LED Sources in Photometry at NIST

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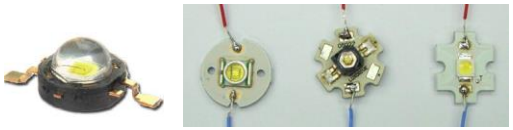
Outline

1. Needs for LED Standards
2. NIST Calibration Services for LED products
3. NIST MAP2 Solid-State Lighting
4. Related activities in CIE, CCPR, and IEA

"LED standards"
"LED products"

LED lamps

LED packages (high-power LEDs)



1. Needs for LED standards

(1) Check standards for luminous flux and color

- Primary traceability from total spectral radiant flux standards for a sphere-spectroradiometer system.
- Verify the uncertainty of sphere-spectroradiometer systems or goniophotometers measuring LED products.

(2) Reference standards for luminous flux

- Traceability of luminous flux (absolute scale of the sphere system) from calibrated LED lamps, (relative spectral calibration from total spectral radiant flux)

(3) Transfer standards for intercomparisons

- Proficiency test artifacts (e.g., NIST MAP)
- Intercomparison of luminous flux (and color) (future CCPR, RMO comparisons)

(4) LED standard (reference) Illuminants

Benefits of LED standards for photometry

(1) The same type of light sources most commonly measured in the industry nowadays.

- Lower uncertainty as reference/check standards for measurement of LED products.

(2) Low aging, good short-term stability

- Similar to standard detectors in photometry
- Shelf-life (long-term) is not well known.
- Stabilization time depends. (LED lamps generally take longer time. Temp-controlled LED package is fast)

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NIST Calibration Services for LED products

(POC: Yuqin Zong; zong@nist.gov)

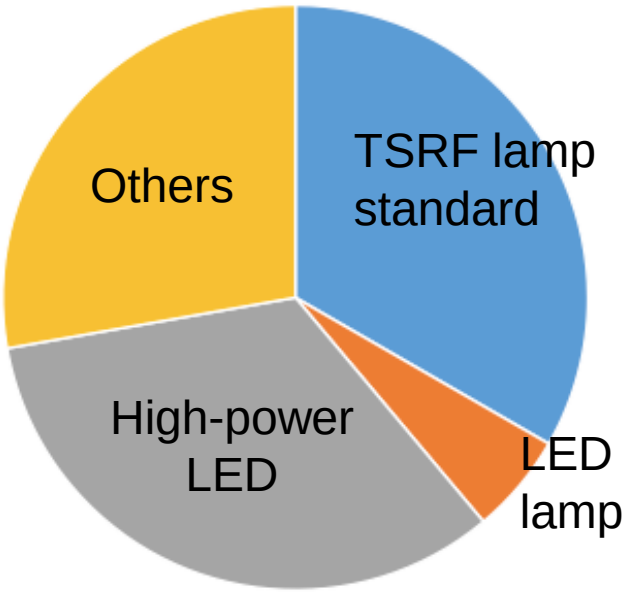
1. LED lamps (customer-submitted)
   Operating conditions: Typically IES LM-79 or CIE S025 and details reported.

2. LED packages (customer-submitted)
   Operating conditions
   - DC, heatsink temp (e.g., 55° C, 55° C)
   - DC, junction temp (LM-85, e.g., 25° C, 55° C)

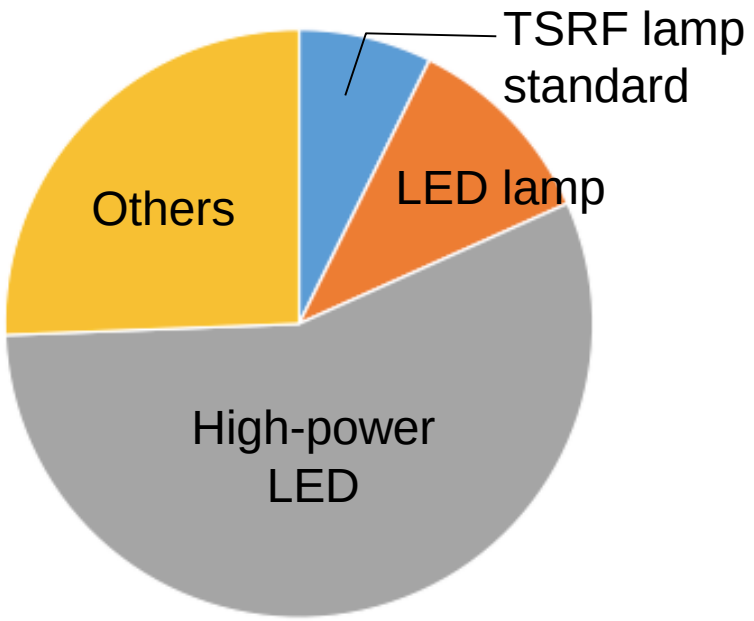
3. Measurement quantities
   - Luminous flux
     $U \approx 1$ % (k=2) or less for white LED and LED lamps
   - Color quantities (x, y, u', v', CCT, Duv, R_a)
     $U \approx 0.001$ (k=2) or less in u', v' for white LED and LED lamps
   - CIE Averaged LED luminous intensity.. $U \approx 1$ to 4 % (k=2) depending on color.

