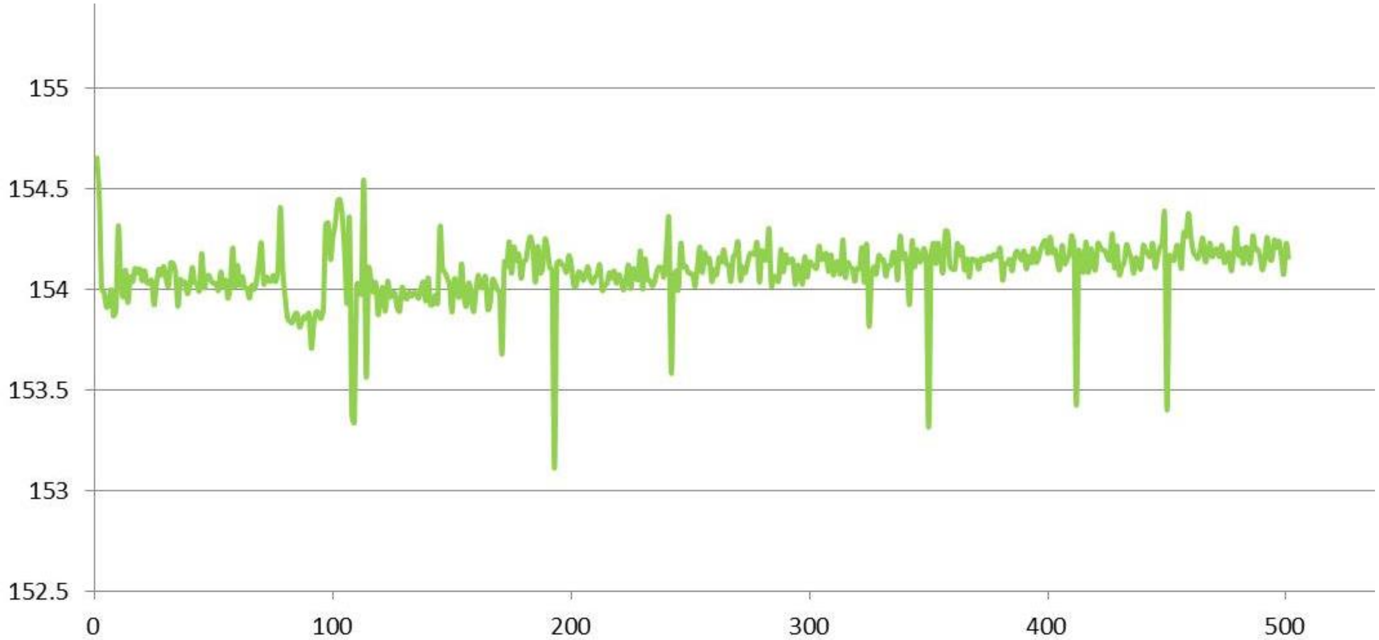
# Current Source Induced LED Photometric Measurement Variations




CORM 2016
Jeff Hulett
www.vektrex.com

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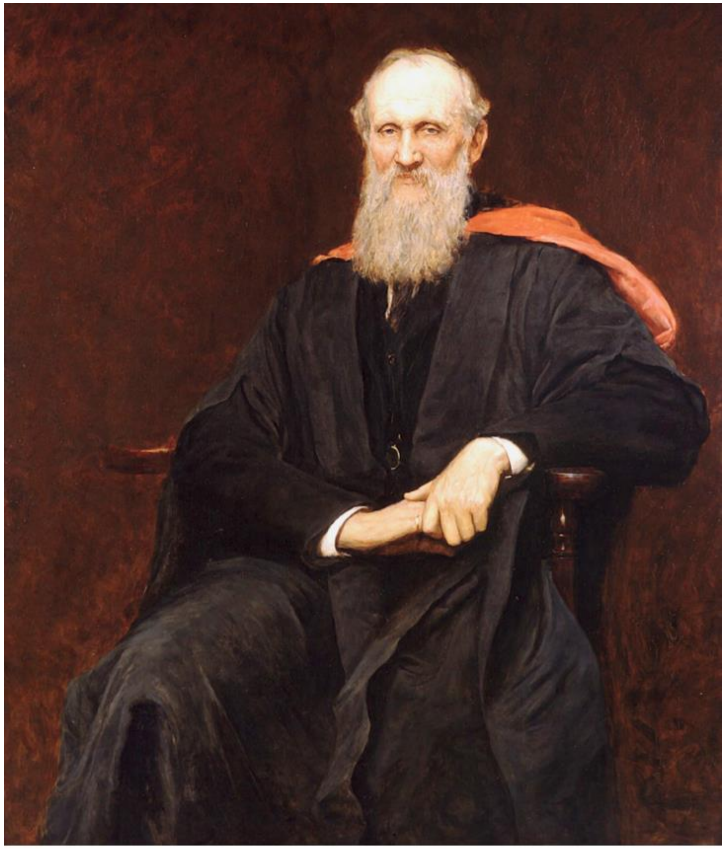
# Measurement is Key to Innovation

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

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







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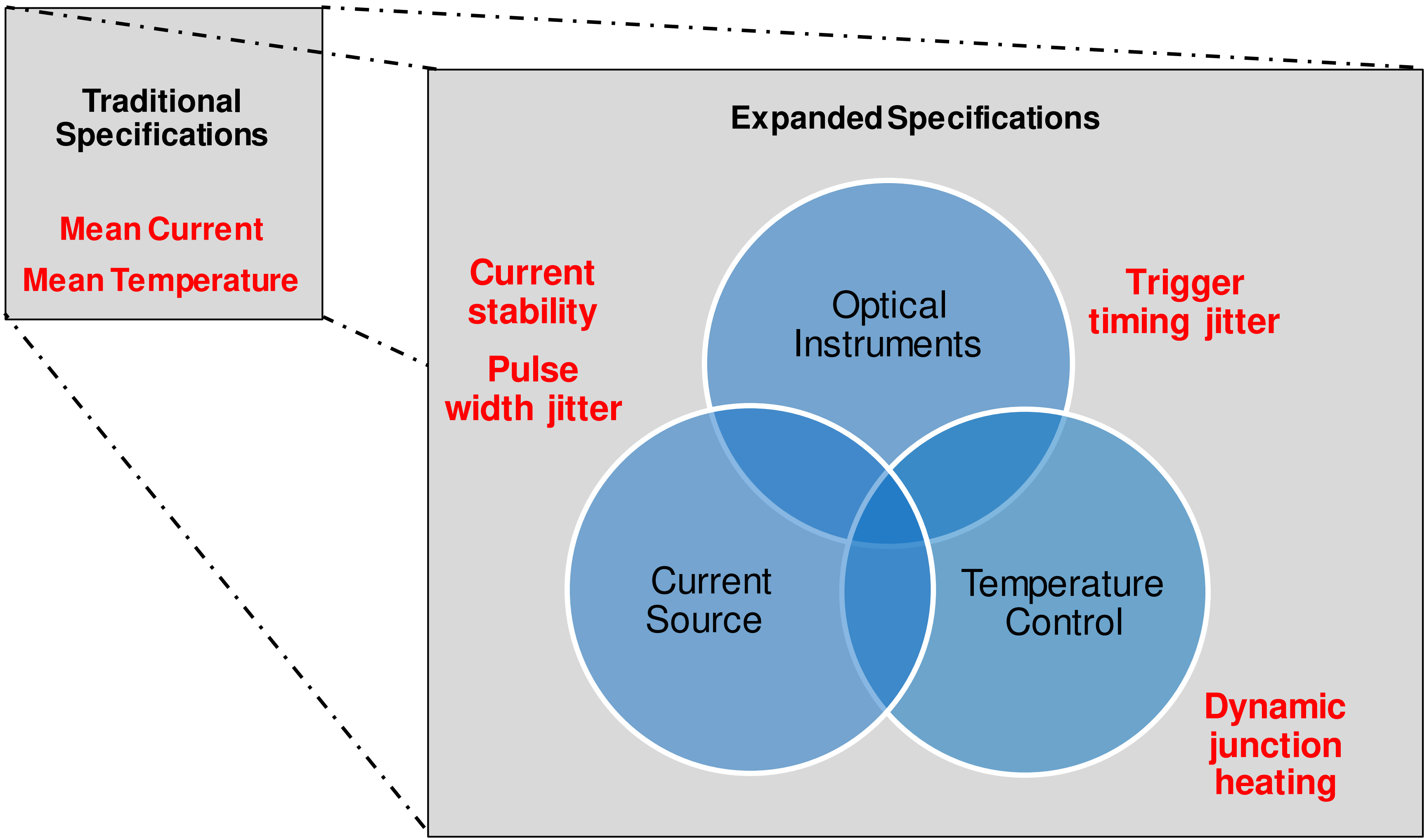
# LED Scientists Need To Challenge The Status Quo

