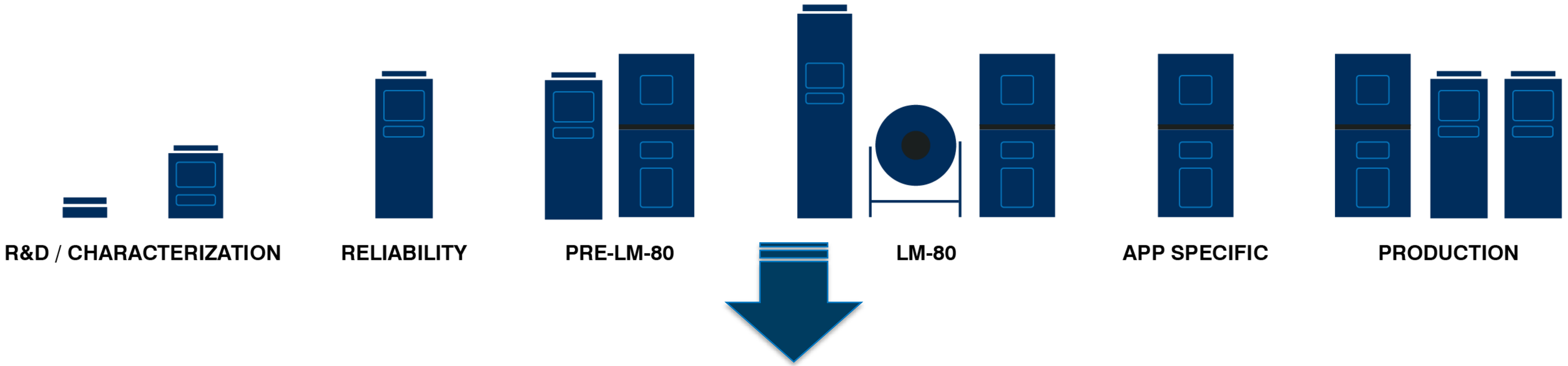
intertek
Total Quality. Assured.

VEKTREX

FACTORS TO CONSIDER WHEN MEASURING ULTRAVIOLET (UV) LEDS

Jeff Hulett – Vektrex, Chief Technology Officer
Jeff Davis – Intertek, Lighting Performance Lead
Carl Bloomfield – Intertek, VP Commercial Infrastructure and Industry Regulations

Vektrex Produces Products To Support the LED and Laser Test Continuum



All utilize Vektrex SpikeSafe Precision Current Sources

AGENDA

01 Intertek and Vektrex Overview

02 Why Do we Need to Test UV LEDs

03 Factors That Can Complicate Testing

04 Typical Equipment Used For Testing LEDs

05 Datasheet and Typical Test Report

07 Conclusion and What's Next

08 Q&A Discussions

1

INTERTEK AND VEKTREX OVERVIEW

VEKTREX ADVANCES MEASUREMENT TECHNOLOGY

- Vektrex advances measurement technology.

- In all our activities, we help companies improve their bottom line with more effective and better ways to test and take measurements.

- With better measurements there is better light.

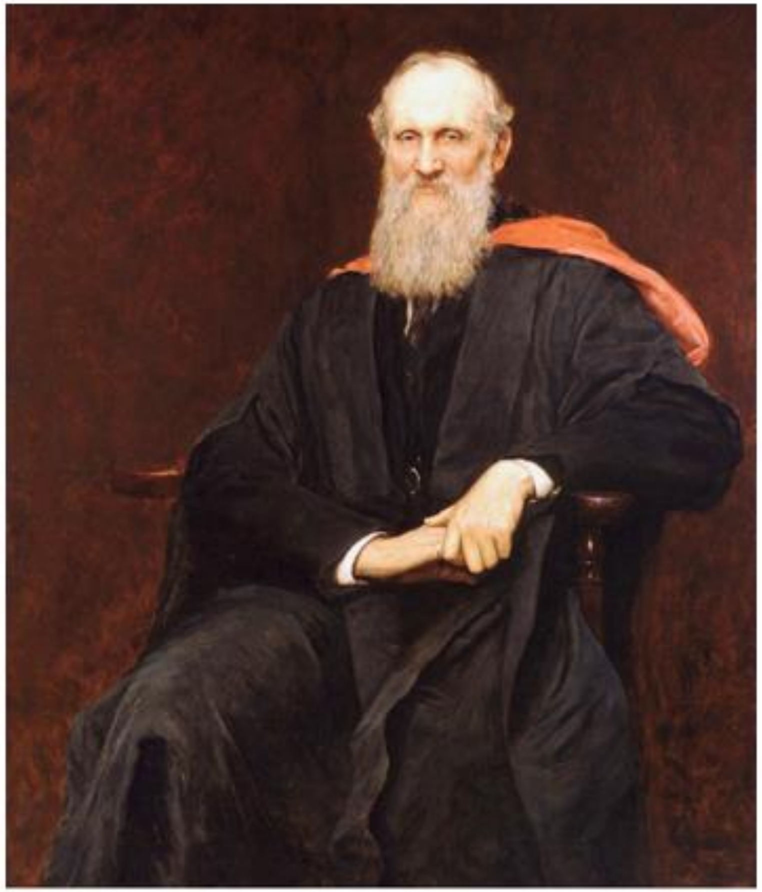
- Vektrex products including precision pulsed sources, SMU's and complete solutions to power and test LED, VCSEL and other light emitting devices.

VEKTREX
PASSION

Measurement is Key to Innovation

"If you can not measure it, you can not improve it."

- Lord Kelvin, determined absolute zero, the basis of the Kelvin temperature scale

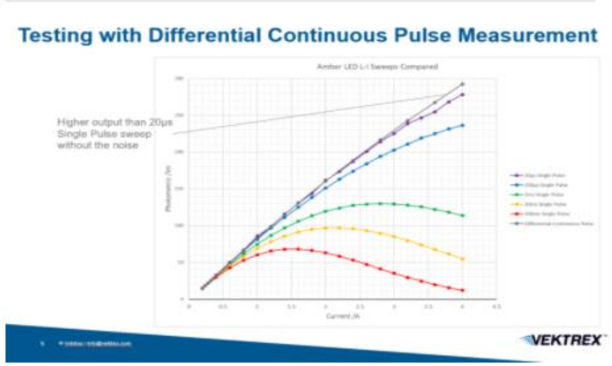


VEKTREX™

VEKTREX PRODUCTS AND SOLUTIONS INCLUDE

SpikeSafe SMU & High Current SMU

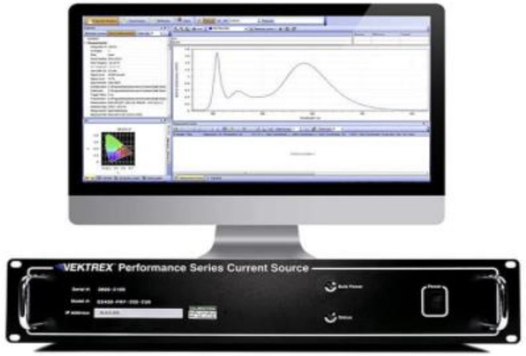
20A Sources & Source Measure Units



Differential Continuous Pulse Measurement

Burn-In and Reliability Systems

Turnkey LM-80 Solutions



Measurement Research

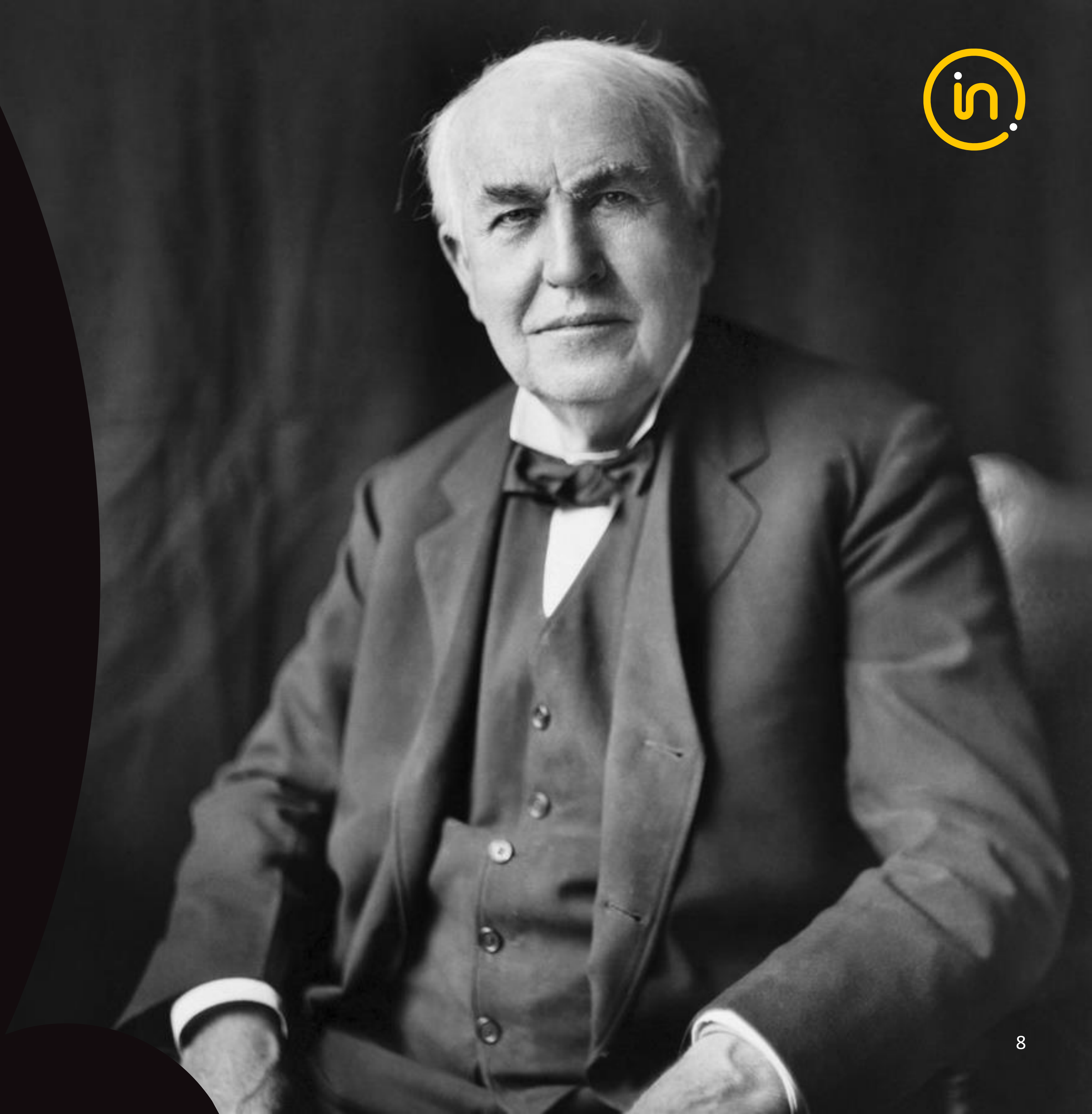
ETL Testing Laboratories founded by Thomas Edison in 1896.

125 years later, we have the world's largest network of product safety, performance and EMC testing laboratories.

Edison Once Said:

"I find out what the world needs. Then I go ahead and try to invent it!"