FY 2016 Total Flux Calibrations

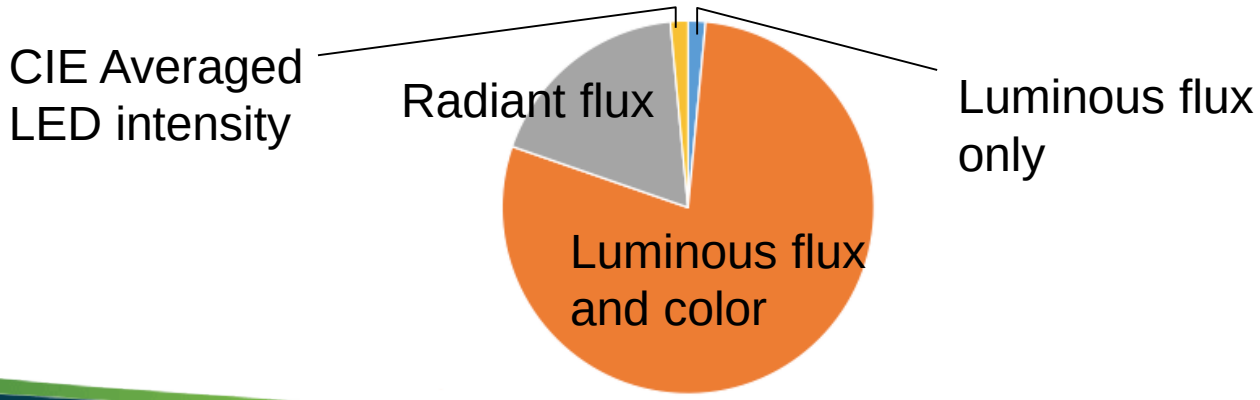
Number of requests



Number of artifacts

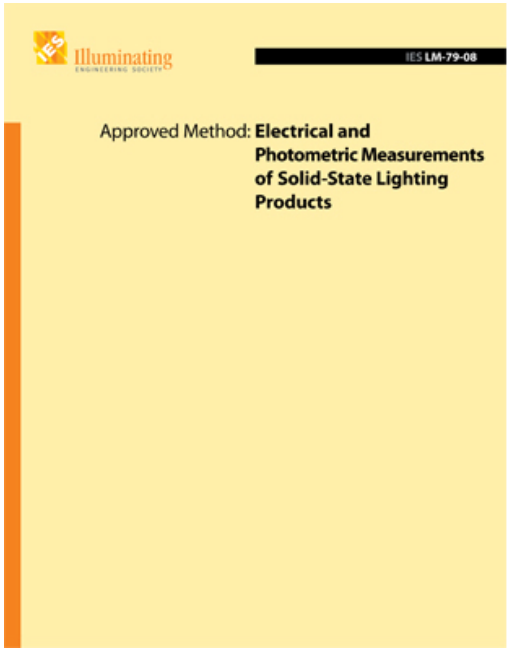


Type of LED measurements

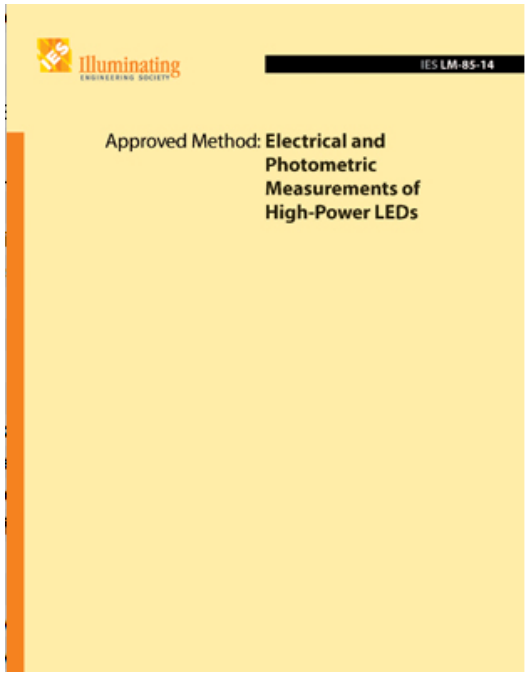


NIST's major contributions to the test method standards

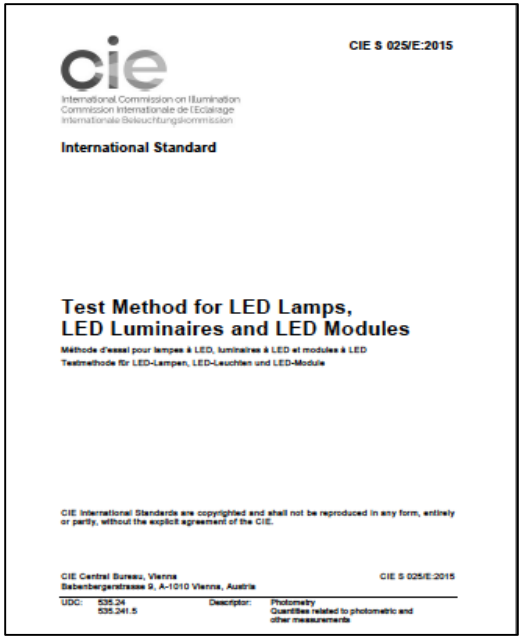
IES LM-79 (2008)
Measurement of SSL products
Y. Ohno 2008 WG Chair
Cameron Miller, Revision Chair



IES LM-85 (2014)
Measurement of High-Power LEDs
Y. Ohno 2014 WG Chair
Yuqin Zong, Revision Chair



CIE S025 (2015)
Test method for LED lamps, LED modules, and LED luminaires
Y. Ohno TC2-71 chair



