High-performance LED test solutions.
VEKTREX™

LM-85 Research

Preliminary Findings

Research Question – Are the three LM-85 methods equivalent?

- All tie measurements to a specific junction temperature

- Assumption:
  - If Tj(measurement 1) = Tj(measurement 2),
  - Then Φ (measurement 1) = Φ (measurement 2)

- But is it always the same?

Possible LM-85 error sources

- Phosphor temperature differences
- Current rise/fall time
- Current shape
- Pulse width errors
- Measurement timing

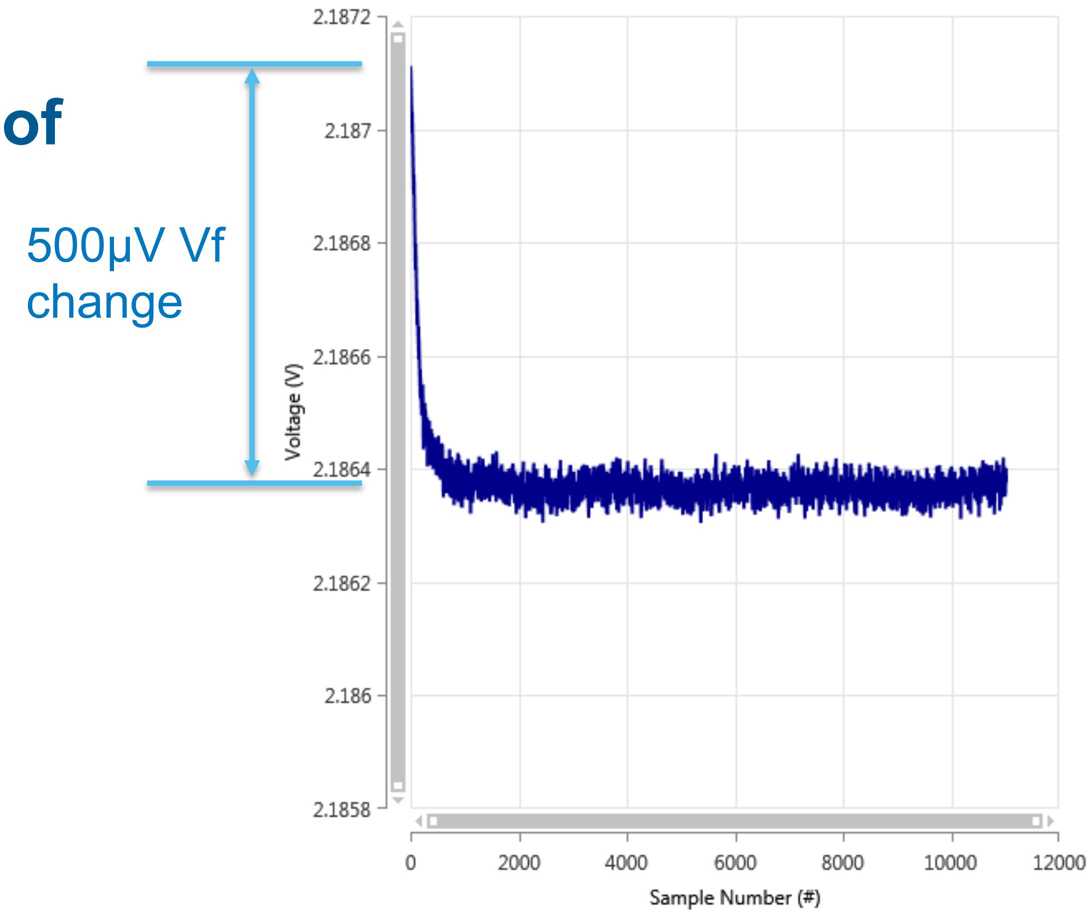
Research by Yuqin Zong of NIST indicated phosphor could be a significant error source

VEKTREX™

LM-85 research goals

- Compare three LM-85 methods
- Determine if phosphor produces an error
- Expose, quantify other error sources
- Develop guidelines for improved methods

Vf monitor plot shows final 0.3C of temperature stabilization



Methodology

- Use identical LEDs for phosphor/no phosphor tests
  - Royal blue pump
  - White
- Best-of-class instrumentation
  - Back thinned, temperature stabilized spectrometer
  - TEC platform with 0.01C stability
  - Precision pulsed current source with microamp stability
  - Electro-Optical “LED Bench” software
  - Fast sampling precision digitizer

Testing steps

1) DC: Platform set to 25C, Tj was allowed to rise, platform maintained at 25C, untriggered measurement with ms integration time

2) Continuous Pulse: Platform temperature adjusted to match DC Vf, untriggered measurement with 100X DC integration time