THOMAS EDISON



WE ARE UNIQUELY POSITIONED TO DELIVER ATIC SOLUTIONS WITH OUR GLOBAL NETWORK

42,000+
employees

Global Market Leader in Assurance

3,000
auditors

90,000+
audits

100+
countries

Global Market Leader in TIC

1,000+
labs and offices

80+
languages

Assurance | Testing | Inspection | Certification

Systemic approach to Quality and Safety with ATIC Solutions

INTERTEK SERVICES FOR LIGHTING INDUSTRY

North American Certification
(cETLus)

International Evaluations
(CB, CE, NOM, KTC, CCC, BSMIA, and others)

Optical Radiation
(LM 79, LM 80, LM 85, LM 84, CIE S 025 and others)

Energy Efficiency
(ENERGY STAR®, NRCAN, CEC, DLC, Eco-Design)

Performance
(HALT, EMC, Vibration, Transient, IP, DALI®, Zhaga)

Environmental
(RoHS, Reach, WEEE, California Prop 65, and other Chemicals)

Data Acceptance
(SATELLITE)

Global Market Access
(SASO, Kuwait, Singapore, Russia, and others)

Advisory Services
(Consulting, Cyber Security, Software Testing, Training)

2

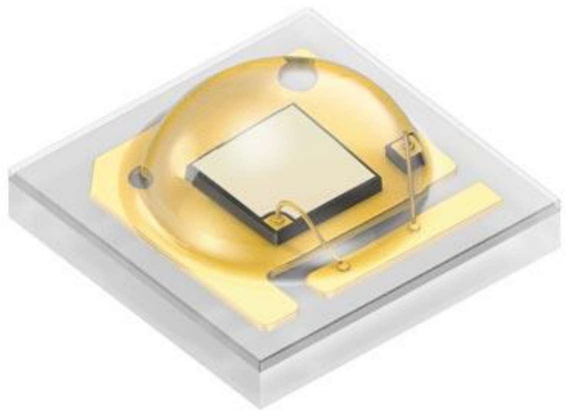
WHY DO WE NEED TO TEST UV LEDS

INTRODUCTION

- Over the last decade LEDs have been playing a more important role in lighting products. In addition to general lighting applications LEDs are now being used more frequently in various other applications such as automotive, germicidal, horticultural and medical to name a few.

- Standards such as IES LM-80 and LM-85, developed by the Illuminating Engineering Society (IES), have played a pivotal role in creating standardized test methods for LEDs. Although intended for all LEDs the existing standards do not properly address challenges that can occur when testing ultraviolet (UV) LEDs. The IES is currently developing new test methods for the optical and electrical measurement of UV LEDs.

- This presentation will focus on some of the challenges that can occur when testing UV LEDs.



STANDARDS USED IN TESTING LEDS

STANDARD	TITLE	COMMENTS
ANSI/IES LM-80-20	Measuring Luminous Flux and Color Maintenance of LED Packages, Arrays, and Modules	Currently includes UV LEDs
ANSI/IES LM-85-20	Optical and Electrical Measurements of LED Packages and Arrays	Currently under revision
CIE 127:2007	Measurement of LEDs	
CIE 225:2017	Optical Measurement of High-Power LEDs	
CIE 226: 2017	High-Speed Testing Methods for LEDs	
IEC 62717:2019	LED Modules for General Lighting – Performance Requirements	
LM-XX (For UV LEDS)	Exact Title TBD as document is under development	New standard in the ballot phase within the IES specific to testing UV LEDs

OBJECTIVE

- Historically LEDs have been classified based on the wavelength they produce (e.g., white LEDs vs amber LEDs), or by the amount of power they produce (e.g., high power vs low power), and with the recent pandemic we are seeing a classification based not only on wavelength but also based on intended usage (e.g., visible LEDs for UV disinfection).

- Like all light sources, LEDs optical performance will change over time and being able to characterize that performance is ever more critical based on intended applications. UV LEDs are known to be more voltage and temperature sensitive than other LEDs and it is important to be able to accurately measure such products.

- Accurate data sheets will help the industry:
  - Supports luminaire manufacturers with their designs and claims validation
  - Supports development efficacy claims
  - Results in faster end user designs

3

FACTORS THAT COMPLICATE TESTING

FACTORS THAT COMPLICATE TESTING

- ***Factor #1 UV-C LEDs are not very efficient***
  - UV-C LEDs are only about 2-3% efficient at converting electricity to light.
  - Other LED types are 40%+ efficient
- They must be driven at high power to get appreciable optical output.
- This means UV-C LEDs tend to be larger and they need higher drive currents – look for currents to increase until the industry can improve efficiencies.

UV-C Efficiency is Terrible

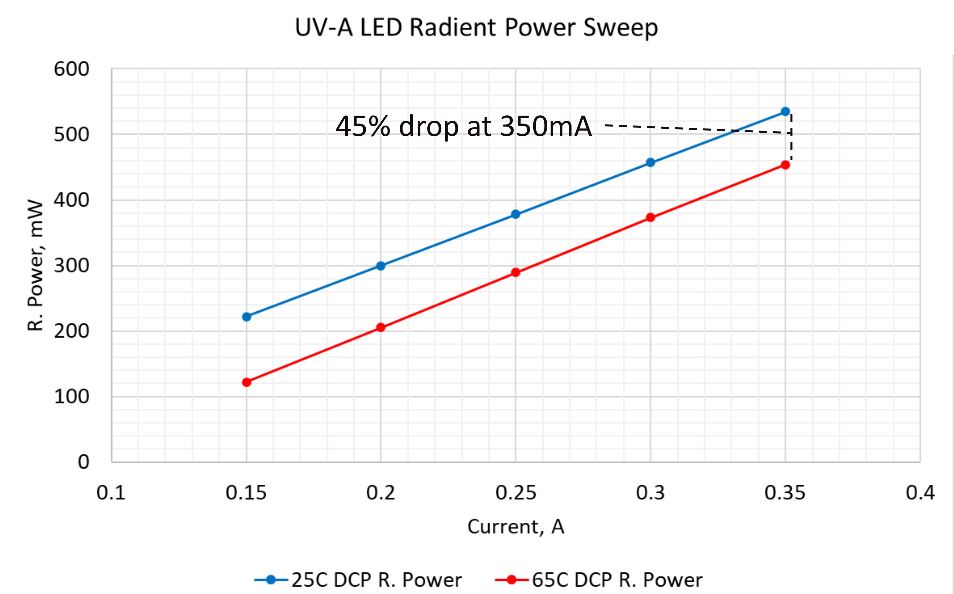
Manufacturer	Part No.	Wavelength	Voltage	Current	E. Power	R. Flux	Efficiency
Nichia	NCSU434B	280	5.7	0.35	1.995	0.062	3.1%
Nichia	NCSU334B	280	5.5	0.35	1.925	0.07	3.6%
Luminus	XFM-5050-UV 2 Chip	275	13	0.8	10.4	0.22	2.1%
Luminus	XFM-5050-UV 4 Chip	275	7	3.2	22.4	0.44	2.0%
Bolb	6060 SMD	270	7	0.35	2.45	0.072	2.9%
Osram	SU CULDN1	275	5.7	0.35	1.995	0.07	3.5%
Luminleds	L1F3-U410200014000	415	3.2	2	6.4	2.61	40.8%
Nichia	NWSU333B	385	3.7	3.5	12.95	5.5	42.5%

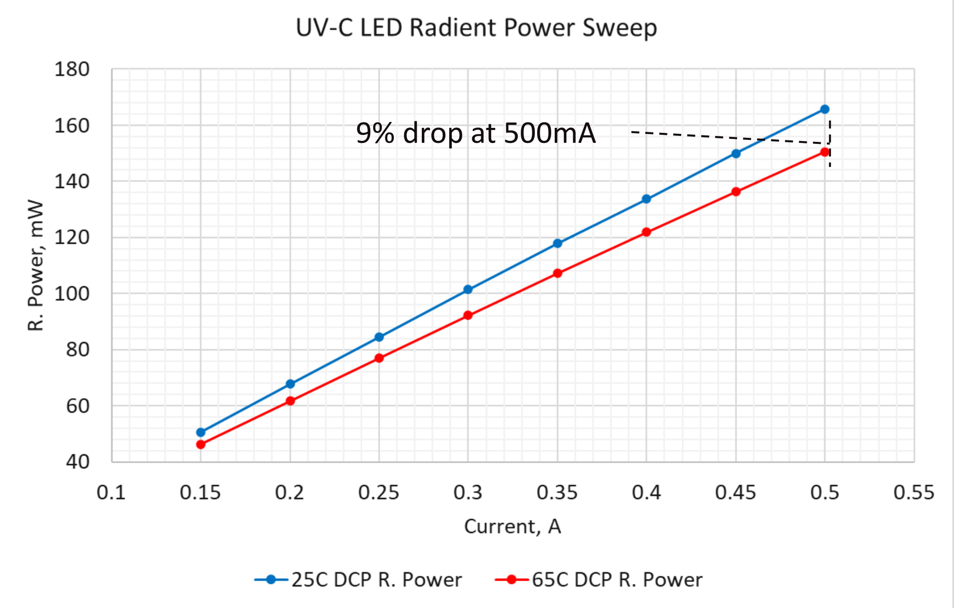
FACTORS THAT COMPLICATE UV LED TESTING

- ***Factor #2: LEDs are temperature sensitive***
- LED output reduces as temperature increases
  - UV-A LEDs can decline over 1%/˚C
  - Some UV-C LEDs decline about 0.2%/˚C, similar to blue visible LEDs
  - Peak wavelength also decreases with increased temperature

- To be meaningful, LED measurements must be associated with a temperature
  - Often this is the package temperature
  - Or sometimes the junction temperature

- If the LED temperature changes during the measurement, the measurement results are impacted, and may be invalid

