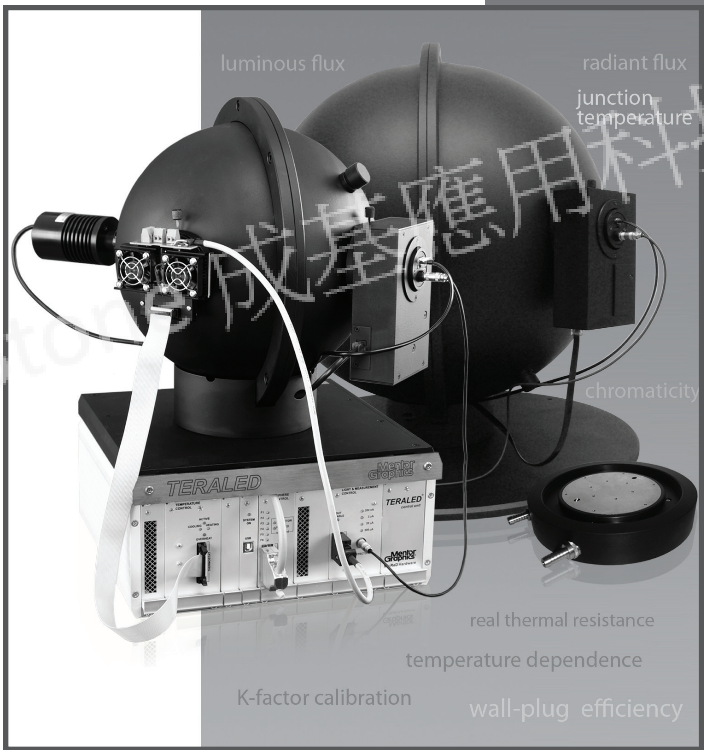
TeraLED®

Thermal and Radiometric Characterization of LEDs

Technical Specification



Mentor Graphics®

MECHANICAL ANALYSIS

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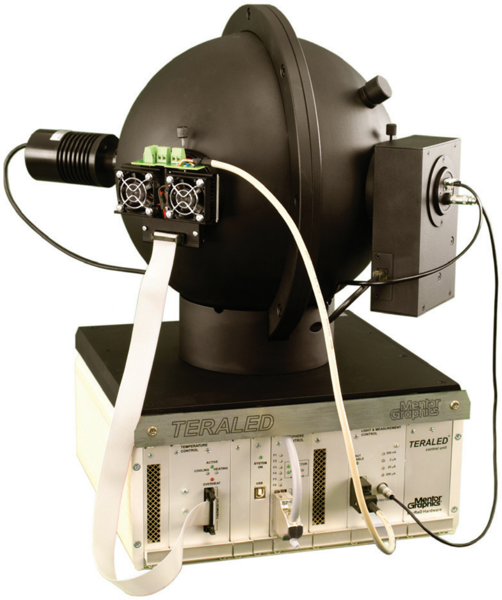
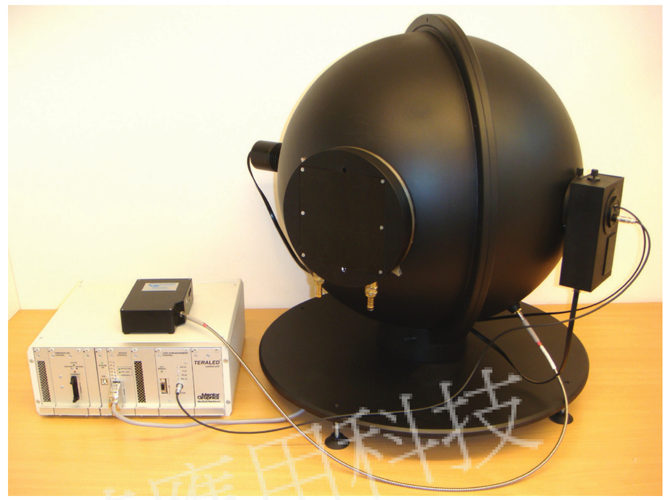
TeraLED HARDWARE OPTIONS

