Selection and Characterization of Proficiency Test Artifacts for NVLAP Solid State Lighting Products Testing Accreditation

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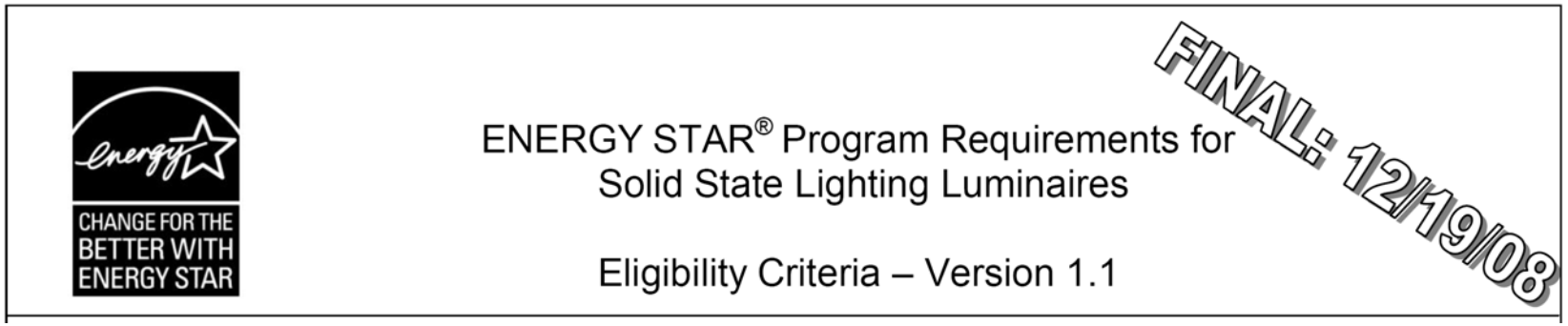
NIST

ENERGY STAR® program (SSL 1.1)



CIE Publication No. 13.3 – 1995 *Method of Measuring and Specifying Color Rendering of Light Sources*

CIE Publication No. 15 – 2004 *Colorimetry*

IESNA LM-58 – 1994 *Spectroradiometric Measurements*

IESNA LM-79 – 2008 *Approved Method: Electrical and Photometric Measurements of Solid-State Lighting Products*

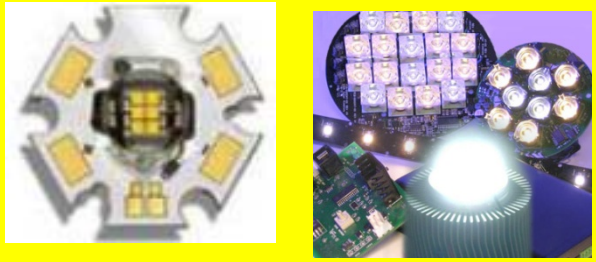
IESNA LM-80 – 2008 *IES Approved Method for Measuring Lumen Maintenance of LED Light Sources*

ANSI C82.77 – 2002 *Harmonic Emission Limits – Related Power Quality Requirements for Lighting (Power Factor)*

Measurement of LED/SSL Products

LED chips/packages

LED modules/clusters



SSL products

Measurement quantities

- Total luminous flux (lm)
- Luminous efficacy (lm/W)
- Correlated Color Temperature (K)
- Color Rendering Index
- Color Spatial Uniformity
- Zonal Lumen Density

NVLAP SSL Proficiency Testing

3.4.2 Laboratories applying for initial accreditation shall participate satisfactorily in a bi-lateral proficiency testing with NIST before accreditation will be granted. Solid state lighting luminaires along with instructions for specimen handling, preparation (including seasoning and pre-burning), conditioning, mounting, and testing, and data forms are provided to the participating laboratory. The completed test data forms are sent by the participating laboratory to NIST. The results are summarized in a report, which is edited and sent by NVLAP to the participant.

3.4.3 As NVLAP prescribes, NVLAP or a proficiency testing contractor conducts rounds at regular intervals. Solid state lighting luminaires along with instructions for specimen handling, preparation (including seasoning and pre-burning), conditioning, mounting, and testing, and data forms are provided to the participating laboratories. The completed test data forms are sent by the participating laboratories to NVLAP or, as directed, to the proficiency testing contractor. The results of all participants are summarized in a Tech Brief, which is edited and sent by NVLAP to the participants. The identity and performance of individual laboratories are kept confidential.

DOE Solid State Lighting CALiPER Program

Commercially Available LED Product Evaluation and Reporting

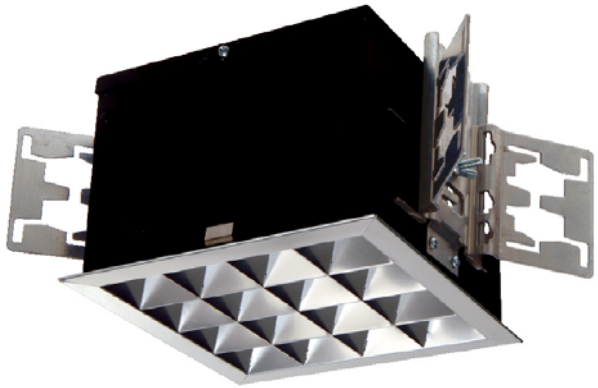
- All replacement lamps tested through CALiPER are integral replacement lamps
  - including light source, thermal management, driver and power supply electronics, and optics
  - as opposed to individual LED chips or separate arrays or LED engines
- Selecting products for testing (~20/round)
- Qualified, independent laboratories perform testing
- Based on IESNA draft standard LM-79
  - Electrical measurements
  - Integrating Sphere
    - Relative spectral distributions
    - Total radiant flux (gives efficacy)
    - Color quantities
  - Goniophotometry
    - Intensity distributions
    - Zonal lumens (gives efficacy)
    - Beam characteristics

Bi-lateral Proficiency Testing with NIST

Time line

- NIST prepares 2 – 3 sets of bi-lateral artifacts
- NIST distributes a set to a lab 1 month before on-site
- On-site assessment occurs
- Lab may measure bi-lateral artifacts, again
- NIST analyzes data and prepares a report

What goes into a set of bi-lateral artifacts?