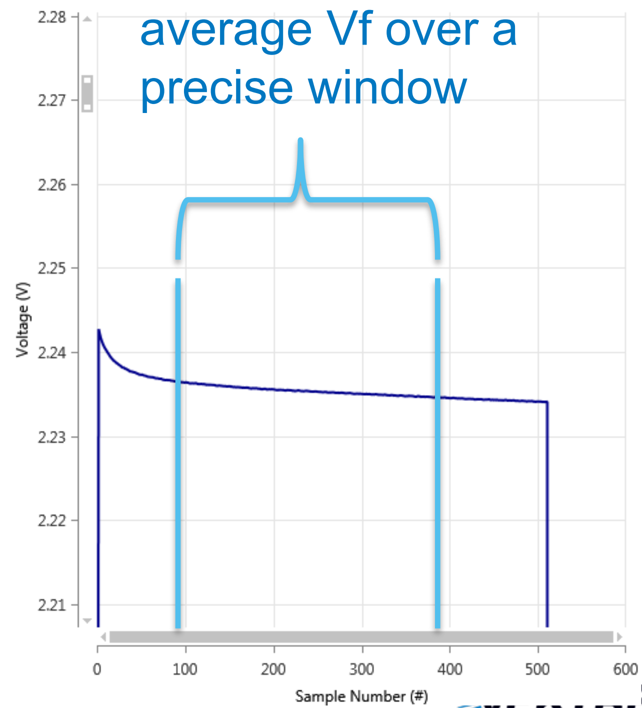
3) Single Pulse: Platform temperature adjusted to match DC Vf, triggered measurement with 10ms delay, DC integration time

Precise digitizer timing allows temperature matching within 0.03C

- SpikeSafe precise triggering combined with highly accurate digitizer allows Vf to be compared precisely

- Resulting measurements are taken with junction temperatures matching to within 0.03C

Digitizer can acquire and average Vf over a precise window

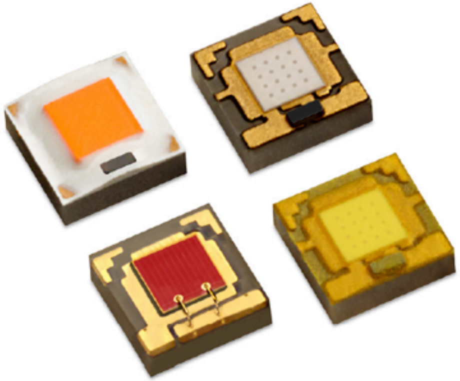


Lumileds provided sample LEDs, other samples purchased on-line

LUXEON CZ Color Line

Maximum punch in any application

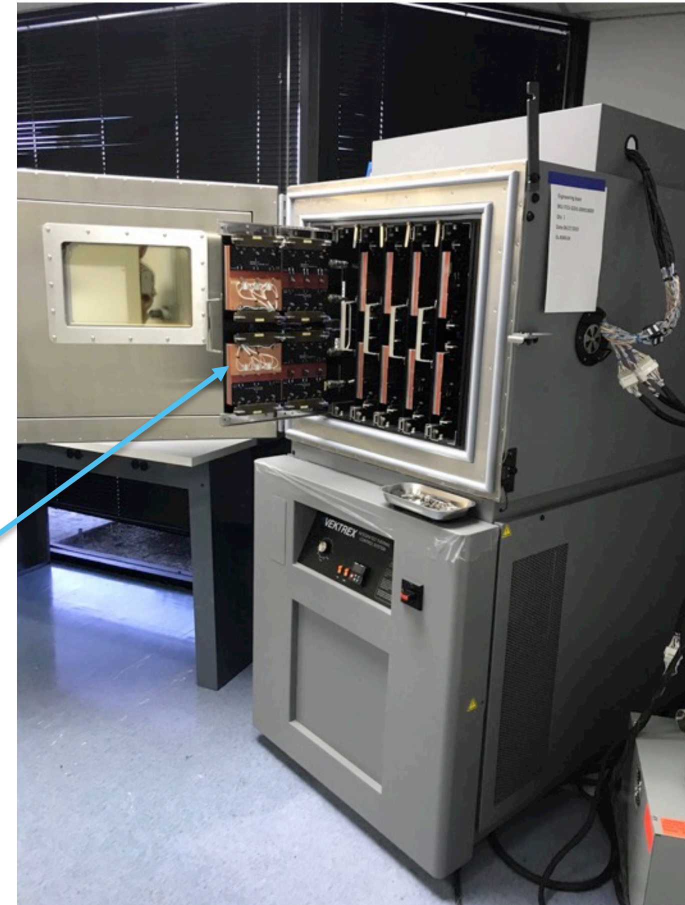
LUXEON CZ Color Line is an optically advanced portfolio of Color and White LEDs. Designed to maximize punch, the LUXEON CZ Color Line is the optimal LED solution for architecture, entertainment and emergency vehicle lighting applications.