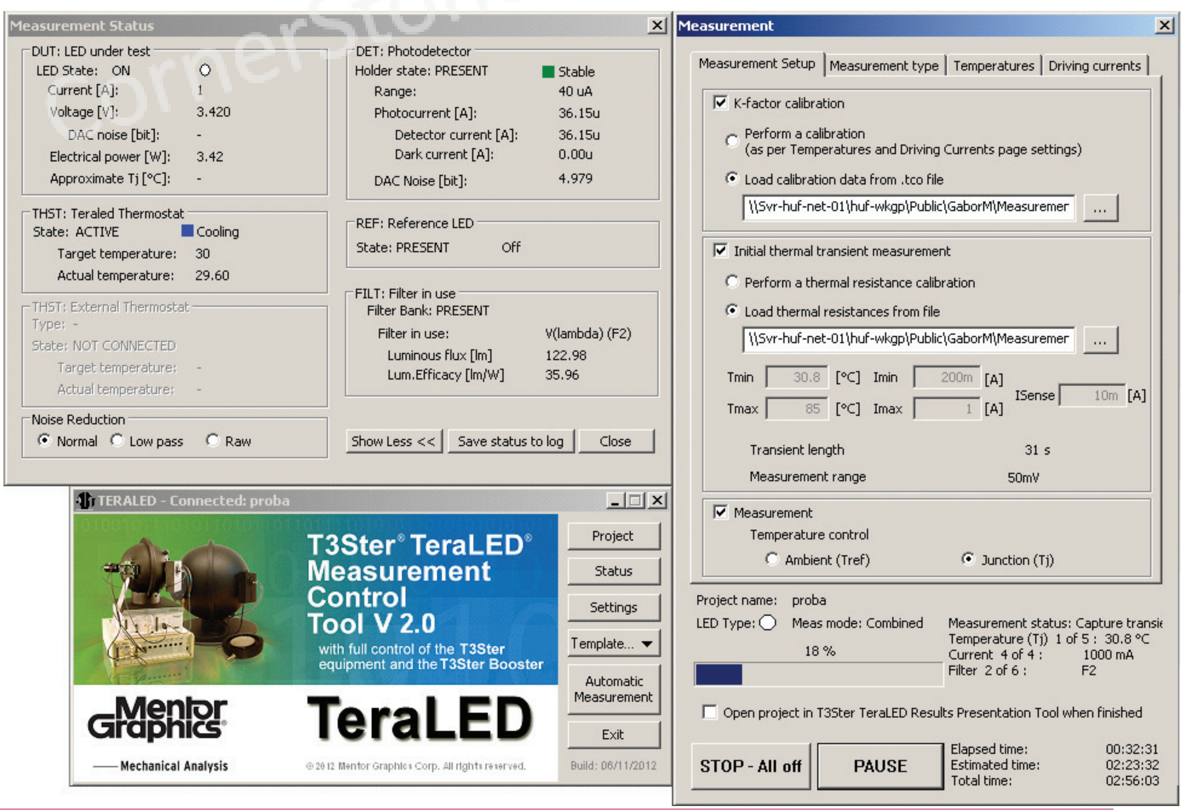
Depending on the dimensions and power level of the LED or LED module to be tested, appropriate measurement environment is needed. The T3Ster TeraLED system, offering two different integrating spheres with appropriate temperature controlled cold plates as DUT holders meets these needs and supports the measurement of a wide range of LED devices.



Ø30cm integrating sphere for LEDs and LED modules up to 55mm in diameter, ~10 W dissipated power and 4000 lm. Temperature control of the LED under test is provided with a Peltier-based cold plate.