Bi-lateral Proficiency Testing with NIST

White Lights – Photometric Scale

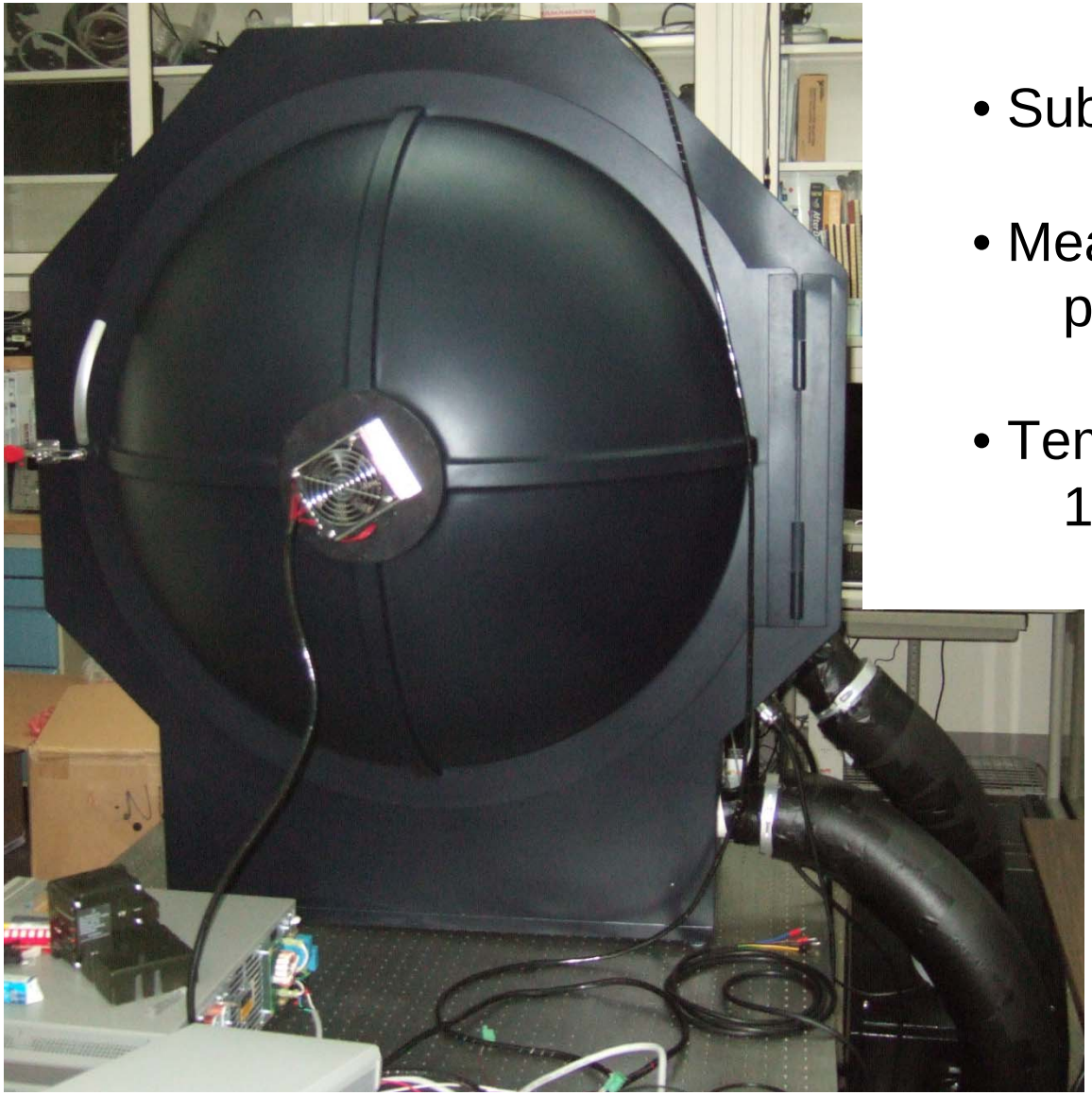
Power dependence

- Voltage ranges (AC and DC)
- Frequency ranges

Temperature dependence

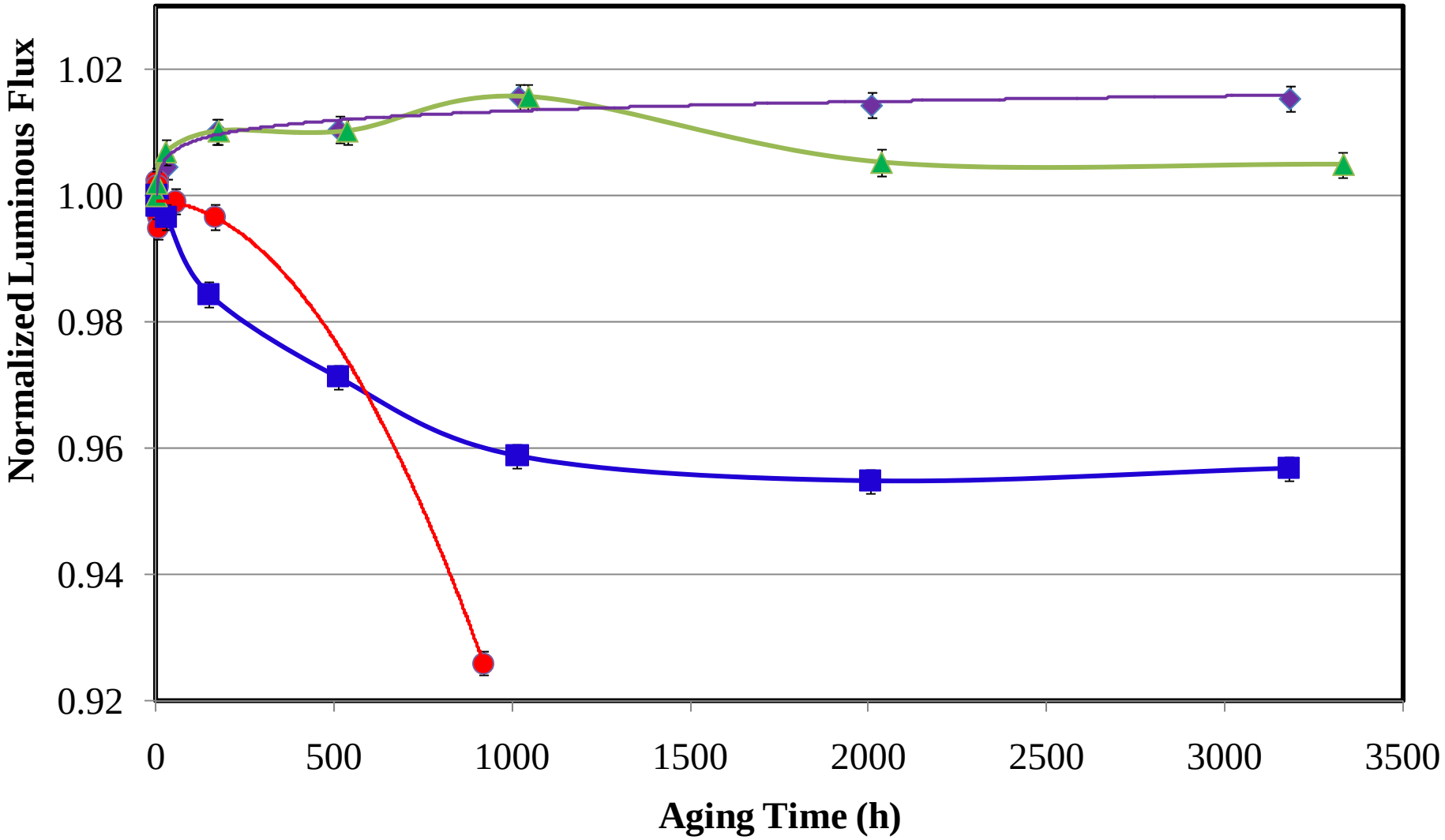
20°C – 30°C

Temperature Dependence



- Substitution photometry
- Measurement of small SSL products
- Temperature range
  15° C to 55° C

Aging Characterization



Artifact Characterization

Based on CALiPER results pick specific products

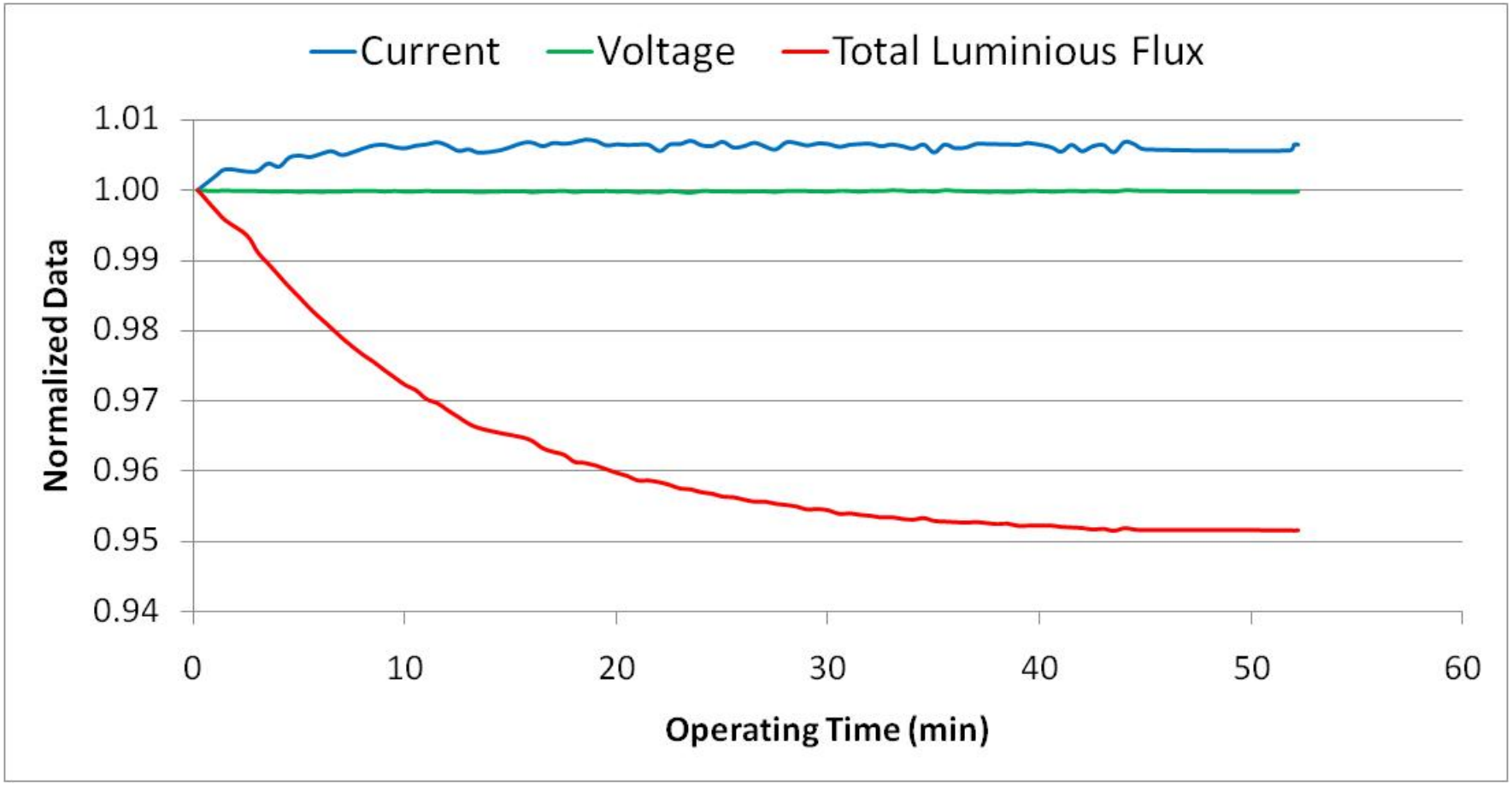
Measure, age 24 h, measure, age 24 h, measure, 120 h measure – seasoning

