UV LEDs:
A Measurement Update

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INSTRUMENT MARKETS

Presentation Overview

1. Measurement Fundamentals/Variables
2. UV LEDs
3. Measurement of UV LEDs

Why is UV Measurement Important?

Communication:

•Between stakeholders (equipment, chemistry, end users, substrate, same company with multiple locations)

•Wide range of technical knowledge (chemists, suppliers, users)

- Repeat tests and experiments across multiple facilities
- Transfer production and processes
- Troubleshoot applications
- Speak the same language
- Understand differences between instruments

Bottom Line:

Measurement saves time and money

Broadband UV Sources

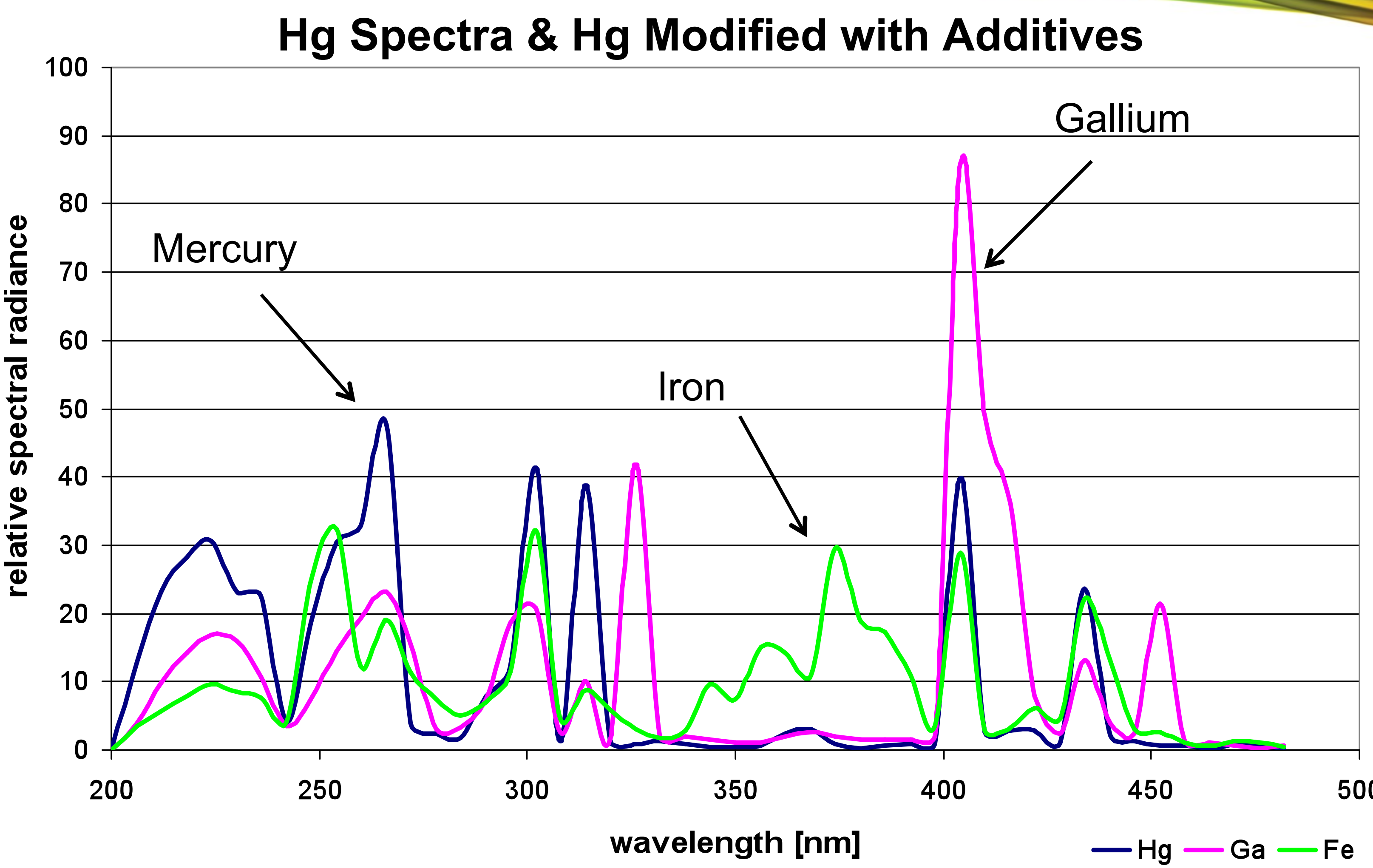
Arc Lamps

Spot Sources

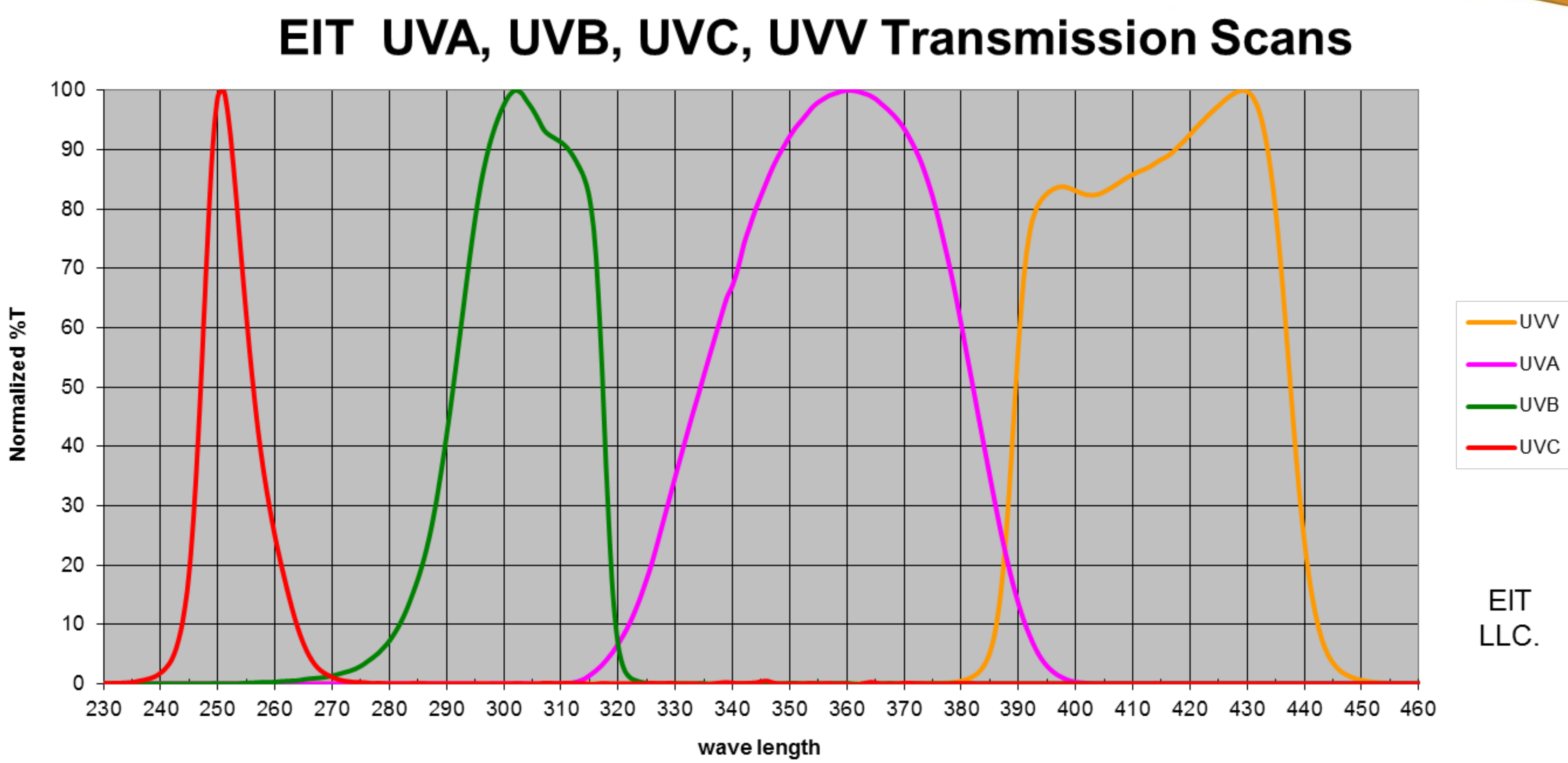
Microwave Lamps

Images Courtesy: Dymax, Heraeus, Miltec, Nordson Corporation

Broadband Spectral Output



Instrument Responses

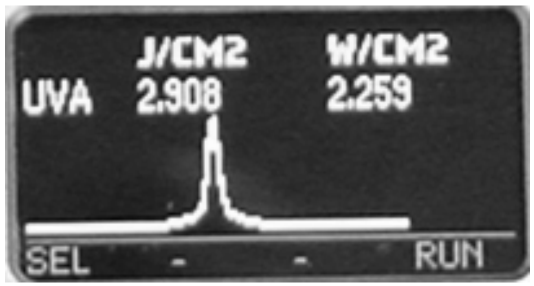


The traditional approach has been to define the band response based ONLY on the filter response

UV Measurement Strategies

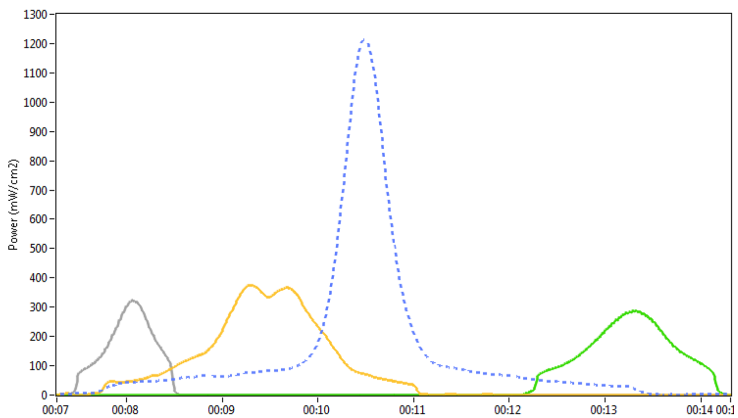
1. Radiometers

