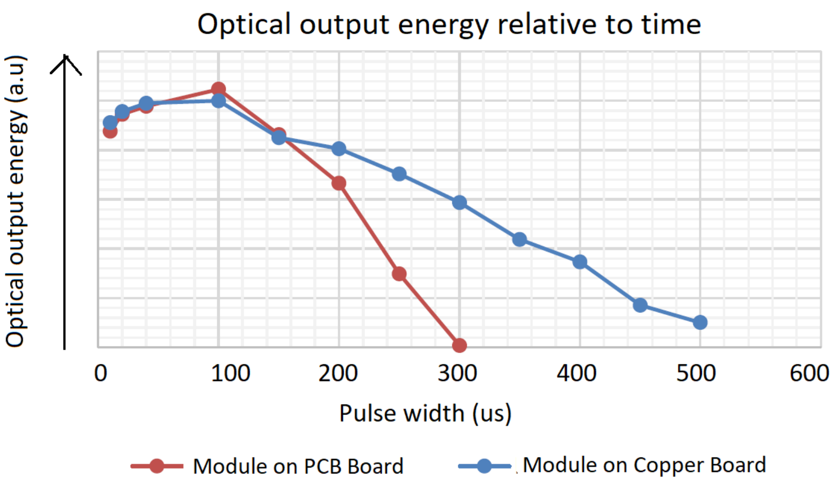
(1) For illustration purpose only. Measurements done on a similar product by SeeingMachines company.

4.4.2 Solutions to Improve the Thermal Behavior

There are several ways to improve the pulse handling capability for an optimized light output power:

- By introducing a fast modulation inside a long pulse width in order to bring a better efficiency and less heat out of the module while keeping the brightness on the camera.
- Using larger and better heatsink is helpful for the type 2 thermal degradation. However, for most of the industrial applications where system integration is crucial, this is not always an option, due to the limitation of packaging size.
- Improving the thermal management between the VCSEL module and PCB is a good way to reduce the type 1 thermal degradation. For the pulsing driving mode, the substrate of VCSEL and metal core PCB work as “thermal capacitor”. A larger substrate will be helpful to absorb the heat impact. A separate insulated thermal pad (with direct thermal path PCB) could be helpful to reduce the thermal resistance between PCB dramatically; therefore the metal mass inside the PCB can do more to absorb the heat impact. The figure below shows the comparison between the performances of a copper board versus a non-metal core PCB board.

Figure 23:
Evaluation of Module Optical Peak Power Behavior for Two Different Types of PCB(1)



(1) Measurements done at 3 A on a similar product soldered on either a copper or PCB board. The Photodiode amplitude is proportional to the optical peak intensity.

The graph above shows that the copper board performs better than a PCB board. In both cases, the use of low duty cycle pulses provides the better efficiency in terms of optical intensity over the electrical power:

- This reduces intra-pulse heating and allows enough pulse-to-pulse cooling
- Optimized parameters depend on specific operating conditions in terms of repetition rate during a burst, of burst on/off ratio, of laser electrical connections, of current level and of laser and driver cooling, e.g:

- On the graph for pulse widths up to 150 µs (at 3 A) the two boards performances are comparable.
- For the burst illumination from 150 µs onwards, the module soldered on the copper board shows a better efficiency and peak power than when it is soldered on a PCB board but it is also shown that after 400 µs the performance drops significantly, so it is always important to have a good thermal management at long pulses.

5 Setup Description

The module is soldered onto a small copper-core PCB which is clamped on a temperature controller copper block. The temperature block is enclosed in a small chamber to prevent humidity from the air to condense at low temperature.

5.1 List of Equipment Used in the Setup

5.1.1 Electro-Optical (EO) Test Bench

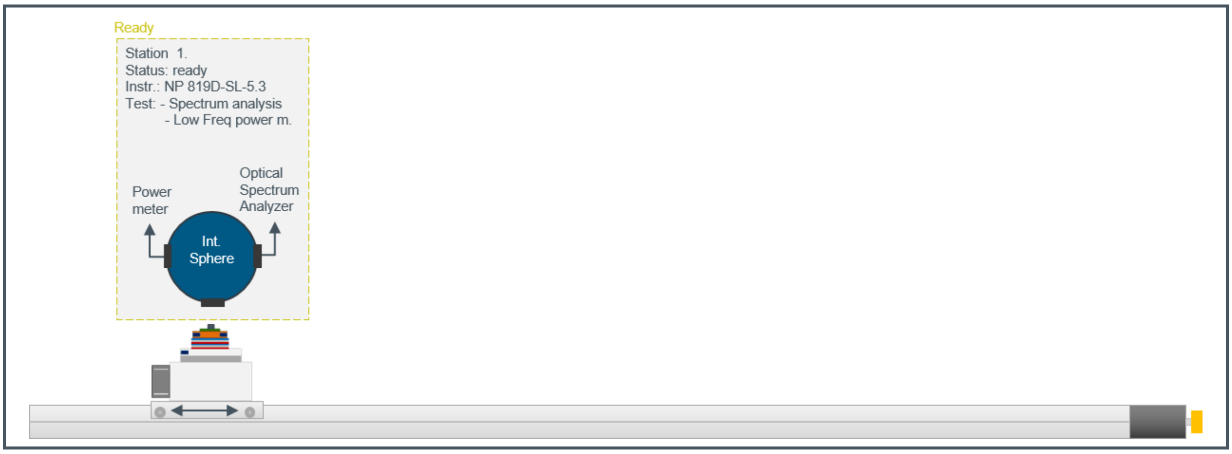
In order to determine the electro-optical properties of the modules, an EO bench is used. The device under test is mounted on top of a thermal system that can be moved under different test station through a linear motorized rail.

