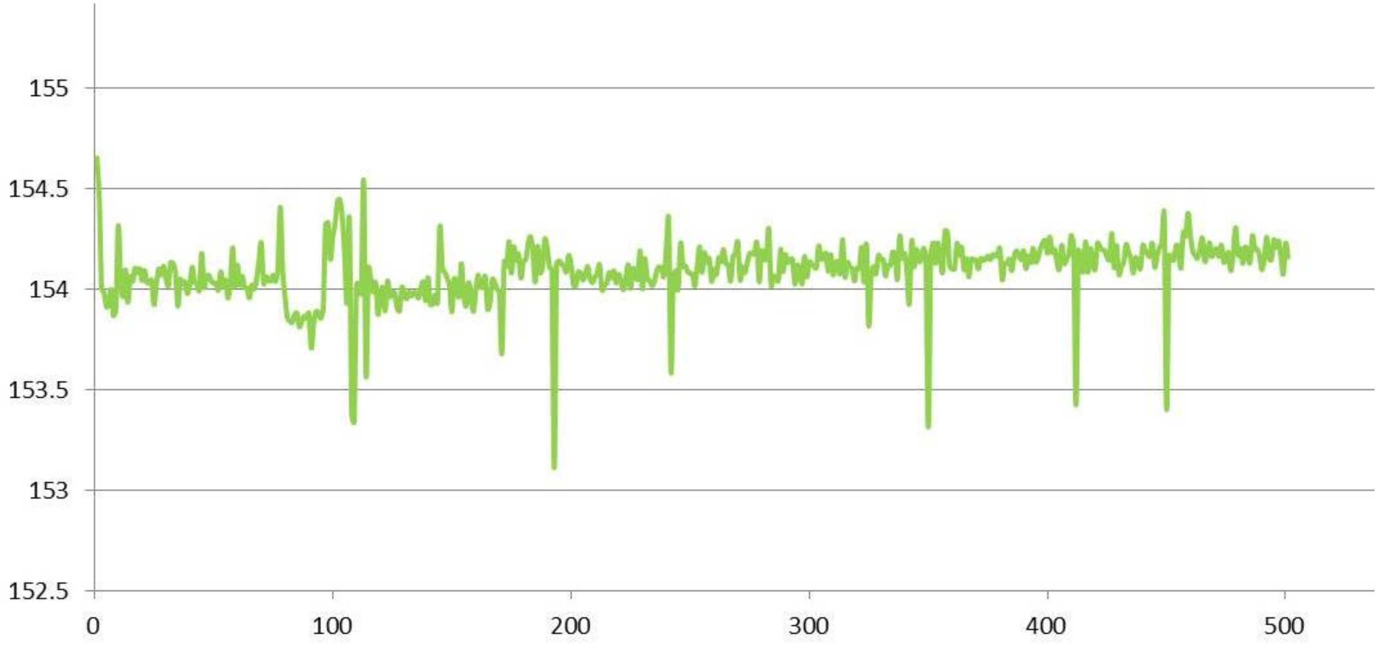
Current Source Induced LED Photometric Measurement Variations



CORM 2016
Jeff Hulett
www.vektrex.com

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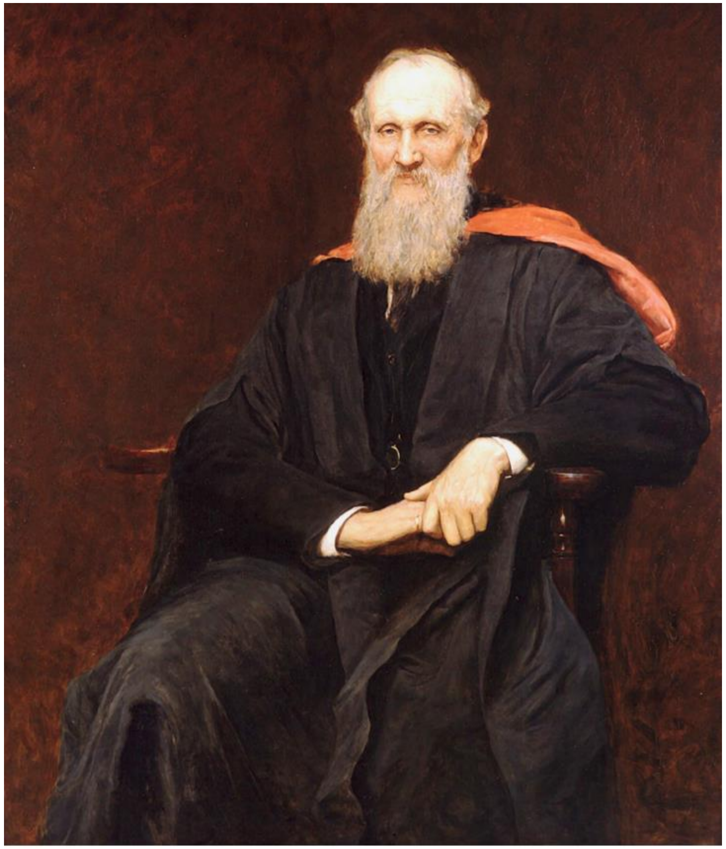
Measurement is Key to Innovation