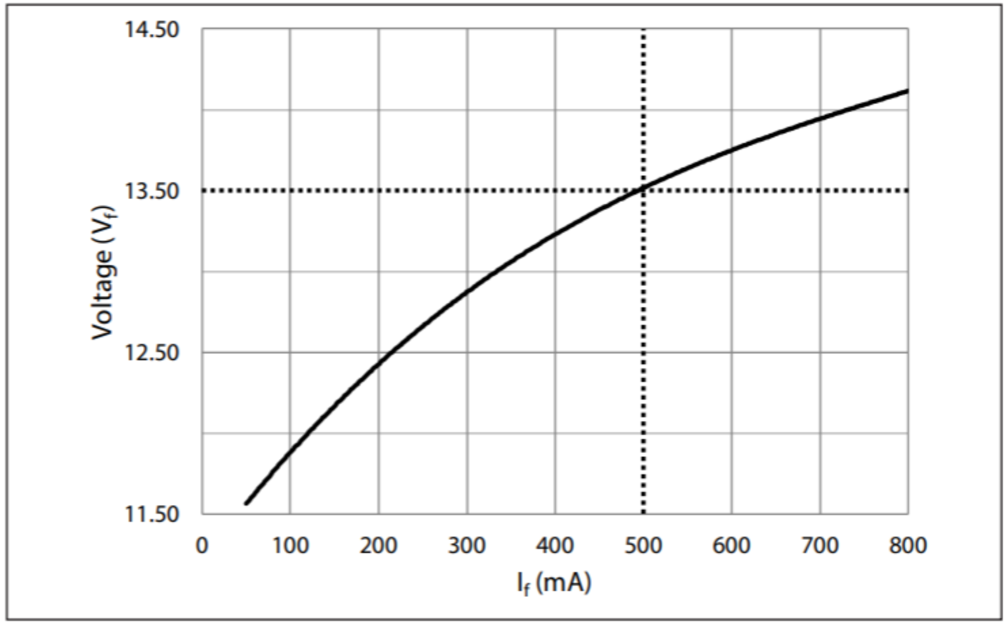


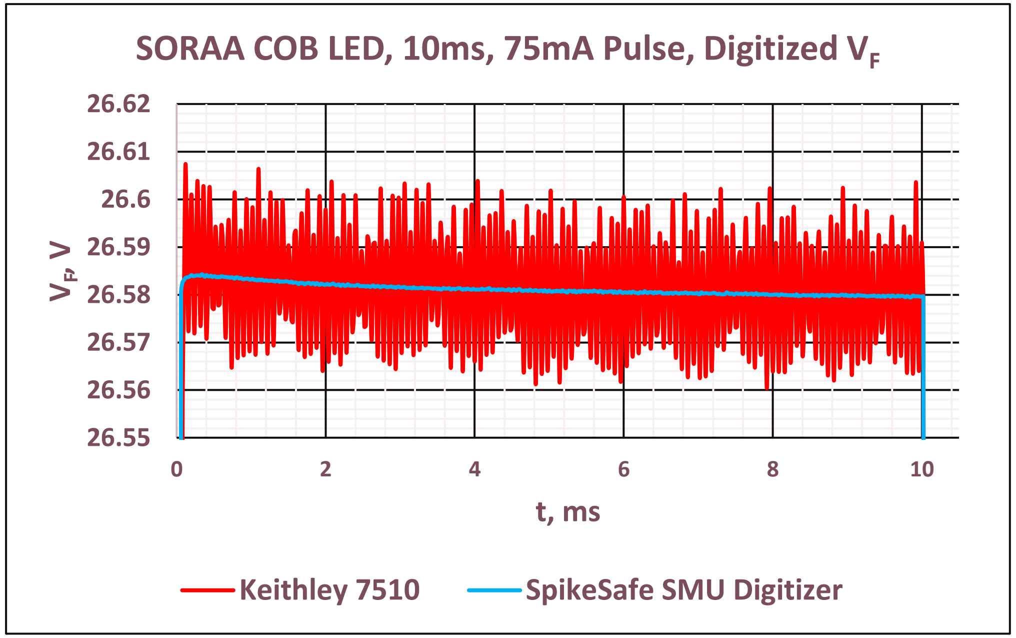


FACTORS THAT COMPLICATE UV LED TESTING

- ***Factor #3 UV-C LEDs have a much higher forward voltage***
  - Visible and UV-A LEDs V_F: 2-3.5V
  - UV-C LED V_F: 5-7V

- Thus, a two-chip in series UV-C LED operates above 10V
  - This eliminates many test instruments that are designed for 10V maximum operation.
  - Even if the instrumentation is rated for >10V operation, it places additional demands on pulsed current sources and DAQ systems.
    - Example: Keithley 7510 Digitizing DMM noise
      - 10V range – approx. 1mV
      - 100V range – 120mV



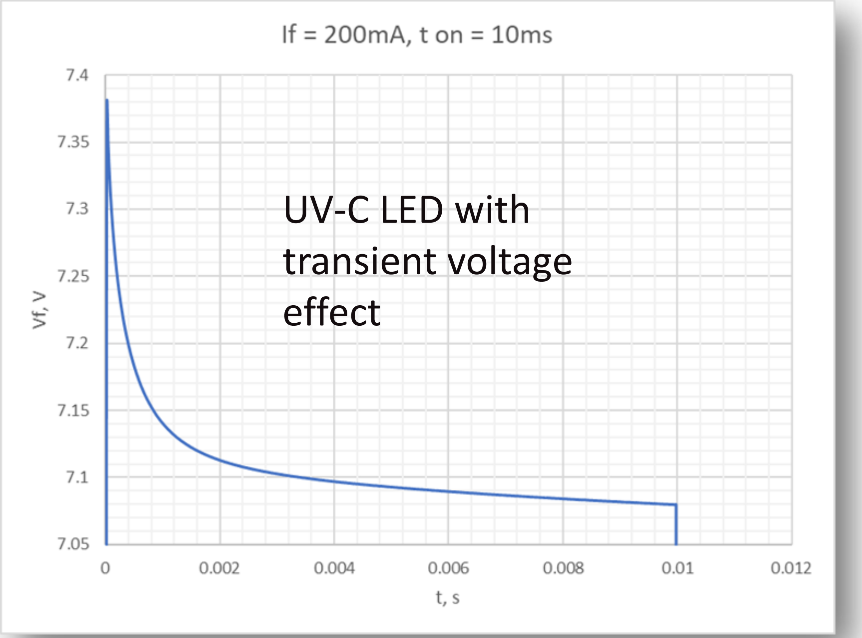


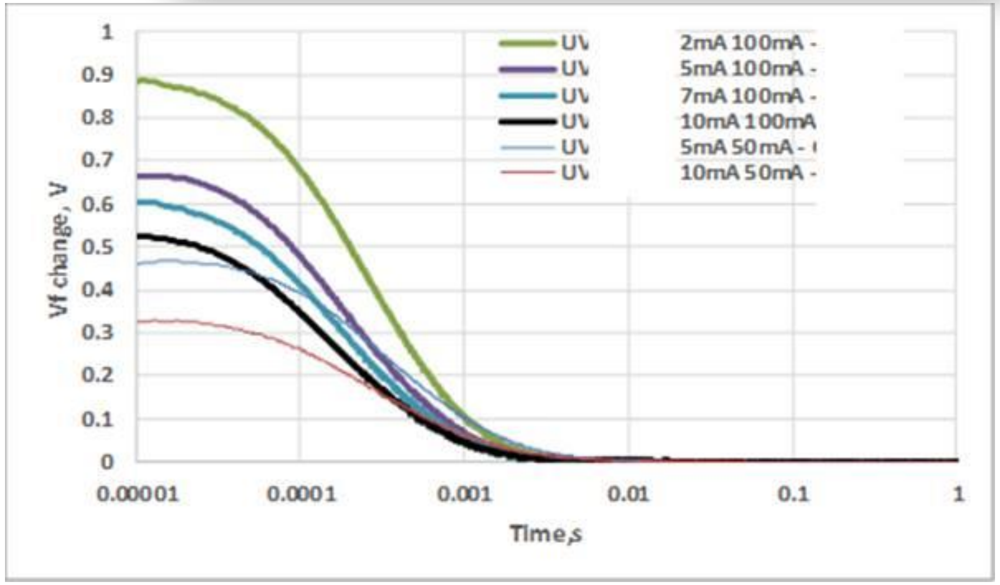
FACTORS THAT COMPLICATE UV LED TESTING

- ***Factor #4 Some UV-C LEDs exhibit a transient voltage effect***
  - Effect increases VF during the first milliseconds of operation
  - Optical output not impacted

- This effect makes it impossible to use forward voltage to infer temperature using the JEDEC method
  - Inferring temperature with VF is fundamental to most industry-practiced measurement methods

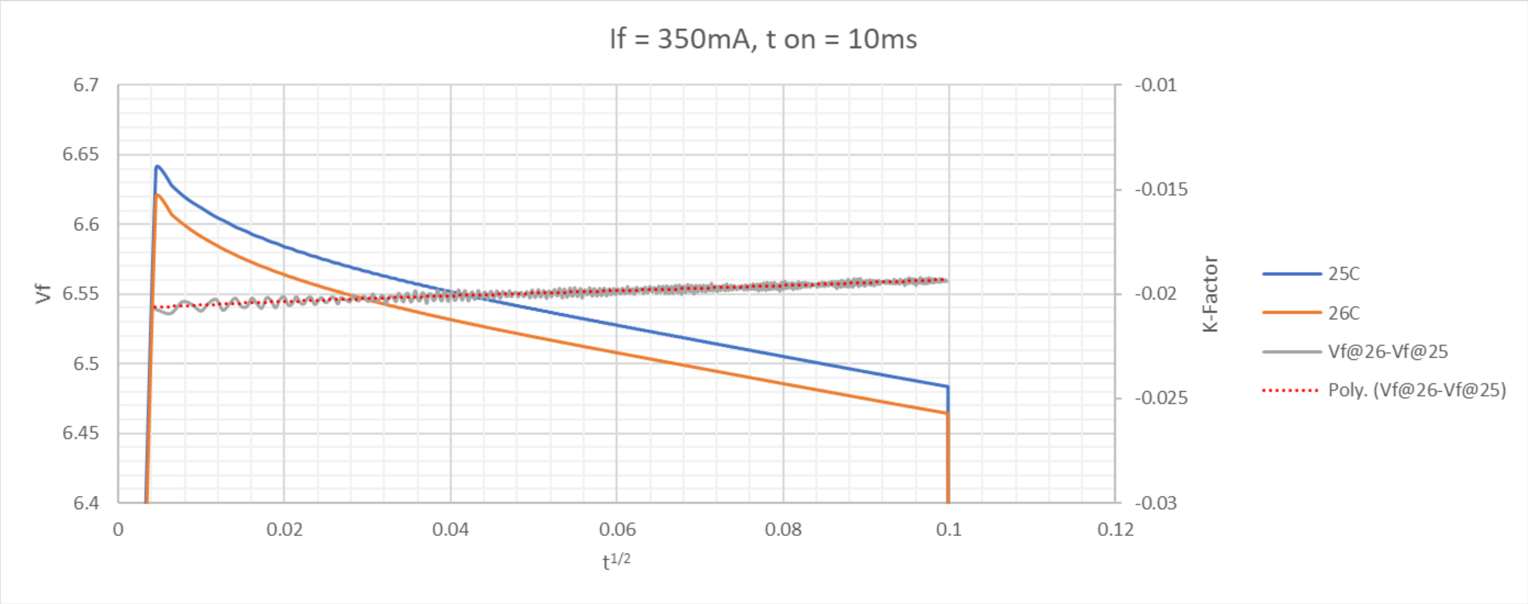
- The IES developed LM-92 in part to address this issue
  - LM-92 includes techniques to use other ways to infer temperature