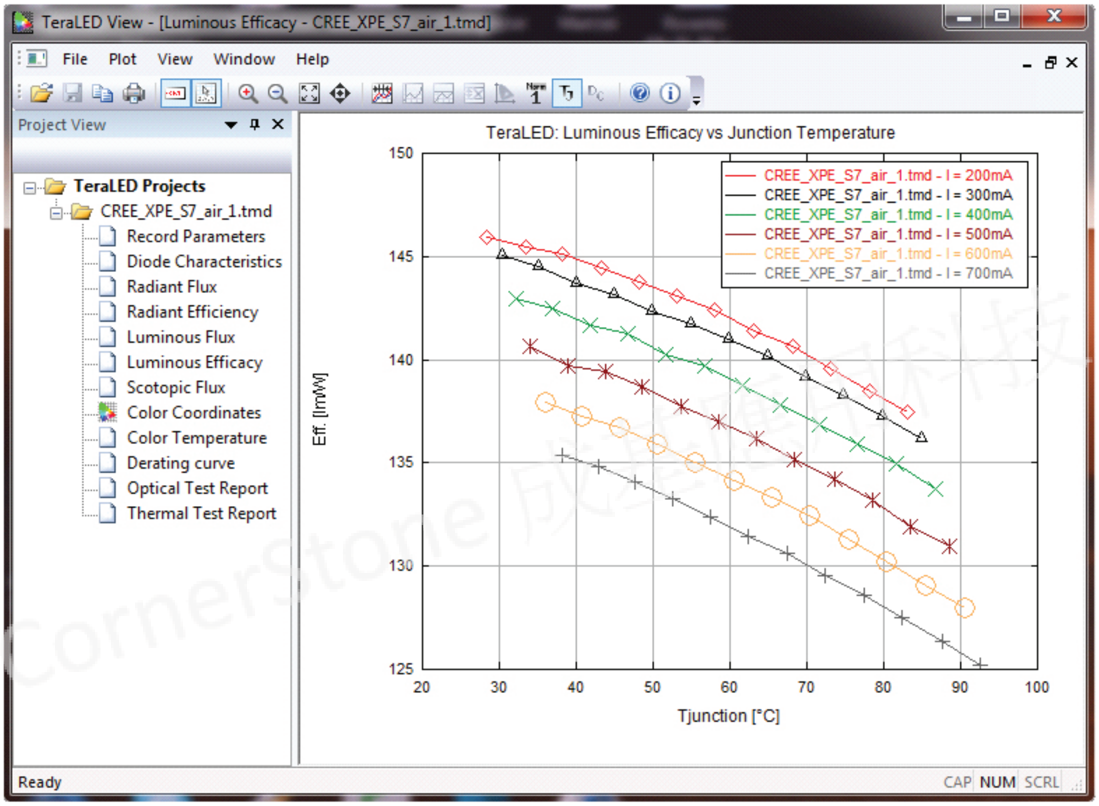
Ø50cm integrating sphere for LEDs and LED modules up to 120mm in diameter, 50 W dissipated power and 9000 lm. Temperature control of the LED under test is provided with a liquid cooled cold plate.