- 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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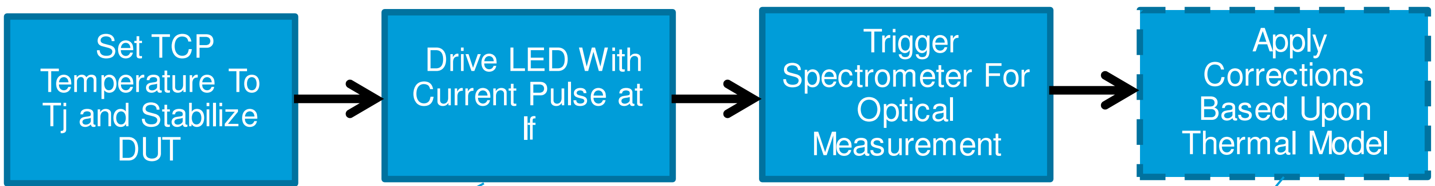
# Popular Industry Measurement Methodology

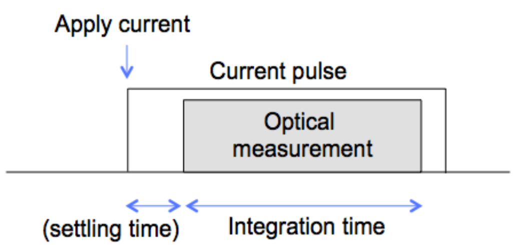
- Current source drives LED
- Brief pulse to limit heating
- Ambient temperature control
- Unknown junction temperature
- Simple, fast measurements

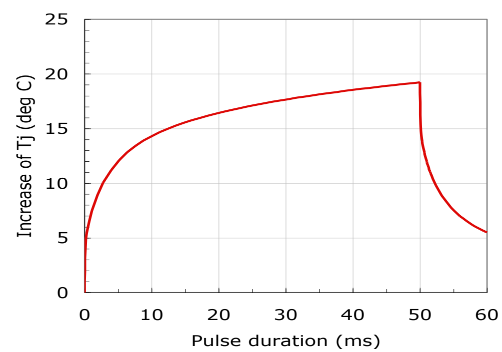
"Does it really matter that the measurement is wrong if everyone is doing it the same way?"

– attendee at TILS 2016

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




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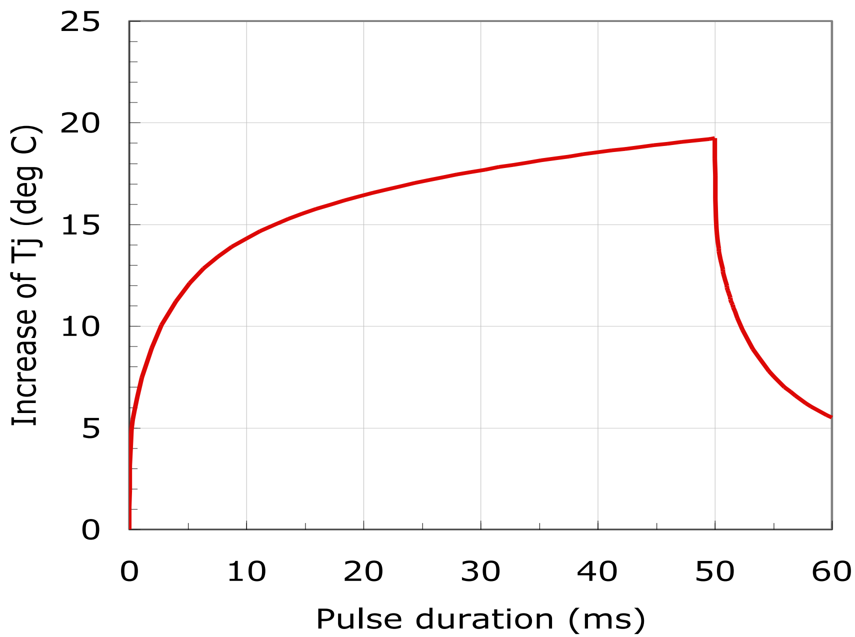
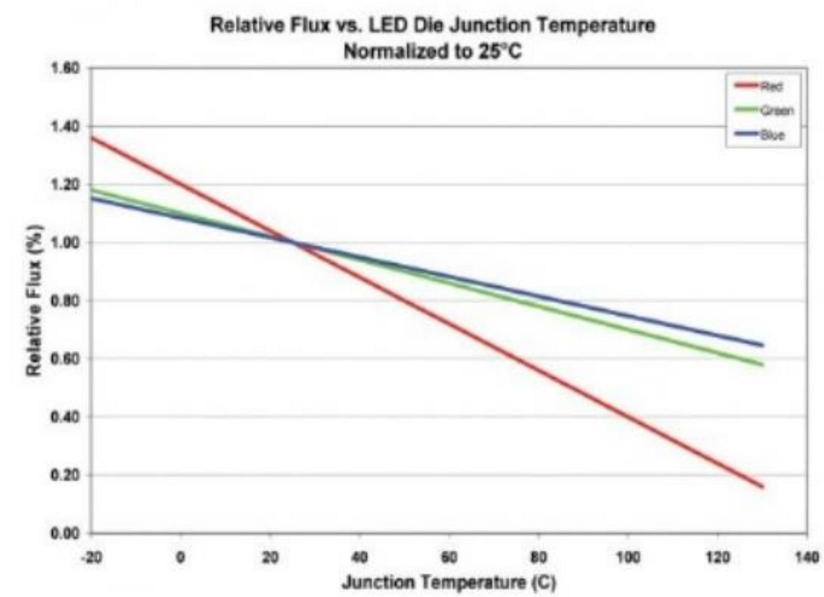
# Popular Industry Method: Critical Temporal Issue – Dynamic Junction Heating Reduces Flux