Measure luminaires 3 times – repeatability, stability time

	Current	Voltage	Power	Flux	Efficacy
Model 1	0.024 %	0.005 %	0.035 %	0.024 %	0.012 %
Model 2	0.139 %	0.005 %	0.101 %	0.015 %	0.086 %
Model 3	0.031 %	0.002 %	0.042 %	0.082 %	0.071 %
Model 4	0.014 %	0.002 %	0.016 %	0.054 %	0.038 %

Age 500 h, measure, age 1000 h, measure, age 1000 h, measure

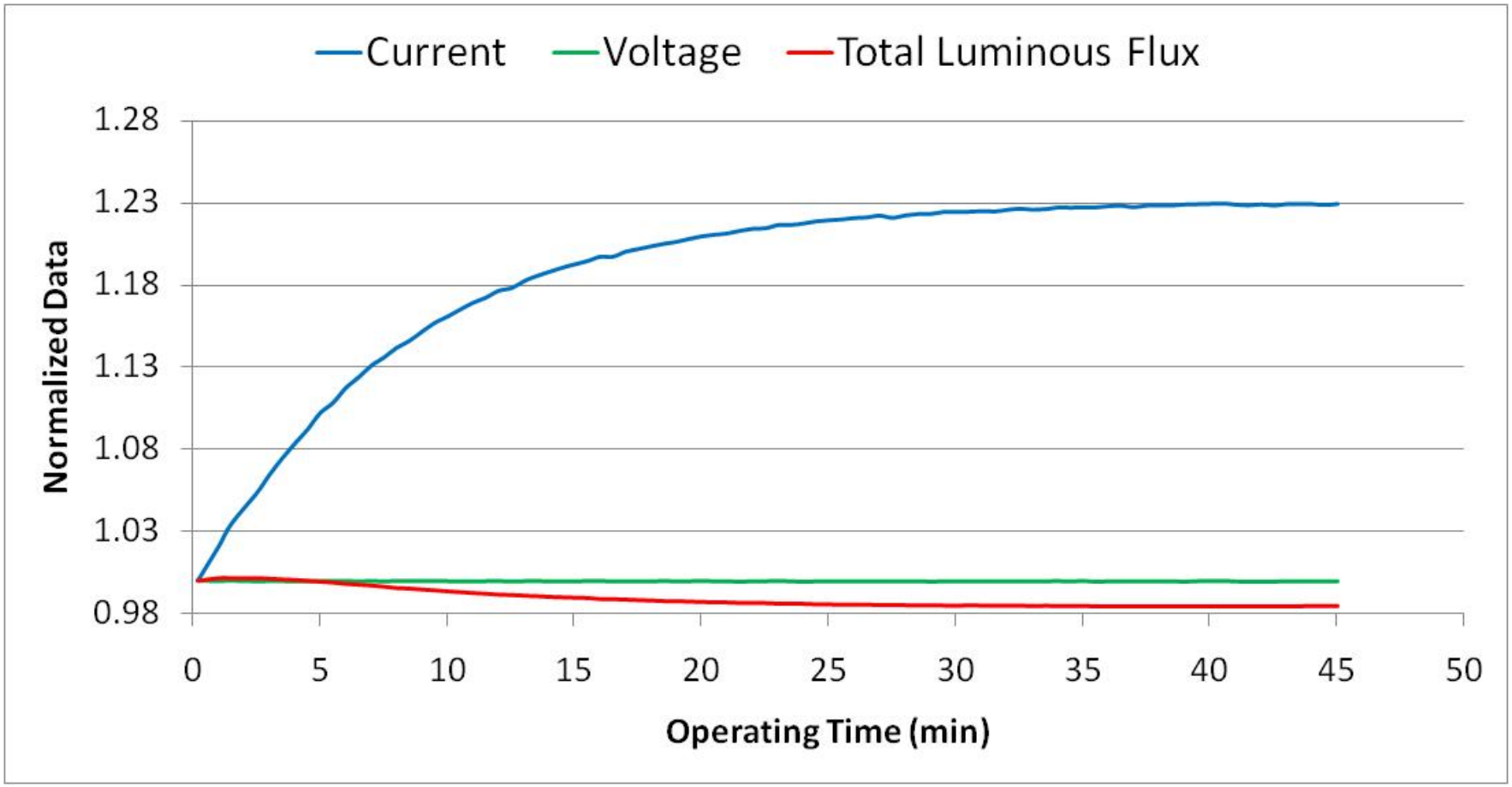
Stabilization Curves



LM-79-08 suggests (max-min) of 3 readings 15 min apart over 30 min < 0.5 %

5 min apart over 15 min:	30 min	0.23 % different
10 min apart over 30 min:	43 min	0.04 % different

Stabilization Curves

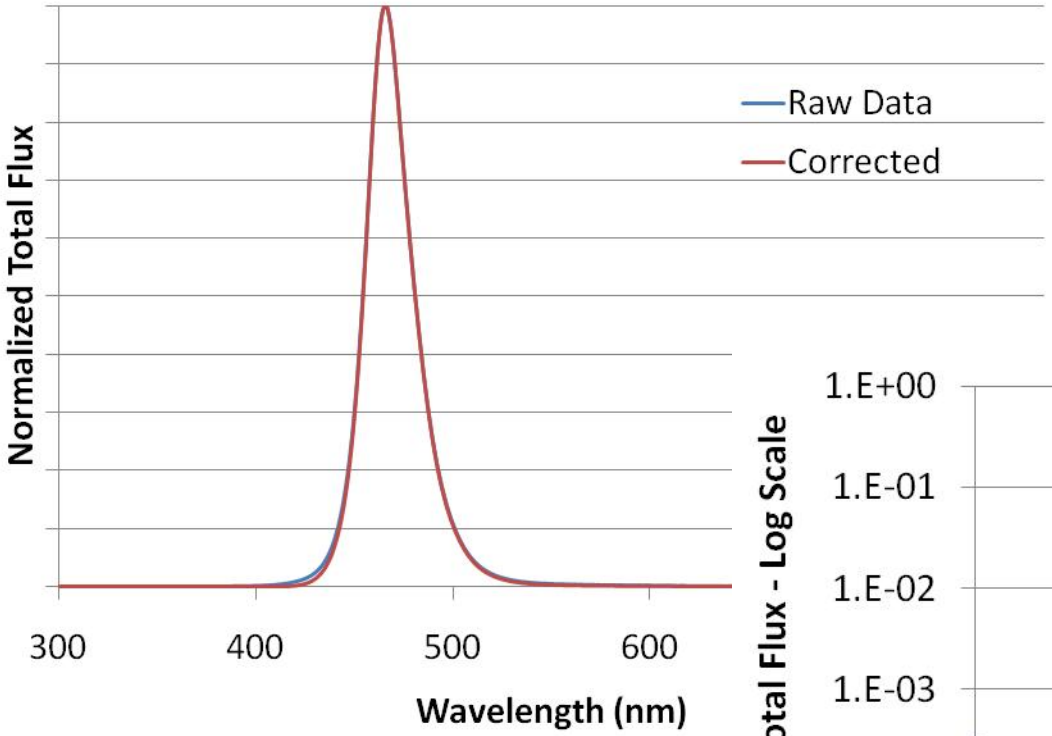


5 min apart over 15 min:	39 min	0.05 % different	optically: 23 min	1.4 %
10 min apart over 30 min:	?? min		optically: 34 min	0.3 %