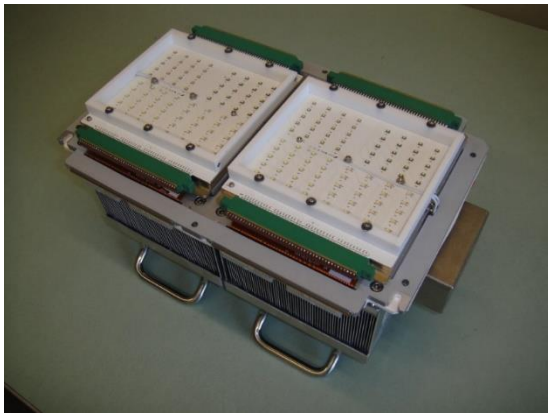
Developing LED Standards at NIST

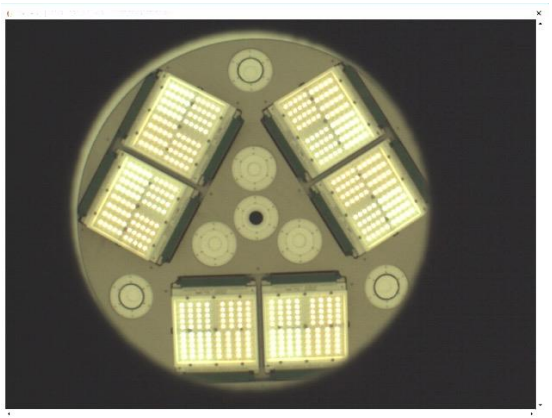
(POC: Yuqin Zong, yuqin.zong@nist.gov)

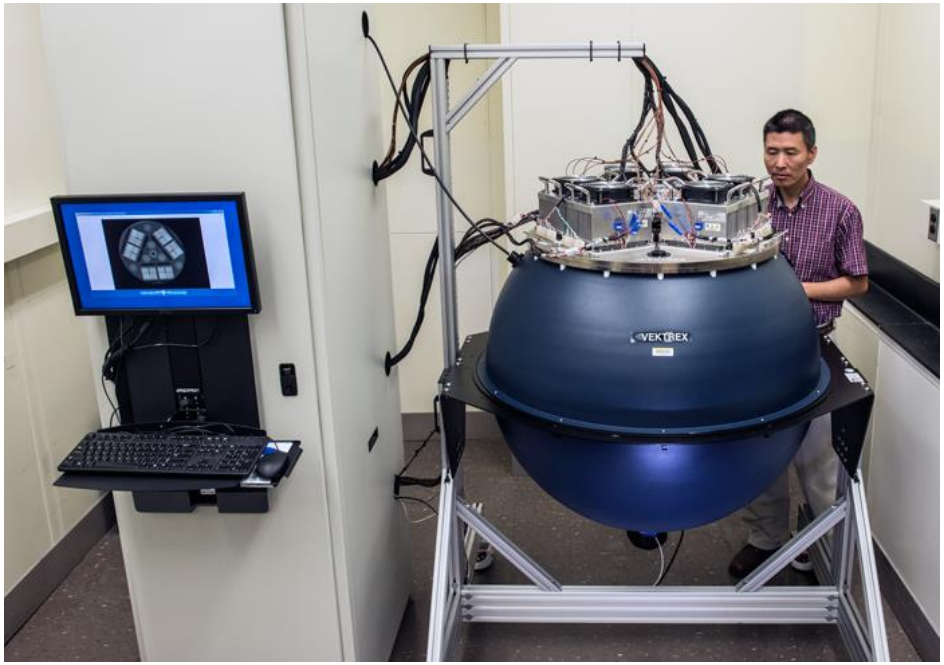
- LED package mounted on temperature-controlled heatsink
- First batch (10 LEDs) has been aged for more than a year
- Second batch (25 LEDs) aging started December 2015
- Also evaluating commercial “standard LED” products
- Long-term stability measurement started in January 2016.

NIST LED lifetime test facility (for LED packages)

(POC: Yuqin Zong, yuqin.zong@nist.gov)







- Automated measurements of luminous flux maintenance & color shift.
- Produces low uncertainty data under real operating conditions
- Enables developing accurate LED lifetime prediction models.

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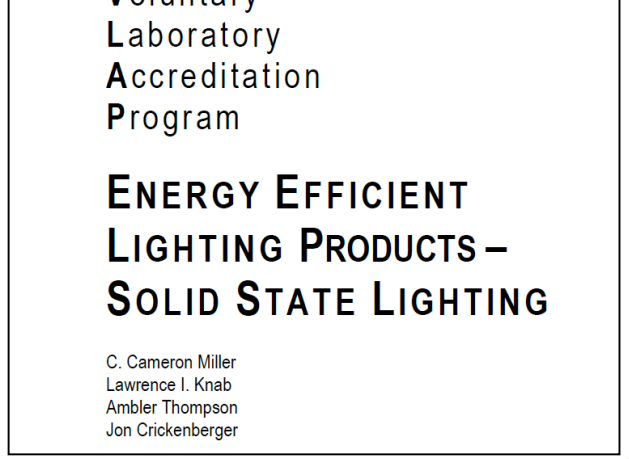
4. Related activities in CIE and CCPR

NIST Measurement Assurance Program for SSL

(POC: Maria Nadal, maria.nadal@nist.gov)

- Proficiency Test program for SSL testing laboratories. (bilateral comparisons between NIST and applicant labs)
- Serving NVLAP and other accreditation bodies providing SSL accreditation for Energy Star and DOE programs.
- MAP1 ran from 2010 to 2014 with 118 participants.