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

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

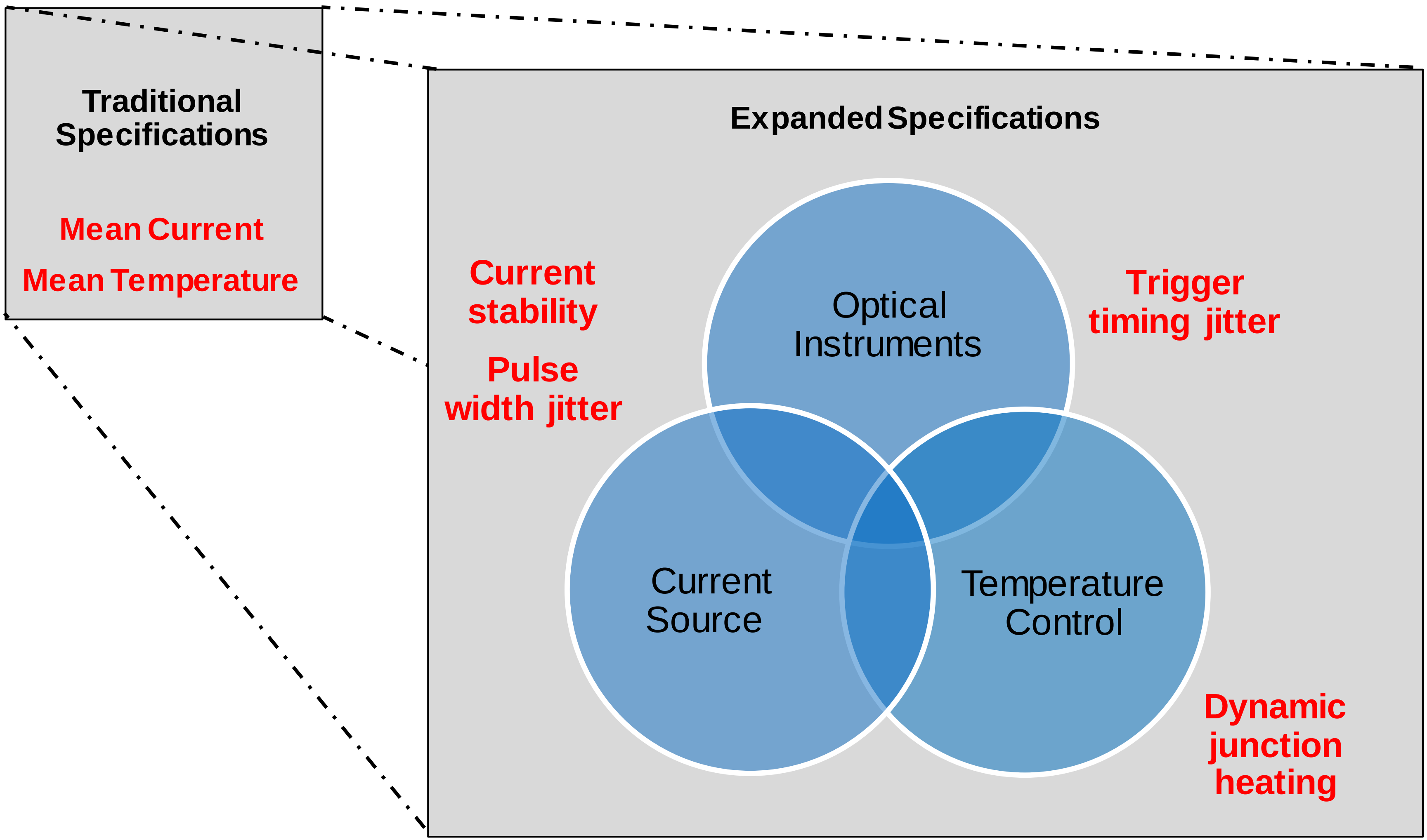


LED Scientists Need To Challenge The Status Quo

- High power LEDs are increasingly difficult to measure with traditional systems/equipment
- Present methods sometimes exhibit poor repeatability
- Measurement variations complicate long-term studies
- Error sources are not well understood
- Too much reliance on trusted vendors/instruments

Just as accurate timekeeping facilitated safe navigation and ultimately world exploration, more accurate photometric measurements will drive LED innovation

To Reduce Measurement Error, Instrument Specifications Must Expand to Include Temporal Current and Temperature Specifications



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Popular Industry Measurement Methodology

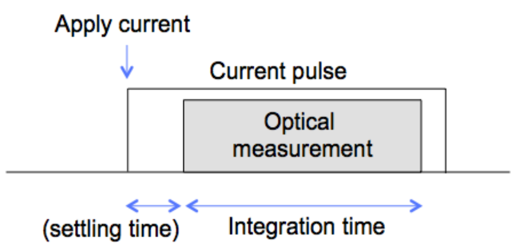
- Current source drives LED
- Brief pulse to limit heating
- Ambient temperature control
- Unknown junction temperature
- Simple, fast measurements

“Does it really matter that the measurement is wrong if everyone is doing it the same way?”

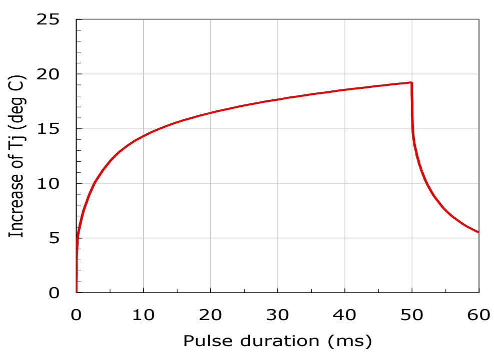
– attendee at TILS 2016

Popular Industry Method: Essentially LM-85 Single Pulse Without Temperature Corrections

Set TCP Temperature To Tj and Stabilize DUT → Drive LED With Current Pulse at If → Trigger Spectrometer For Optical Measurement → Apply Corrections Based Upon Thermal Model



Optical measurement is made during pulse



How corrections are applied is vague; if small they may be left uncorrected and used as input to uncertainty calculation

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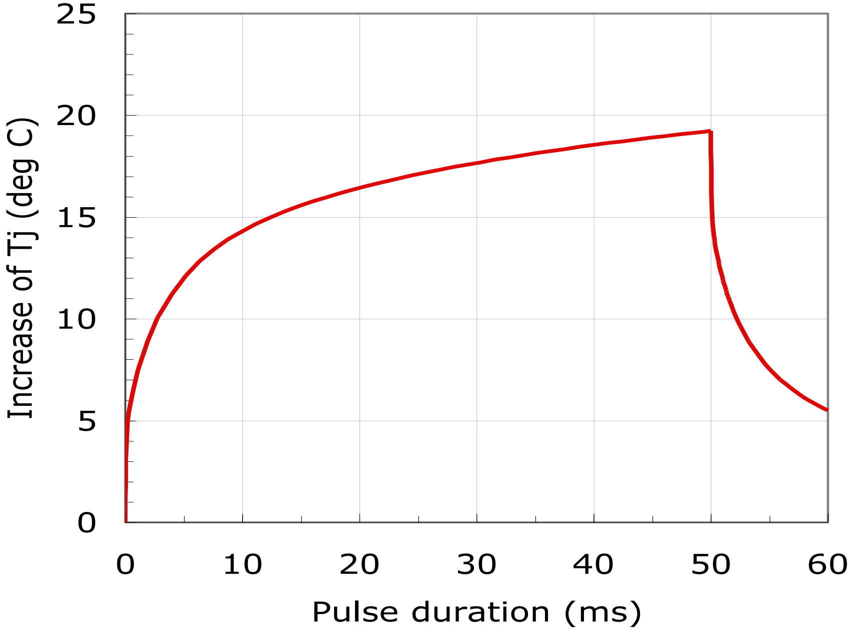
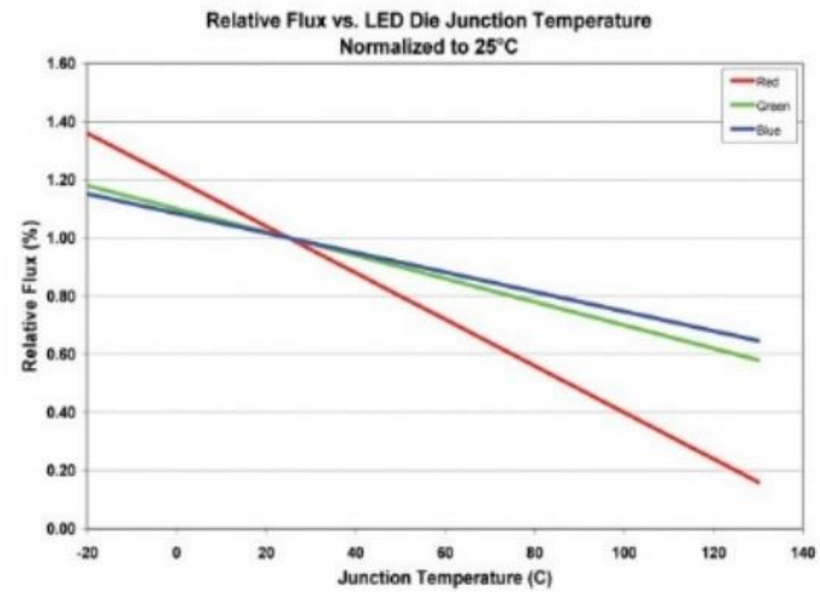
Popular Industry Method: Critical Temporal Issue – Dynamic Junction Heating Reduces Flux