- Absolute units
- Want a "number"



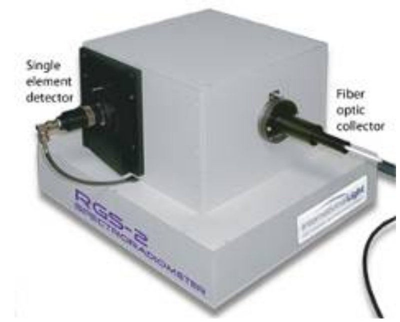
2. Profiling Radiometers

- Measure the peak irradiance and total energy density
- X-Axis: Time / Y-Axis: Irradiance



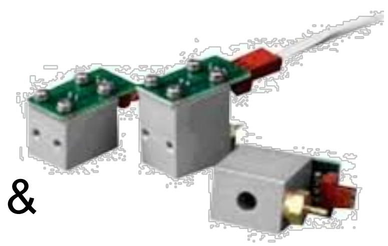
3. Spectral Radiometer

- Profile of UV irradiance as a function of bandwidth
- R&D vs. Production



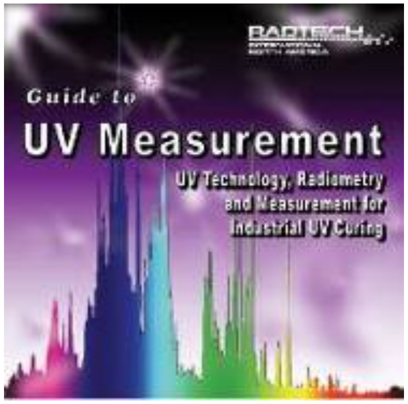
4. Relative Instruments

- Signal proportional to lamp brightness (%)
- Sensor & Display
- Continuous feedback & monitoring of UV conditions



Challenges Measuring Broadband UV Sources

Past efforts to improve & understand UV measurement:



- 3M, Heraeus, International Light, EIT
- RadTech Measurement CD
- Educate & Communicate

Why are there differences between instruments?

Optics

- Different Bands/Manufacturers
- Define response by 10% Power Point or 50% Power Point (FWHM)

Electronics

- Dynamic range
- Sampling rates
- RMS vs Instantaneous Watts
- Threshold Differences

Calibration Sources/Points

- One source type does not always fit

Data Collection Techniques

- User Errors

User Expectations

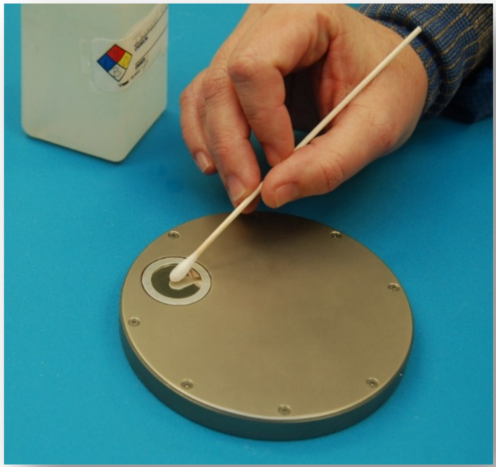
- Fraction of a percent?