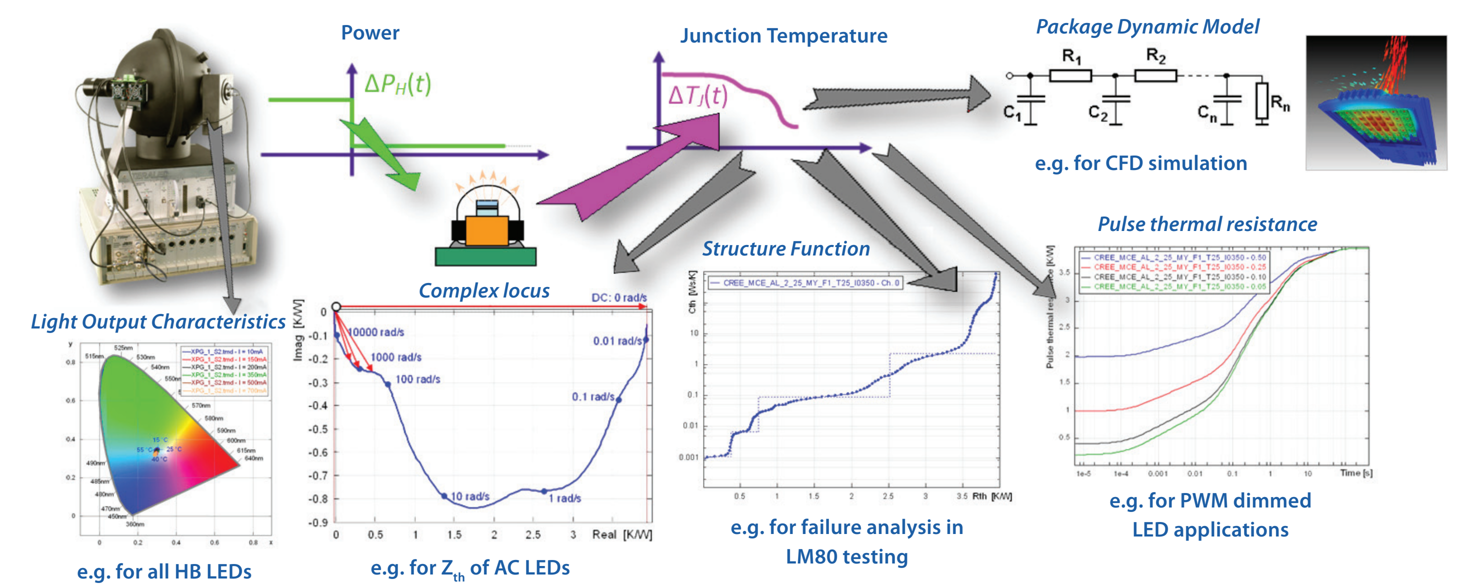
TeraLED SOFTWARE SUITE 2.0

Fully automated measurements are controlled by the ***TeraLED Measurement Control Tool*** that masters all hardware parts connected to the TeraLED system, such as T3Ster, and T3Ster Booster, as well as supported spectrometer types, and supported liquid based thermostats.

For fair comparison between LEDs, the software enables performing measurements at preset real junction temperature values. The real junction temperature and the real thermal resistance of LED packages are identified according to the latest LED thermal testing standard JEDEC JESD51-51. All light output characteristics are measured according to the recommendations of the JEDEC JESD51-52 standard. Following the recommendations of this optical measurement results can be presented as function of the LED forward current and the reference or junction temperature.