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A Snapshot of 118 Solid State Lighting Testing Laboratories' Capabilities

C. Cameron Miller, Hannah Hastings & María E. Nadal

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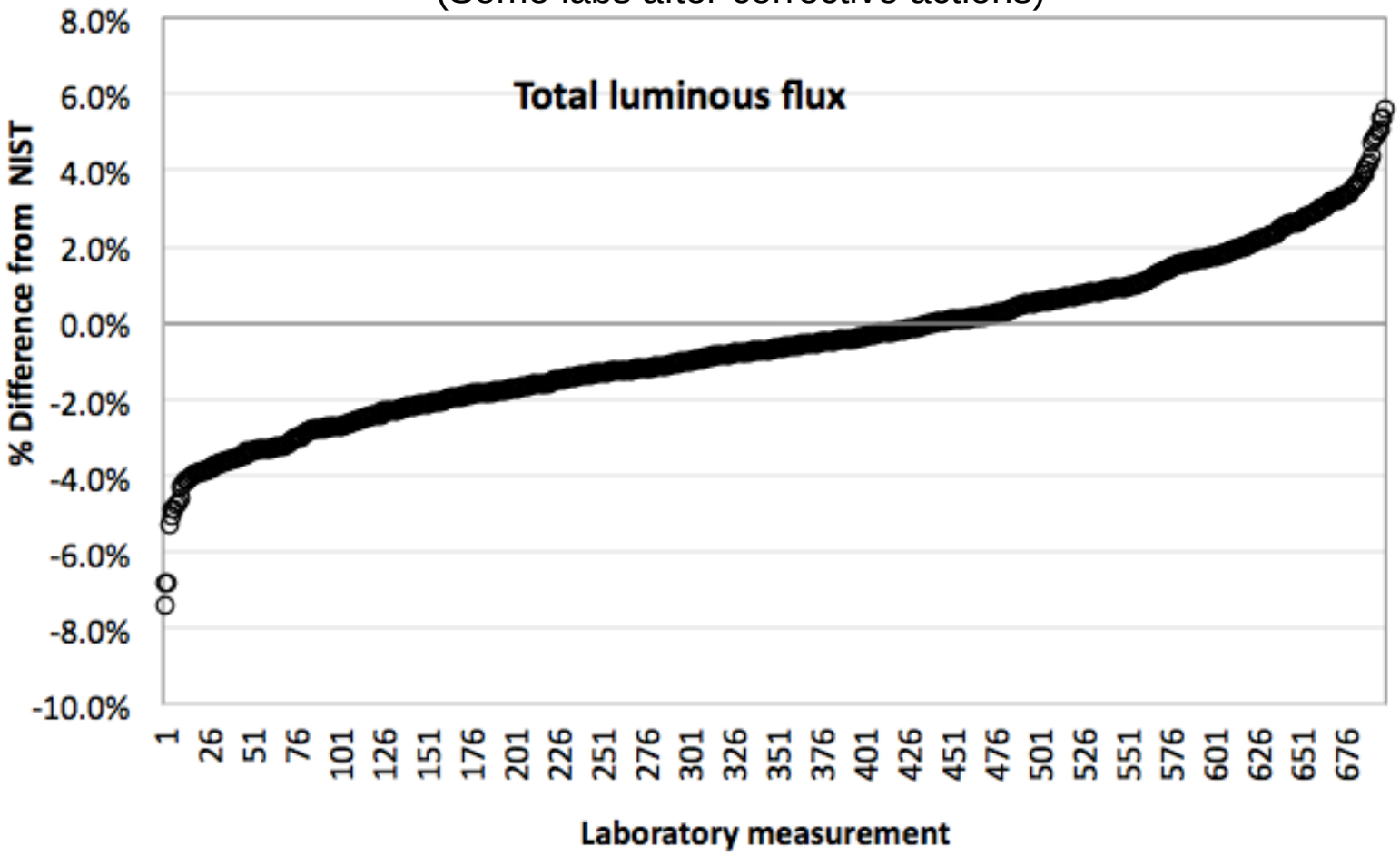
Published online: 23 Jun 2016.

An example plot of MAP1 results - all labs, all artifacts

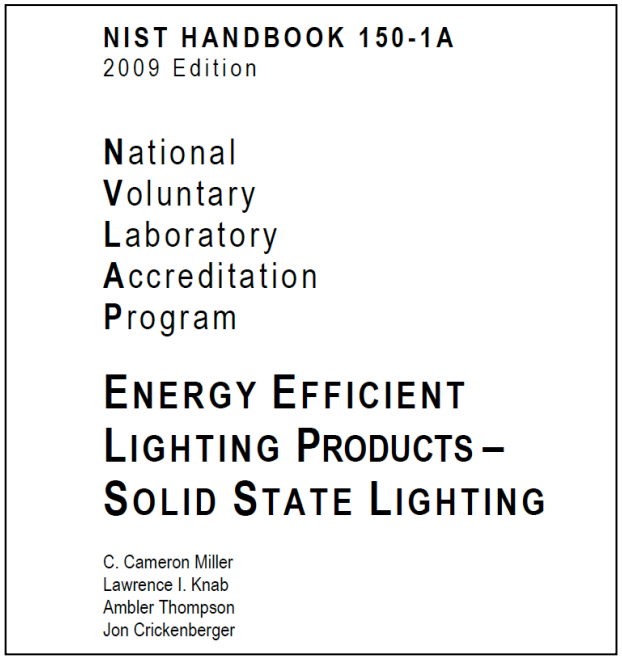
(Some labs after corrective actions)



NIST Measurement Assurance Program

For Solid State Lighting

- Proficiency Test program for SSL testing laboratories. (bilateral comparisons between NIST and applicant labs)
- Serving NVLAP and other accreditation bodies providing SSL accreditation for Energy Star and DOE programs.
- MAP1 ran from 2010 to 2014 with 118 participants.
- **MAP2 started in January 2015 using a new set of artifacts.**



MAP2 Artifacts

MAP2 Artifacts (1)