Junction rise, CREE 3W LED on heat sink, 50ms current pulse



Flux vs Temperature Normalized to 25C



20C rise in 50ms = 4% decrease in flux

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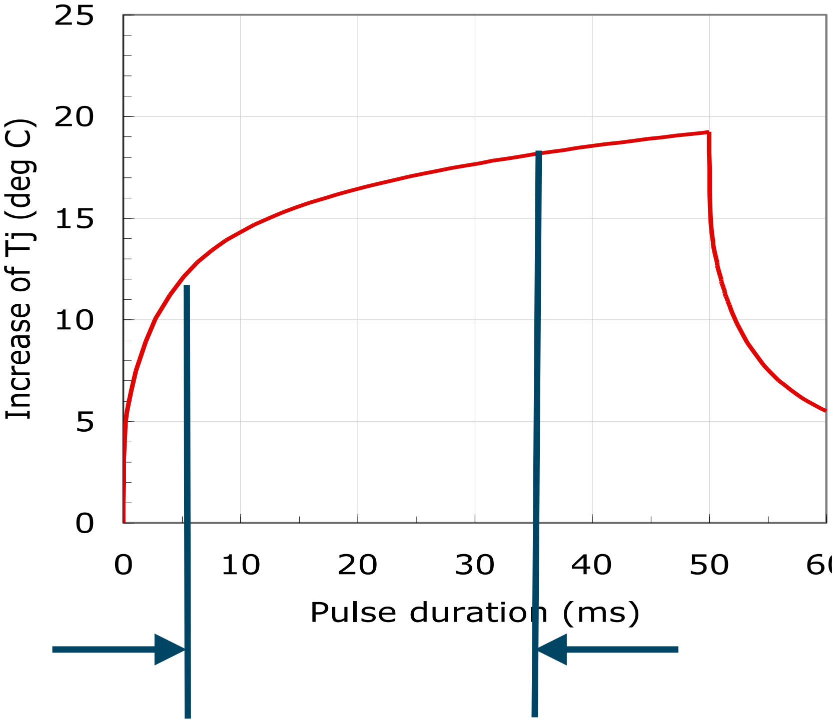
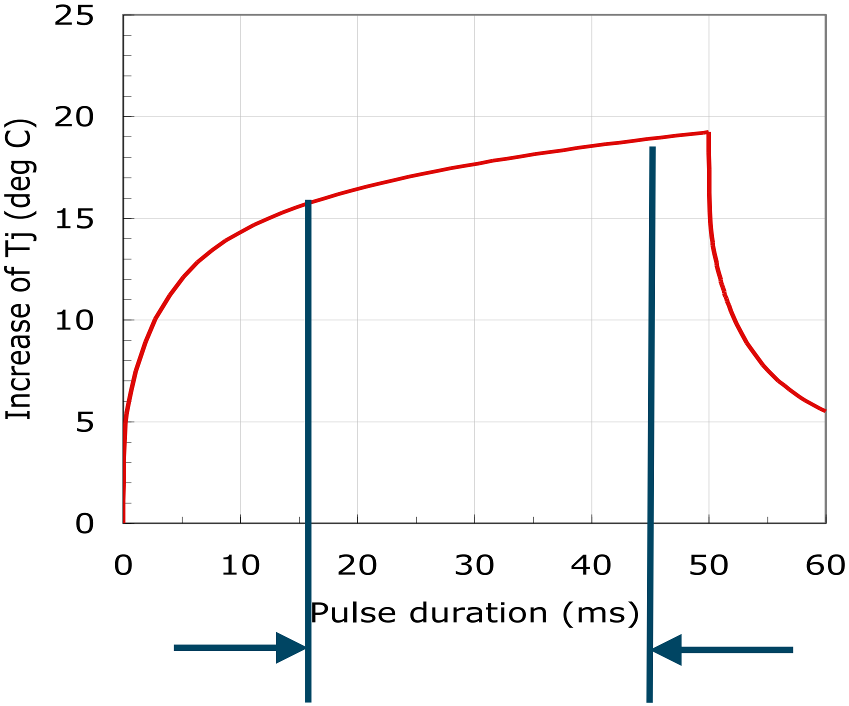
Popular Industry Method: Spectrometer Timing Uncertainty Means LED Tj Associated With Measurement Varies



Measurement aperture 1:
Average Tj +15C



Measurement aperture 2:
Average Tj +17C

Example: 10ms trigger jitter => 2C difference => 0.4% measurement uncertainty

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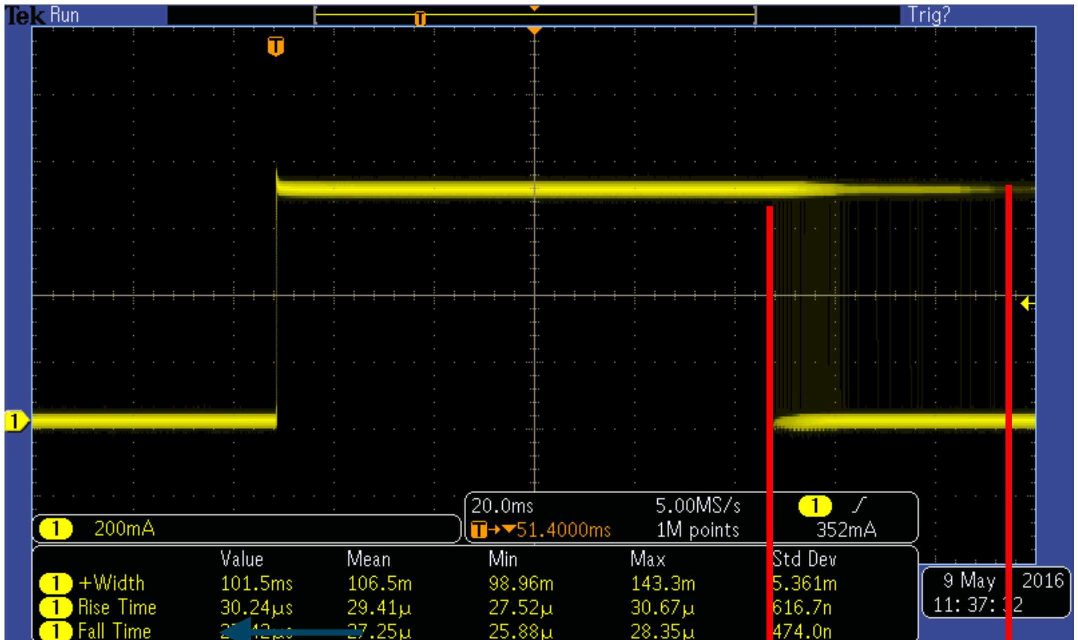
Popular Industry Method: Current Source Pulse Width Jitter Produces Measurement Temperature Uncertainty