UV Measurement Challenges

Instrument Cleanliness

Irradiance W/cm²			
Band	Before	After	Difference
UVA	1223	983	-19.6%
UVB	1066	888	-16.7%
UVC	277	257	-7.2%
UVV	889	757	-14.9%

Energy Density J/cm²			
Band	Before	After	Difference
UVA	349	282	-19.2%
UVB	284	239	-15.9%
UVC	75	68	-9.33%
UVV	309	264	-14.6%



Data collected 3/24/16

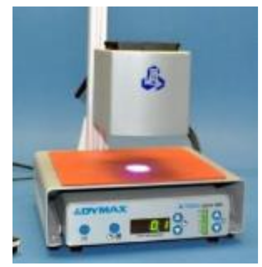
Before: Data collected with contaminated optics

After: Data collected after cleaning

UV LEDs

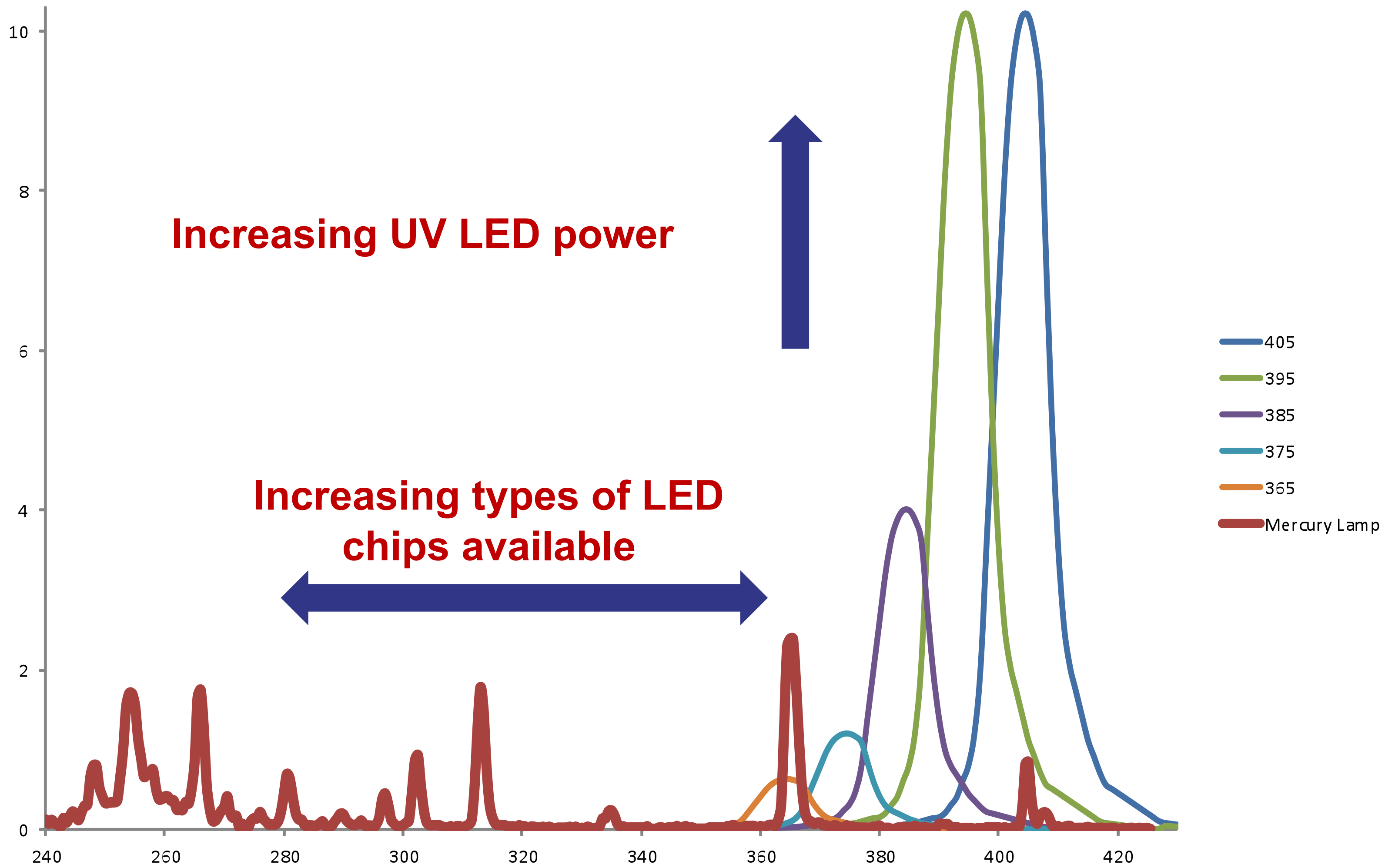
Wide variety of UV LED sources

- Multiple suppliers with wide level of expertise, support, finances
  - More than someone with SMT equipment?
- Experience in industrial UV, visible lighting, semiconductor industry?
- Ties to formulators?
- Match source to your application & process
- Economics of source selected (ROI)



Images courtesy Baldwin, Dymax, Integration Technology, Excelitas & Phoseon Technology

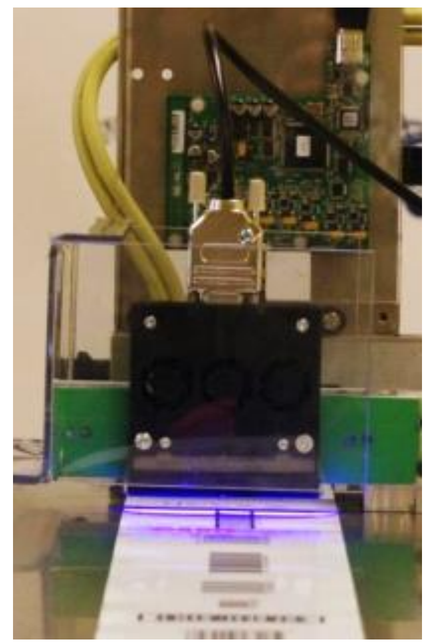
UV LED Power Output vs. Wavelength



UV LEDs: Measurement

What do you want to measure?