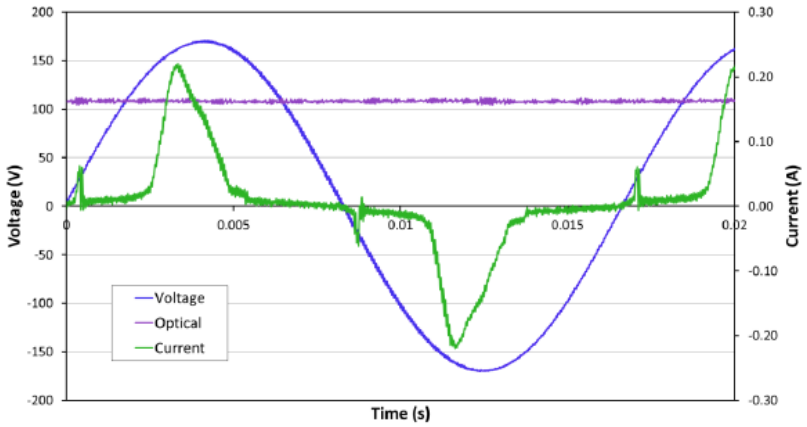
	L Type - Phillips EnduraLED 800 Series A19
	Operating: 120.0 V, 60 Hz AC Power
	Nominal values: 12.5 W, 2700K, 80 CRI, 800 lm
	C Type - CREE A19 Series LED Lamp
	Operating: 120.0 V, 60 Hz AC Power
	Nominal values: 9 W, 5000K, 80 CRI Ra, 800 lm
	G Type - Sylvania Ultra PAR16 LED Lamp
	Operating: 120.0 V, 60 Hz AC Power
	Nominal values: 7 W, 3000 K, 84 CRI Ra, 350 lm
	W Type - Phillips LED A shape, medium base, E26
	Operating: 120.0 V, 60 Hz AC Power
	Nominal values: 11 W, 5000 K, 80 CRI Ra, 830 lm

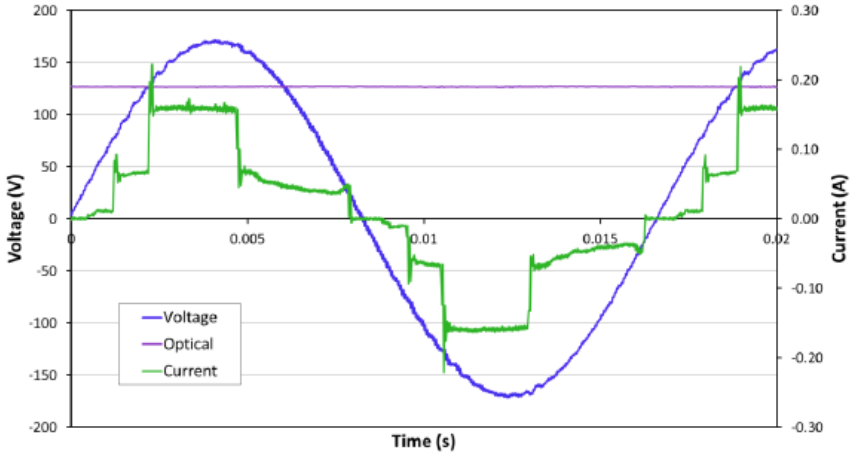
Specific firms and trade names are identified in this presentation to specify the experimental procedure adequately. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

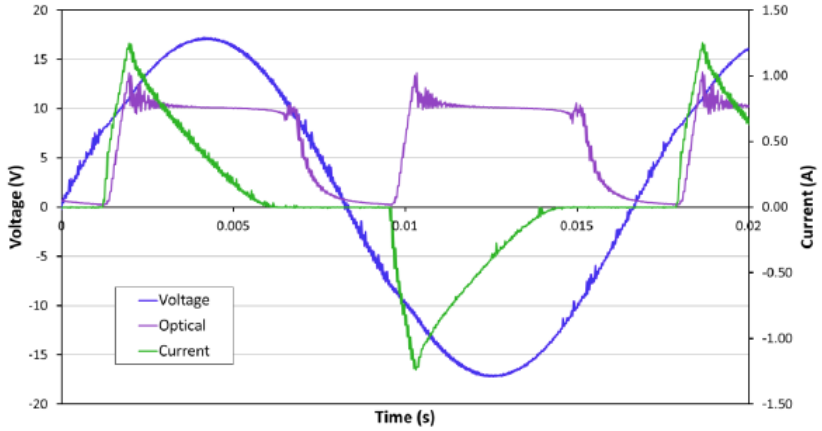
MAP2 Artifacts (2)