Example: 42% Pulse Width Jitter

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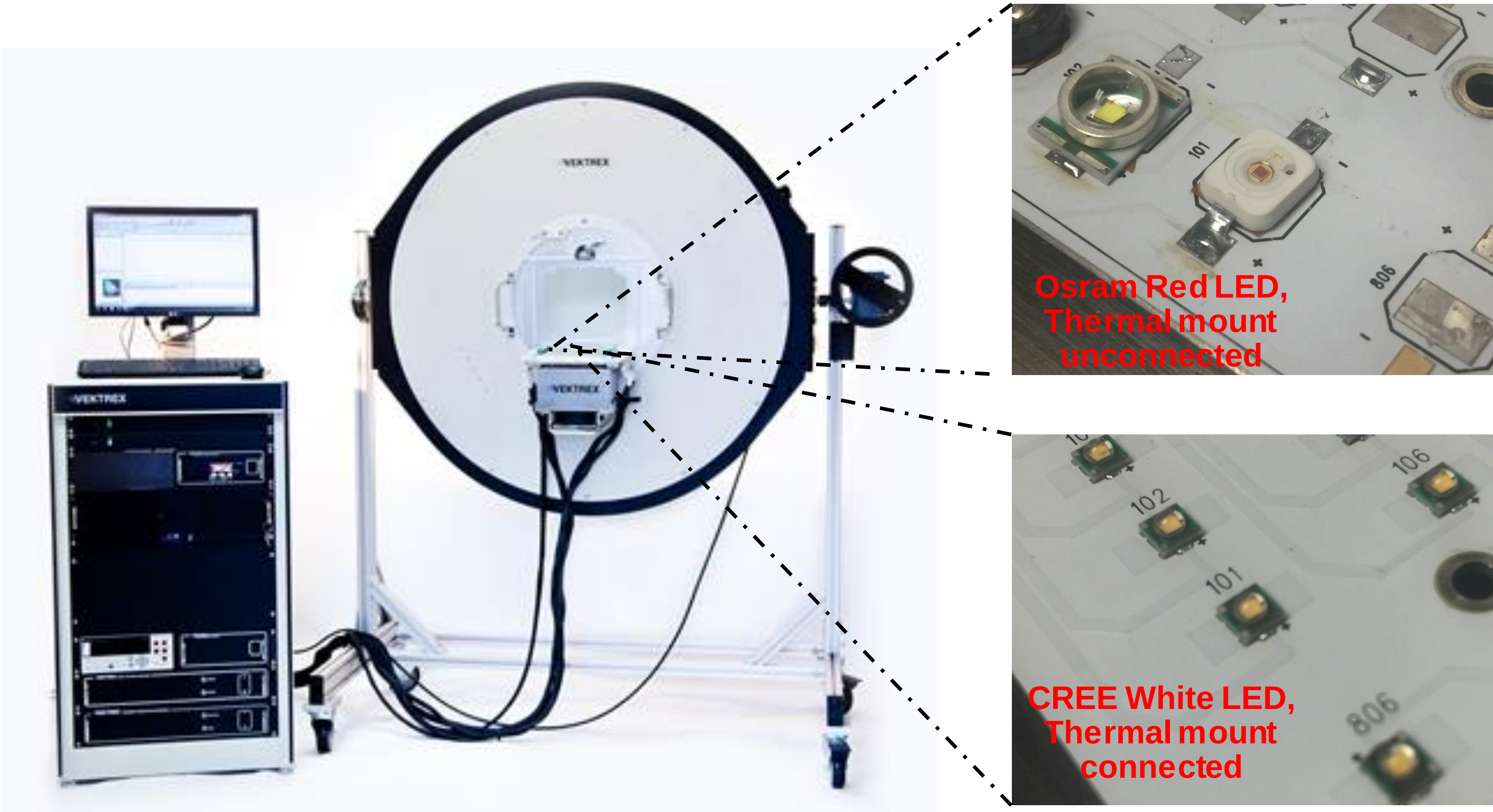
Vektrex Experiment: Quantify Industry Method Error Sources

- 500 repeated measurements at 1s intervals
- Investigate stability of measurements compare peek excursions with average values
- 3 different timing/triggering implementations

Mode	Timing Controlled By	Link	Timing Variability
CAS-140/Keithley Sychchronous Mode	Software application	GPIB commands to current source & spectrometer	40-50ms
CAS-140/Keithley Triggered Mode	Spectrometer	Hardware trigger line	1-5ms
CAS-140/Vektrex Triggered Mode	Current source	Hardware trigger line	150ns

Vektrex Experiment Setup: Two LED Types Tested



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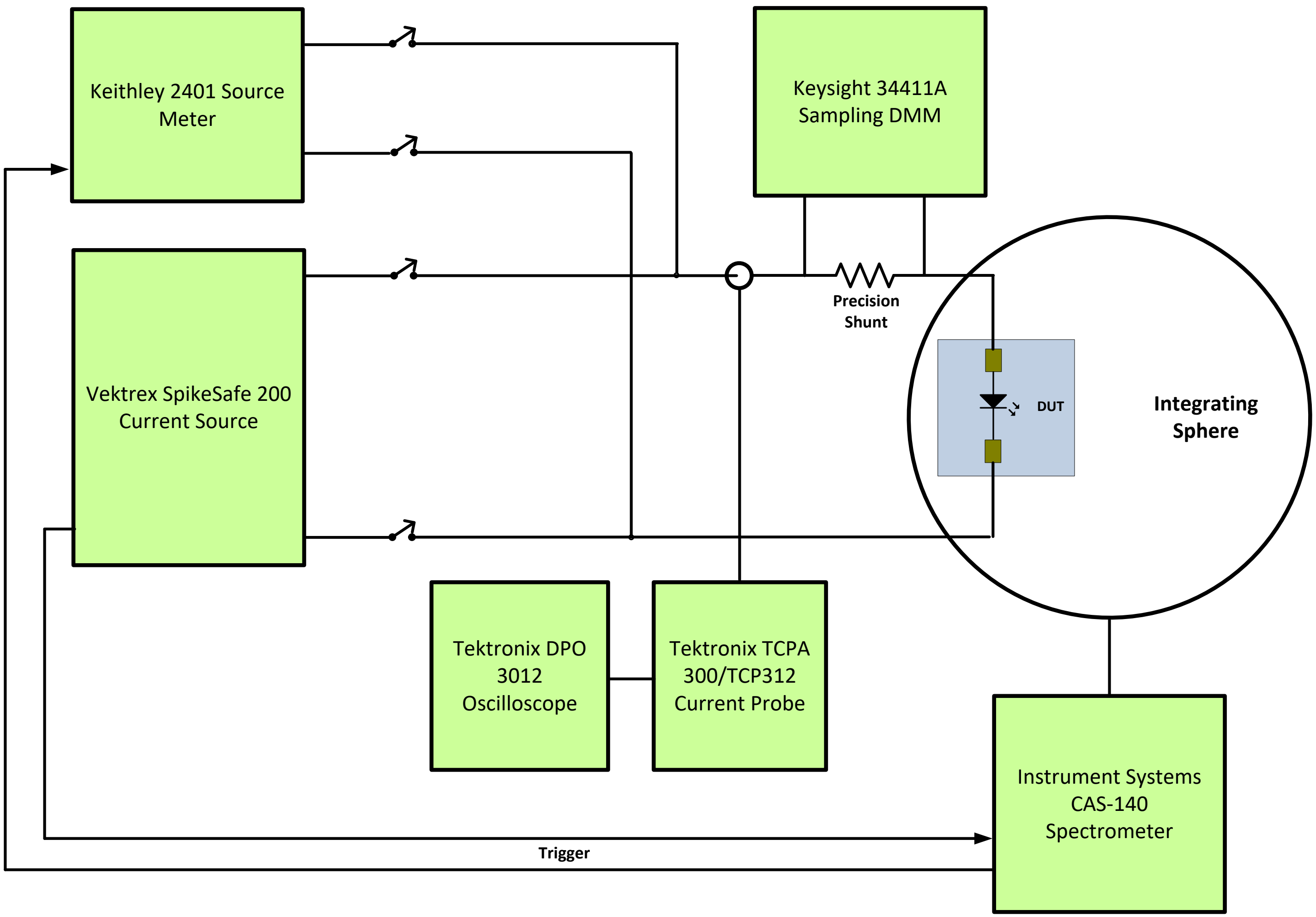
Vektrex Experiment: Equipment Block Diagram