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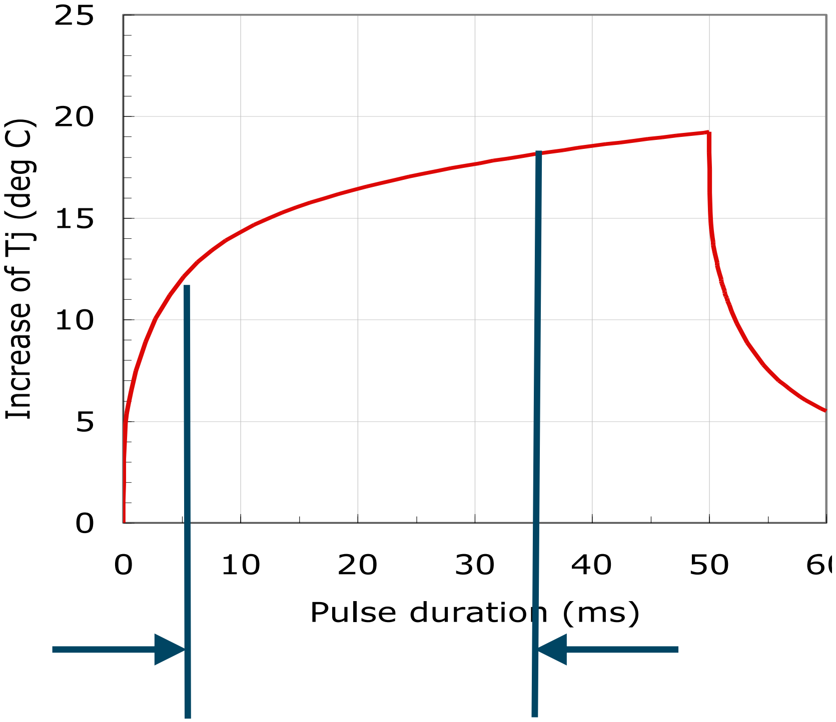
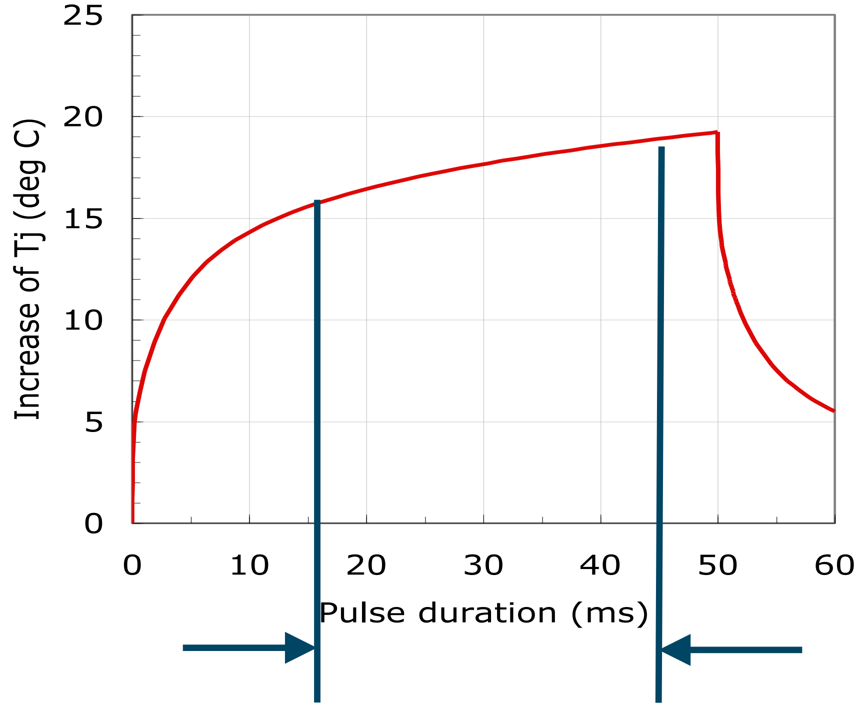
# Popular Industry Method: Spectrometer Timing Uncertainty Means LED Tj Associated With Measurement Varies