Bi-lateral Proficiency Testing with NIST

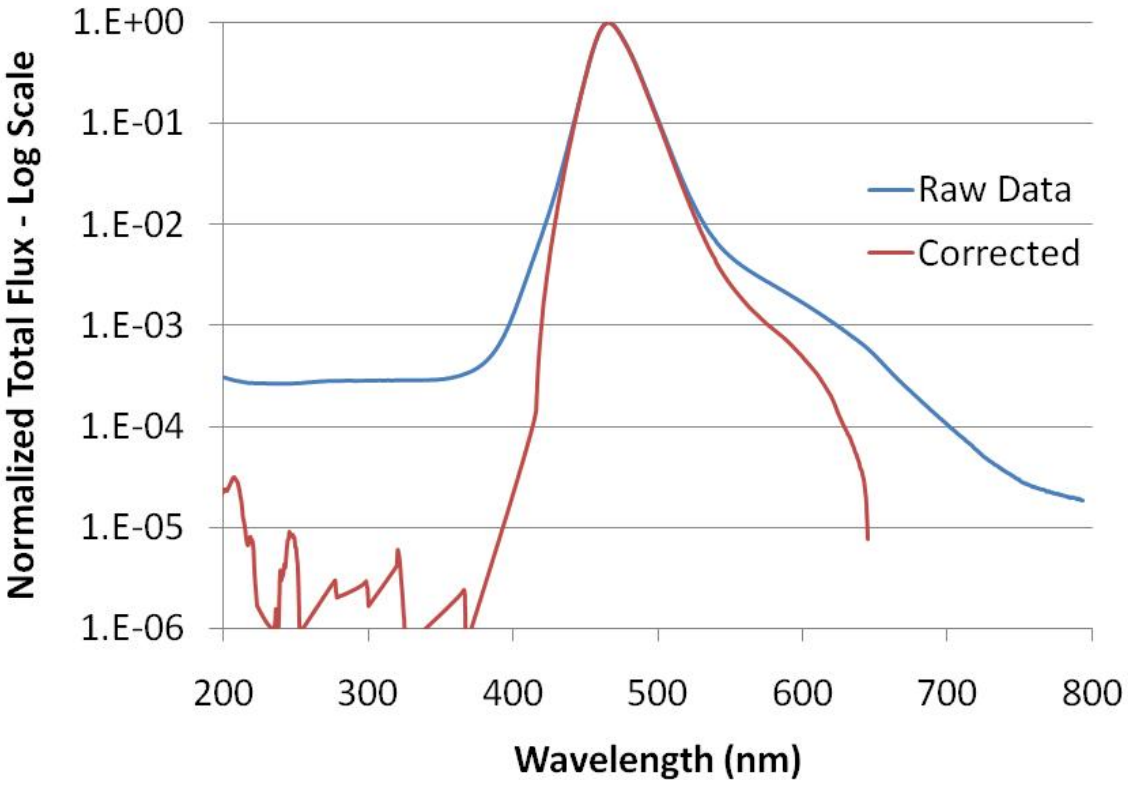
Bi-lateral artifacts outside the white box?