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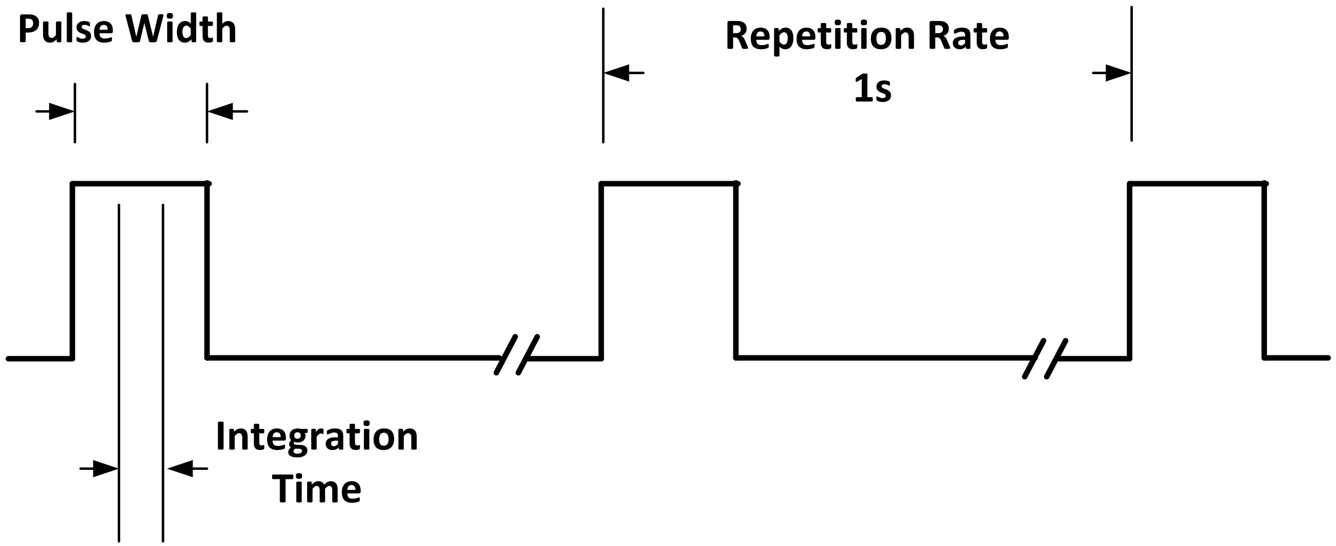
Vektrex Experiment: Measurement Single Pulse Timing



500 measurement samples collected

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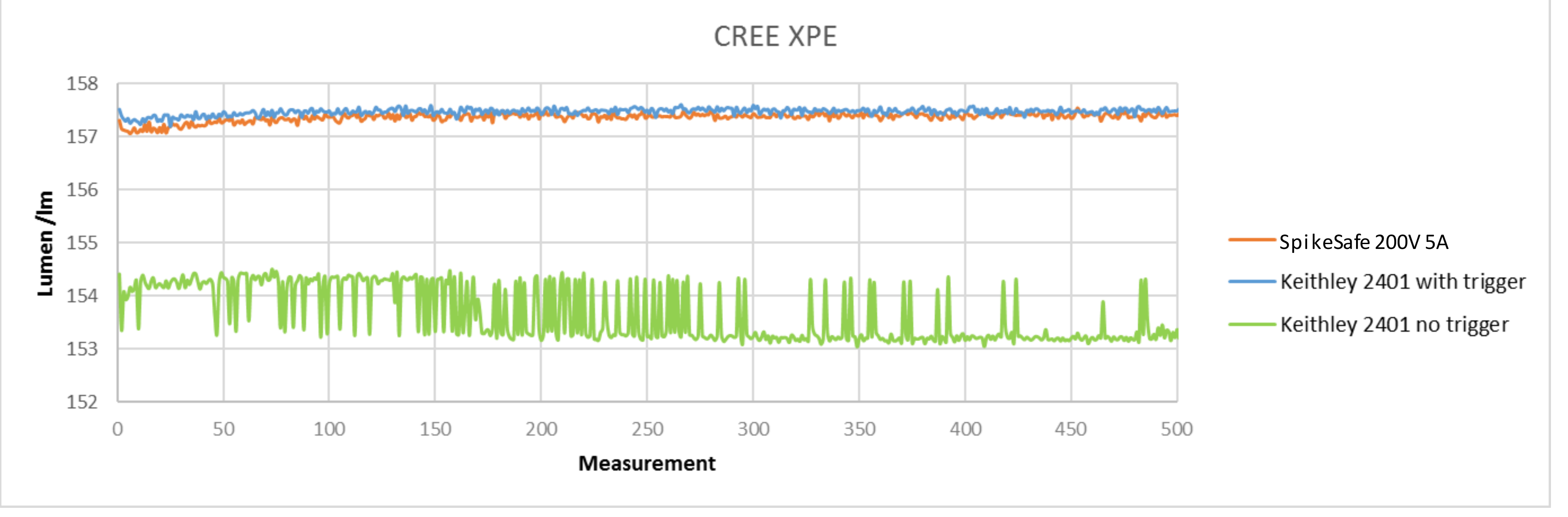
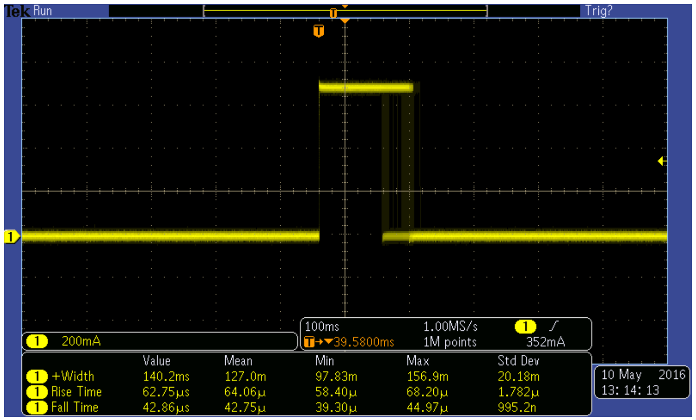
Vektrex Experimental Scenarios

Scenario	Measurement Type	Load	Spectrometer Trigger Mode	Current Source Type	Pulse Parmeters		
					Current	Width	Period
1	Single Pulse	Cree XPE White On MCPCB	Synchronous	Keithley	700mA	127 ms	1s
			Triggered (Trigger out)	Keithley		15.35 ms	
			Triggered (Trigger in)	Vektrex		15 ms	
2	Single Pulse	Osram LY Red off MCPCB	Synchronous	Keithley	1A	104.5 ms	1s
			Triggered (Trigger out)	Keithley		15.37 ms	
			Triggered (Trigger in)	Vektrex		15 ms	
3	Continuous	Bridgelux BXRA	Untriggered	Vektrex	2A	100us	1s