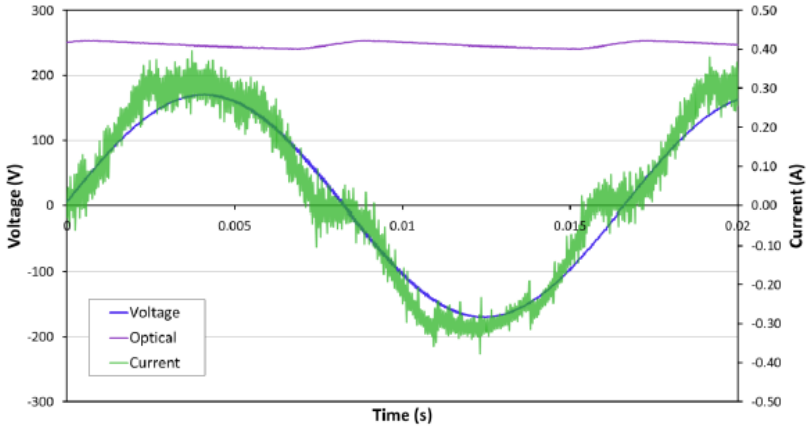
	B Type - Sylvania Ultra LED MR16
	1st – AC power: 12.0 V, 60 Hz; 2nd – DC power, 12.0 V constant voltage
	Nominal values: 6 W, 3000 K, 85 CRI Ra, 350 lm
	LV Type - Bulbrite Frosted E26 medium screw (optional)
	1st – AC: 11.0 V, 60 Hz; 2nd - DC: 4.1 A constant current
	Nominal values: 50 W, 2856 K, 100 CRI Ra, 790 lm
	T Type - Philips EnduraLED T8
	Operating voltage: 120.0 V AC, 60 Hz (Retrofit lamp)
	Nominal values: 19 W, 100-277 V, 85 CRI Ra, 1600 lm
	U Type - Philips LED T8 InstantFit
	Operation: 120.0 V AC, 60 Hz with instant start ballast (Replacement lamp)
	Nominal values: 19 W, 100-240 V, 80 CRI, 2000 lm

Waveforms of some of these lamps





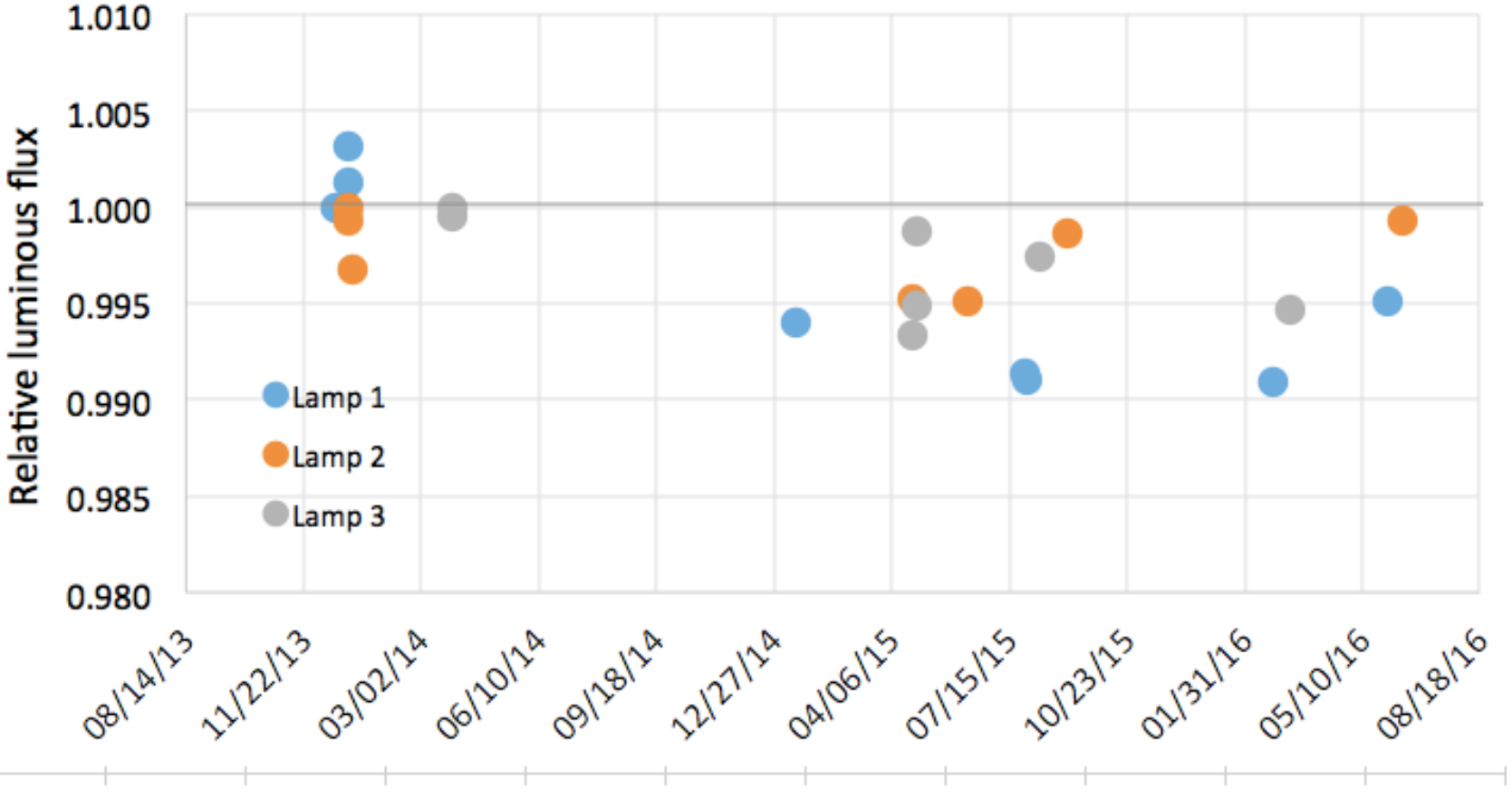




NIST 2.5 m sphere (used for all LED sources)