Blue LED Source - Fluorescence



466 nm peak

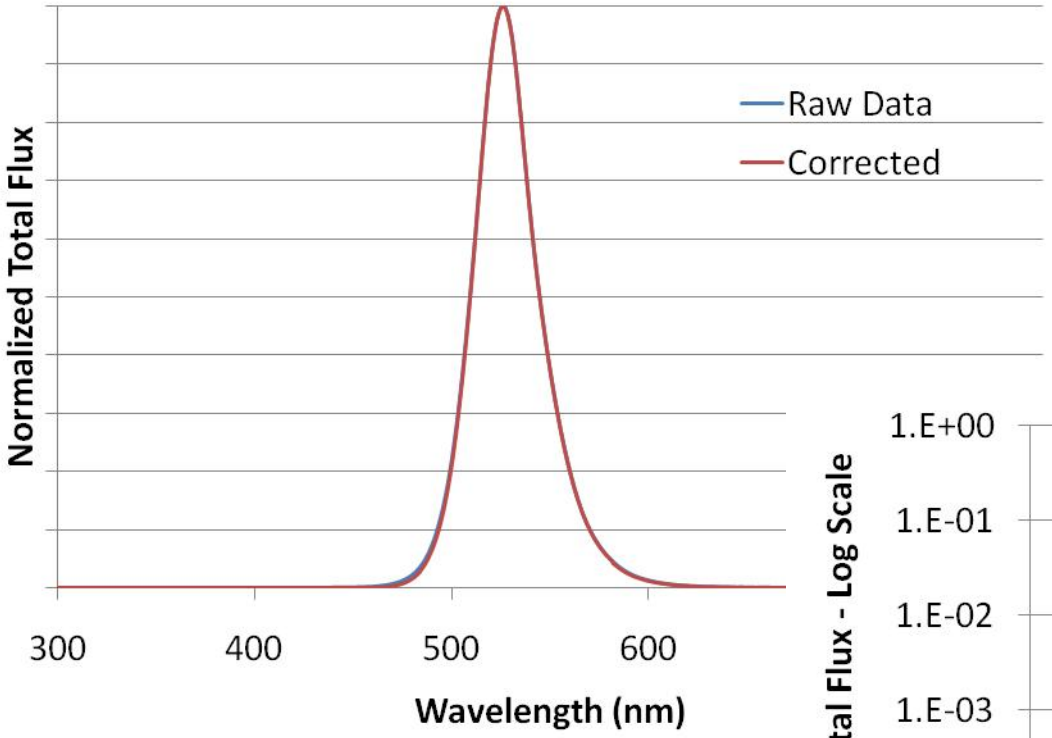
Raw Data
x - 0.1309
y - 0.0773



Corrected Data

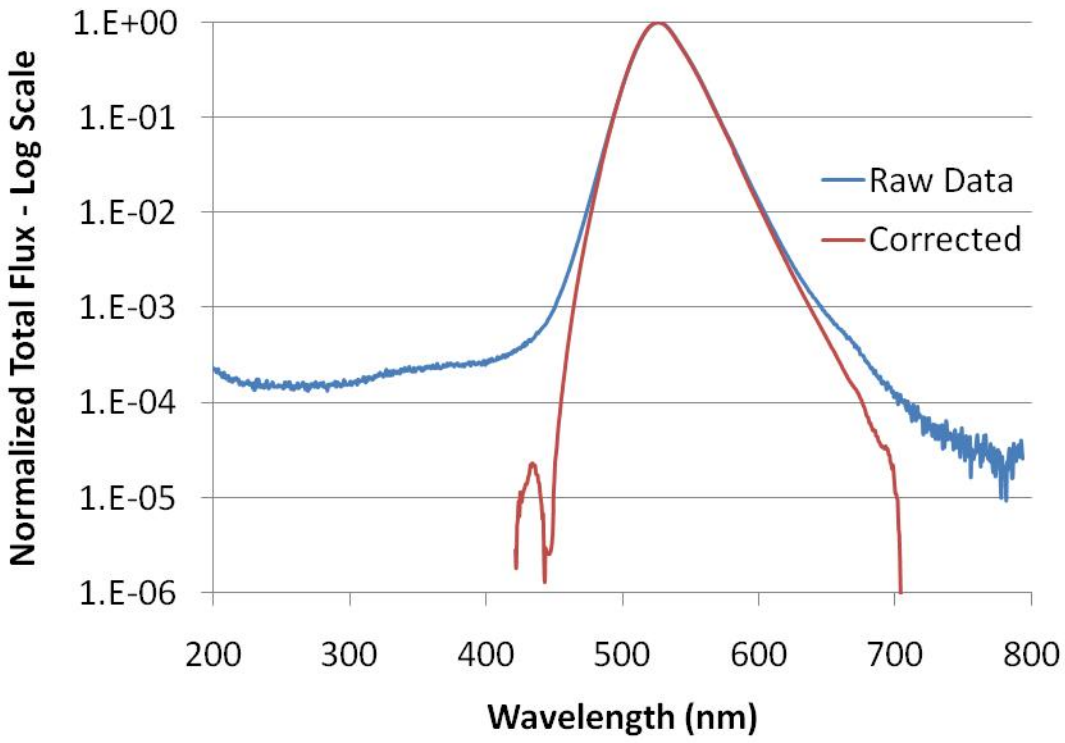
x - 0.1289	0.0020
y - 0.0747	0.0026

Green LED Source – Stray Light



526 nm peak

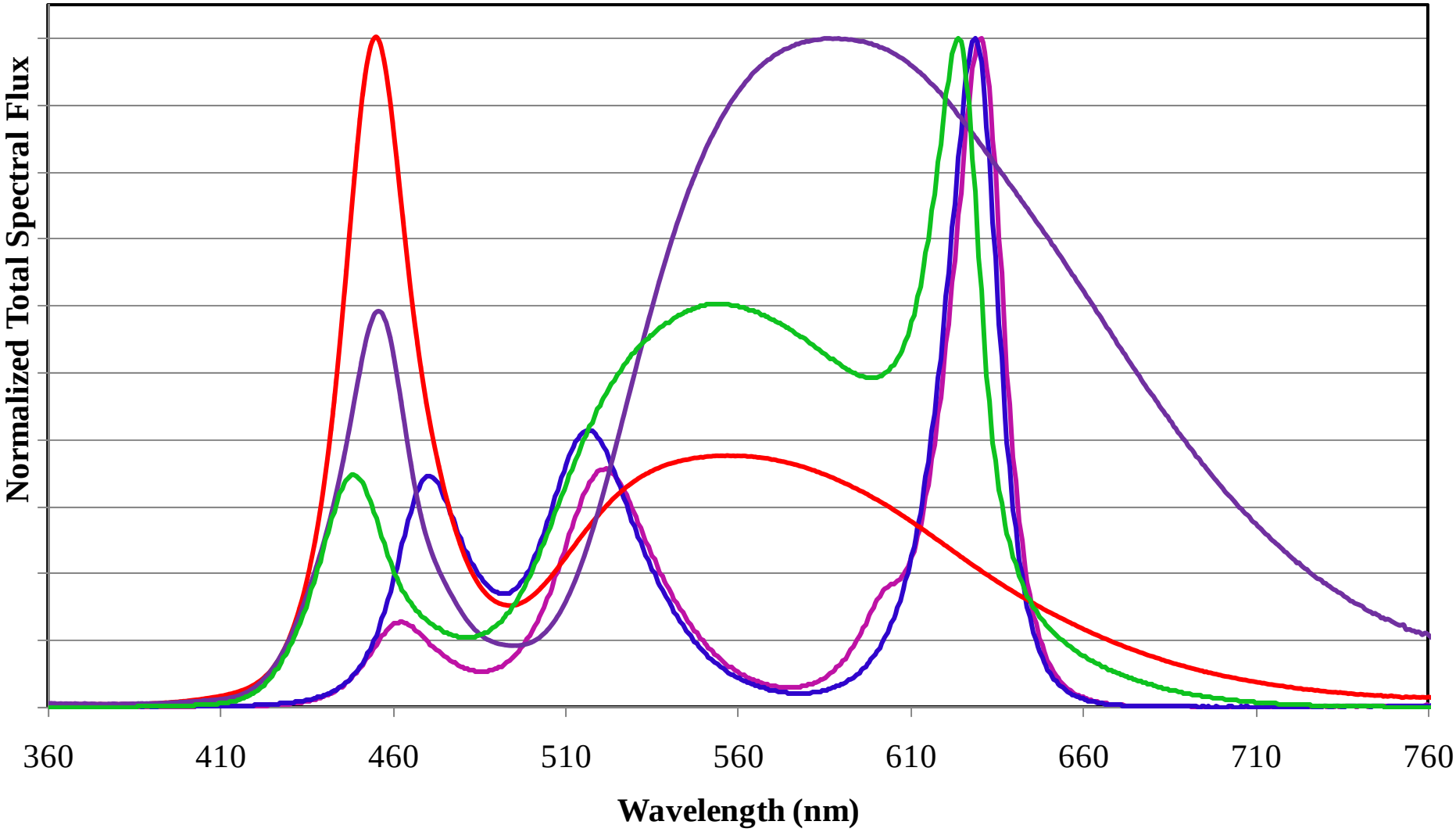
Raw Data
x - 0.1986
y - 0.7238



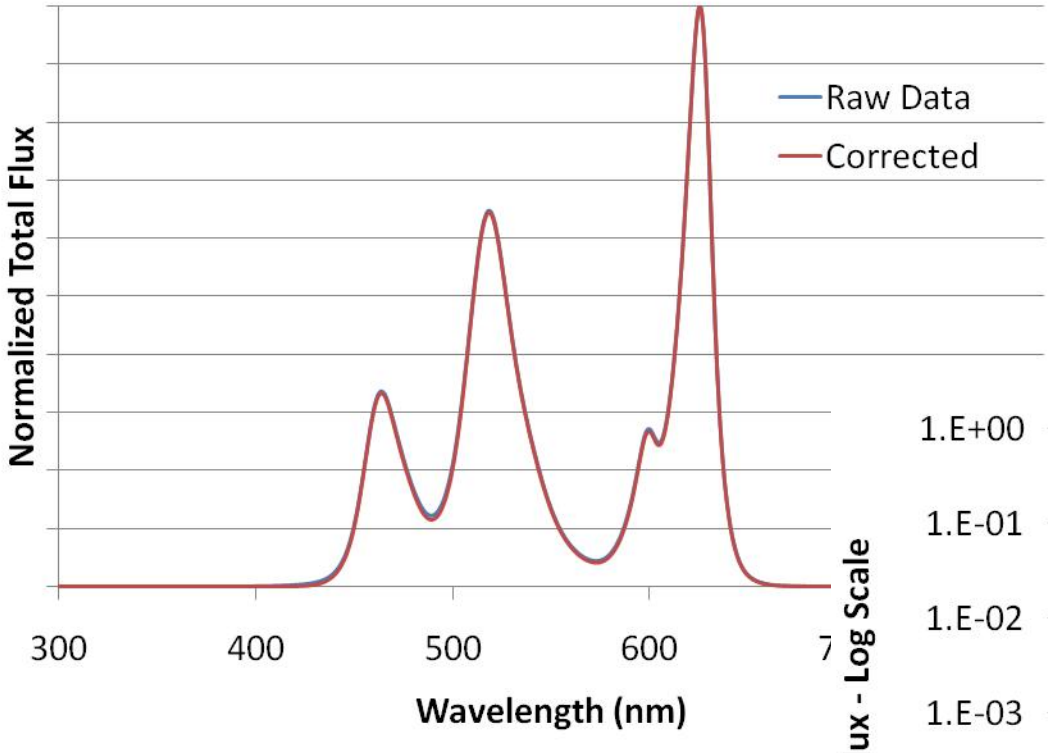
Corrected Data

x - 0.1976	0.0010
y - 0.7298	-0.0059

Color Characterization