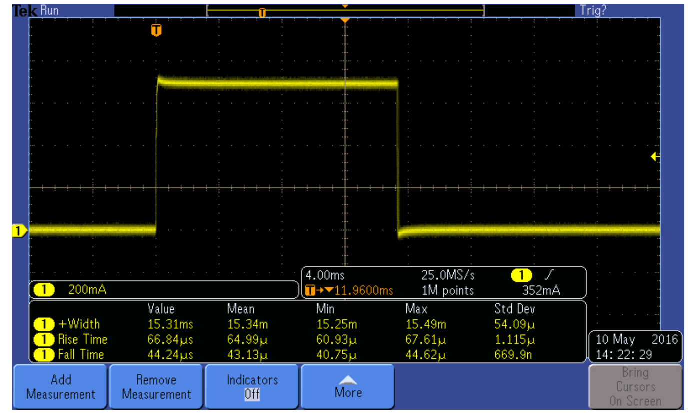
Scenario 1: Cree XPE Flux – 500 Measurement Data



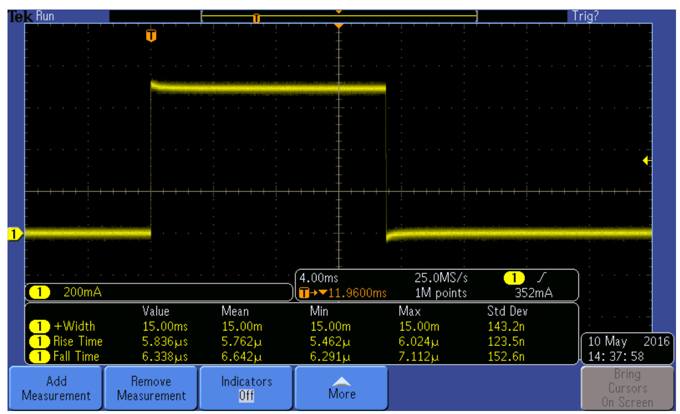
Scenario 1: Cree XPE Current Waveforms



Keithley synchronous mode, 127ms pulse 30ms jitter



Keithley triggered 15.3ms pulse, 250us jitter



SpikeSafe 5ms, no measurable jitter

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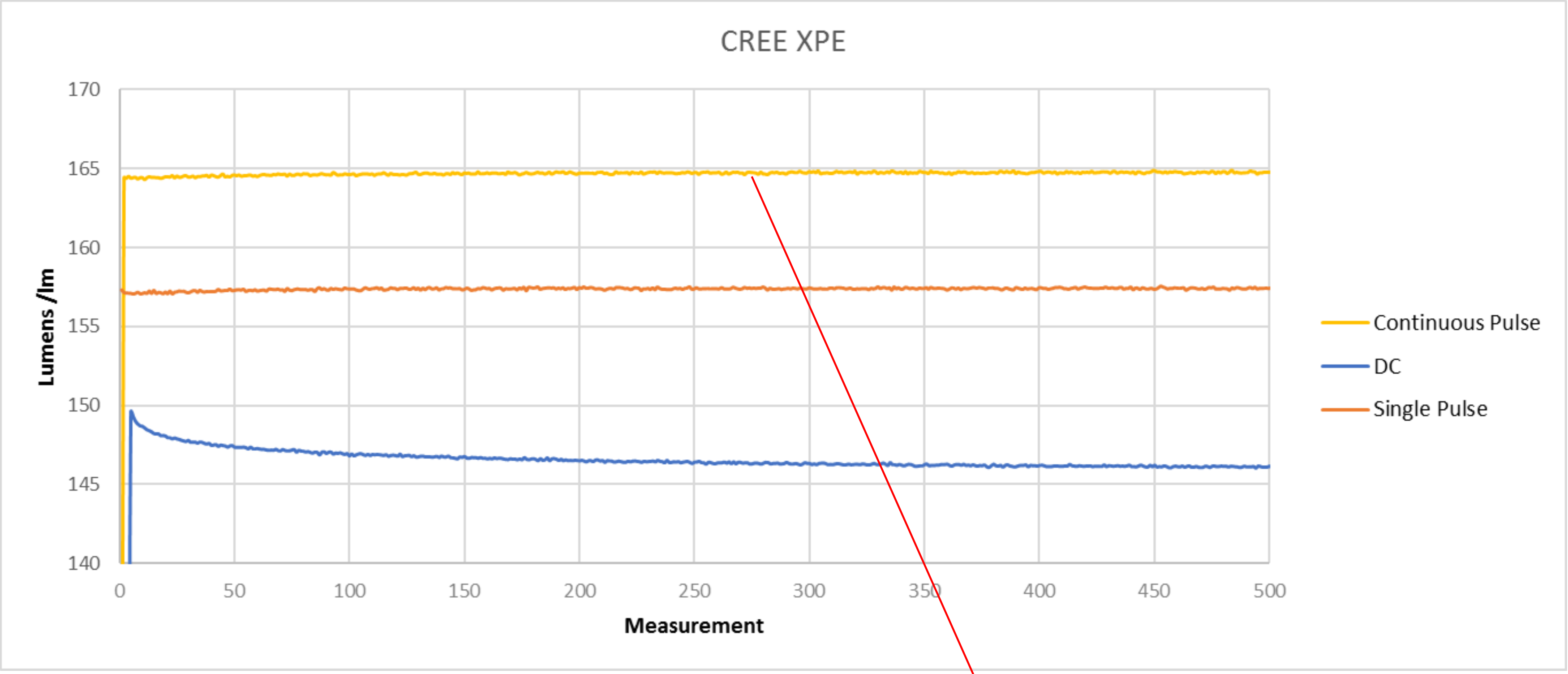
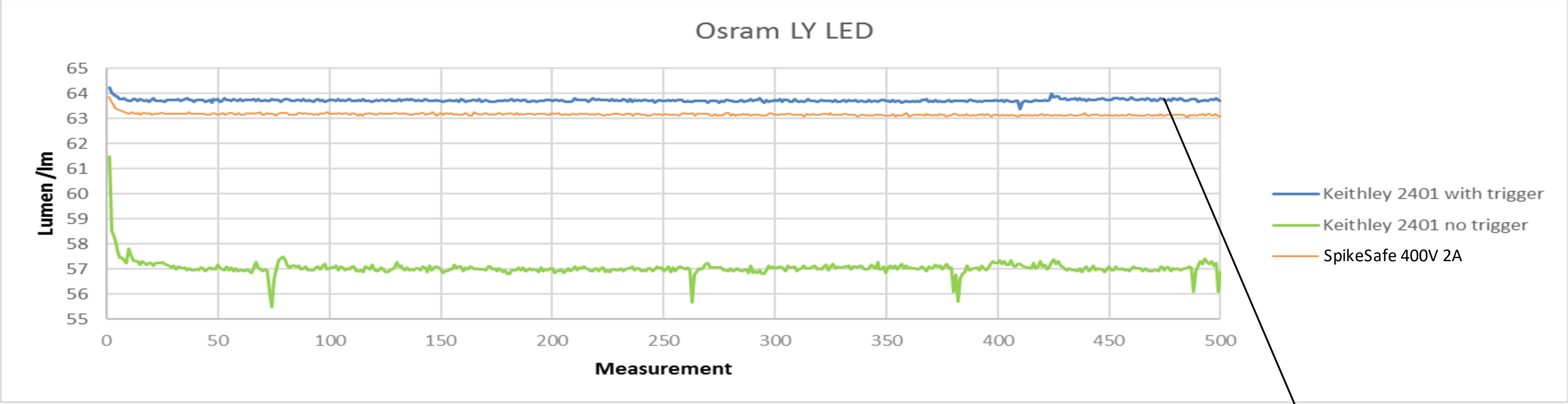
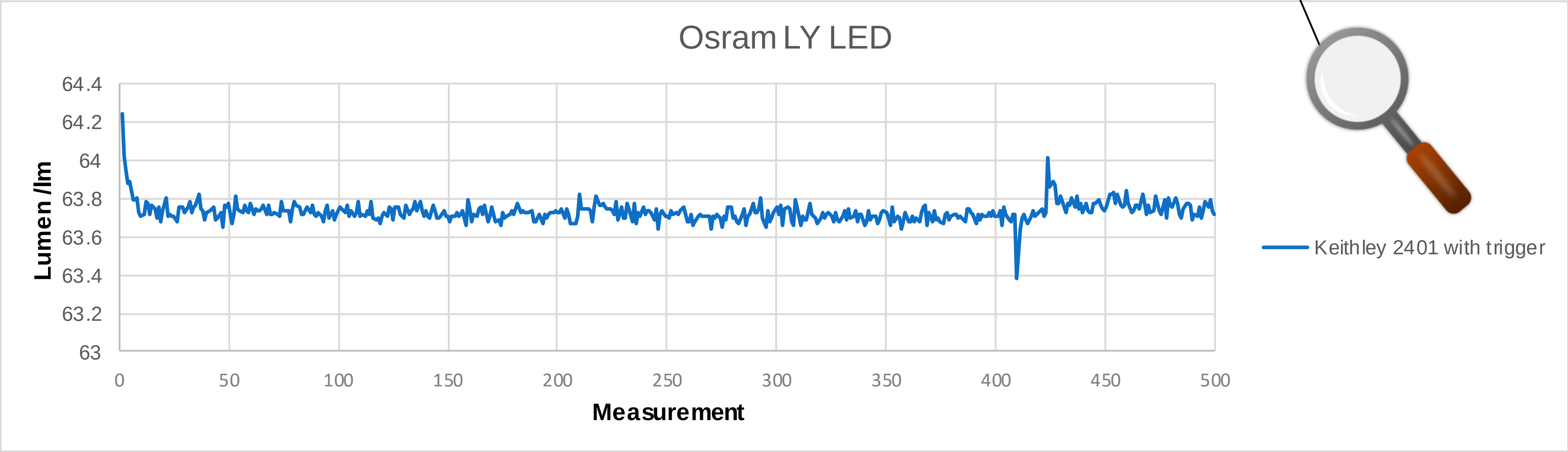
Scenario 1: Cree Part Measured With LM-85 Methods to Evaluate Flux Drop From Average Heating