VEKTREX™

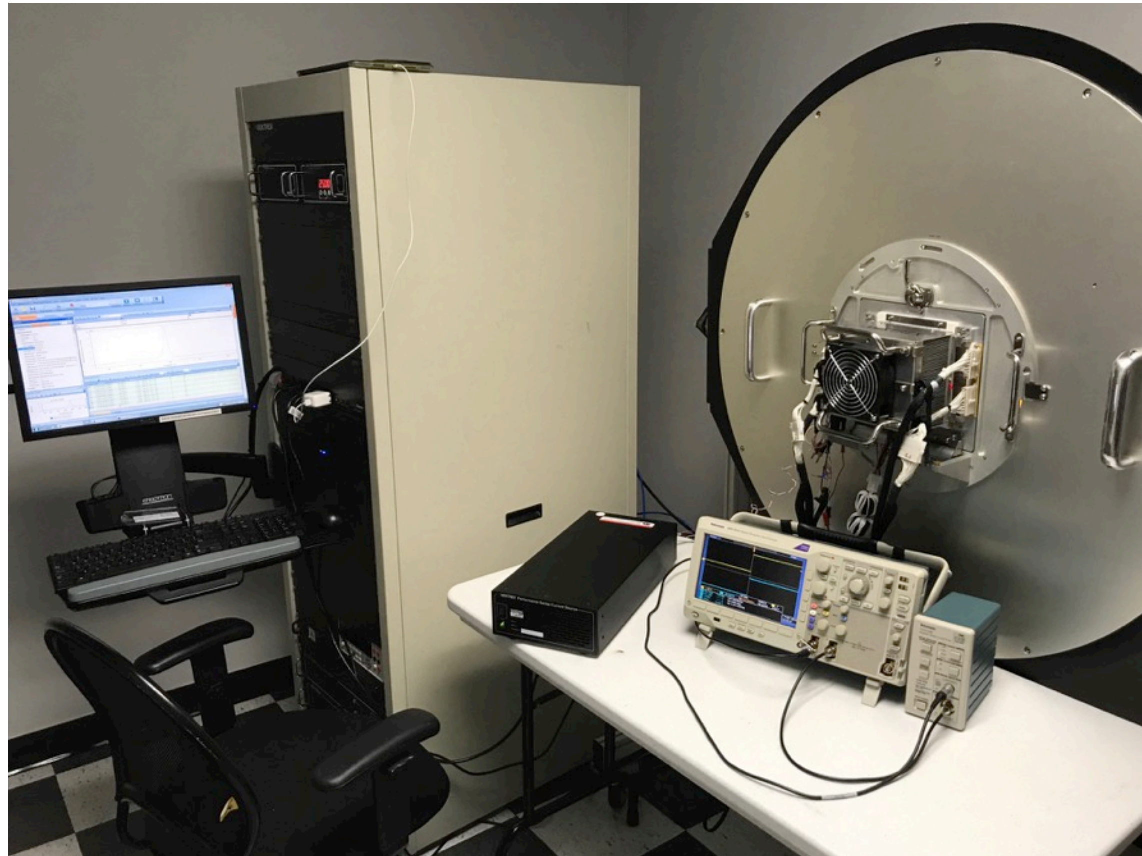
Samples were stabilized for 100 hours prior to testing