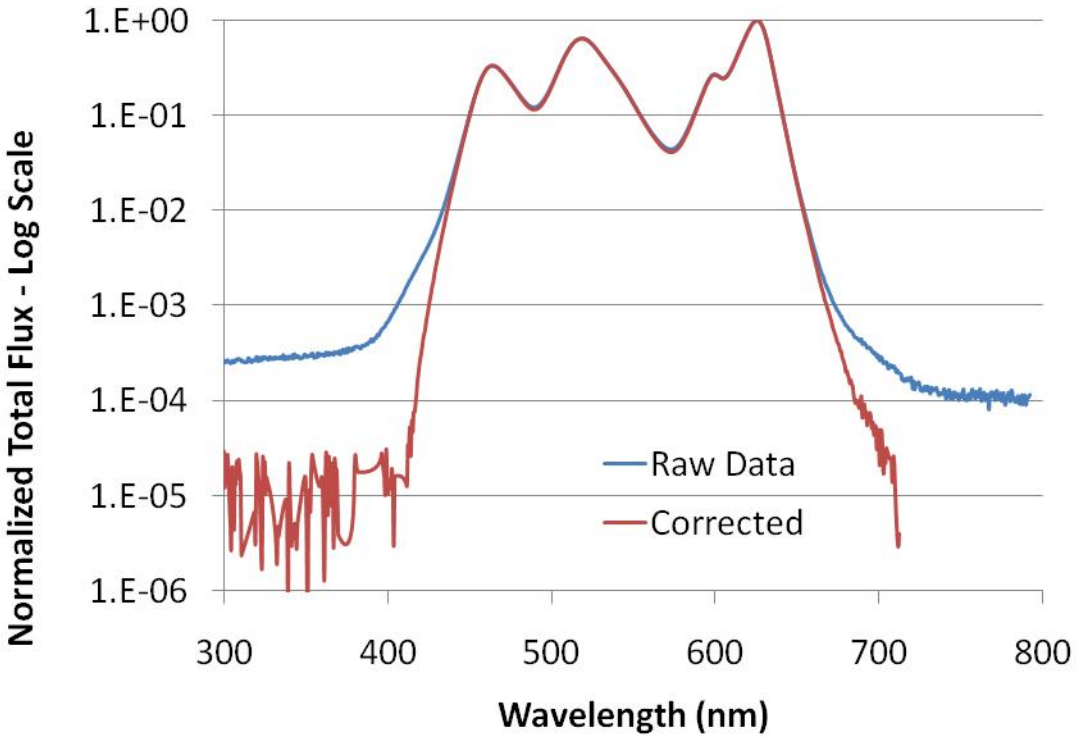
Color Measurements – Stray Light



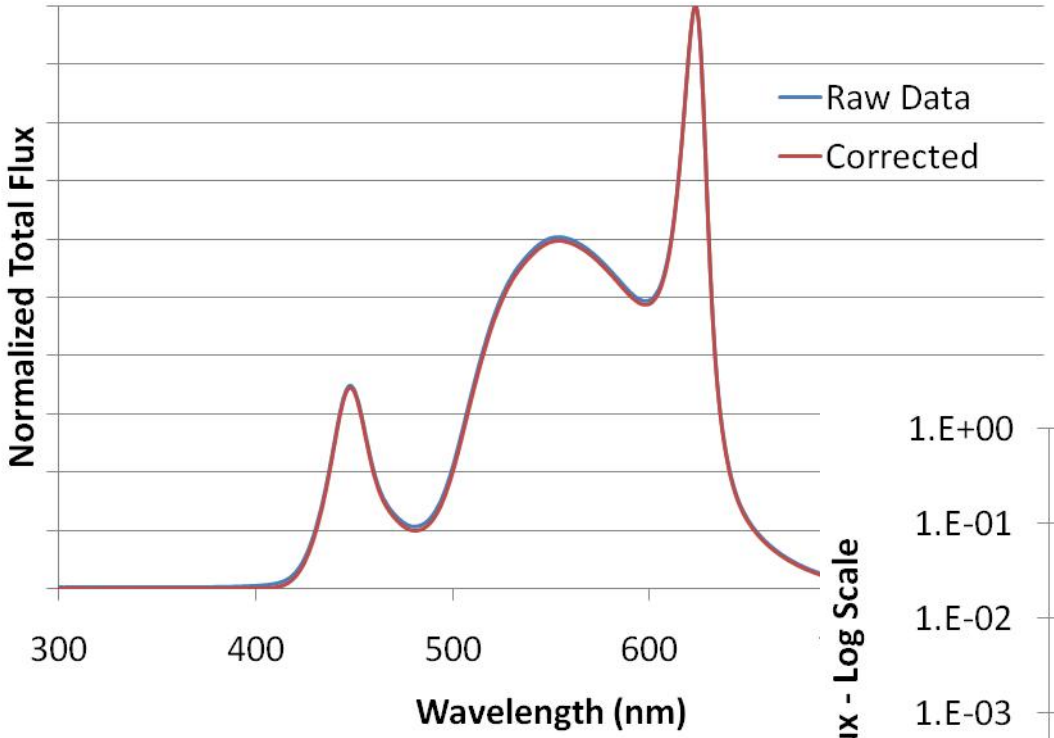
Raw Data
x - 0.3742 CCT 4318.6
y - 0.4007 Duv 0.0127

Corrected Data
x - 0.3757 CCT 4289.1
y - 0.4021 Duv 0.0129

0.0014 -29.5
0.0014 0.0002



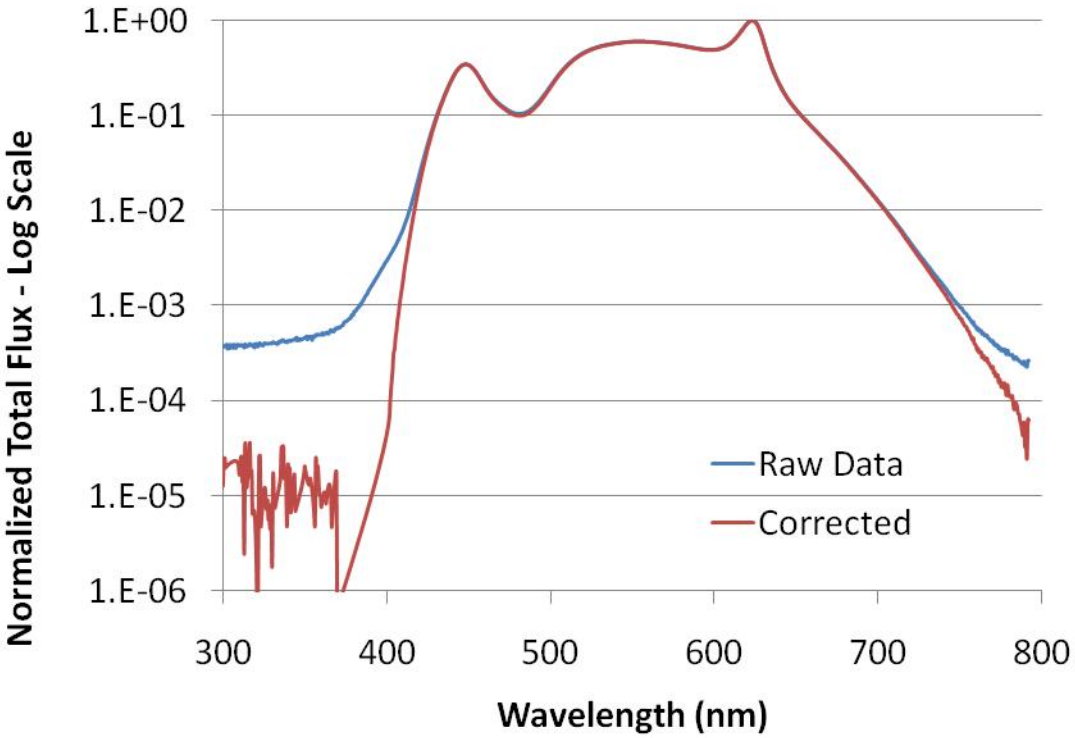
Color Measurements – Stray Light



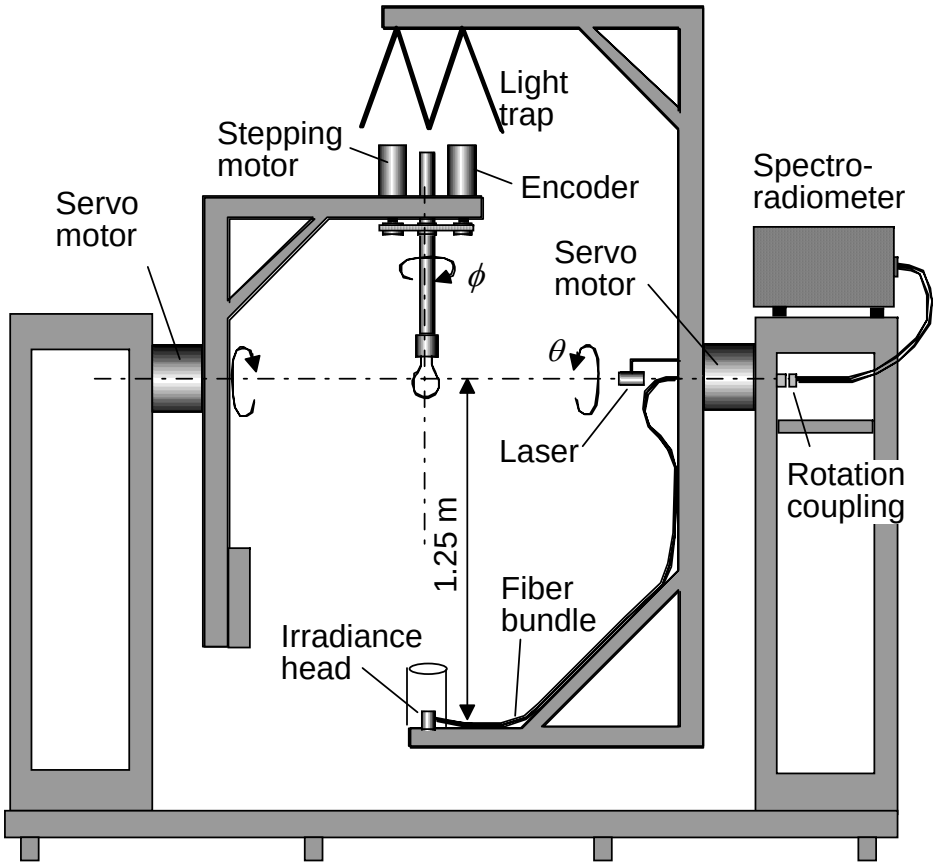
Raw Data
x - 0.4078 CCT 3742.2
y - 0.4314 Duv 0.0164