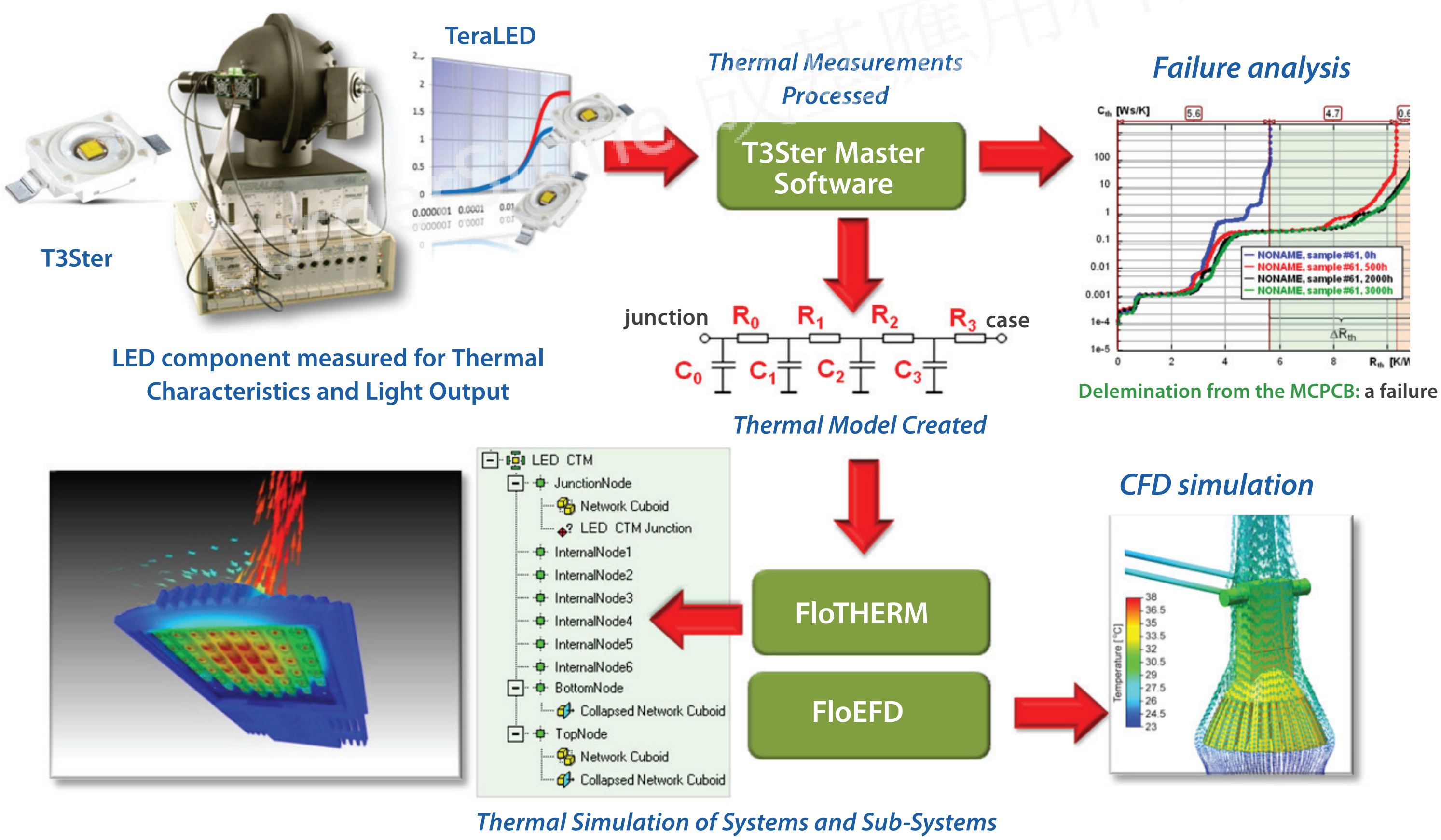


As part of the TeraLED Software Suite, the ***TeraLED View Results Presentation Tool*** is provided to visualize all measurement results of the T3Ster TeraLED setup. Characteristic plots, detailed thermal and optical test reports can be exported and/or copied to Windows clipboard.



***T3Ster TeraLED**: Comprehensive Solution compliant with the JEDEC JESD51-51 and JESD51-52 standards with full support of the JESD51-14 standard*

LED package compact thermal model is directly exportable from T3Ster Master to FloTHERM® for CFD simulations. The TeraLED View tool provides LED data that can be used in the LED module of FloEFD® v12 for LED thermal simulations completed with hot lumen calculations.