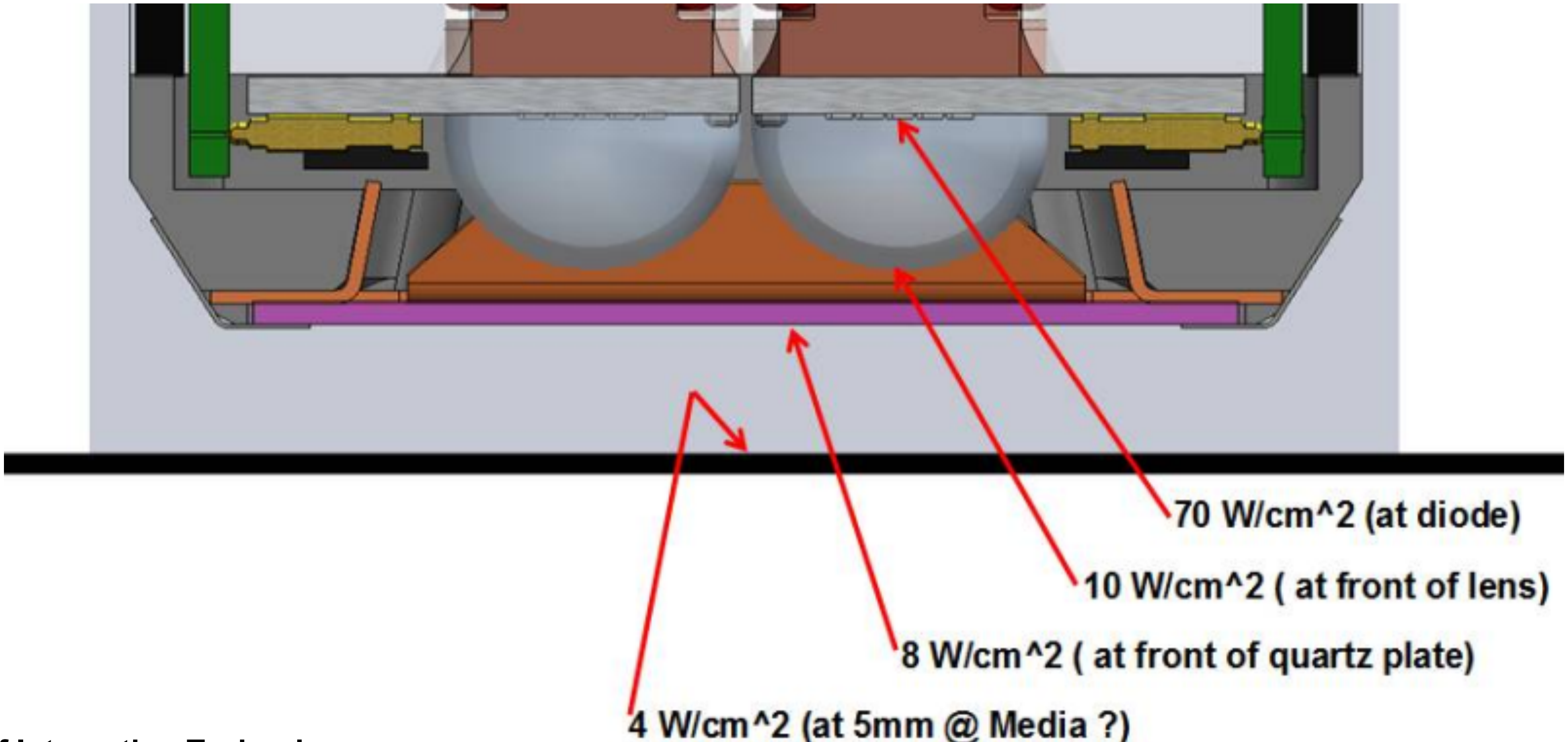
- What do you want to measure?
  - Individual LED
  - Array
  - **Production system**
- What values do you want?
- Industrial UV: W/cm^2 & J/Cm^2
- Visible LEDs: Flux?/Color?



UV LEDs: Measurement

Where do you measure?

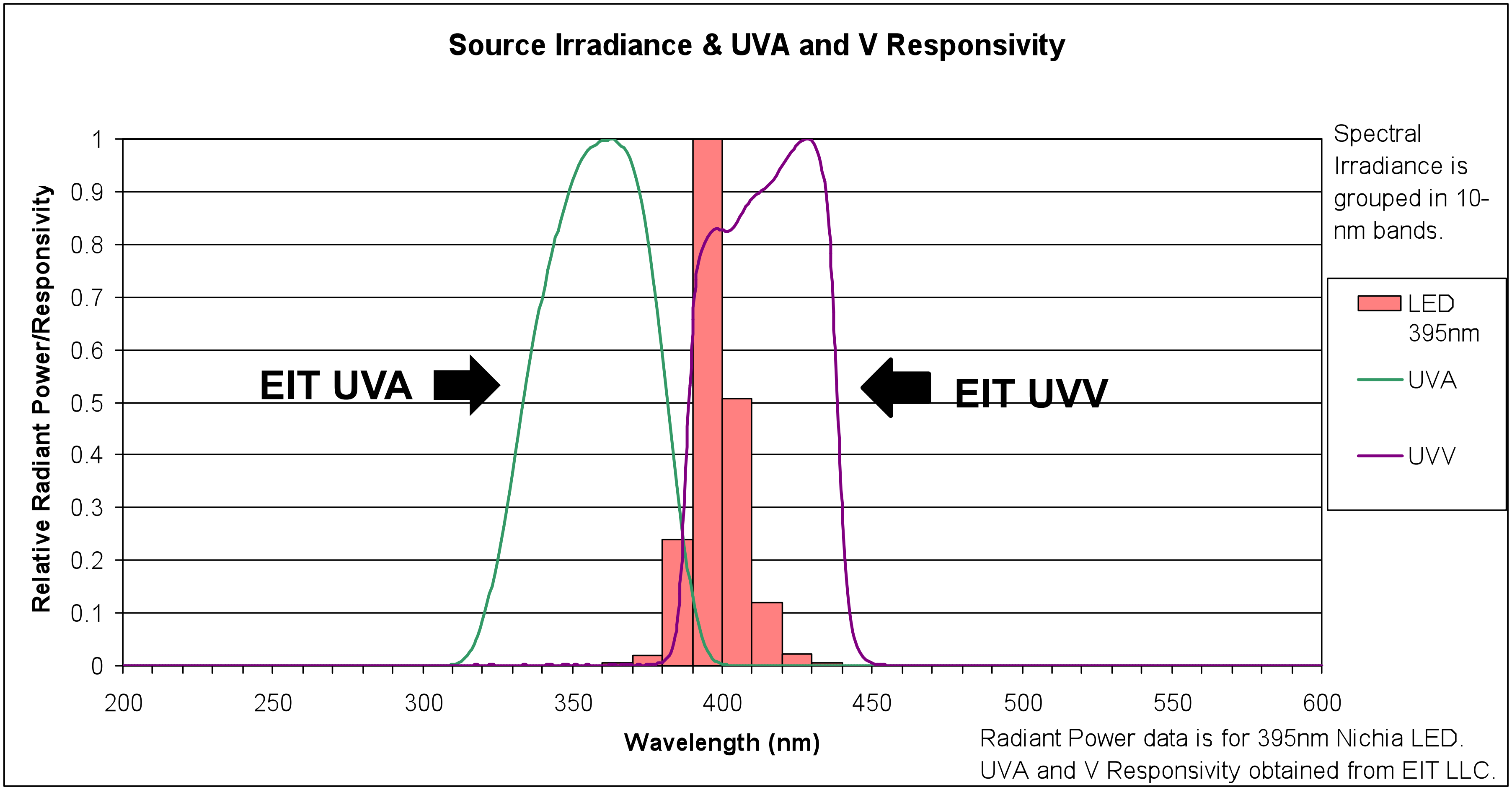
- Where is the proper location for the UV Irradiance Value?
- How do we compare systems and communicate values?