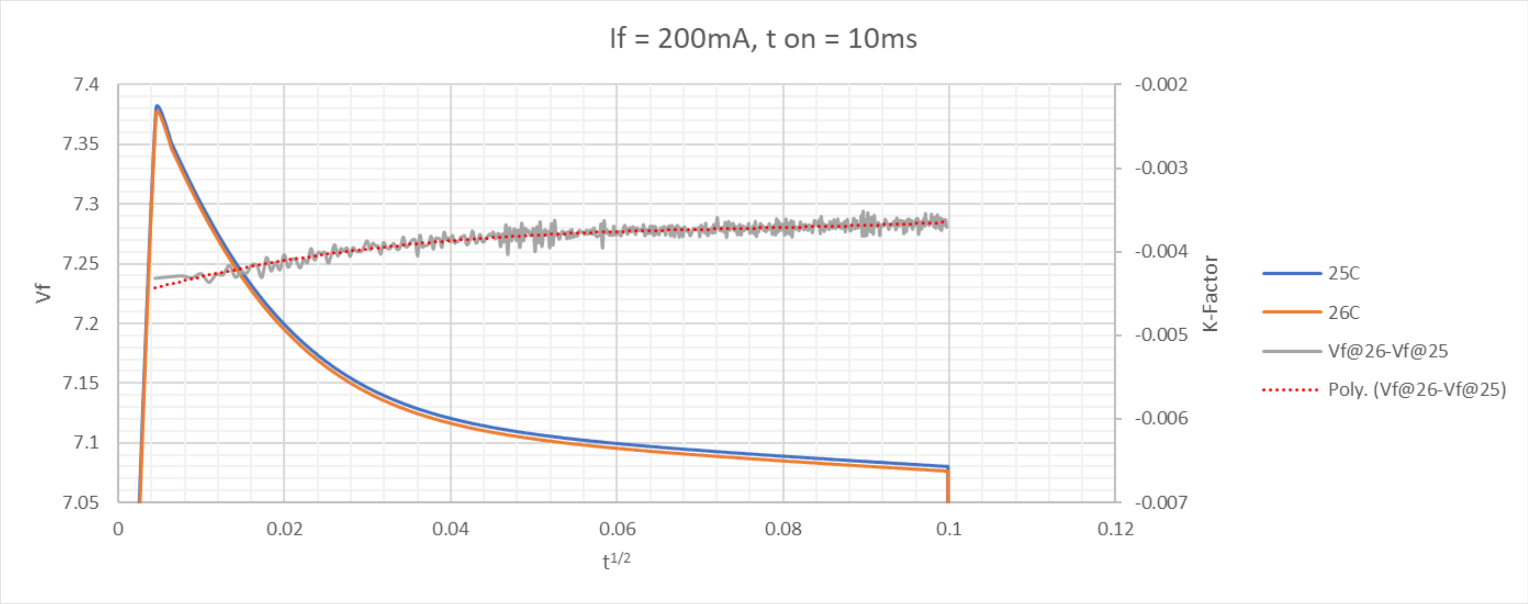


Signify data – reported to IES

UV-C LED TRANSIENT VOLTAGE EFFECT TEST USES TWO PULSED MEASUREMENTS TO IDENTIFY PARTS LIKELY TO HAVE THE EFFECT



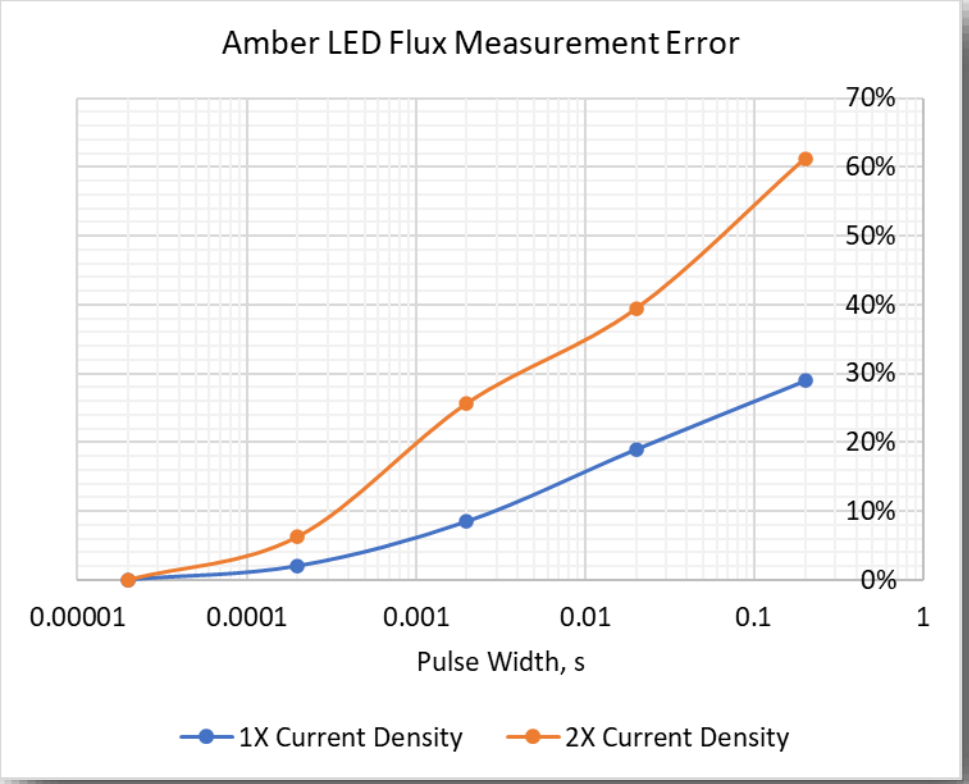
UV-C LED no transient voltage effect



UV-C LED has transient voltage effect

BREAKDOWN OF LED MEASUREMENT METHODS

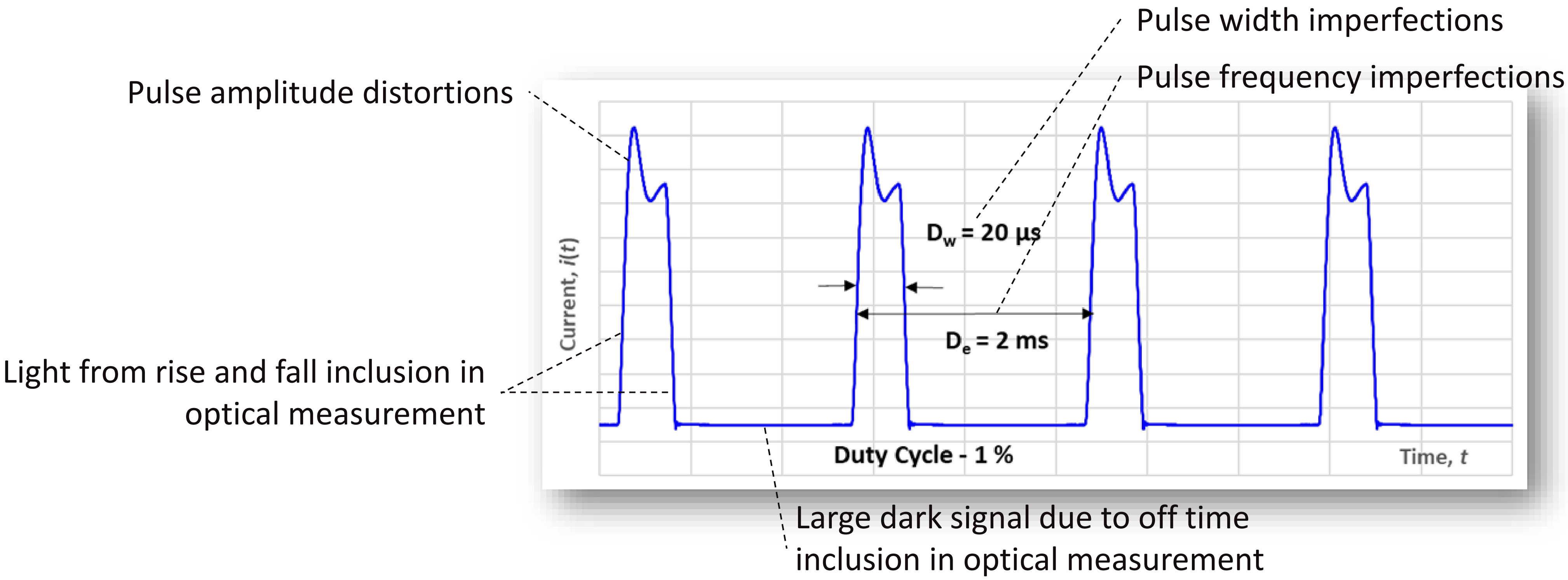
- **Direct Current (DC) – Long stabilization times, high heating, difficult to know Tj**
- **Single Pulse (SP) – Traditional method, but heating causes errors**
- **Flash Pulse (FP) – New proposed method to reduce heating but not fast enough to completely eliminate heating**
- **Continuous Pulse (CP) – Reduces heating but significant errors due to pulse shape**
- **Differential Continuous Pulse (DCP) – Error elimination makes very short pulses possible Tj can be assumed to be equal to the ambient temperature**



Heating-induced error associated with various measurement methods used on an amber LED

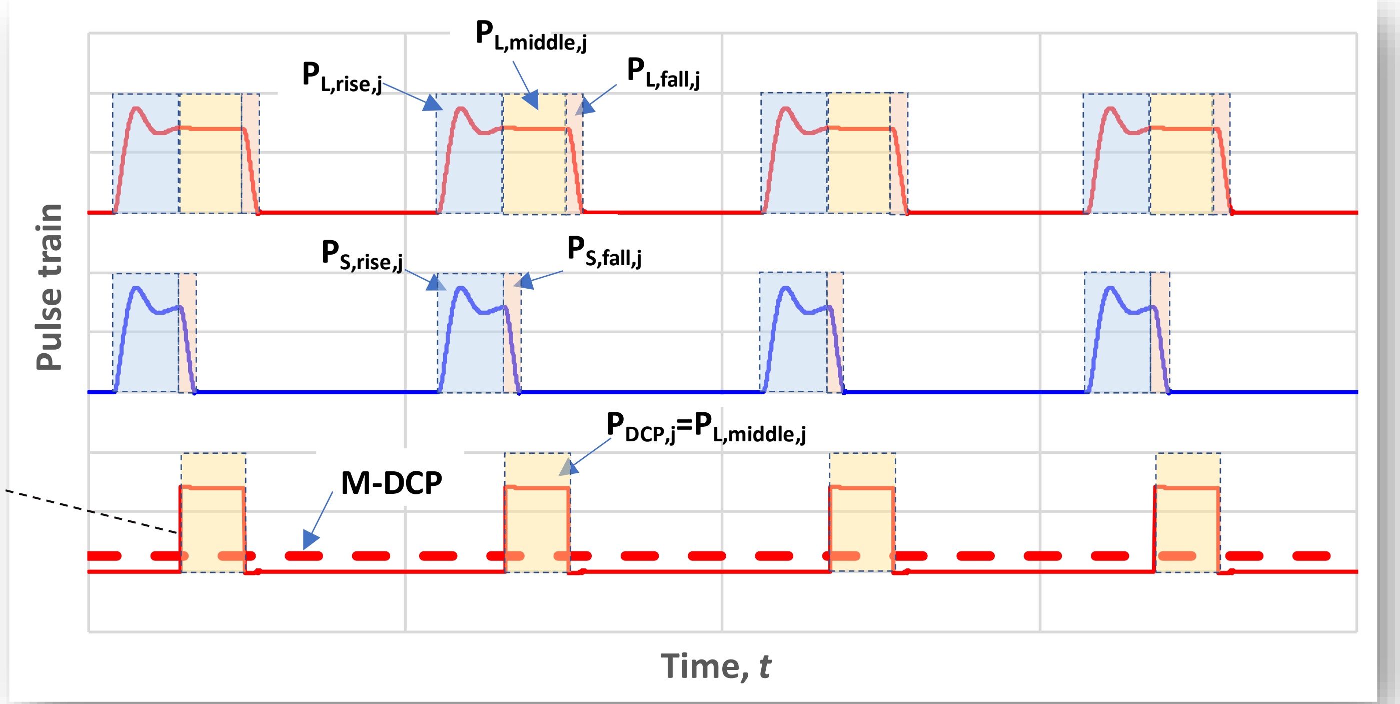
DCP IS BASED ON CONTINUOUS PULSE (CP) MEASUREMENTS

- CP powers the DUT with a continuous, low-duty-cycle train of narrow pulses.
- The optical measurement is made for the time-averaged signal including both on and off time.
- CP measurements are subject to several significant errors.



DIFFERENTIAL CONTINUOUS PULSE (DCP) TAKES THE DIFFERENCE OF TWO CP MEASUREMENTS – ONE WITH LONG PULSES (E.G. 20 MS) AND ONE WITH SHORT PULSES (E.G. 10 MS)

Light remaining after subtraction is from middle, flat portion of long pulse, amplitude, timing, and dark current errors subtract out



IES REJECTED MOST MEASUREMENT METHODS WHEN LM-92 WAS DRAFTED

- **To be relatable, measurements must be tied to a junction temperature. DC, SP, FP methods generally infer junction temperature using VF. But Vf is not always reliable due to transient voltage effect**

- **So DCP, a variant called M-DCP, or a new method based upon high-speed sampling called CPT was chosen as the allowed method for UV LED measurements**

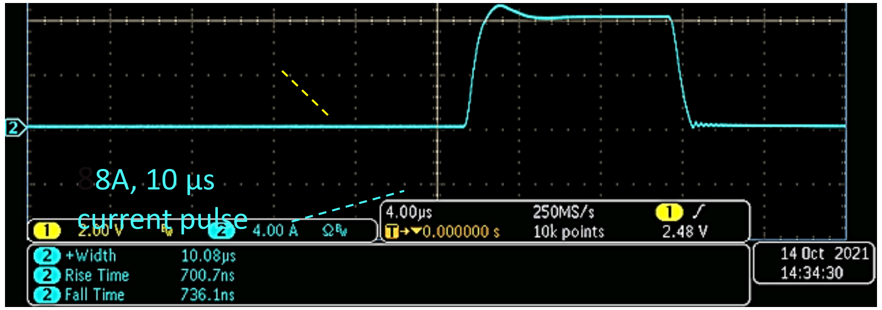
Table 8-1. Measurement Method Parameters and Applicability

Test Current, I_T	Method	Pulse 1 Parameters	Pulse 2 Parameters
$I_T > 10\%$ of $I_{nominal}$	CPT, DCP or M-DCP*	10 µs, 1% duty cycle	20 µs, 2% duty cycle
$1\% < I_T < 10\%$ of $I_{nominal}$	CPT, DCP, or M-DCP*	25 µs, 10% duty cycle	50 µs, 20% duty cycle
$I_T < 1\%$ of $I_{nominal}$	Any method allowed; DC or long pulse should be used	N.A.	N.A.