- Mounted on copper load boards
- 100 hour burn-in at 55C



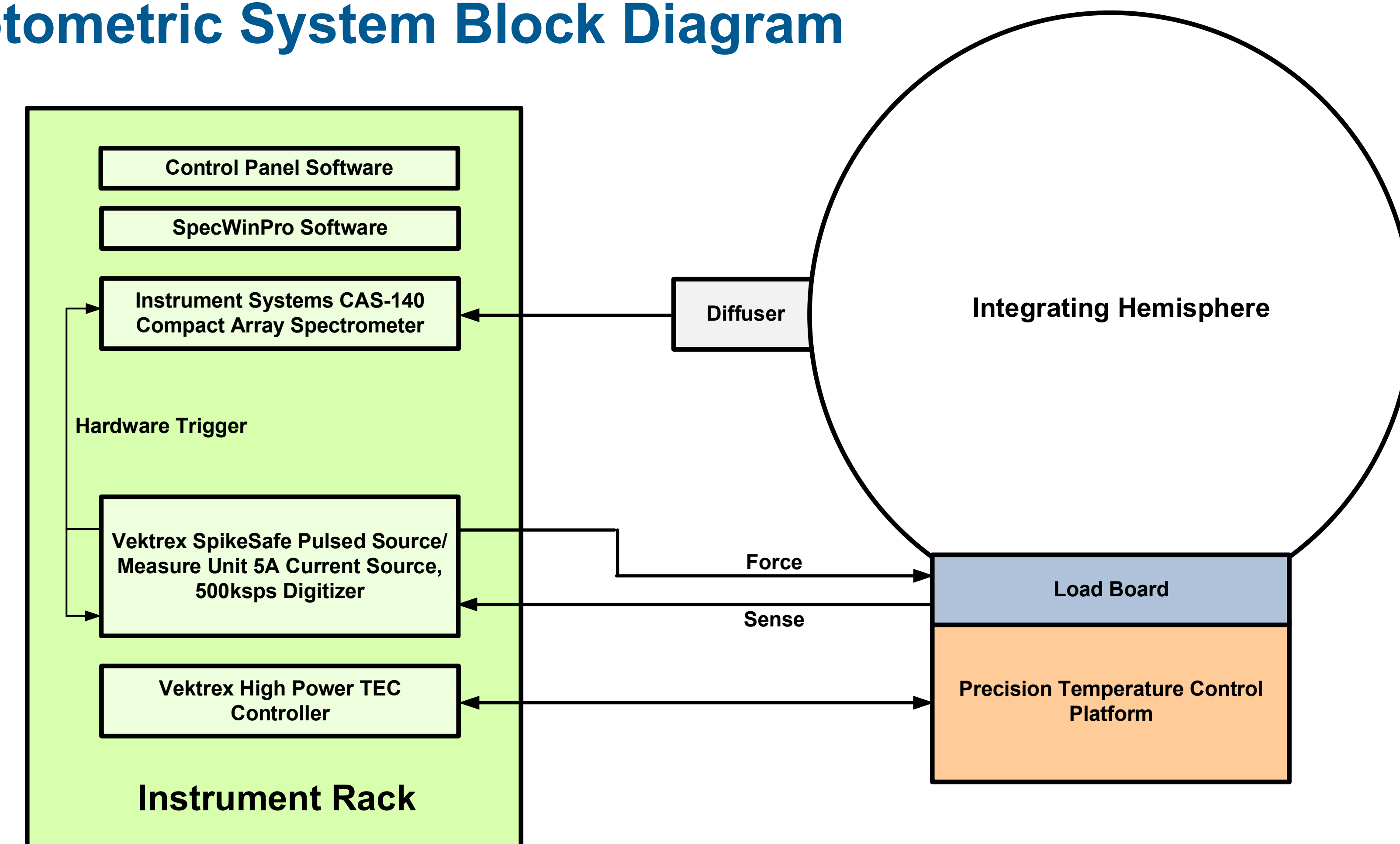
Vektrex ITCS LM-80 Chamber

Photometric system uses integrating hemisphere



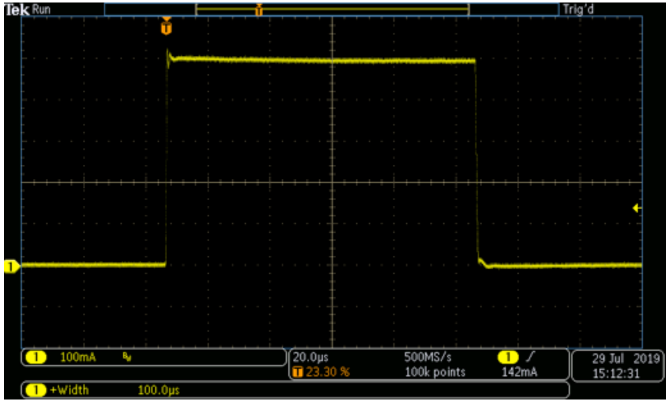
VEKTREX™

Photometric System Block Diagram



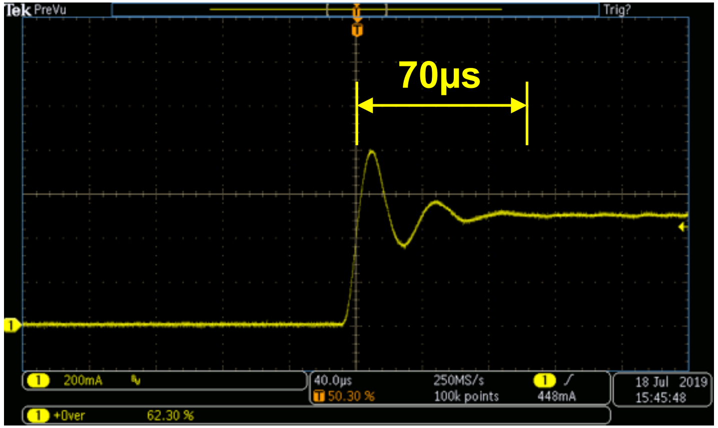
VEKTREX™

Precision pulsed source measure unit with sub-microsecond pulse accuracy allows accurate continuous pulse measurements