Courtesy of Integration Technology

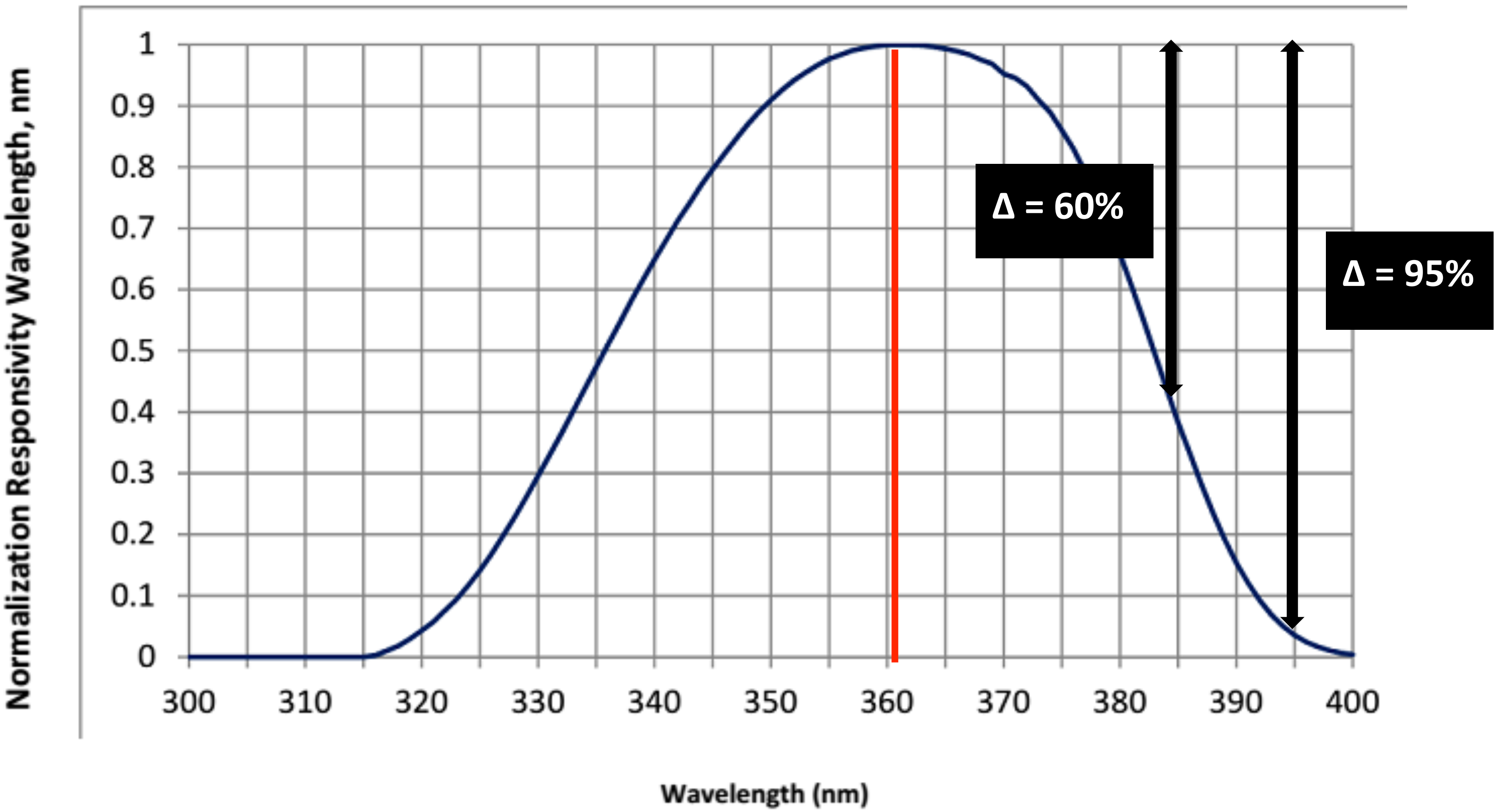
Measurement of 395 nm LED

Is the instrument response matched to the source?