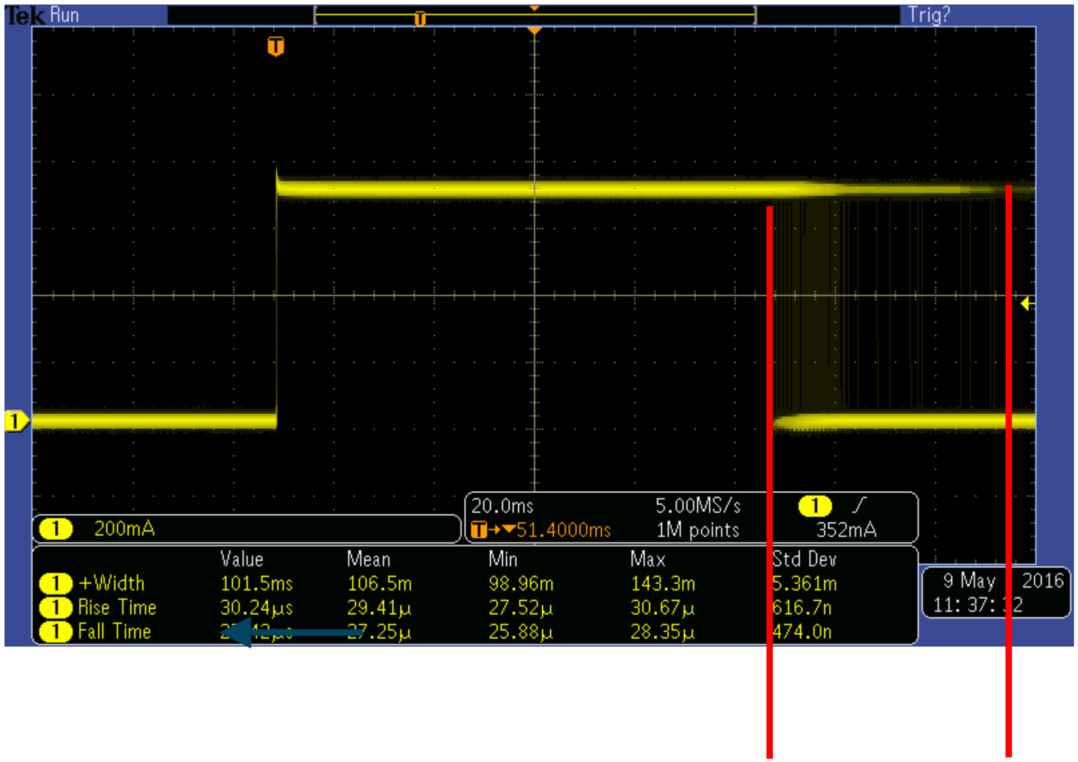

Measurement aperture 1:
Average Tj +15C




Measurement aperture 2:
Average Tj +17C

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

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




Example: 42% Pulse Width Jitter

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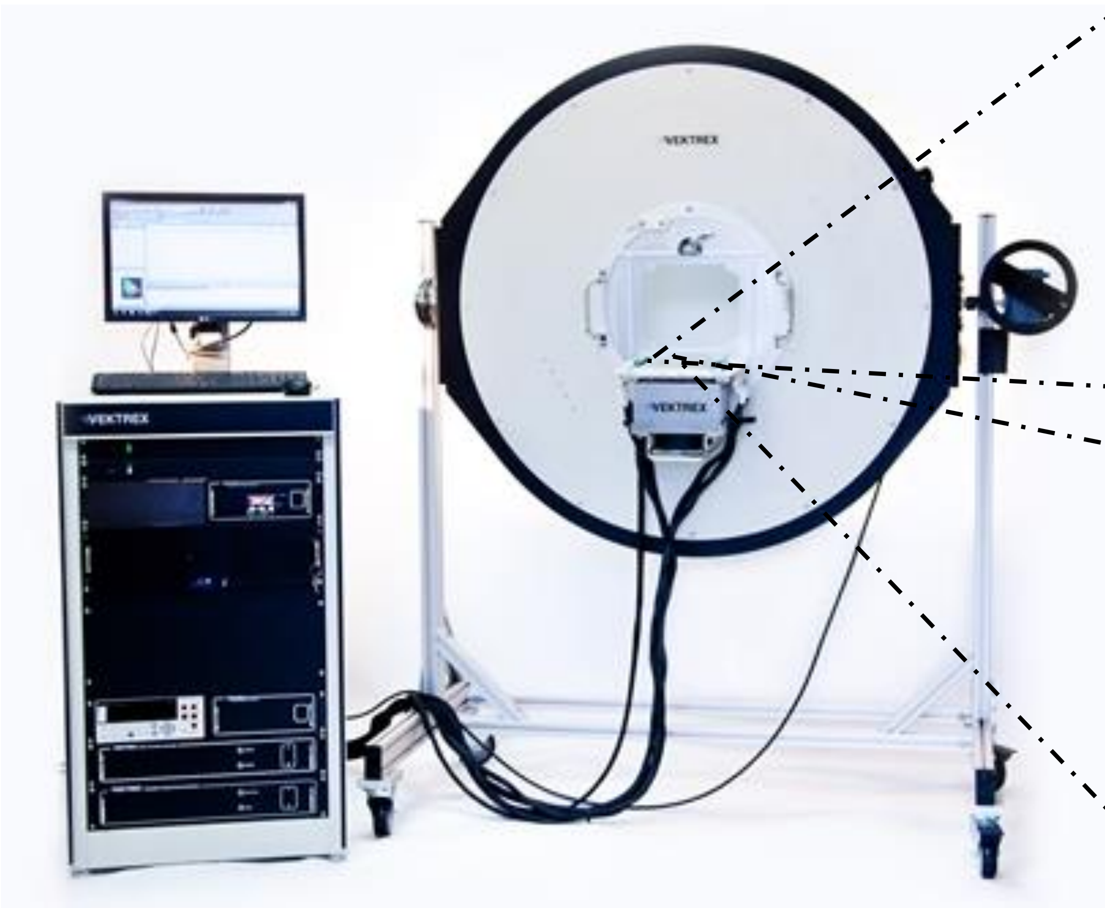
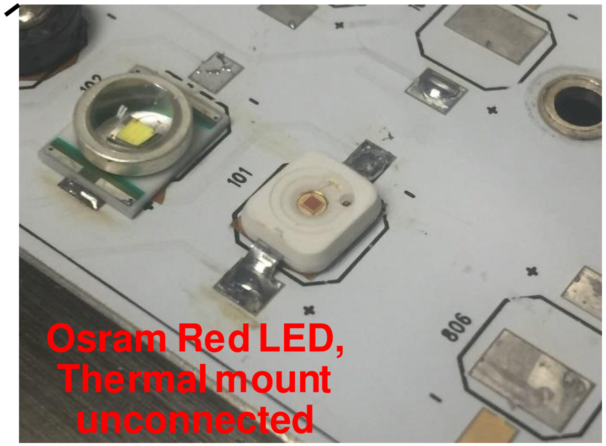
# Vektrex Experiment: Quantify Industry Method Error Sources

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

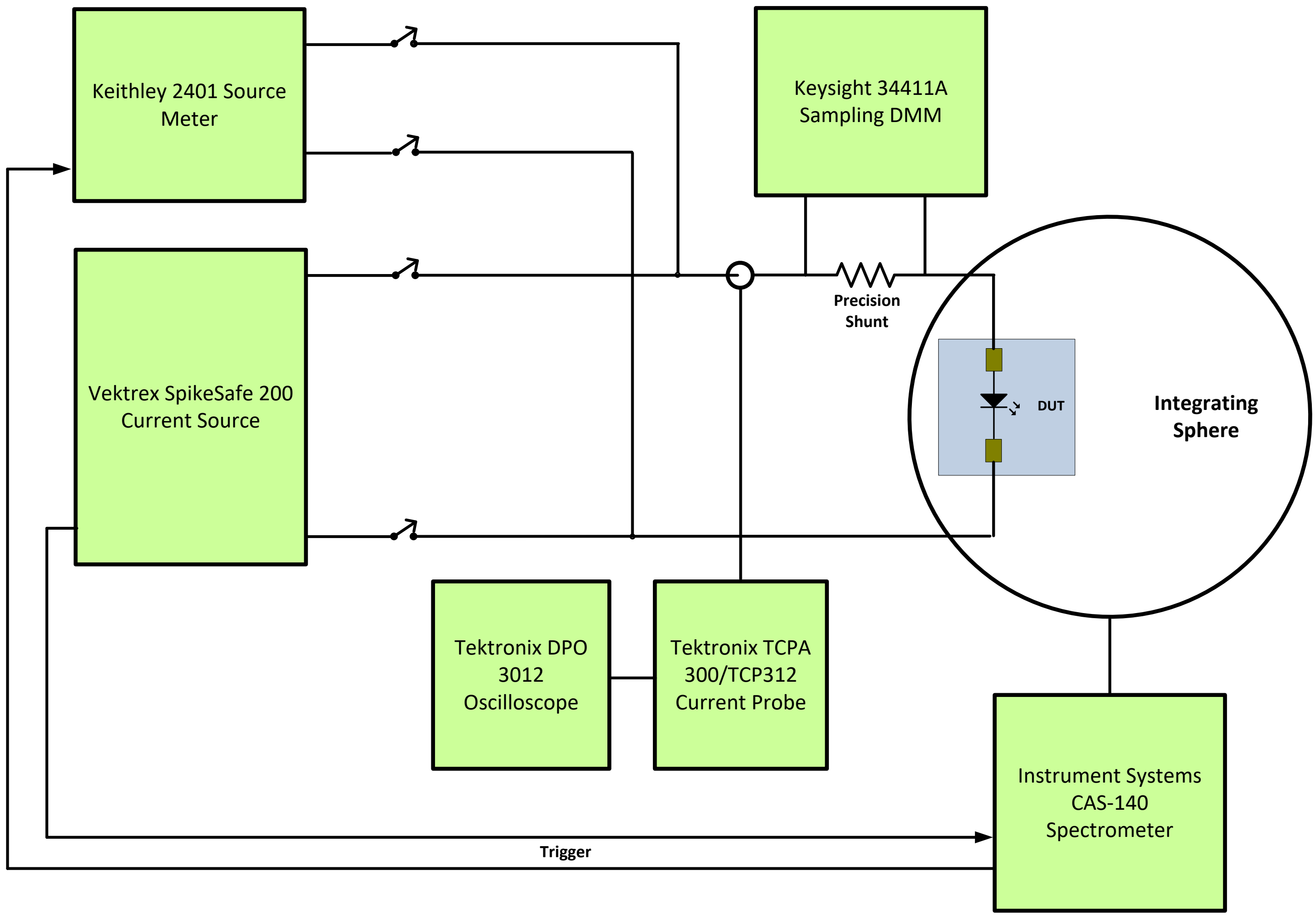
| Mode | Timing Controlled By | Link | Timing Variability |
|---|---|---|---|
| CAS-140/Keithley Sychchronous Mode | Software application | GPIB commands to current source & spectrometer | 40-50ms |
| CAS-140/Keithley Triggered Mode | Spectrometer | Hardware trigger line | 1-5ms |
| CAS-140/Vektrex Triggered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