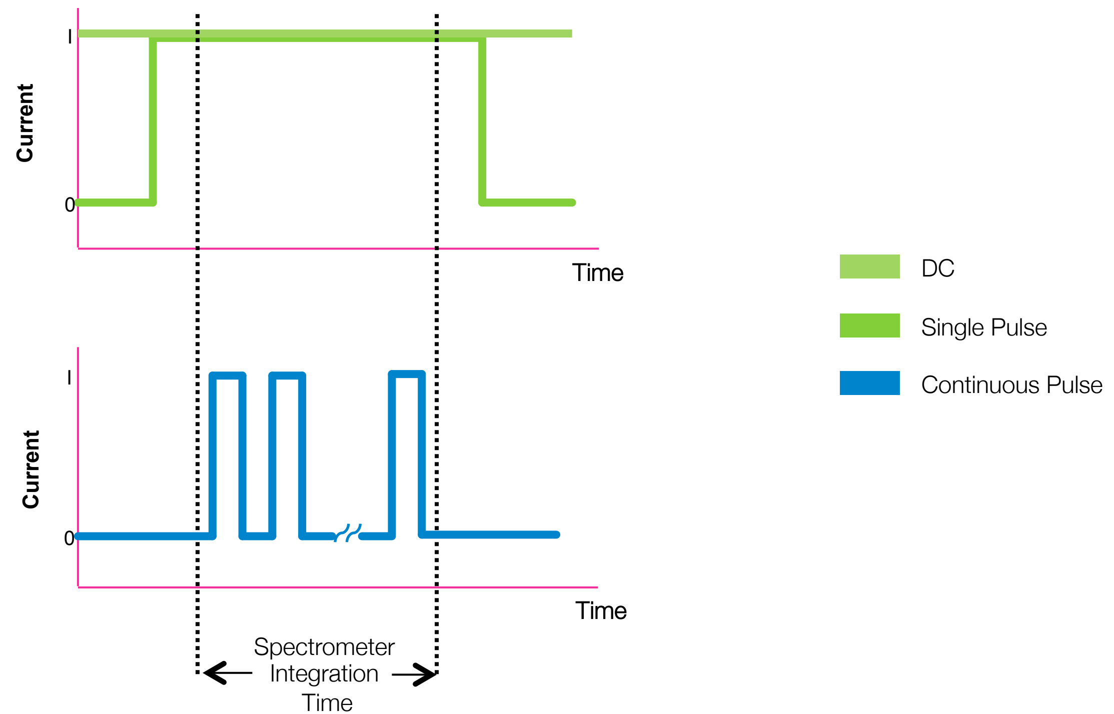


Vektrex SpikeSafe SMU 500mA 100µs pulse, note minimal overshoot, fast settle time

Keithley 2600B 500mA 100µs pulse, note large overshoot and ringing that persists for 70µs



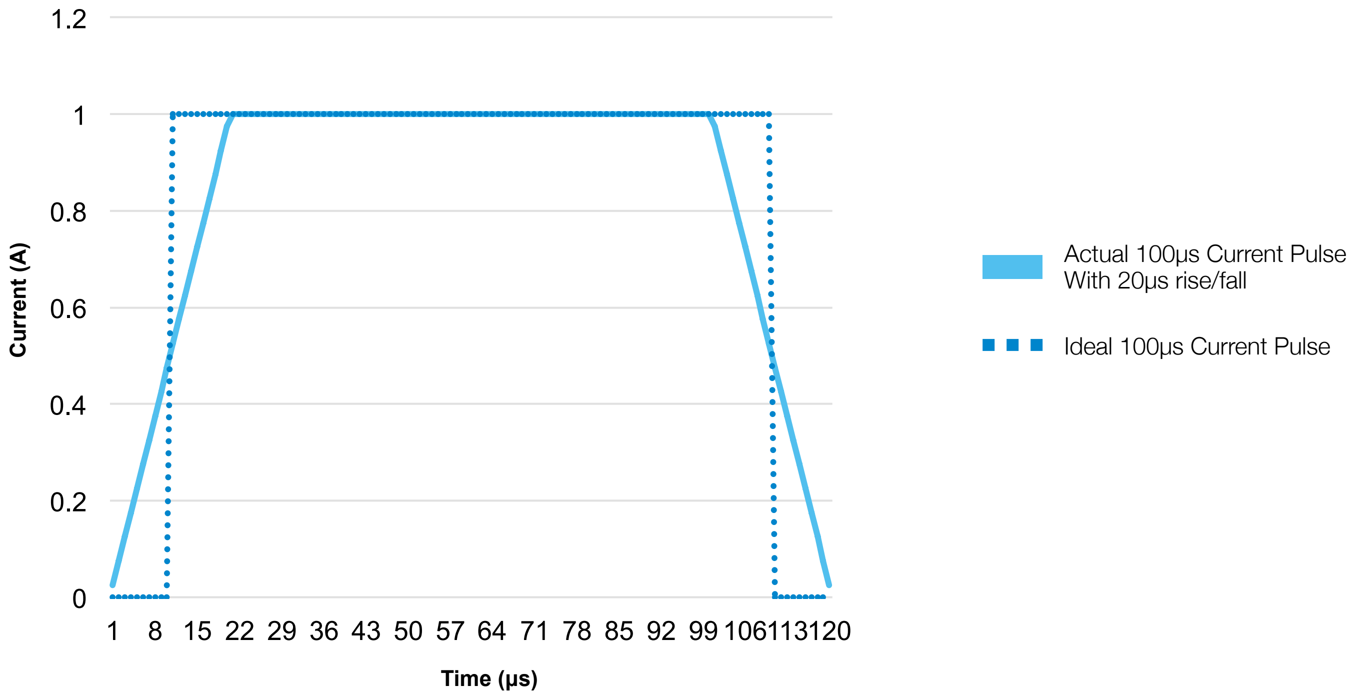
In LM-85 Continuous Pulse method current transitions during integration time