Integrated Design Flow for LED based products: Testing – Modeling – Simulation

DETAILED TECHNICAL SPECIFICATIONS

Optical Characterization[1,2,3,4]		Total flux maximal ratings[5]		
		Ø30cm sphere	*Ø50cm sphere*	*Resolution (Ø30cm sphere)*
Radiant Power	$\Phi_e = P_{opt}$ [W]	Up to 8 W	Up to 20 W	±1 µW / ±10 µW / ±100 µW / ±1 mW
Luminous Flux[6]	Φ_V [lm]	Up to 4000 lm	Up to 9000 lm	±1 µlm ±10 µlm / ±100 µlm / ±1 mlm
Scotopic Flux	Φ_{scot} [lm][7]	Up to 14000 lm	Up to 36000 lm	±2 µlm / ±20 µlm /±200 µlm / ±2 mlm
Color Coordinates[8]	x, y	0…0.7		±0.02
Further derived quantities include: radiant efficiency[9], luminous efficacy[9], correlated color temperature[8]				
Spectral Characterization[10]				
Measurement range, accuracy, and resolution depend on the spectrometer connected to the T3Ster TeraLED system. The TeraLED measurement control software supports different spectrometers through an open software interface[11].				
Electrical Characterization[1]			*Measurement*	
			Range	*Resolution*[12]
Forward Voltage	V_F [V]	TeraLED stand-alone	0…5 V	±1 mV
		T3Ster+TeraLED	0…10 V	12 µV
		T3Ster+booster+TeraLED	0…280 V	12 µV
Forward Current	I_F [A]	TeraLED stand-alone	5 mA…2 A	±1 mA
		T3Ster+TeraLED	100 µA…2 A	12 µA
		T3Ster+booster+TeraLED	100 µA…200 A	5 µA
Thermal Characterization[1,13,14,15]				*Measurement Resolution*
Total Thermal Resistance[13]		R_{th} [K/W]		1%[16]
Partial Thermal Resistance[17]		R_{th} [K/W]		
Thermal Impedance[13, 18]		$Z_{th}(t)$ [K/W]		
Thermal Impedance[13, 19]		$Z_{th}(\omega)$ [K/W]		
Junction Temperature[20]		T_J [°C]		0.01°C [21]
Derating Curve		-		
Thermostats for Device Calibration[22]			*Range*	*Accuracy*
Peltier based thermostat for both spheres, provides reference temperature T_{ref}			10…90 °C	±0.2 °C
TeraLED 50L liquid-cooled cold plate, for TeraLED with the Ø50cm sphere, provides reference temperature T_{ref}			depend on the external liquid based thermostat used	
T3Ster+TeraLED Automatic Measurement Thermal Characterization Outputs[23]				
Device sensitivity through a fully automatic calibration at any sensor current level				
T3Ster+TeraLED			I_{sense}: -25 mA…25 mA	
T3Ster+booster+TeraLED			I_{sense}: 0…200 mA	

Device characteristic plots for complete thermal characterization and analysis provided in a fully automated way:

- Measured Unit-Step Thermal Response – $\Delta T_J(t)$
- Thermal Impedance[18] – $Z_{th}(t)$ and Complex Locus[20] – $Z_{th}(\omega)$
- Thermal Time Constant Spectrum
- Pulse Thermal Resistance[24]
- Structure Functions (cumulative, differential)[24]

Detailed thermal evaluation in T3Ster Master software, R_{thJC} identification according to JEDEC JESD 51-14

1. Measurement sequence: L-I-V-T, parameters are: T_{ref}, I_F. Maximum forward voltage and forward current depend on the hardware used (stand-alone TeraLED, T3Ster+TeraLED, T3Ster+booster+TeraLED). With high voltage boosters the maximum forward voltage range can be extended to 280V. With the high current boosters there is no practical limit on the maximum forward current.

2. Light output characteristics are obtained from optical filter based measurements. Luminous flux is measured with a V(λ) filtered matched to the CIE V(λ) function with spectral mismatch error $f_1 \leq 1.5\%$. For other filters spectral mismatch error is smaller than 5%. Measurement of light output characteristics complies with the JEDEC JESD51-52 standard (extension of the CIE 127-2007 recommendations for thermal measurements of power LEDs).

3. Optical measurements are based on CIE technical report CIE 127:2007 "Measurement of LEDs", using the strict substition method for total flux measurements. The system is pre-calibrated with tracable standard LEDs with different colors. The procedure is in full compliance with the JEDEC JESD51-52 standard.

4. As a result of a combined T3Ster-TeraLED measurement setup, all relevant optical characteristic plots can be plotted as function of real junction temperature, reference temperature (thermostat temperature, between 10°C and 90°C) and current (as specified above). Each relevant characteristic plot can be displayed in absolute and relative scale as well.

5. There are different photocurrent measurement ranges. The specified limits correspond to the highest range. Maximum ratings are provided as measured with the same detector system for the different spheres. Depending on the current sphere coating status and filter transmission characteristics these limits can be different – they are typically higher in an actual setup.