# Vektrex Experiment Setup: Two LED Types Tested






# Vektrex Experiment: Equipment Block Diagram



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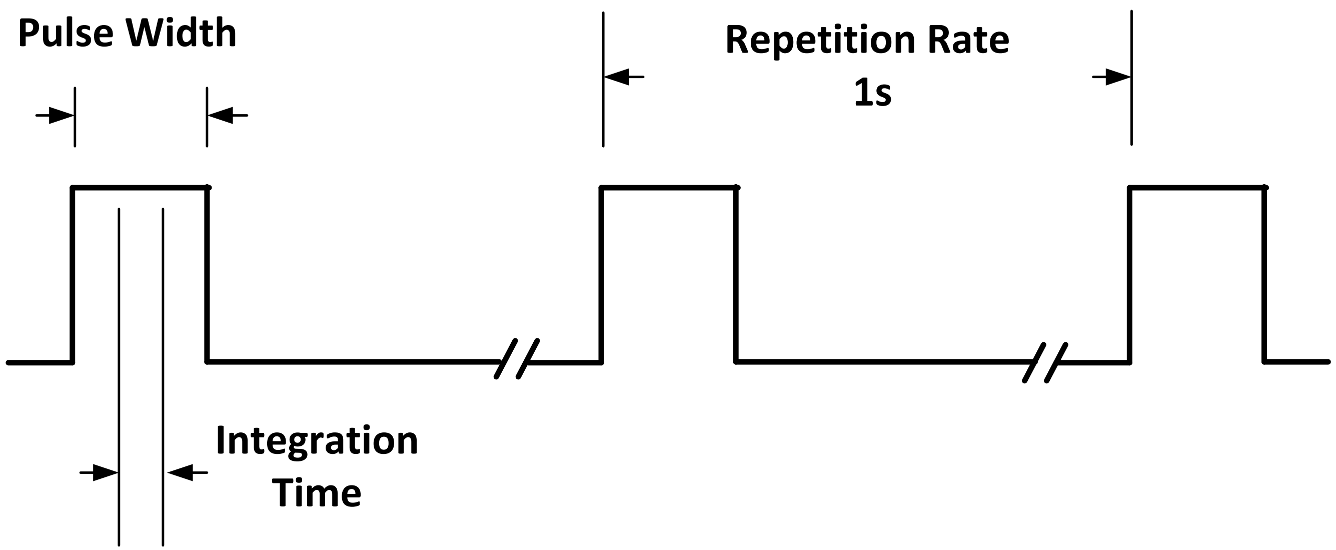
# Vektrex Experiment: Measurement Single Pulse Timing




500 measurement samples collected





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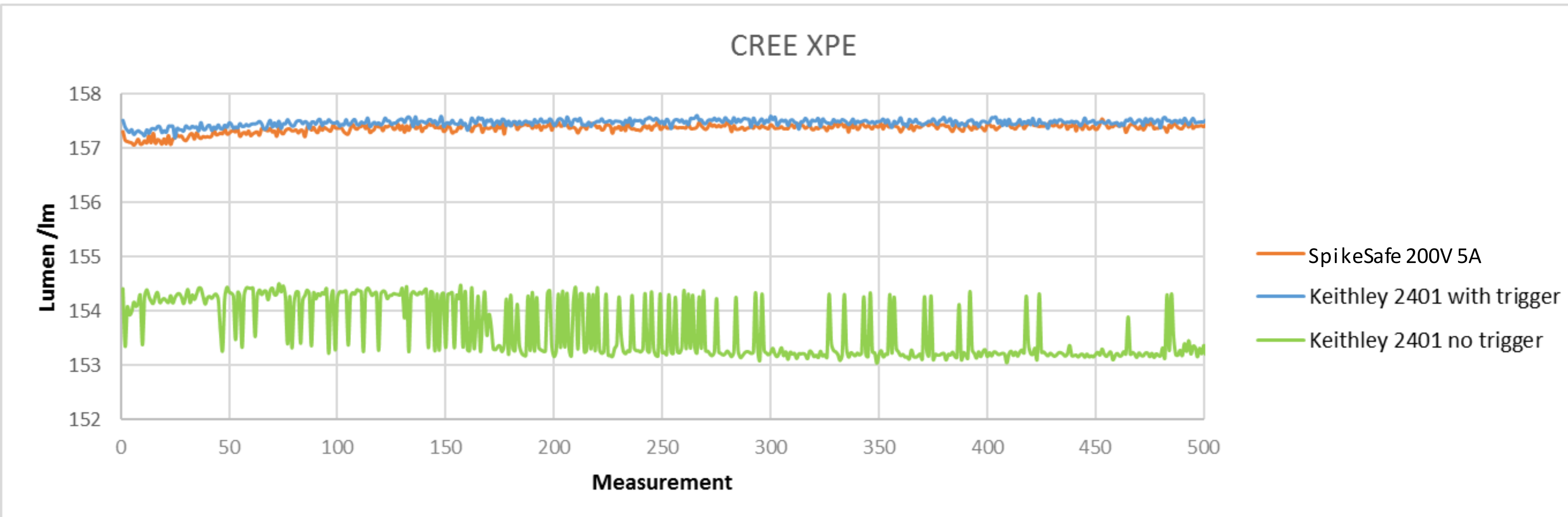
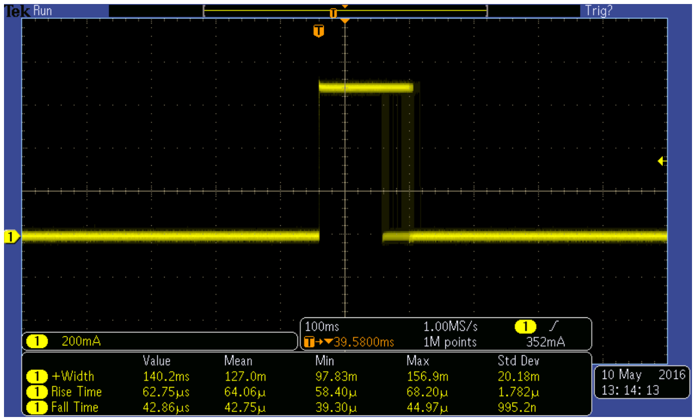
# Vektrex Experimental Scenarios