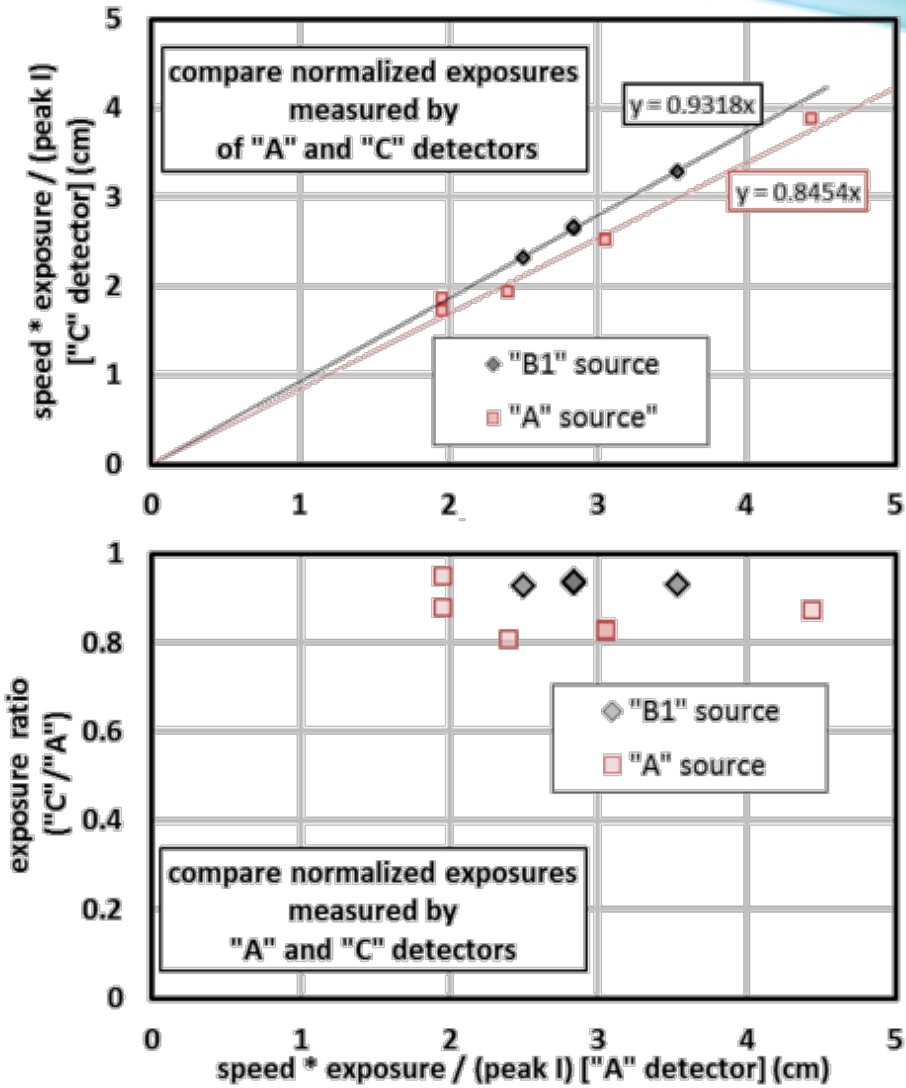


Measurement of 395 nm LED

Using UVA to measure a 385 nm or 395 nm LED



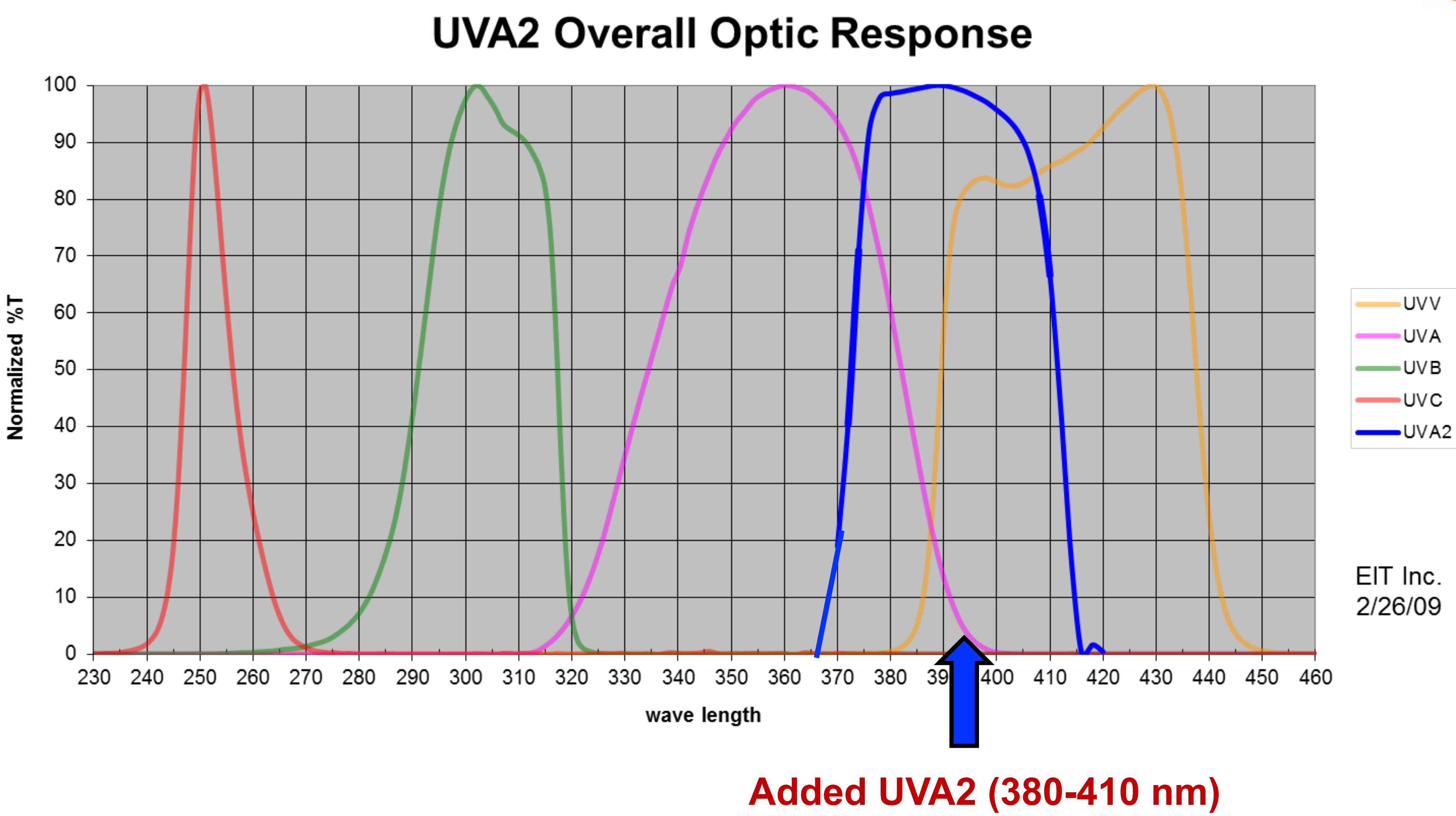
NIST comparison of high power UV LED sources



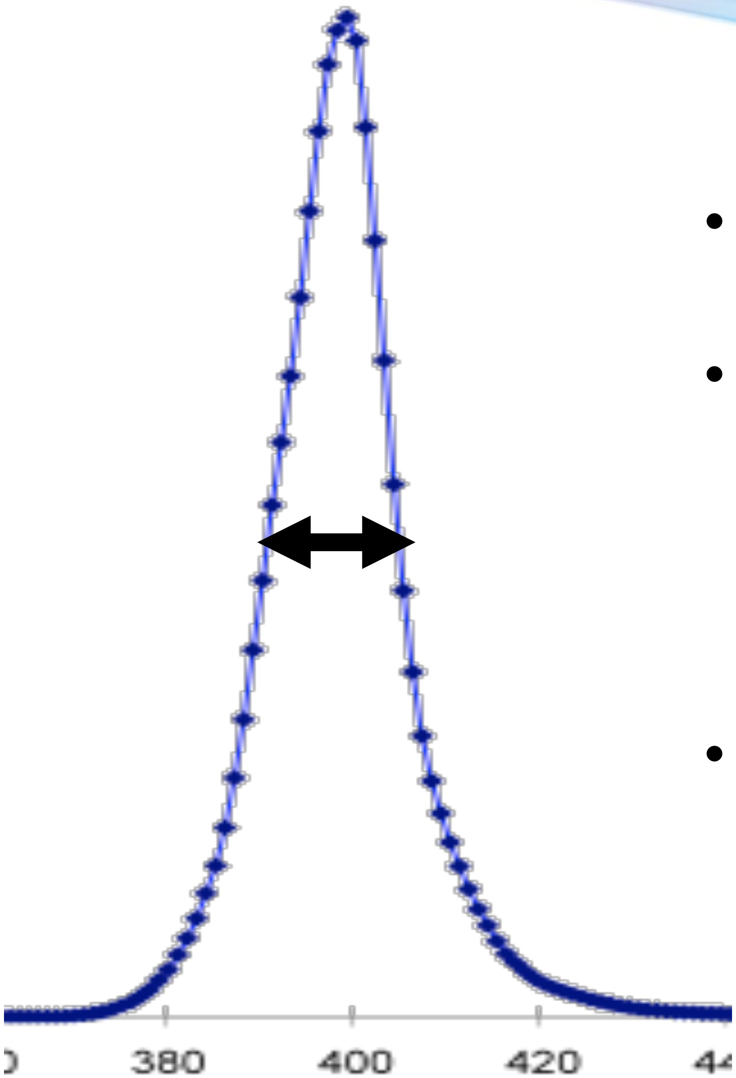
From NIST report (Figure 9)

- Study completed by Dr. Robert F. Berg, NIST
- Looked at three LED units with two different radiometers
- No surprise there were differences
- CORM Meeting at NIST on May 18th
- Path forward?