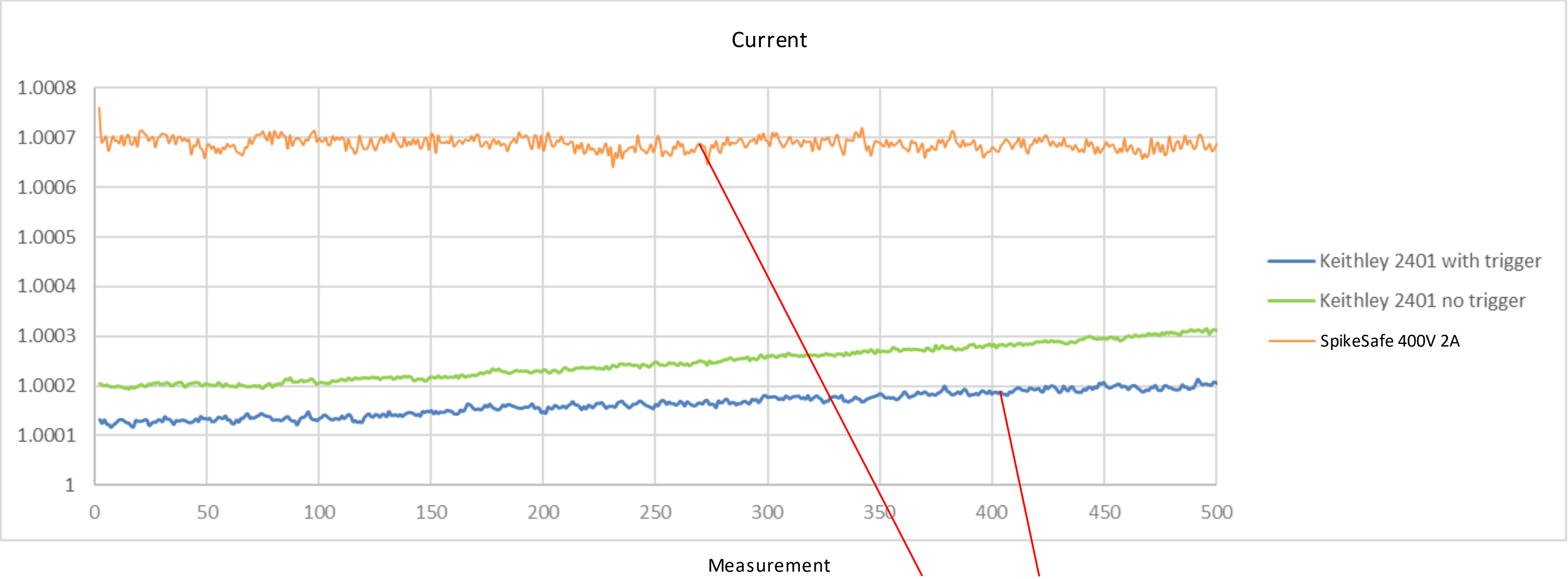
Continuous pulse measurement closely approximates true flux at ambient temperature

Scenario 2: Osram LY Flux – 500 Measurement Data





Scenario 2: Osram LY – Current Drive Was Investigated To Look For Source of Glitches