| 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 | | 127 ms | |
| | | | Triggered (Trigger out) | Keithley | | 15.35 ms | |
| | | | Triggered (Trigger in) | Vektrex | 700mA | 15 ms | 1s |
| 2 | Single Pulse | Osram LY Red off MCPCB | Synchronous | Keithley | | 104.5 ms | |
| | | | Triggered (Trigger out) | Keithley | | 15.37 ms | |
| | | | Triggered (Trigger in) | Vektrex | 1A | 15 ms | 1s |
| 3 | Continuous | Bridgelux BXRA | Untriggered | Vektrex | 2A | 100us | 1s |

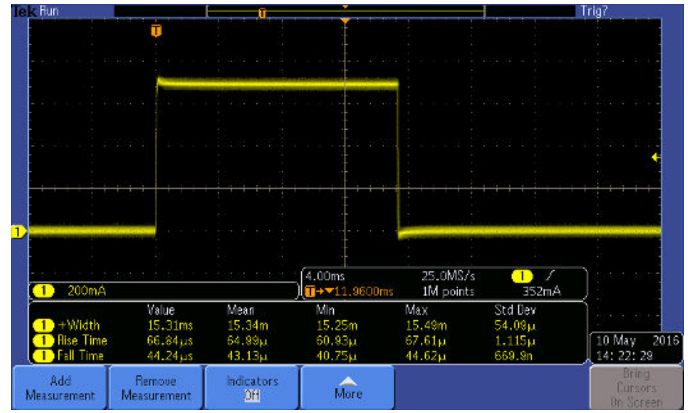
# Scenario 1: Cree XPE Flux – 500 Measurement Data