EIT UVA2 Bandwidth Response



UV LED Emission Spectra



- Width of the LED at the 50% Power Point
- Variations between suppliers:
  - Binning
  - Longer wavelengths
  - Sold as +/- 5 nm from center wavelength (CWL)
- Overall spread of UV LED made us rethink width of UVA2 band

395 nm LED array output measured on a spectral radiometer Courtesy EIT

Proposed “L” Bands

Broadband Source Ranges

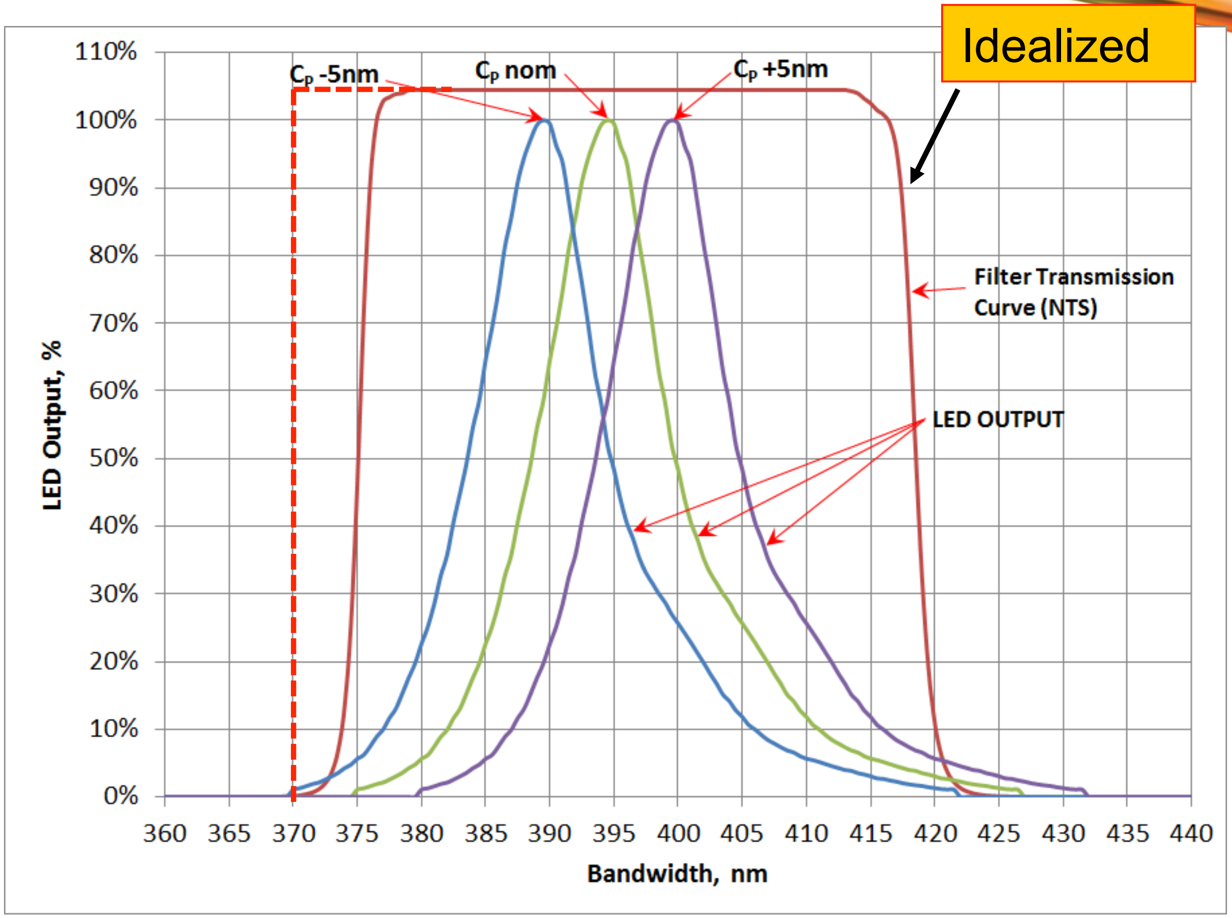
Band Name Identifier	Approximate Wavelength Range
UVA	315-400nm
UVB	280-315nm
UVC	240-280nm
UVV	400-450nm

Proposed “L” LED Bands

EIT Band	Wavelengths, Cp	Measurement Range
L405	400-410nm	380-430 nm
L395	390-400nm	370-420 nm
L385	380-390nm	360-410 nm
L365	360-370nm	340-390nm

Proposed UV L395 nm Band

- “Wide” (+/- 100 nm) vs. “Narrow” (+/- 50 nm) Approach
- Advantages & Disadvantages to each approach
- **Goal: Flat Response**