A software is able to acquire automatically the LIV curve optical power and spectrum making three scan loops over the desired driving conditions and at different temperatures.

The equipment used for this purpose is listed below:

- Power source and measurement unit
    - Keysight B2912A Source/Measure Unit
- Optical power measurement
    - Newport 819D-SL-5.3-CAL2 integrating sphere with calibrated sensor
    - Newport 1936-R powermeter
    - PicoScope 4824 oscilloscope
- Radiant imaging camera
    - RadiantVision system prometric camera model IP-PMY16
- Temperature control
    - TE Technology TC-36-25 temperature controller
    - TE Technology CP-121 cold plate
- Spectra acquisition
    - Yokogawa AQ6374 Optical Spectrum Analyzer

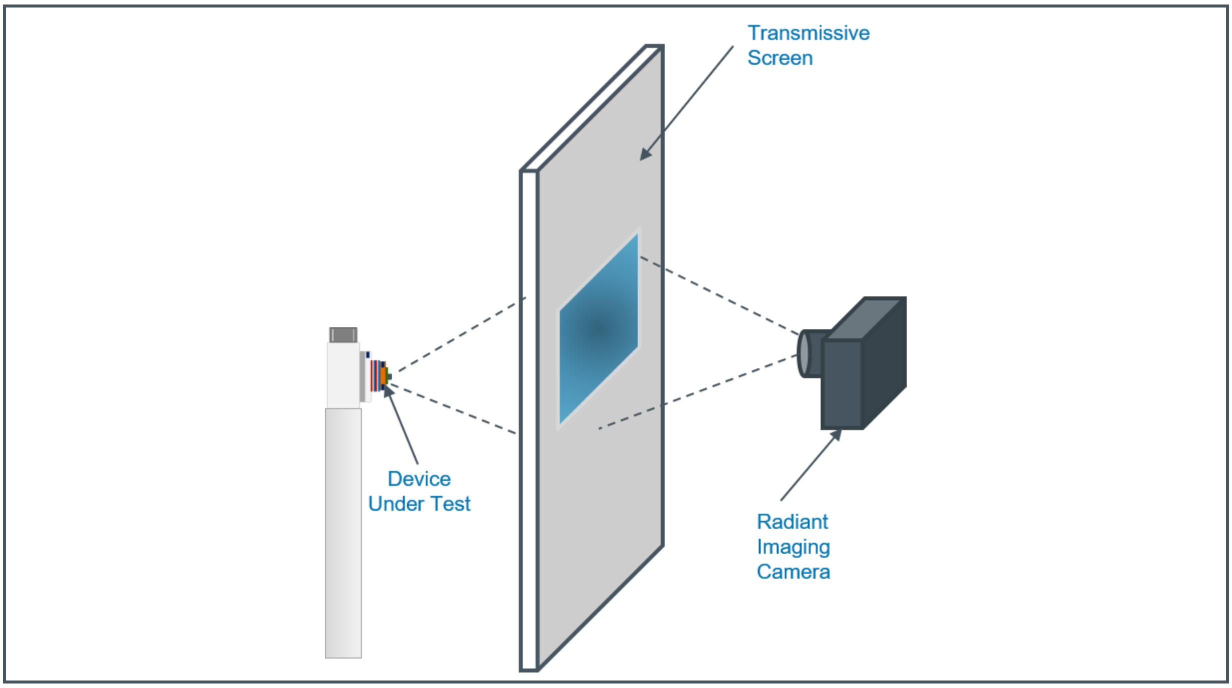
Figure 24:
Electro-Optical Test Bench



5.1.2 Field of Illumination Measurement Setup

The field of illumination is measured in transmission mode (through a translucent flat screen) by means of a calibrated camera.

Figure 25:
Field of Illumination Setup Description



6 Revision Information

Changes from previous version to current revision v2-00	Page
Document security class changed from “Confidential” to “Public”	

- Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
- Correction of typographical errors is not explicitly mentioned.

7 Legal Information

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