A HIGH-PERFORMANCE PULSED SMU WITH 10MS MINIMUM PULSE CAPABILITY IS REQUIRED FOR DCP MEASUREMENTS

	SMU Feature Comparison					
SMU Type:	**Pulsed Current**	**10µs Pulse Width**	**Digitizer**	**Timing acuracy**	**Rise Time**	**Use for DCP?**
Gen 1 SMU	No	No	No	milliseconds	100s of microseconds	No
Gen 2 SMU	Yes	No	No	10s of microseconds	10s of microseconds	Possible, PL > 500 µs
Graphical SMU	Yes	No	Yes, ground-referenced	100s of microseconds	10s of microseconds	No
Pulser/SMU	Yes	Yes	Yes, ground-referenced	2µs	9 µs	Possible, PL > 20 µs
Precision Pulsed SMU	Yes	Yes	Yes, true-differential	30ns	0.5-2 µs	Yes, PL > 2 µs

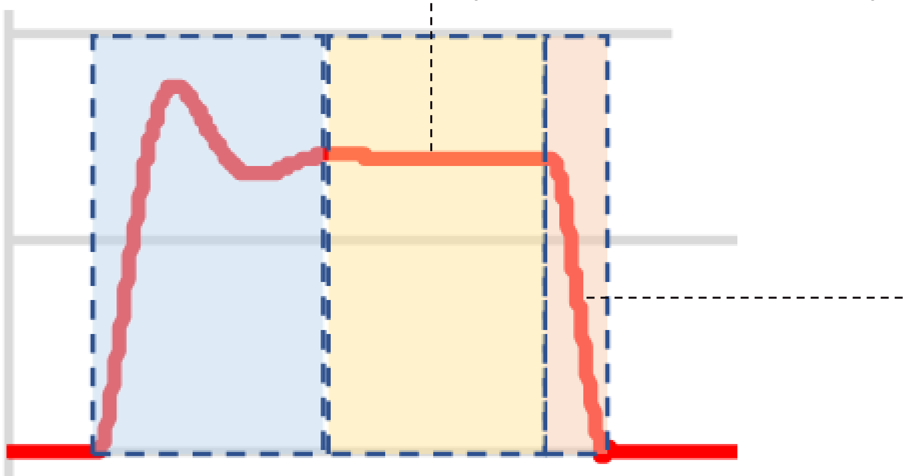
Precision Pulsed SMU



Precision Pulsed SMU current pulse

UV LED I-V MEASUREMENT METHOD CHANGES DEPENDING ON TRANSIENT VOLTAGE EFFECT

- **If no transient voltage effect = measure Vf in 2nd half of long pulse**
  - **Requires precision timing alignment between source and measure**
  - **Vektrex SMU achieves this with industry-first falling edge trigger and negative delay**

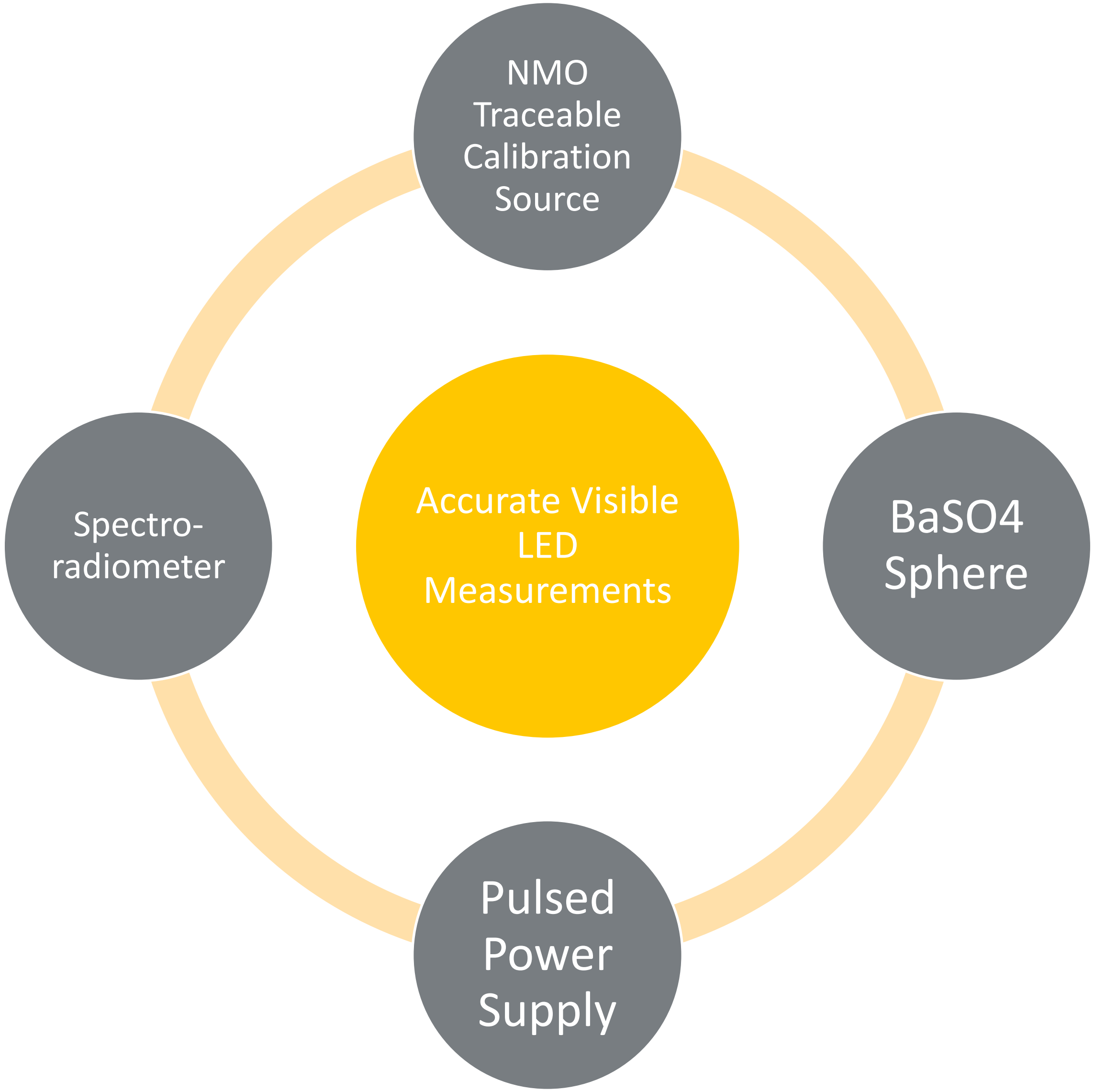


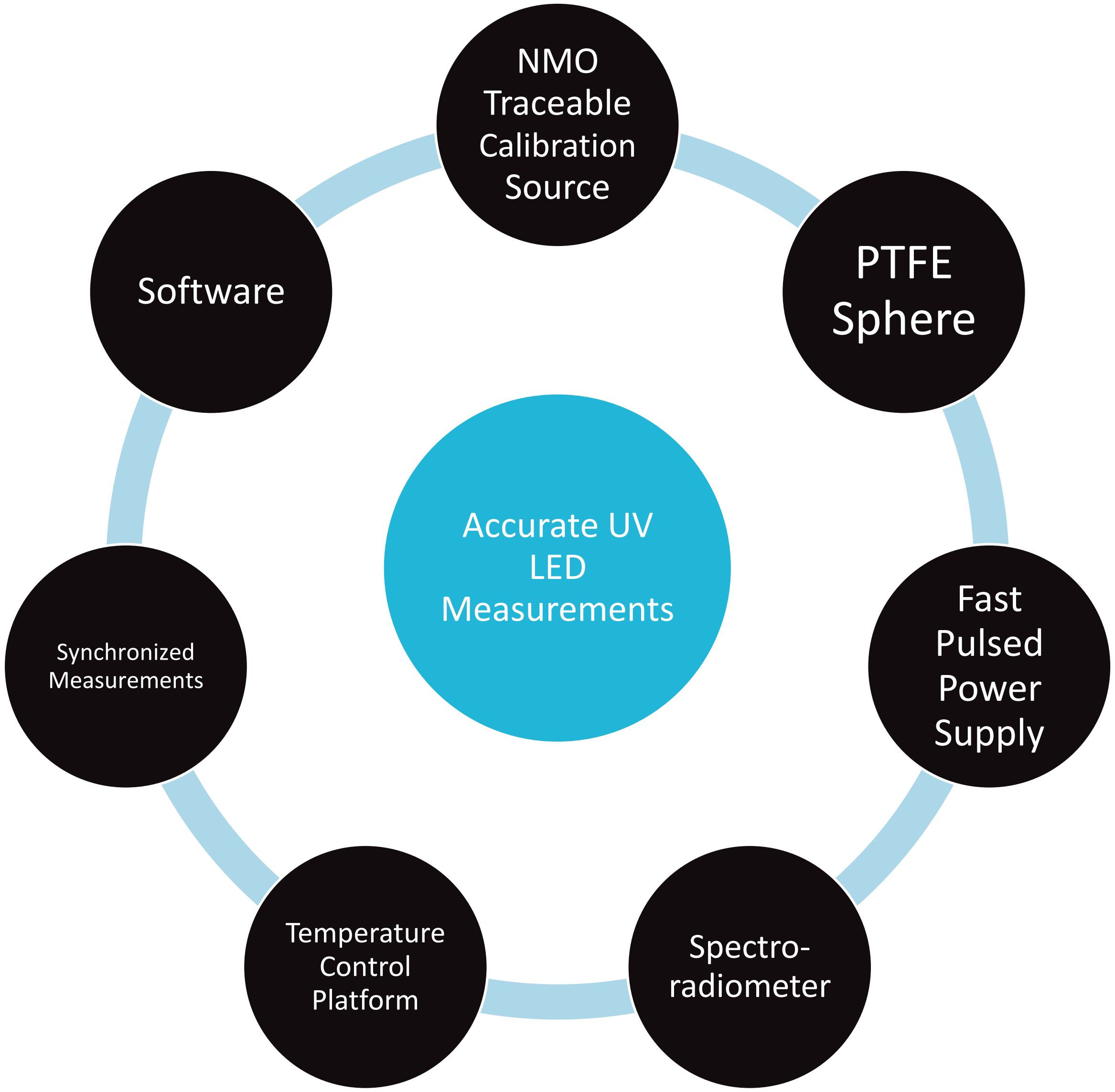
- **If transient voltage effect = measure Vf after delay long enough for transient to dissipate**
  - **Tj is inferred with Peak wavelength or optical power**
  - **Time consuming process**