# Scenario 1: Cree XPE Current Waveforms



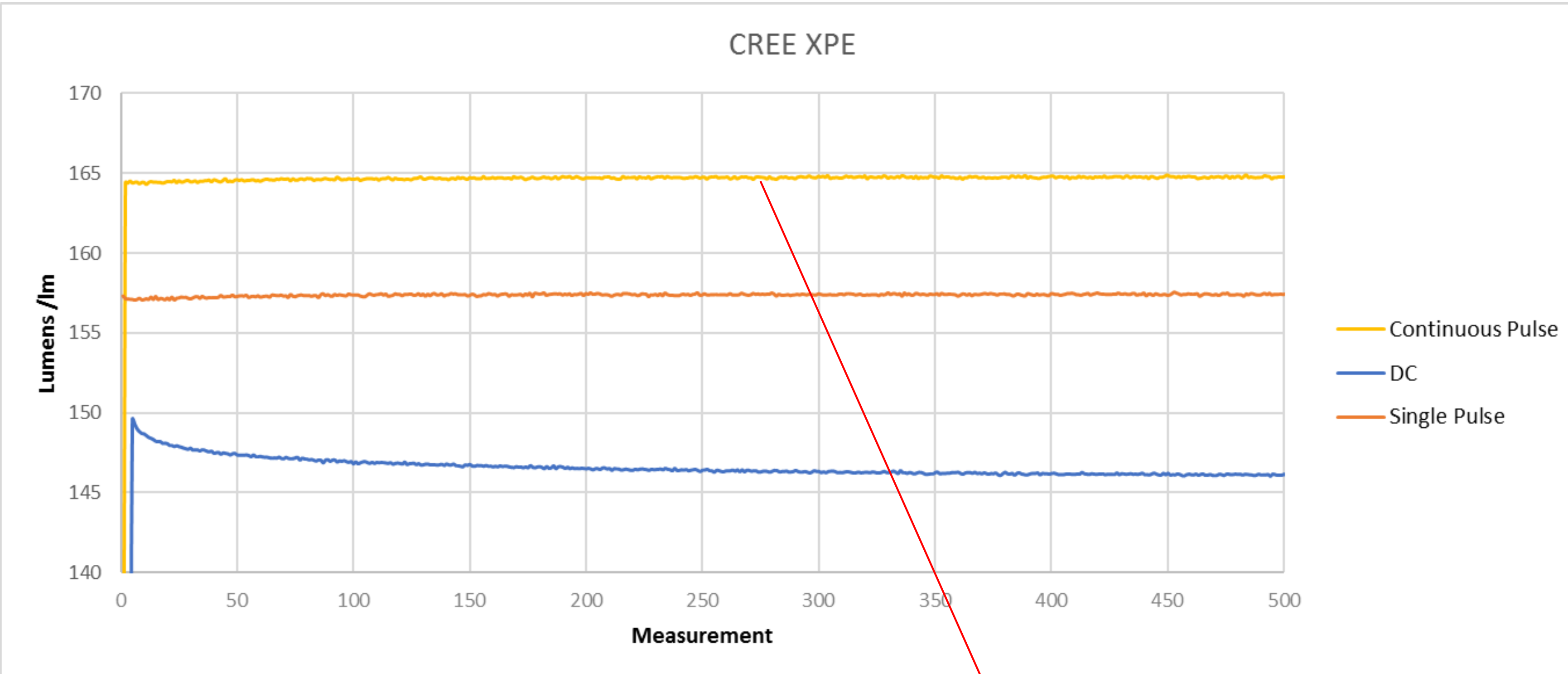

Keithley synchronous mode, 127ms pulse 30ms jitter




Keithley triggered 15.3ms pulse, 250us jitter


SpikeSafe 5ms, no measurable jitter

# 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



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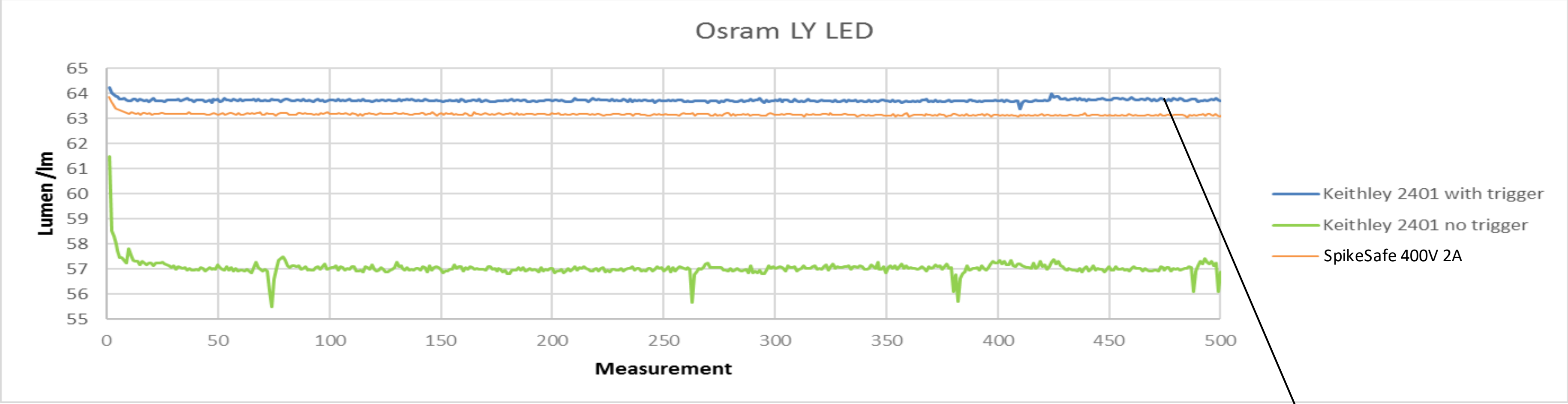
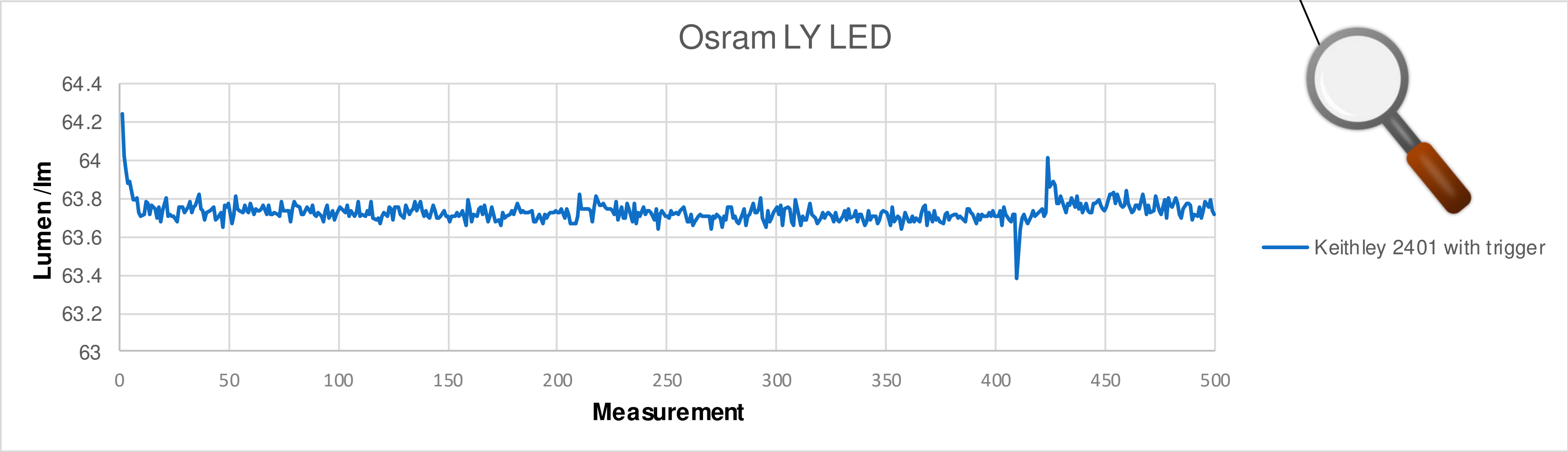
# Scenario 2: Osram LY Flux – 500 Measurement Data