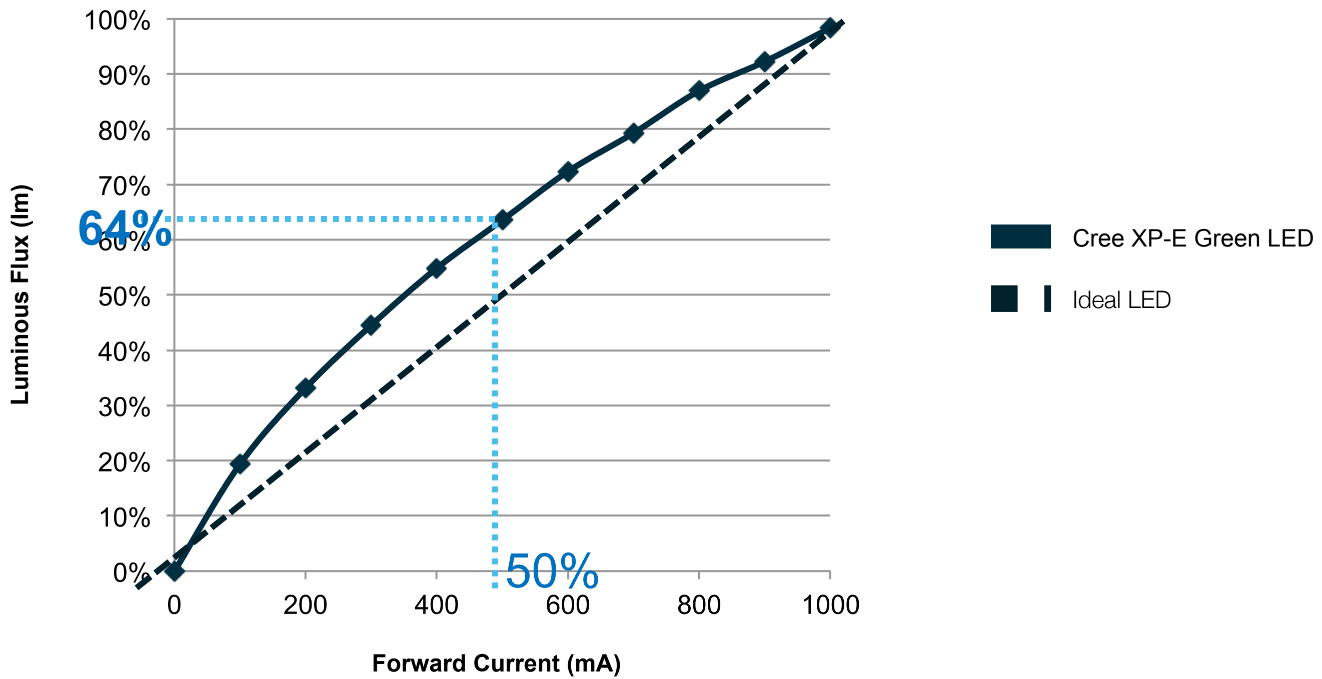
Expected and Unexpected Error Sources

	DC	Single Pulse	Continuous Pulse
Amplitude	+ or -		
Pulse Width	N/A	Usually N/A	+ or -
Rise/fall Time	N/A	Usually N/A	+, increases with shorter pulse widths
Phosphor Temperature	N/A	+, may be small	+
Unknown Amber LEDs	N/A	-	