4

TYPICAL EQUIPMENT USED FOR TESTING LEDS

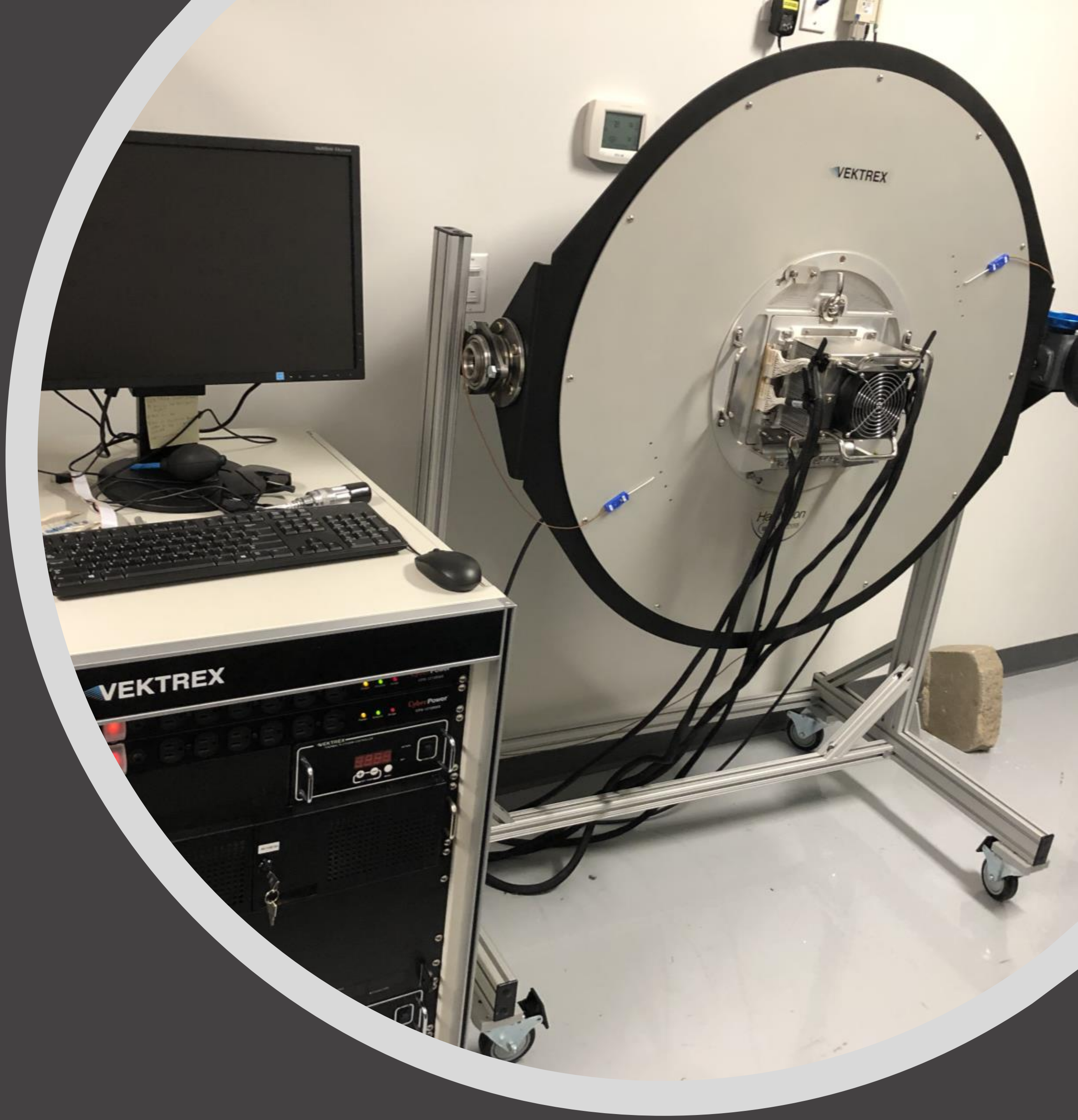
TYPICAL TEST EQUIPMENT USED





TEST EQUIPMENT FOR MEASURING VISIBLE LEDS

- Barium Sulfate or Similar Coated Sphere
  - High Reflectance in the Visible Spectrum
- Spectroradiometer
  - CAS 140C
- Spectral Flux Standard Lamp
  - Typically, Incandescent/Halogen
- DC Pulsed Power Supply
  - Conforming to IES LM-85

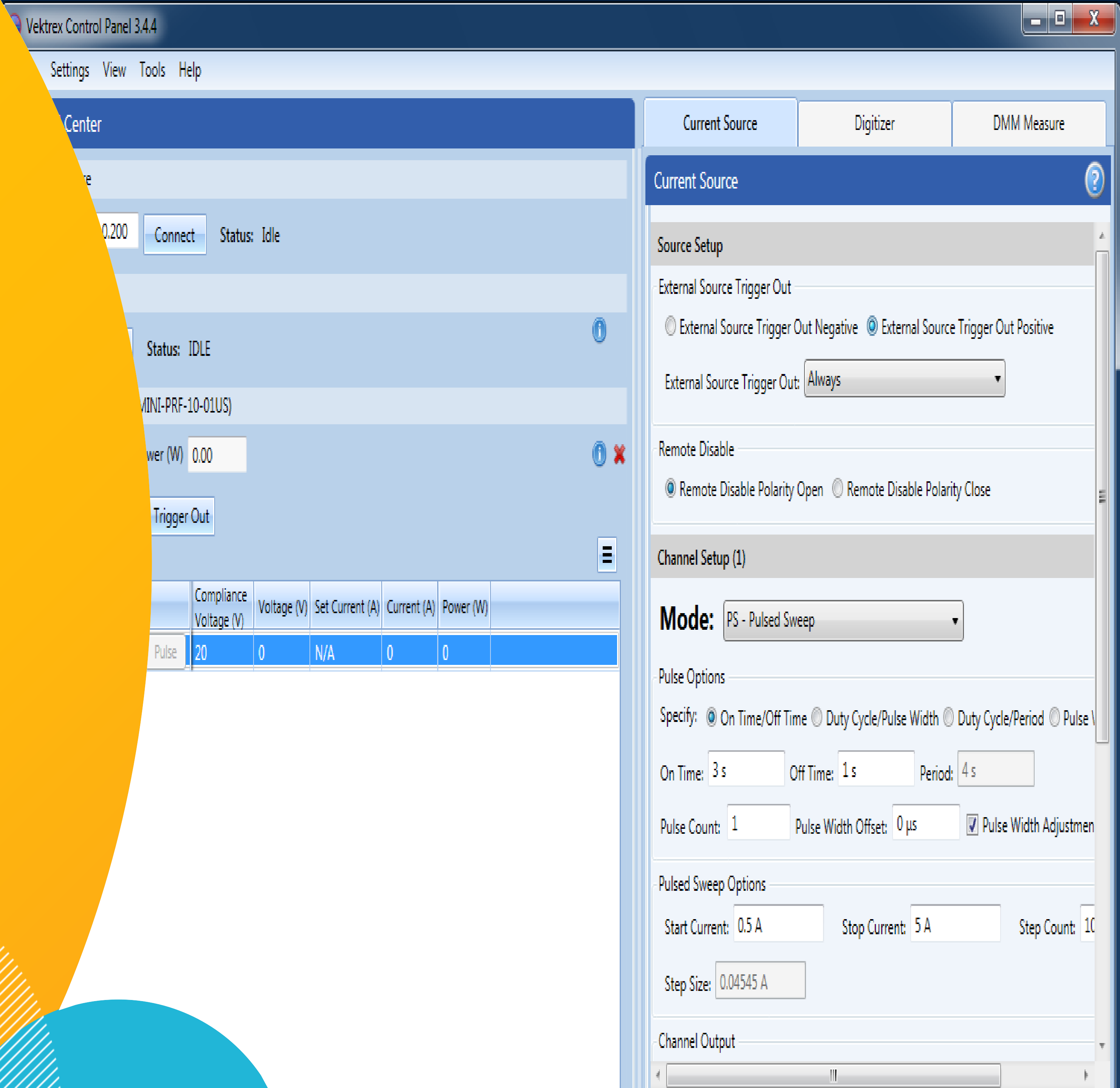


TEST EQUIPMENT FOR MEASURING UV LEDS

- PTFE Coated Sphere
  - Adequate Reflectance in Region of Measurement
- Spectroradiometer
  - CAS 140D
- Spectral Flux Standard Lamp
  - Typically, not Incandescent/Halogen
- Fast Pulse DC Pulsed Source / SMU
  - Will need to conform to LM-xx (new UV standard)
- Synchronized Measurements
  - Software to Capture
- Temperature Control Platform

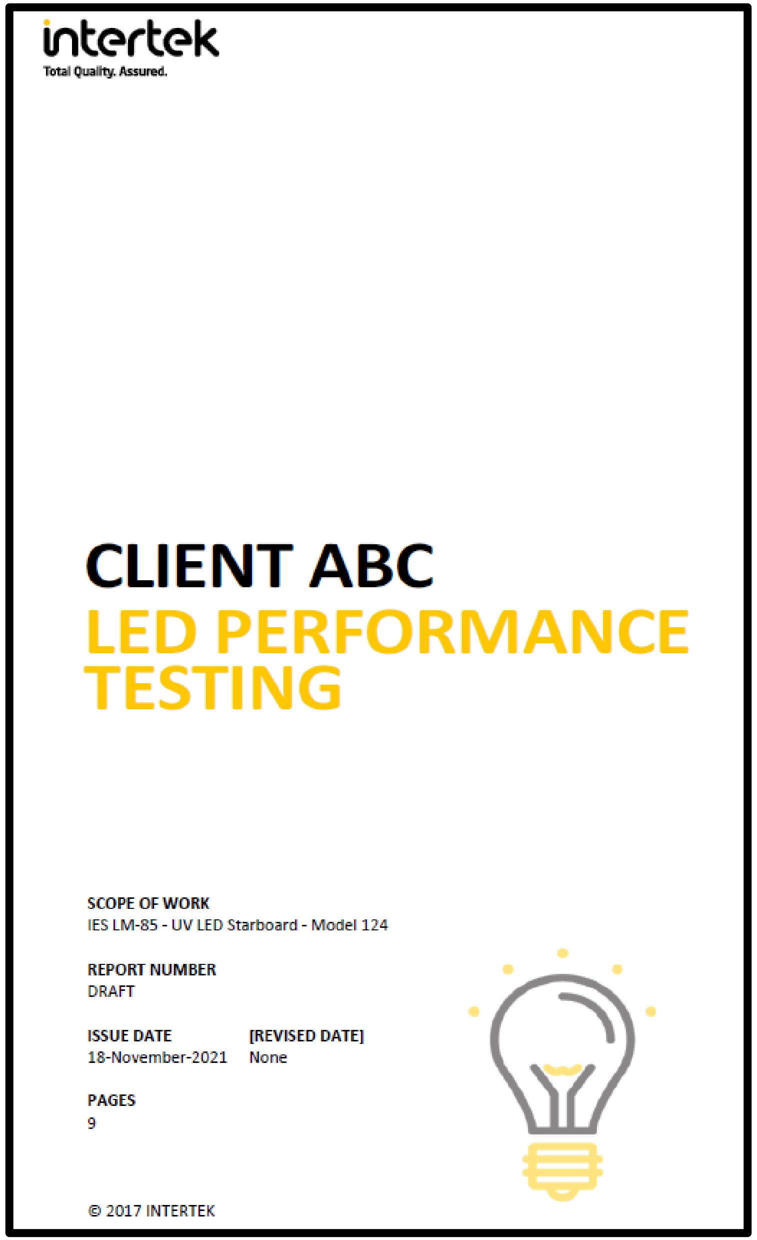
5

DATASHEET AND TYPICAL TEST REPORT



DATASHEETS
WHAT DO DESIGNERS NEED?