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






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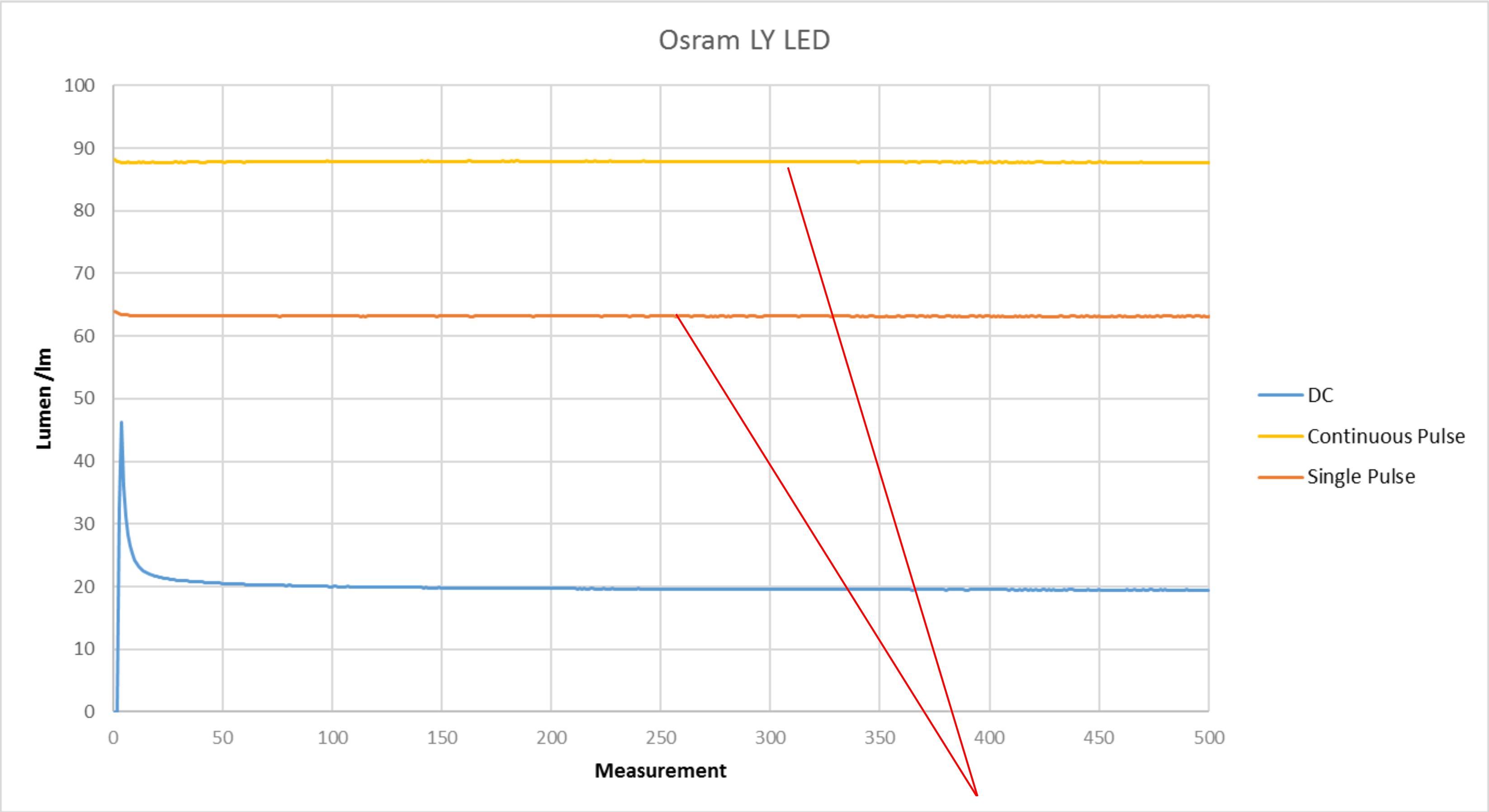
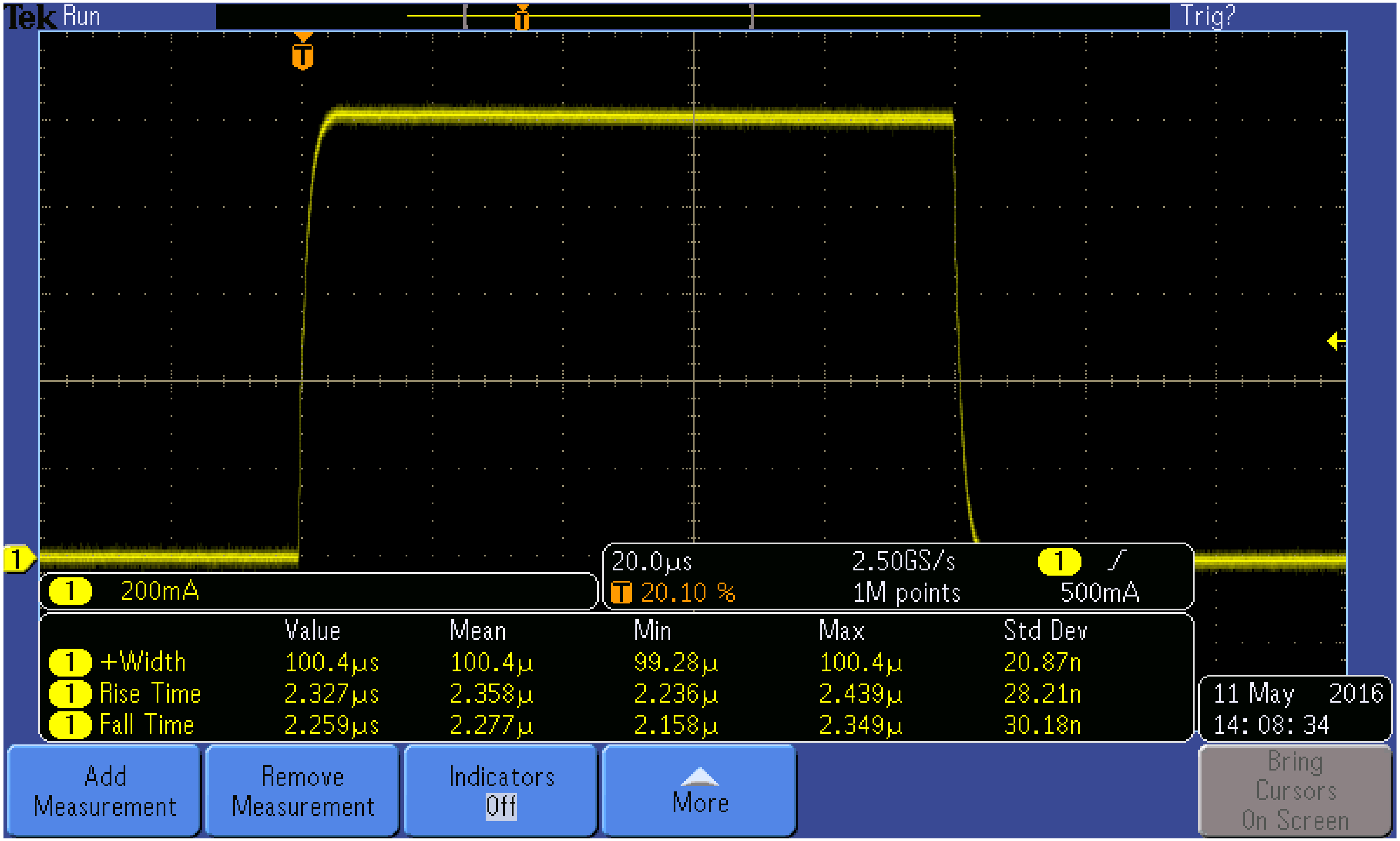
# Scenario 2: Osram LY Flux – LM-85 Measurements

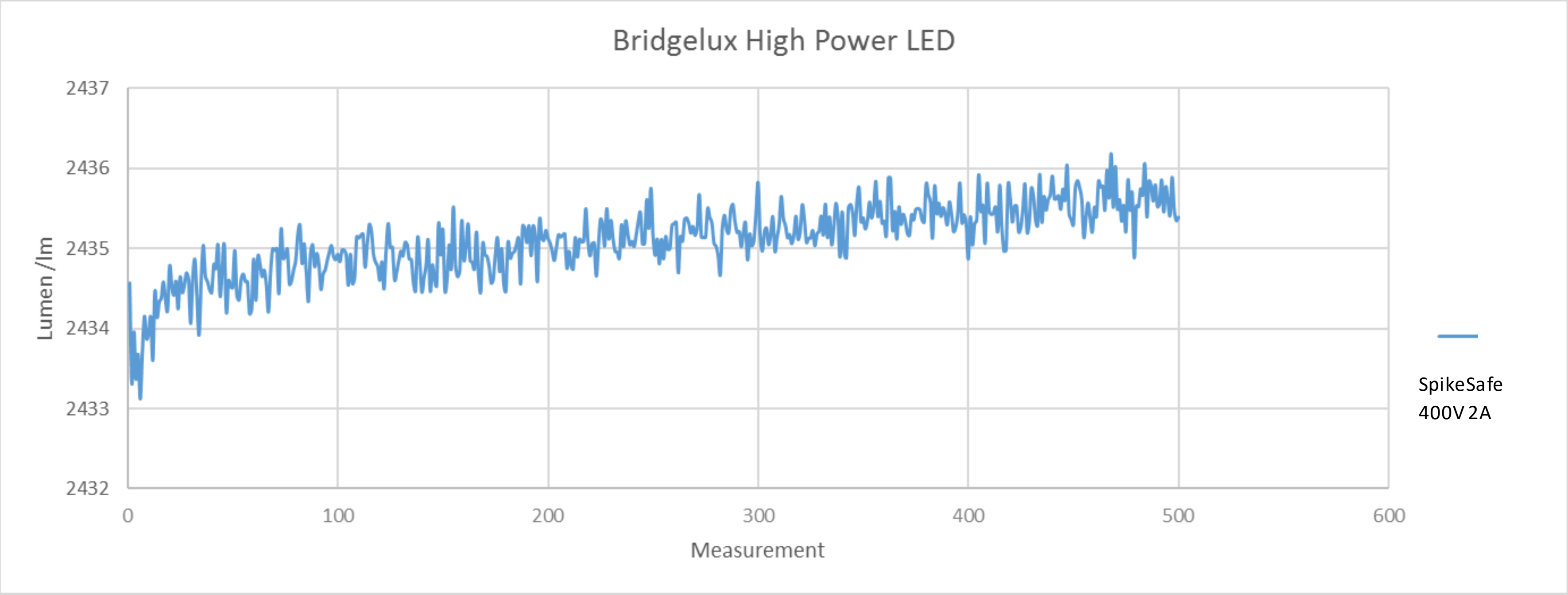



30% drop in flux for single pulse, even with 15ms pulses

# Waveform Used for LM-85 Continuous Pulse Measurements



# 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



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# 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 | | |

# 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