6. For CIE 1931 2° observer. The detector system (sphere + filter + photodetector) is matched to the CIE V(λ) function. The entire radiometric/photometric setup is tracable to a luminous flux standard.

7. Scotopic lumen. Measured with a filter matched to the CIE V'(λ) function.

8. Derived from the corresponding measured total flux values (using the color matching functions describing the CIE 1931 2° observer).

9. Derived from the corresponding measured total flux values (CIE 1931 2° observer) and the measured electrical characteristics.

10. Available only if external spectrometer is physically attached to the fiber optics port of the TeraLED sphere and the TeraLED control software is configured to handle spectrometers.

11. For the spectrometer software interface specificiation refer to the TeraLED users' guide. Measured spectra are processed only if that software feature is licensed.

12. In the most sensitive range.

13. Thermal measurements are based on the JEDEC JESD-51-1 static test method and its JEDEC JESD51-14 compliant transient extension applied to LEDs as decribed by the JESD51-51 standard. Primary measured quantity is $\Delta V_F(t)$ function. After a JEDEC JESD51-51 compliant K-factor calibration this is coonverted to $\Delta T_J(t)$ as follows: $\Delta T_J(t) = \Delta V_F(t)/K$. This is converted to $Z_{th}(t)$ function as follows: $Z_{th}(t) = \Delta T_J(t)/\Delta P_H$ where ΔP_H is the change of the heating power calculated as follows: $\Delta P_H = (I_F - I_{sense})\Delta V_F - P_{opt}$. The measured total thermal resistance is the steady-state value of the measured thermal impedance: $R_{th} = Z_{th}(t = \infty) = Z_{th}(\omega = 0)$.

14. In combined T3Ster-TeraLED or T3Ster-booster-TeraLED setup.

15. There are several thermal transient measurement modes provided by T3Ster. *Cooling transient* (default, preferred method, mandatory when combined with light output measurements): complete step response transient function, see also the JEDEC JESD51-51 standard for thermal characterization of LEDs; *heating transient* (not preferred for LEDs): complete step response transient function; *single pulse transient*: transient response to a single pulse (width of the single pulse programmable). Length of the measured transient response is programmable in all modes.

16. For the total junction-to-ambient heat-flow path.

17. Minimum 1/20 of the total thermal resistance.

18. Smallest time resolution is 1 µs. Applies to both driving point (also known as self-impedances) and transfer impedances. Structure functions, time-constant spectra, pulsed thermal resistance diagrams are derived from driving point thermal impedances.

19. Frequency domain representation of the thermal impedance (a complex quantity, function of angular frequency), derived directly from the measured $Z_{th}(t)$ thermal impedances. Presented in the form of Nyquist-diagrams, also known as complex loci. Derived both for driving point and transfer impedances. Its zero frequency value is equal to the steady-state thermal resistance: $Z_{th}(\omega = 0) = R_{th}$.

20. $T_J = T_{ref} + \Delta T$ where T_{ref} is the reference temperature – the actual value of the programmed cold plate temperature. Choose the change level of the heating power applied at the LED junction such that a recommended minimum change of 3°C of junction temperature is obtained. Junction temperature measurement parameters are also determined by the properties of the cold plate in use (see comment 22 as well).

21. Junction temperature change is measured using the JEDEC JESD51-51 test method. In case of -2 mV/°C temperature sensitivity of the V_F forward voltage and for junction temperature change below ΔT_J = 25°C, the resolution of the junction temperature measurement change is 0.01°C.

22. Thermostat heat-sinking capability for *TeraLED 30P* (Ø30cm sphere, Peltier-cooled cold plate) at 25°C ambient temperature is approximately 10W. Thermostat cold plate surface diameter is 55 mm. Thermostat heat-sinking capability for *TeraLED 50L* (Ø50cm sphere, liquid-cooled cold plate) at ambient temperature (25°C) is approximately 50W, depending also on the parameters of the external liquid based thermostat used. Thermostat cold plate surface diameter is 120 mm.

23. Depends on Device Under Test (DUT).

24. Defined and calculated for driving point thermal impedances only.

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