- Parameters of importance
  - Radiant power
  - Vf
  - I-V
  - Power vs Current vs Temperature
  - Current vs Flux
  - I-V curves for different temperatures
  - L-I curve for different temperature



intertek
Total Quality. Assured.

CLIENT ABC
LED PERFORMANCE TESTING

SCOPE OF WORK
IES LM-85 - UV LED Starboard - Model 124

REPORT NUMBER
DRAFT

ISSUE DATE
18-November-2021

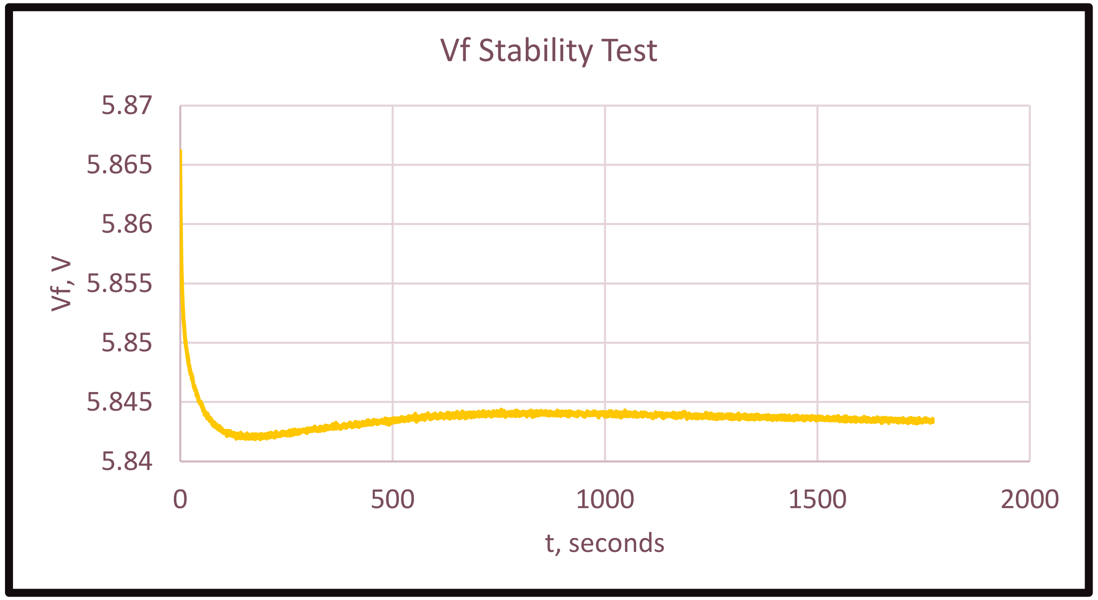
[REVISED DATE]
None

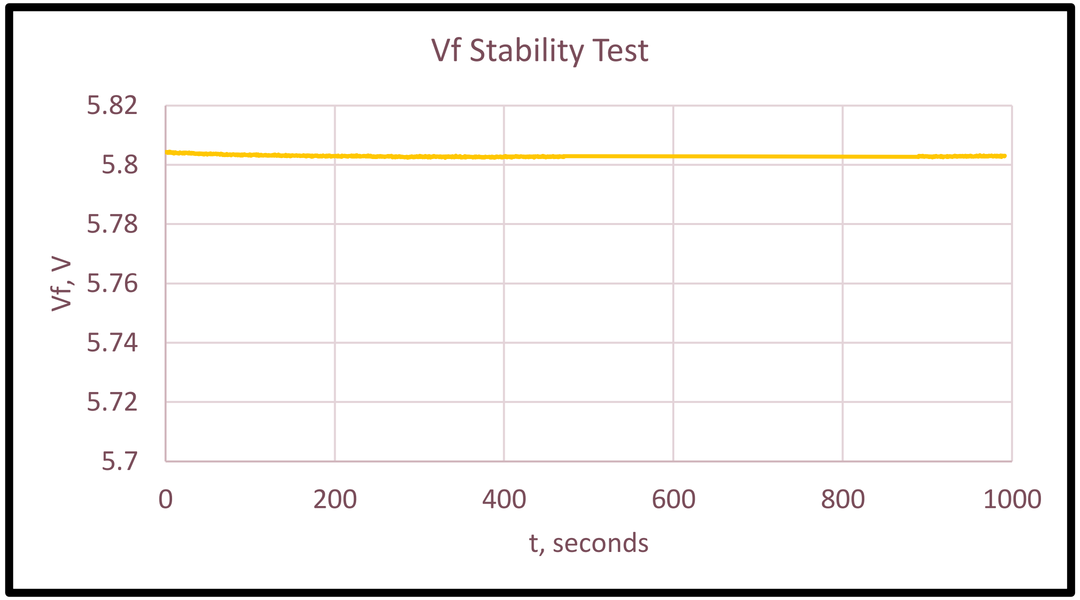
PAGES
9

© 2017 INTERTEK

TYPICAL UV LED TEST REPORT
VF STABILITY TEST

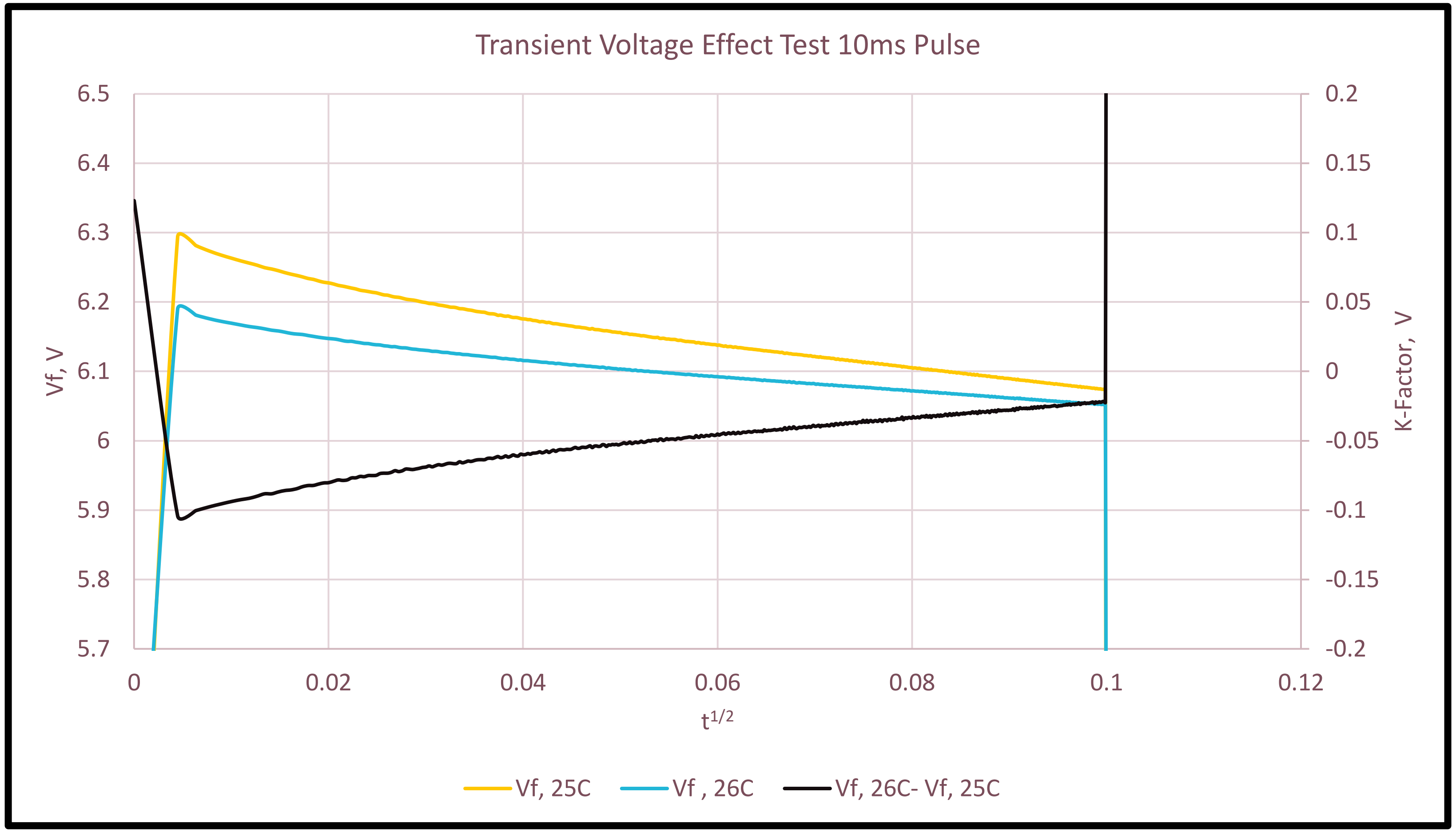
- Vf Stability
- Understand how the LED is behaving before measurements are performed
  - Confirm Stability of Test Setup and Power Source





TYPICAL UV LED TEST REPORT
TRANSIENT VOLTAGE EFFECT

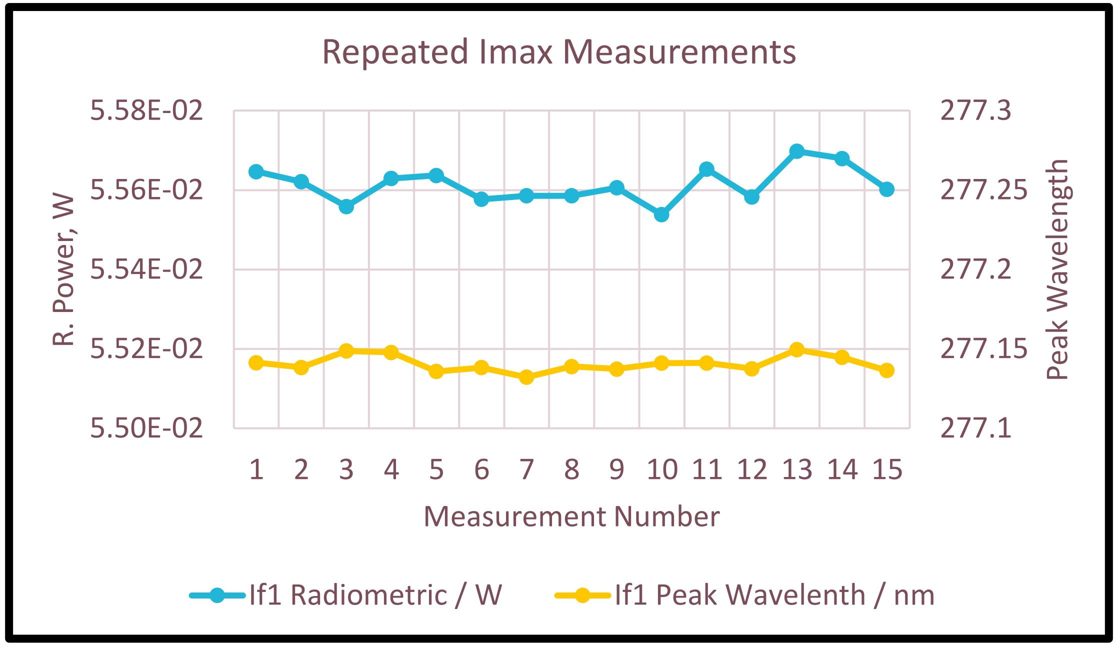
- Characterize the Transient Voltage Effect Before Testing
- When transient voltage effect exists, the temperature rise of Tj can not be calculated
- K- Factor is not linear as would be expected with a traditional LED source