The amp-second product of square and sloped pulses of equal width is the same

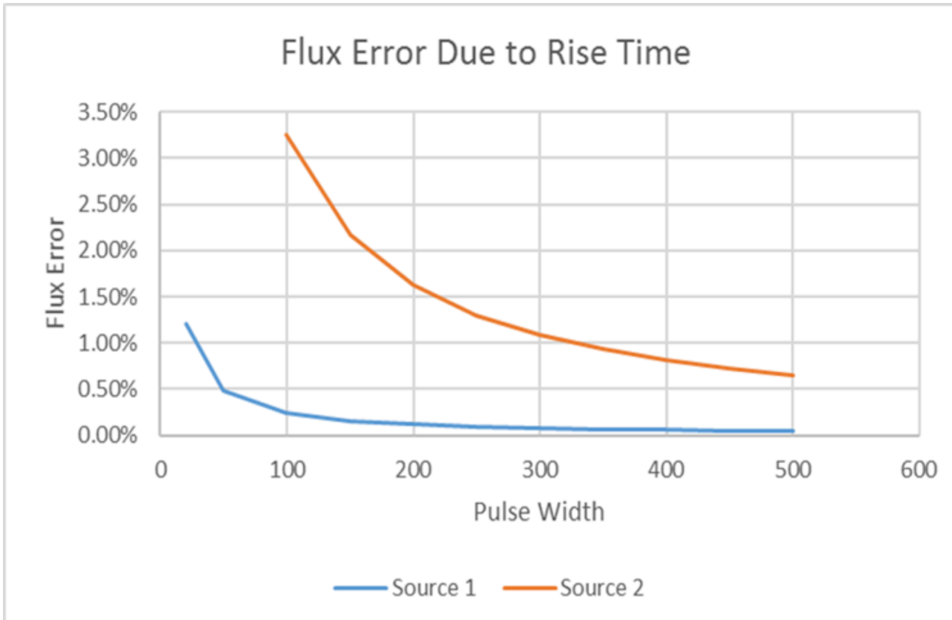


But LEDs produce more light at lower currents



VEKTREX™

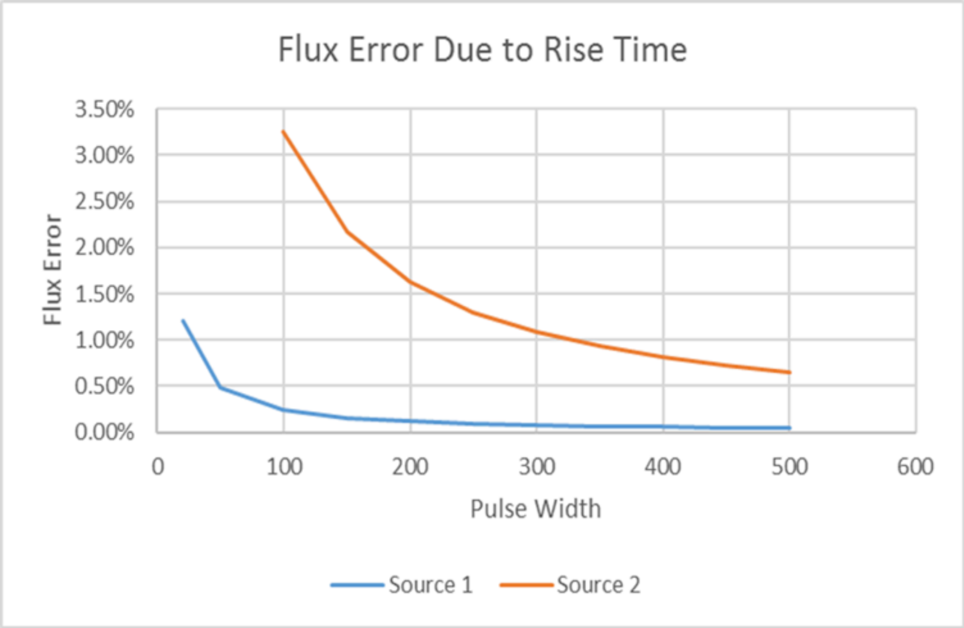
To Minimize Errors, Use Short Pulses with Fast Rise and Fall Times



Instrument	Rise Time Specification
Source 1	2μs
Source 2	30μs

Measurement Error Due To Nonlinear LED Output

The result is a positive error that gets larger as pulses are made more narrow



Instrument	Rise Time Specification
Source 1	2µs
Source 2	30µs

Measurement Error Due To Nonlinear LED Output

Test Data

	White	Royal Blue	Amber	AmberCree
DC, Initial	0%	0%	0%	0%
Continuous, 100us	0.73%	-0.12%	-0.84%	-0.78%
Continuous, 50us	1.11%	0.06%		
Continuous, 20us	1.82%	0.80%		
Continous, 10us	2.69%	1.72%		
Single Pulse	0%	-0.02%	-0.63%	-0.86%
DC, Final	0.12%	-0.16%	-0.02%	0.14%

Test Data & Analysis

Initial and final DC readings indicate parts were stable during testing

	White	Royal Blue	Amber	AmberCree
DC, Initial	0%	0%	0%	0%
Continuous, 100us	0.73%	-0.12%	-0.84%	-0.78%
Continuous, 50us	1.11%	0.06%		
Continuous, 20us	1.82%	0.80%		
Continous, 10us	2.69%	1.72%		
Single Pulse	0%	-0.02%	-0.63%	-0.86%
DC, Final	0.12%	-0.16%	-0.02%	0.14%

VEKTREX™

Test Data & Analysis

Roughly 1% difference between white and royal blue Continuous Pulse measurements correspond to phosphor error