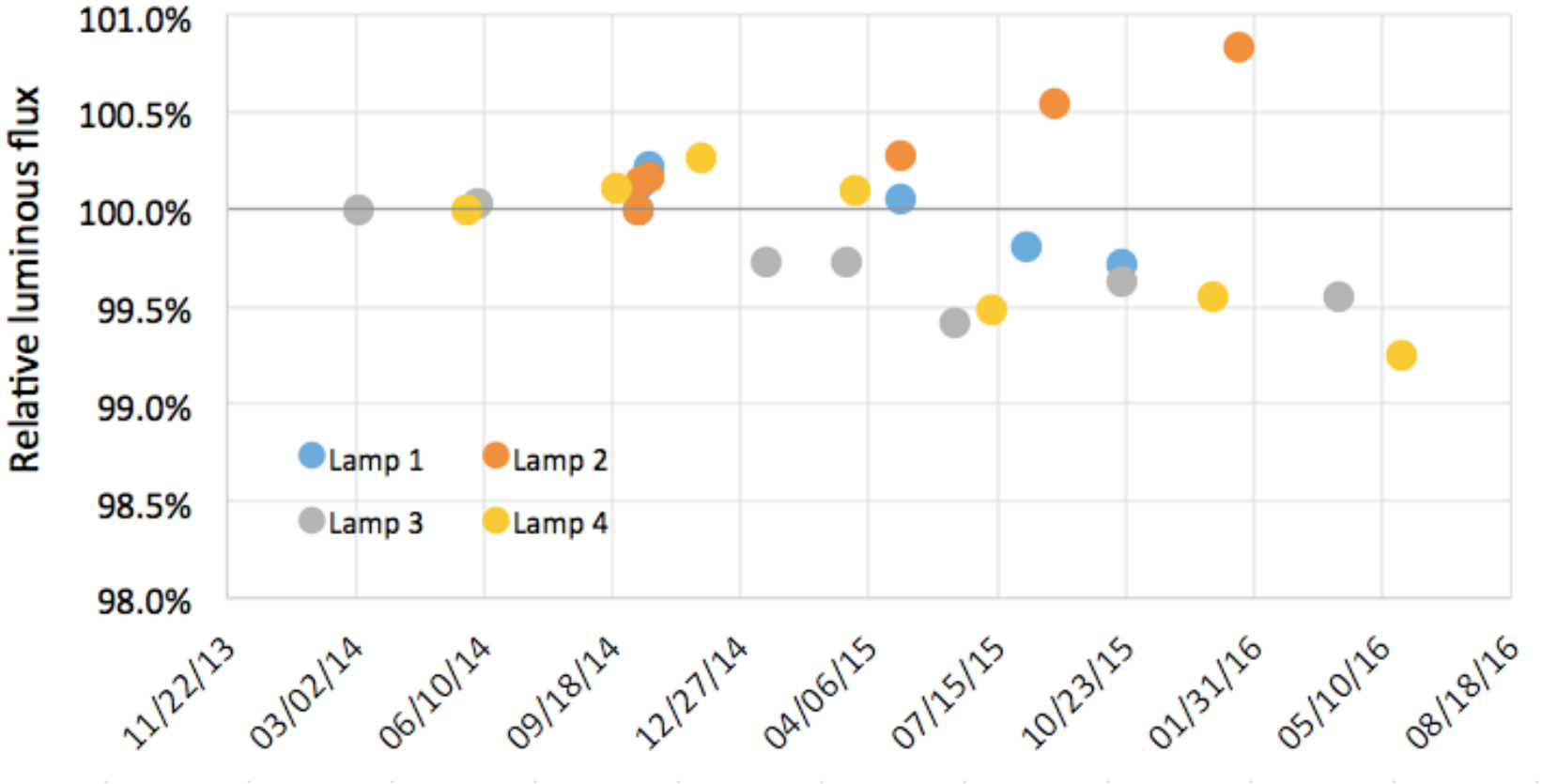
Stability during the measurement campaign