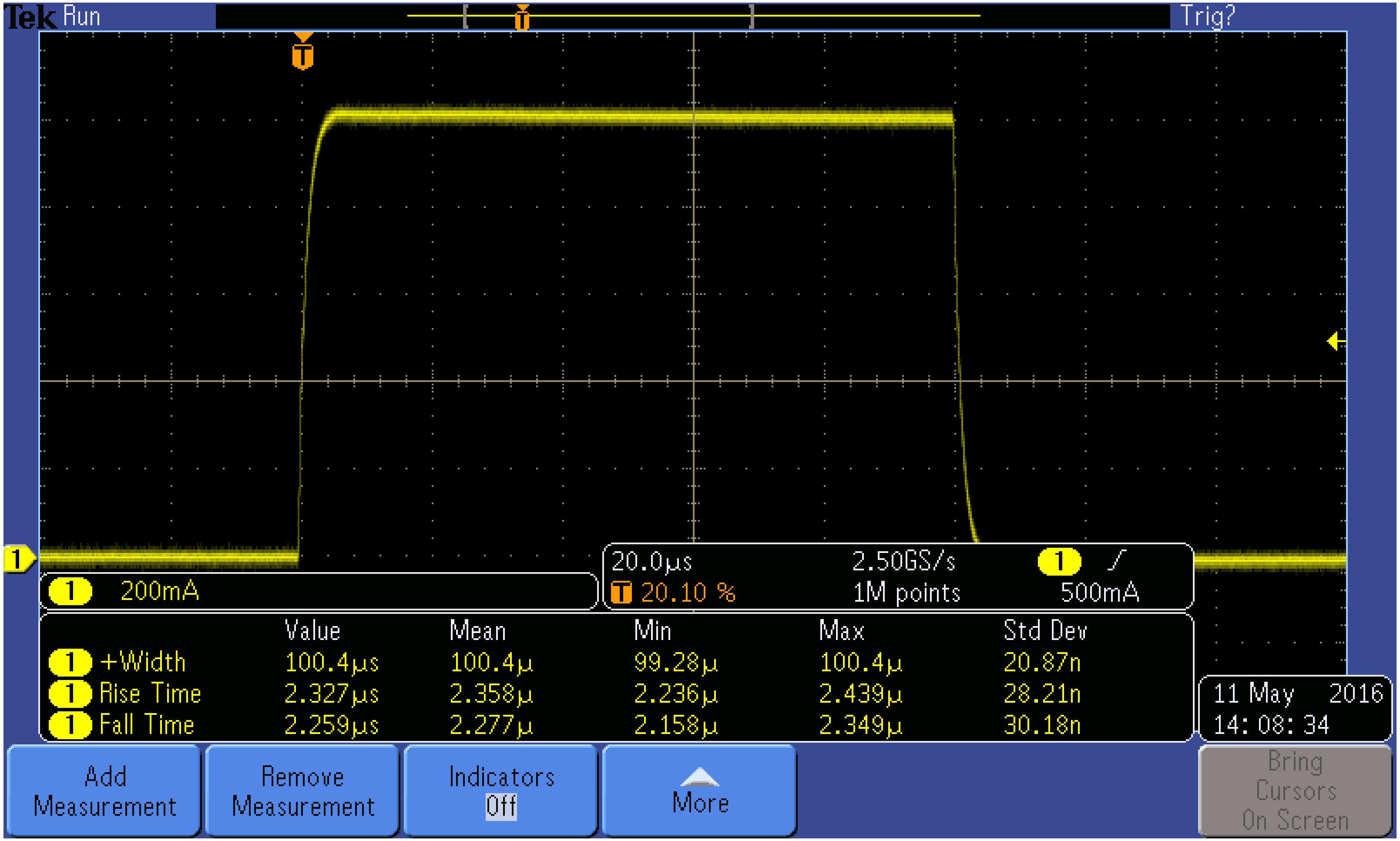


SpikeSafe had more short-term variation, but Keithley exhibited long term drift

Scenario 2: Osram LY Flux – LM-85 Measurements

30% drop in flux for single pulse, even with 15ms pulses

Waveform Used for LM-85 Continuous Pulse Measurements



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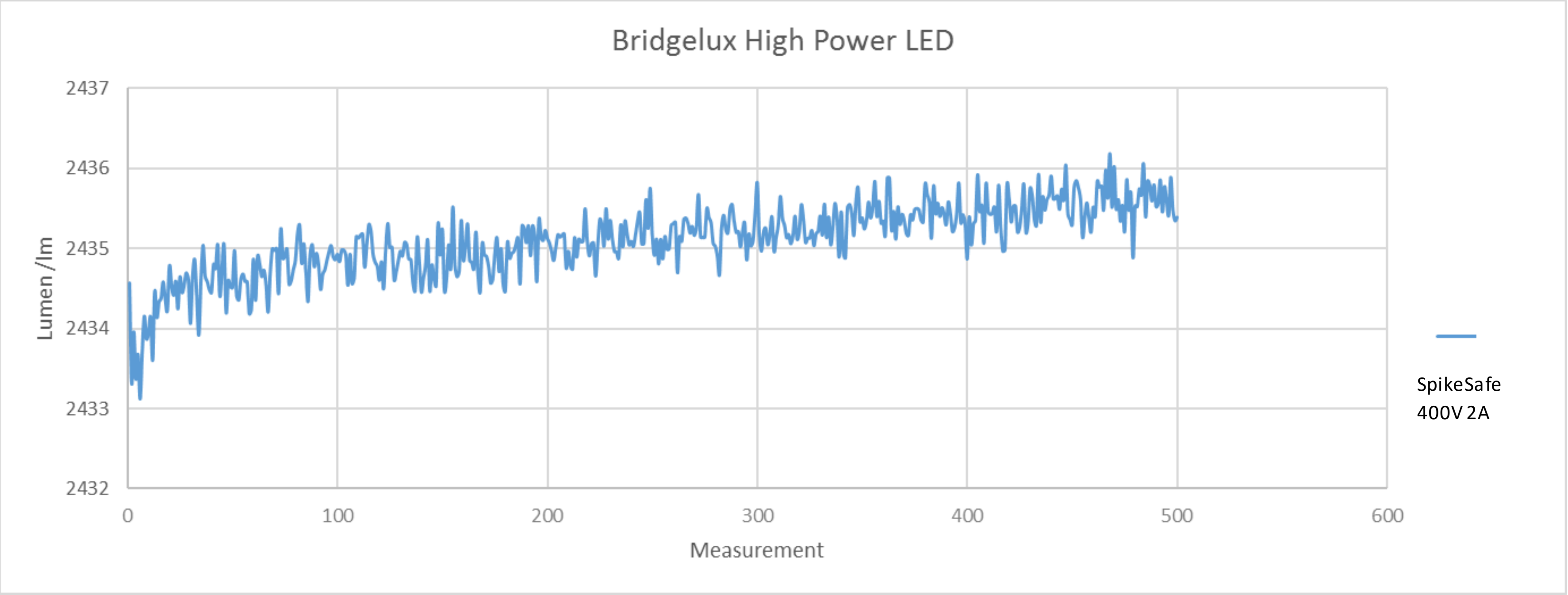
Scenario 3: Bridgelux High Power COB – Continuous Pulse Mode



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Error Magnitude Analysis – Red LED on Kapton Mount

Error	Type	Max %
Average heating	Fixed	38.93%
Additional heating error - Keithley 2401 synchronous mode		9.75%
Absolute current calibration - SpikeSafe 200/400		0.070%
Absolute current calibration-Keithley 2401		0.040%
Timing jitter - Keithley 2401 synchronous	Variable	2.63%
Timing jitter - Keithley 2401 triggered		0.47%
Timing jitter - SpikeSafe 200/400		*
Current stability Keithley 2401		0.030%
Current stability SpikeSafe 200/400		0.004%

* Not measurable

Error Magnitude Analysis – White LED on Thermal Mount

Error	Type	Max %
Average heating	Fixed	4.59%
Additional heating error - Keithley 2401 synchronous mode		2.46%
Absolute current calibration - SpikeSafe 200/400		0.100%
Absolute current calibration-Keithley 2401		0.014%
Timing jitter - Keithley 2401 synchronous	Variable	0.65%
Timing jitter - Keithley 2401 triggered		*
Timing jitter - SpikeSafe 200/400		*
Current stability Keithley 2401		0.001%
Current stability SpikeSafe 200/400		0.010%
* Not measurable		

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Conclusions/Recommendations

- Dynamic heating combined with measurement timing jitter can add significant uncertainty to photometric measurements
- Software triggering jitter errors negate the benefit of longer spectrometer integration times
- Utilize hardware triggering to minimize errors
- Compare results to continuous pulse measurements to evaluate junction heating
- Don’t be satisfied with “we have always done it this way”

NMI Challenges/Recommendations

- Metrology challenges:
  - Stability of long term flux measurements
  - Realistic, practical temperature measurements
  - Current calibration standards
  - Optical calibration standards

- NMI input/guidance needed:
  - Include temporal parameters when specifying current accuracy
  - Foster better ways of monitoring LED temperature

- How can CORM help:
  - Promote standards like LM-85 and TC-263 that tie measurements to temperature