	White	Royal Blue	Amber	AmberCree
DC, Initial	0%	0%	0%	0%
Continuous, 100us	0.73%	-0.12%	-0.84%	-0.78%
Continuous, 50us	1.11%	0.06%		
Continuous, 20us	1.82%	0.80%		
Continous, 10us	2.69%	1.72%		
Single Pulse	0%	-0.02%	-0.63%	-0.86%
DC, Final	0.12%	-0.16%	-0.02%	0.14%

VEKTREX™

Test Data & Analysis

Matching DC and Single Pulse readings indicate phosphor effect does not extend beyond 10ms measurement delay used

	White	Royal Blue	Amber	AmberCree
DC, Initial	0%	0%	0%	0%
Continuous, 100us	0.73%	-0.12%	-0.84%	-0.78%
Continuous, 50us	1.11%	0.06%		
Continuous, 20us	1.82%	0.80%		
Continous, 10us	2.69%	1.72%		
Single Pulse	0%	-0.02%	-0.63%	-0.86%
DC, Final	0.12%	-0.16%	-0.02%	0.14%

VEKTREX™

Test Data & Analysis

Increasing values with decreasing pulse width correspond to expected rise/ fall error

	White	Royal Blue	Amber	AmberCree
DC, Initial	0%	0%	0%	0%
Continuous, 100us	0.73%	-0.12%	-0.84%	-0.78%
Continuous, 50us	1.11%	0.06%		
Continuous, 20us	1.82%	0.80%		
Continous, 10us	2.69%	1.72%		
Single Pulse	0%	-0.02%	-0.63%	-0.86%
DC, Final	0.12%	-0.16%	-0.02%	0.14%

VEKTREX™

Test Data & Analysis

Amber LEDs show unexplained -0.8% error when measured using Single Pulse or Continuous Pulse

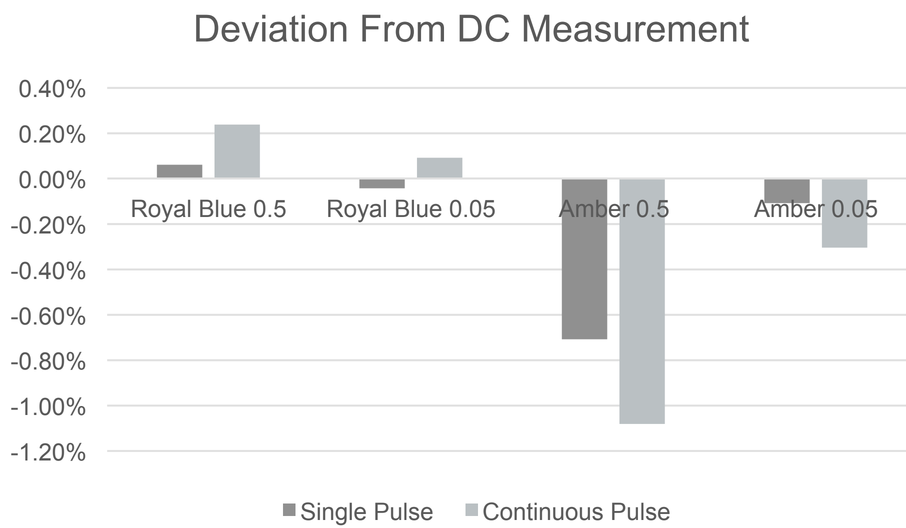
	White	Royal Blue	Amber	AmberCree
DC, Initial	0%	0%	0%	0%
Continuous, 100us	0.73%	-0.12%	-0.84%	-0.78%
Continuous, 50us	1.11%	0.06%		
Continuous, 20us	1.82%	0.80%		
Continous, 10us	2.69%	1.72%		
Single Pulse	0%	-0.02%	-0.63%	-0.86%
DC, Final	0.12%	-0.16%	-0.02%	0.14%

VEKTREX™

Dominant Wavelength Measurement Indicates Change in Junction Temperature Unlikely to be Cause of Amber Phenomenon

- Lumileds Amber
  - Flux change/degree C: 1.6%
  - Dominant wavelength shift/degree C: 0.123nm
  - LED dominant wavelength DC: 594.99
  - LED dominant wavelength Single Pulse: 595.0
- Cree Amber
  - LED dominant wavelength DC: 589.55
  - LED dominant wavelength Single Pulse: 589.58

Additional Tests Showed Smaller Effect At Low Currents As Well



Additional research

- Three additional Lumileds amber samples were tested with very similar results
- Based upon the preliminary findings, Cree will supply additional samples
- Additional testing will try to pinpoint the source of the amber error
- Instrument Systems will also provide an updated spectrometer

VEKTREX™

Measurement recommendations

- Assess the magnitude of phosphor errors before using continuous pulse for phosphor converted LEDs
- Correlate continuous and single pulse measurements back to DC whenever possible using a high speed sampling voltmeter or digitizer
- If using continuous pulse ensure current source rise/fall is <1/100 of pulse width