Example 1

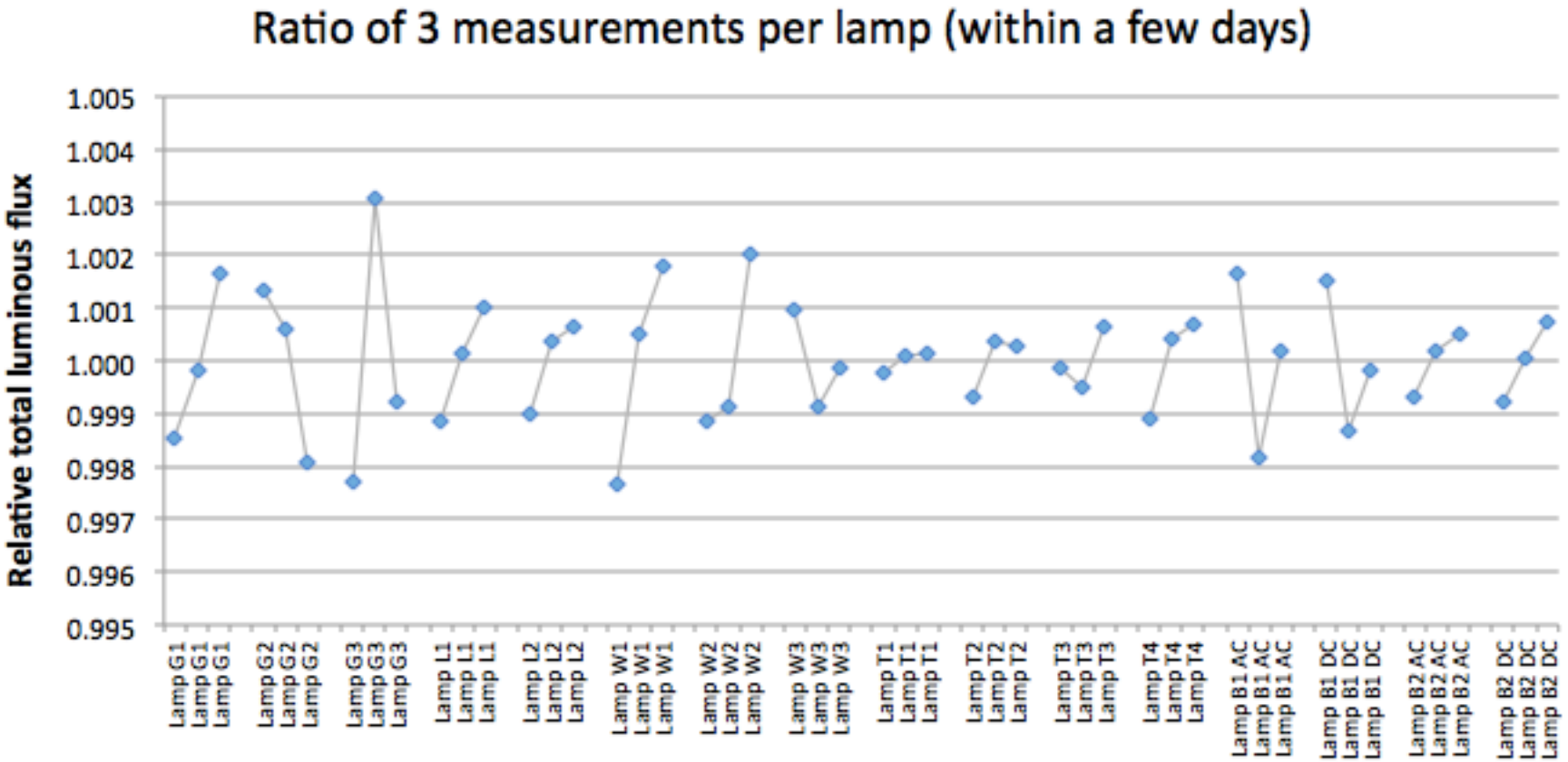


Stability during the measurement campaign

Example 2



Short-term reproducibility
(with no shipping)



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Related activities in CIE

- CIE Div. 2 R2-71 **LED calibration sources" (T. Poikonen)**

  Investigation for defining one or two LED reference spectra (may be called "Illuminants L") for calibration of photometric instruments.

- CIE R1-62 **Typical LED spectra** (Reporter: S. Jost)

  Propose a set of white LED spectra for possible inclusion in CIE 15 4th edition for colorimetric purposes (TC1-85).

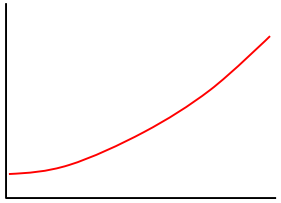
The idea of LED Illuminants

(for calibration of photometers)

Photometric instruments
- Illuminance meters
- Luminance meters
- Goniophotometers

Current practice

Calibrated against:

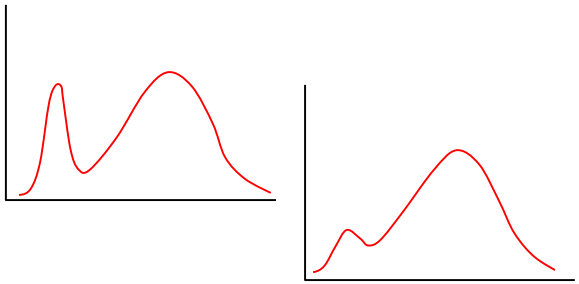


”CIE Illuminant A” or
”CIE Source A”

They measure:

LED products

Spectral mismatch errors



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- Luminance meters
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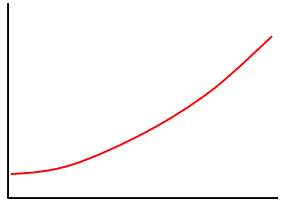
Current practice

Calibrated against:



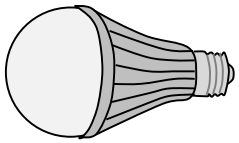
”CIE Illuminant A” or
”CIE Source A”

They measure:

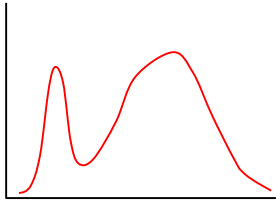
Possible new practice

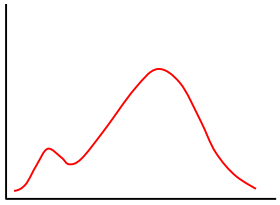
LED products

Much lower uncertainties



”Illuminant L” or
“Source L” ?





Related activities in CCPR

- WG-KC **TG-4 Pilot study for the use of alternative standards for photometric comparisons**

  Chair: Erkki Ikonen (MIKES)

  Members: MIKES, KRISS, LNE, MIKES, MSL, NIST, NMIJ, NRC, PTB

  Scope: to investigate the use of white LED products (but not limited to those) as artifacts for future photometric comparisons in CCPR.

- WG-SP **Discussion Forum on Use of White LED Sources for Photometry**

  Chair: Tatsuya Zama (NMIJ/AIST)

  Members: Alicia Pons (CSIC), Hsueh-Ling Yu (ITRI), Dong-Hoon Lee (KRISS), Jimmy Dubard (LNE), Peter Blattner (METAS), Erkki Ikonen (MIKES), LIN Yandong (NIM), Armin Sperling (PTB), Steven van den Berg (VSL), Joanne Zwinkels (ex-officio)

Related activities in IEA 4E SSL Annex

(POC: Yoshi Ohno, yoshi.ohno@nist.gov)

- IC 2013 Interlaboratory comparison of measurement of SSL products (110 labs) – Final report 2014.

- IC 2017 Interlaboratory comparison of measurement of SSL products using goniophotometers (in preparation)