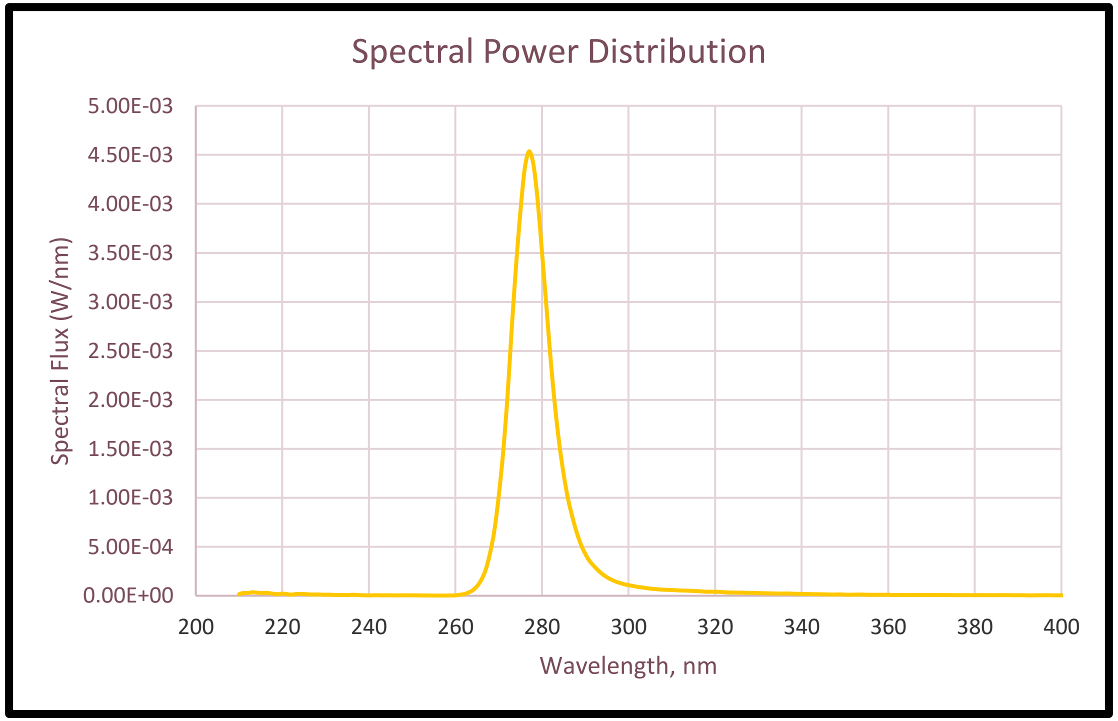


TYPICAL UV LED TEST REPORT
OPTICAL RADIATION PROPERTIES

- Radiometric Power
- Peak Wavelength
  - Standard Deviation
- Forward Voltage
- Spectral Power Distribution

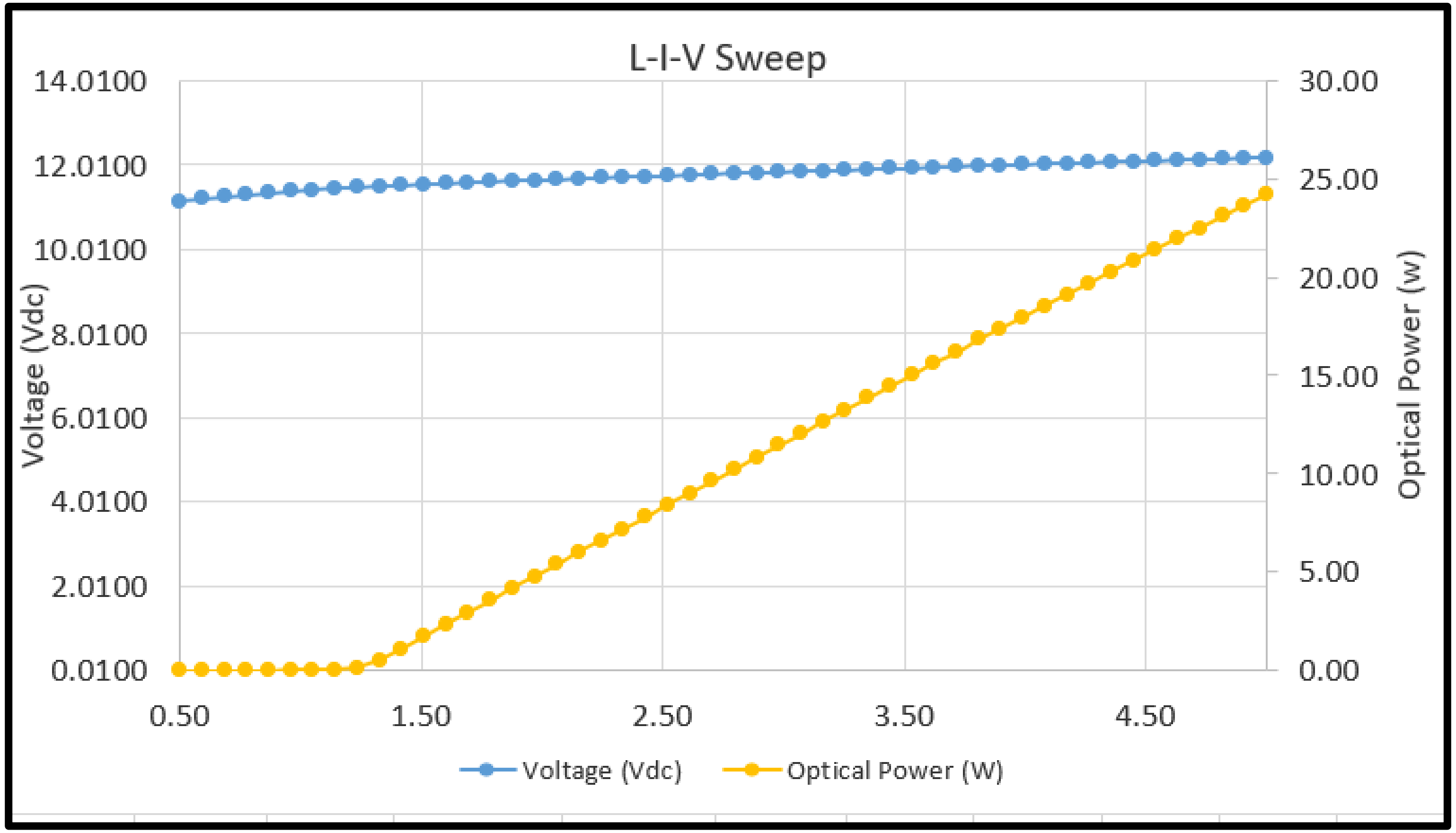
Forward Current (mA)	500.0
Forward Voltage (V)	5.5904
Mean Radiant Power (W)	0.056
Std Dev. %	0.08%
Mean Peak Wavelenth	277.1
Std Dev. nm	0.005





TYPICAL UV LED TEST REPORT
L-I-V TEST

- Current versus Voltage
- Optical Radiation Properties at Each Step
- Fully Customizable and Completely Automated

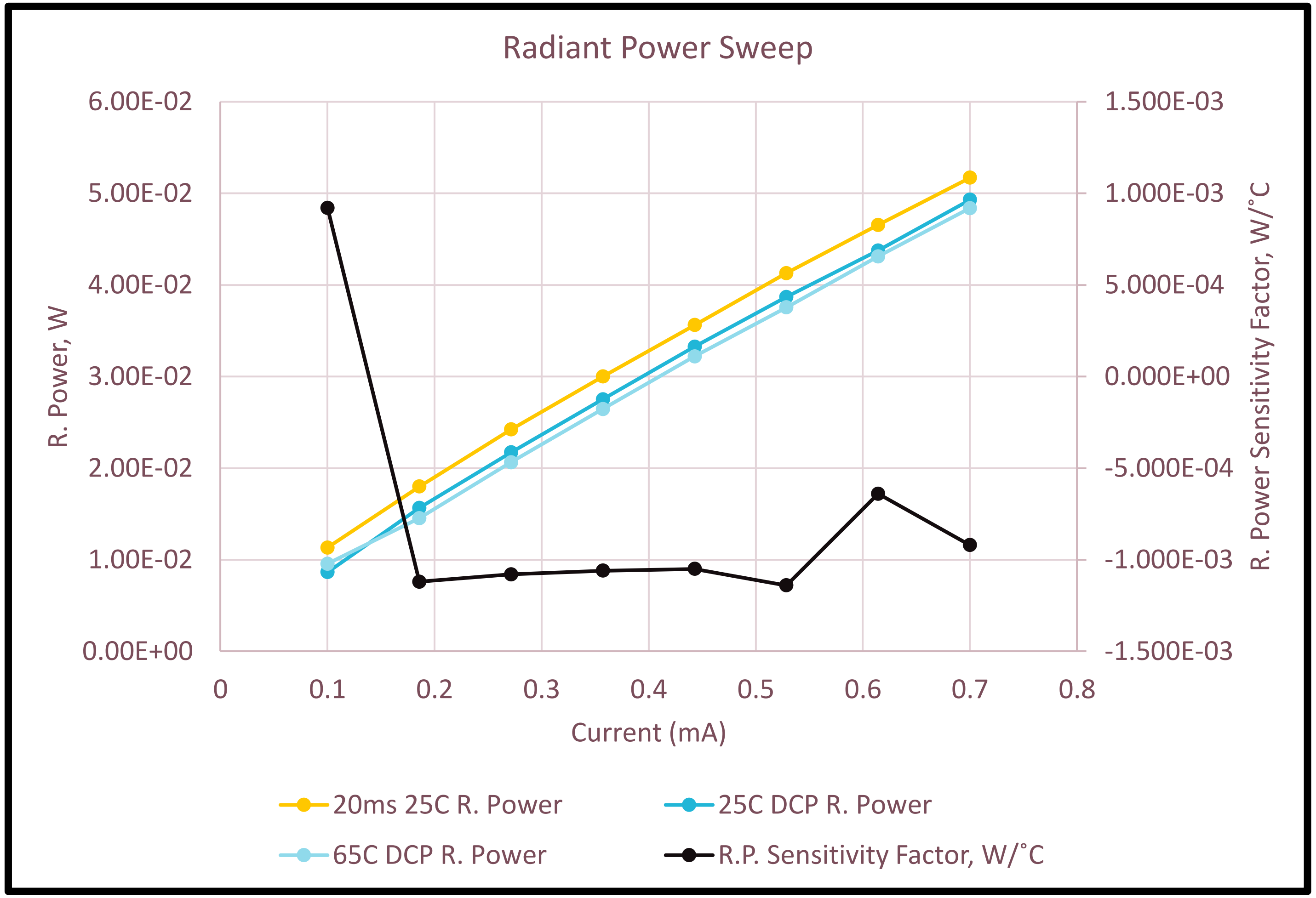


TYPICAL UV LED TEST REPORT
PULSE SWEEP

- Differential Continuous Pulse
  - Multiple Pulse Configurations
  - Multiple Forward Currents
  - Multiple Temperatures

- Compare to 20mS Baseline

- Items to Characterize and Report
  - Forward Voltage
  - Radiant Power
  - Peak Wavelength



6

CONCLUSION AND WHAT'S NEXT

CONCLUSION

- With the increasing reliance on UV LEDs for medical, sanitation, and similar purposes it is even more important to have reliable product data sheets.

- Due to the sensitivity of UV LEDs, the test methodology can play a significant role in the accuracy of the measurements

- Although initial optical radiation measurements are important the long-term performance of UV LEDs is equally important. The IES is currently in the final phases of a new standard specifically for testing optical and electrical properties of UV LEDs

Jeff Hulett

+1 619 37900457

jhulett@vektrex.com

www.Vektrex.com

Jeff Davis

+1 847 718-6323

Jeff.Davis@intertek.com

www.intertek.com

Carl Bloomfield

+1 847 718-6314

Carl.Bloomfield@intertek.com

www.intertek.com

Questions

&

ANSWERS