Corrected Data
x - 0.4091 CCT 3719.4
y - 0.4318 Duv 0.0162

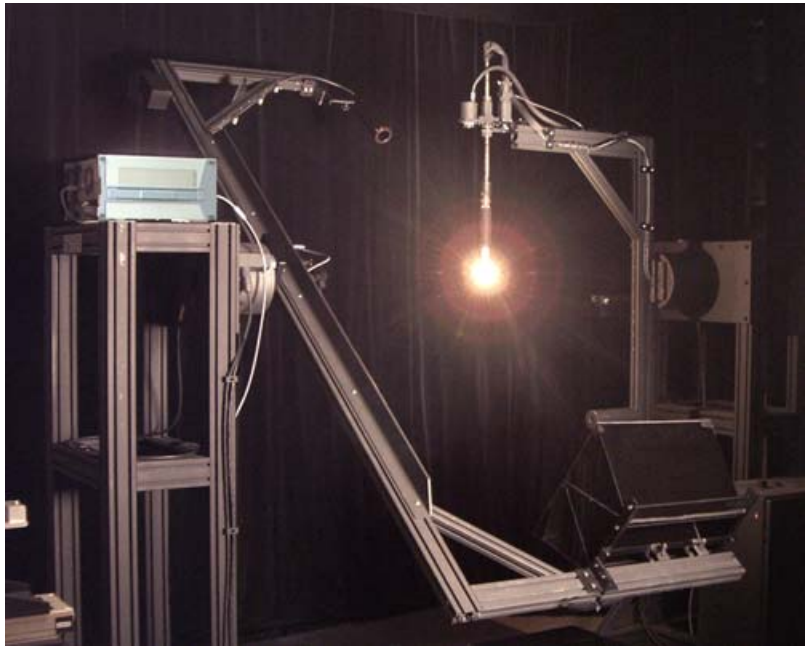
0.0013 -22.8
0.0004 -0.0002



Zonal Flux Measurements



- Total spectral radiant flux scale
- Measurement of small SSL products
  - Angular luminous intensity distribution
  - Color uniformity

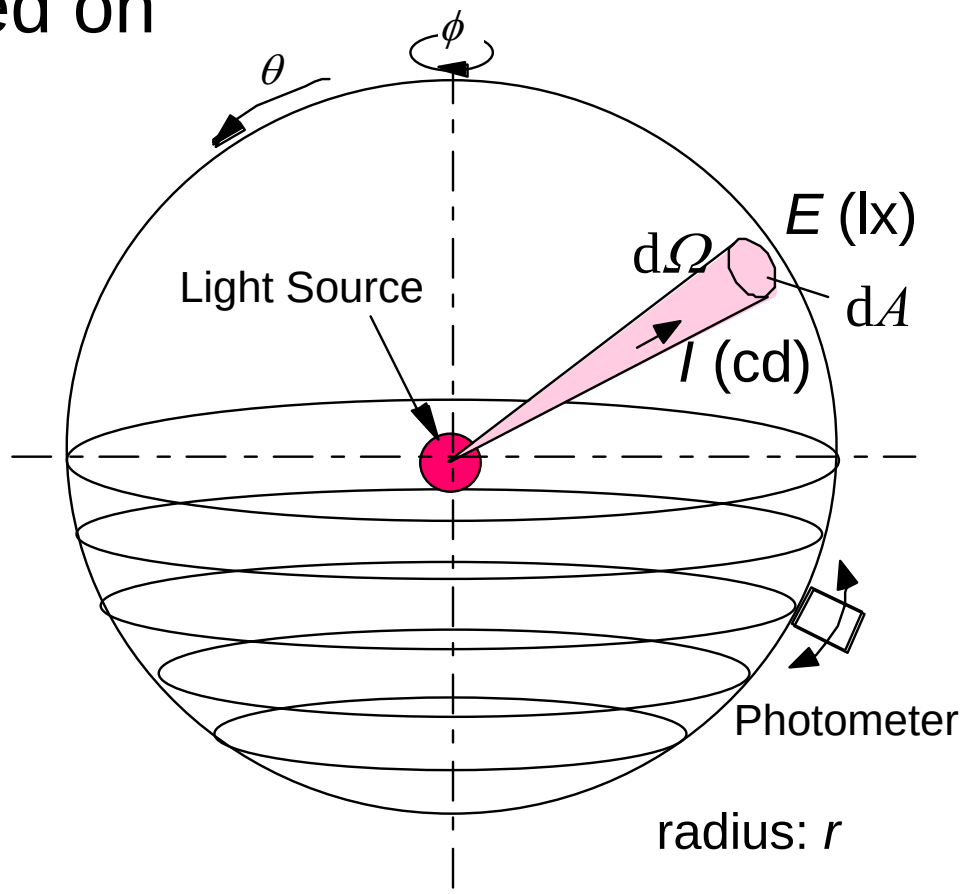


Uncertainty Calculations - Flux

Goniophotometric measurements are multiple points measured on virtual sphere

$$\Phi = \int_A E \mathrm{d}A$$

$$\Phi = r^2 \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi} E(\theta,\phi) \sin\theta \mathrm{d}\theta \mathrm{d}\phi$$

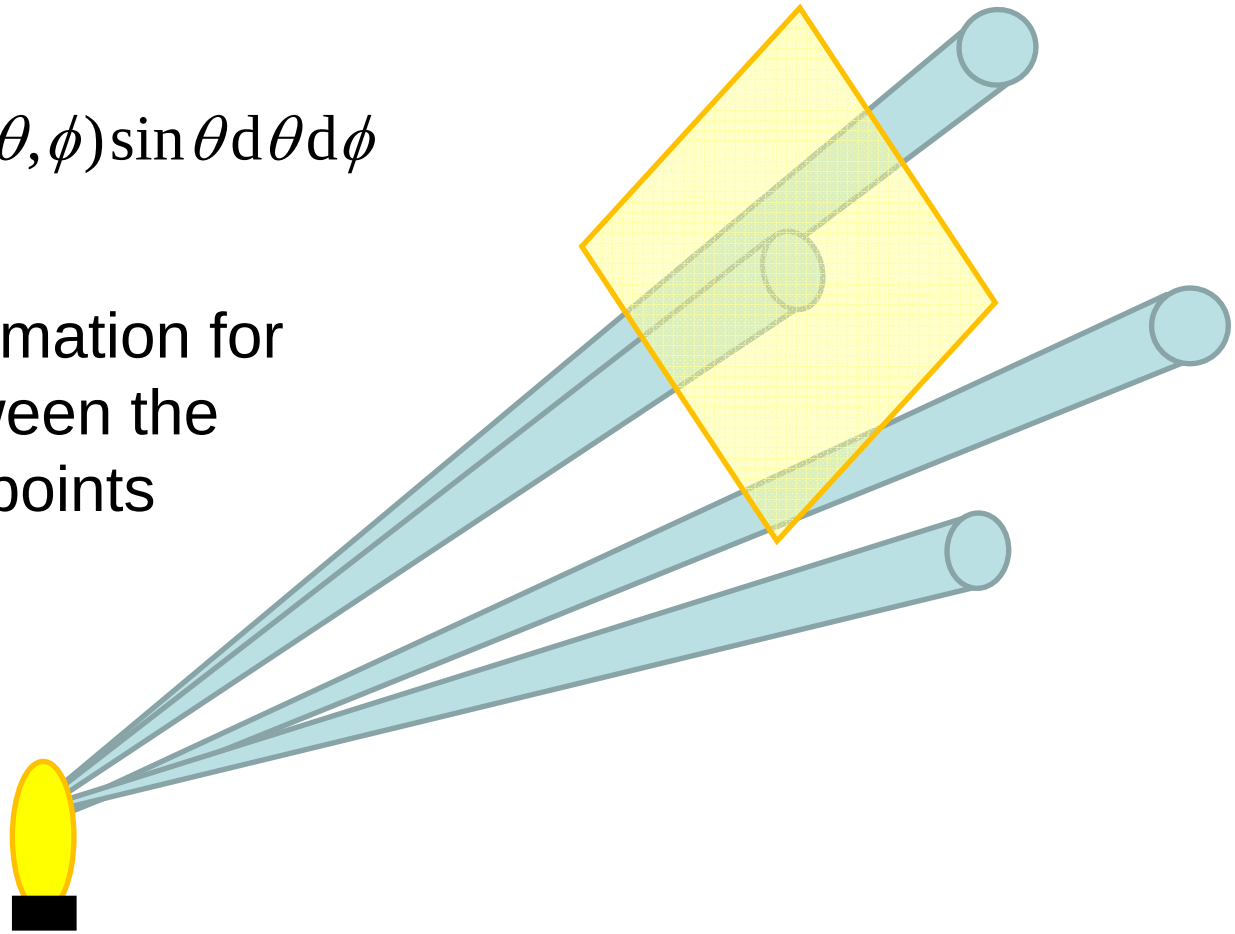


Problem: Sampling 1 % - 5 % of sphere surface

Uncertainty Calculations - Flux

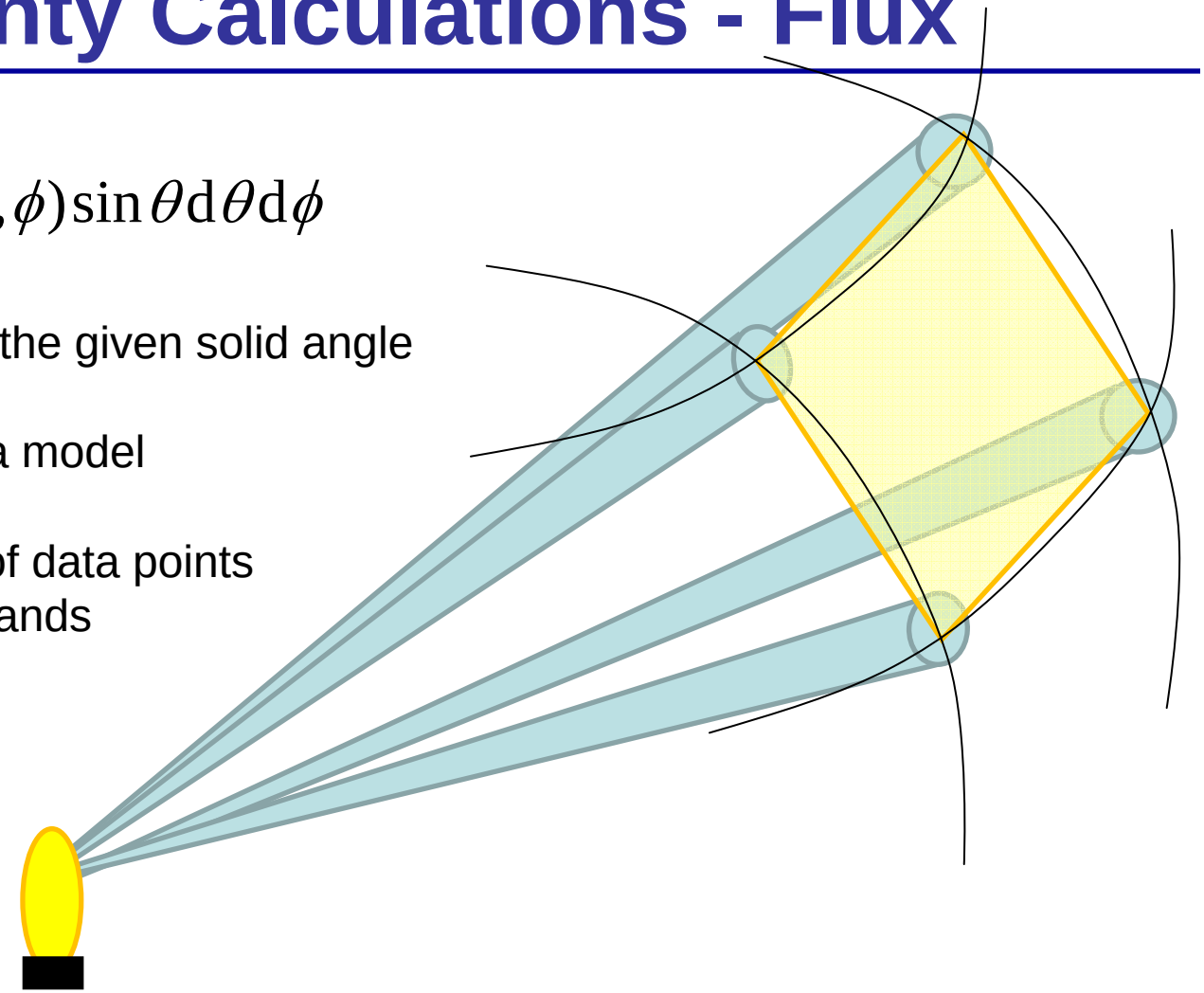
$$\Phi = r^2 \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi} E(\theta,\phi)\sin\theta \,\mathrm{d}\theta \,\mathrm{d}\phi$$

- Linear approximation for the area between the measured points



Uncertainty Calculations - Flux

$$\Phi = r^2 \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi} E(\theta,\phi) \sin\theta \, \mathrm{d}\theta \, \mathrm{d}\phi$$



- Predict the illuminance over the given solid angle

- 2D fit to 16 points, requires a model
  bicubic spline
- Fit includes the uncertainty of data points
  68.5 % confidence bands

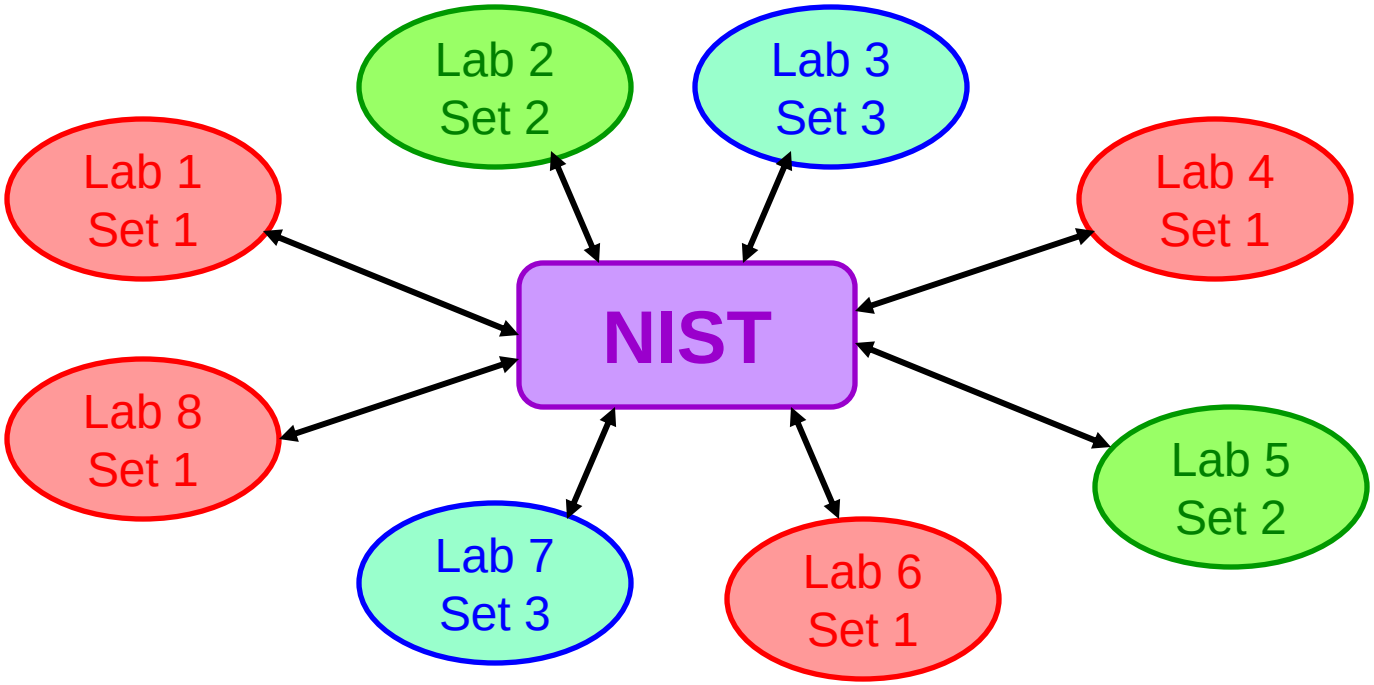
Factors
- solid angle of measurement compare to given solid angle
- uncertainty of the position of the measured point
- initial calibration to a the primary standard

Round Robin Testing

NIST prepares 3 – 4 sets of round robin artifacts

Consists of 4 – 5 different artifact models (Energy Star niche applications)
Each artifact model will have 3 items (12 – 15 total items)

NIST distributes sets in a star pattern



NIST analyzes data and prepares a Tech Brief

Questions?