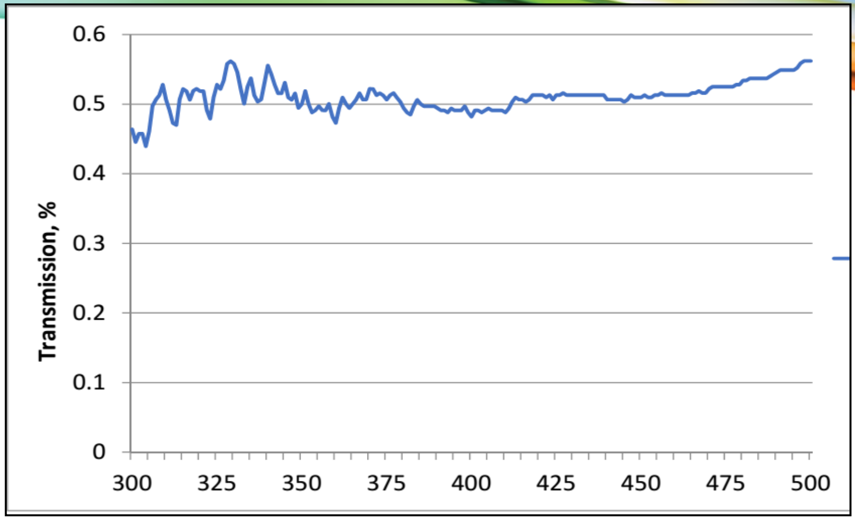


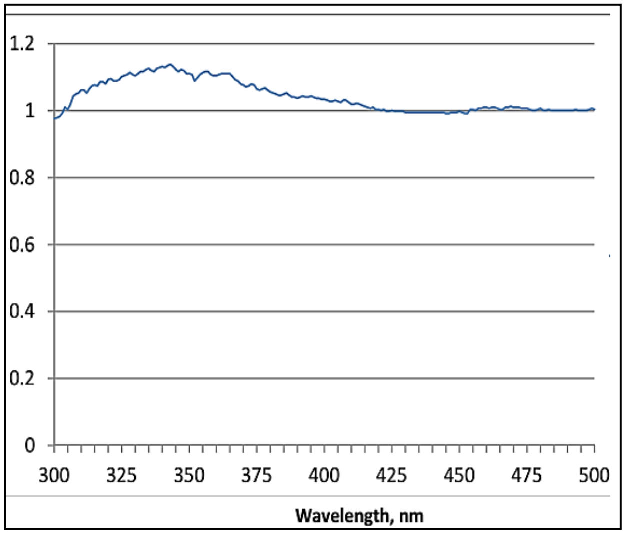
L395 LED Output Spectra Showing ± 5nm Spread of Cp Along with Required Filter Response to Obtain 2% Measurement

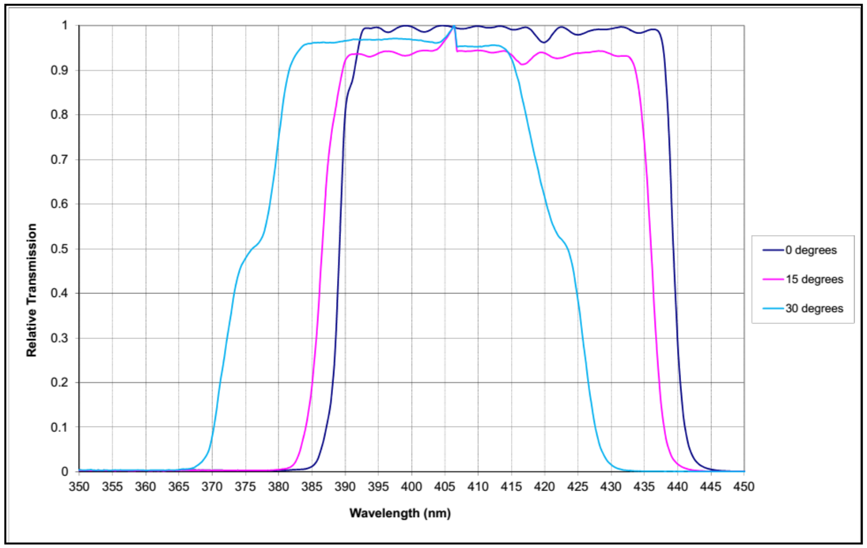
Total Instrument Response

- Control of overall optics to flatten **OVERALL** response of instrument

- **ALL Optical Components NOT just the filter**

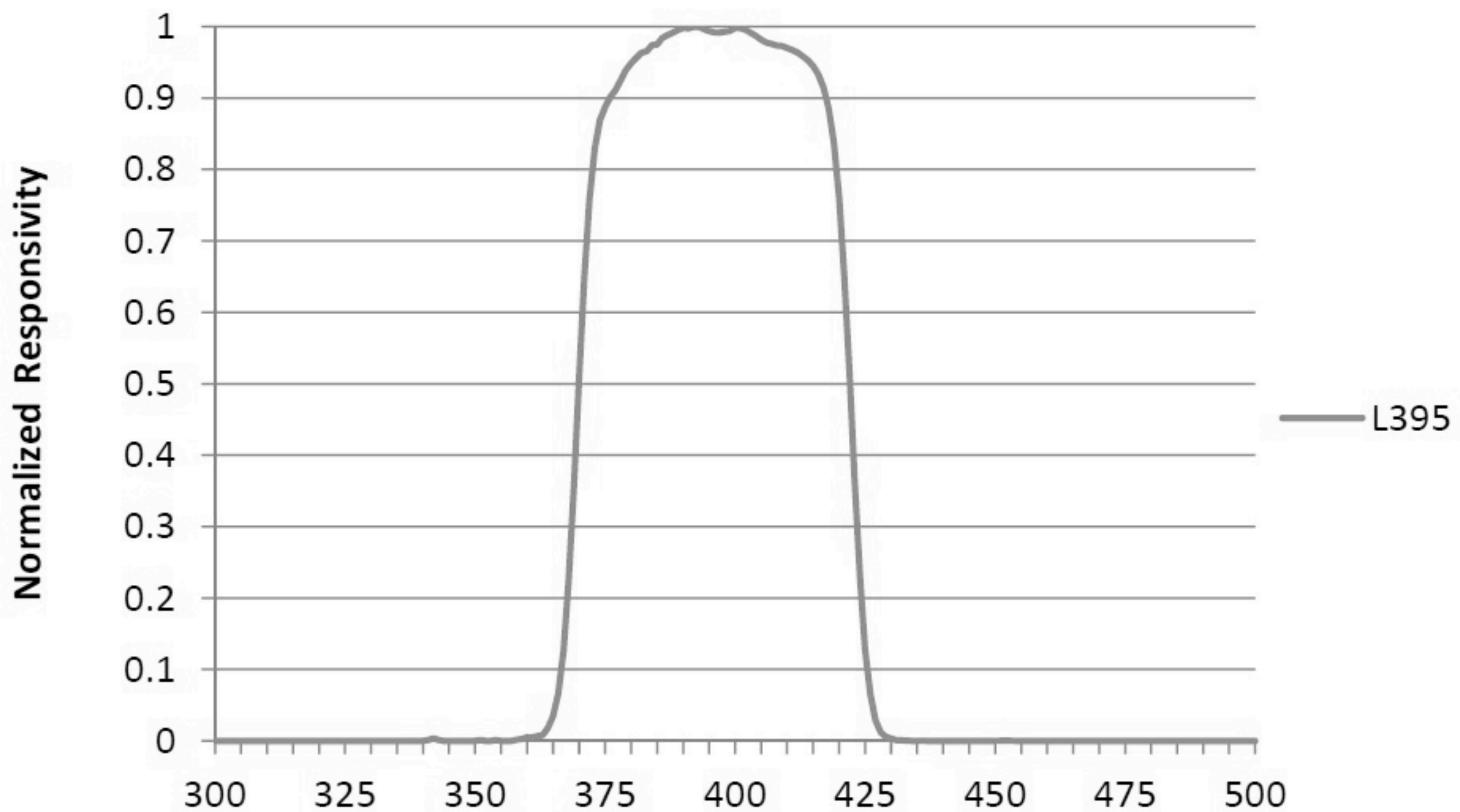




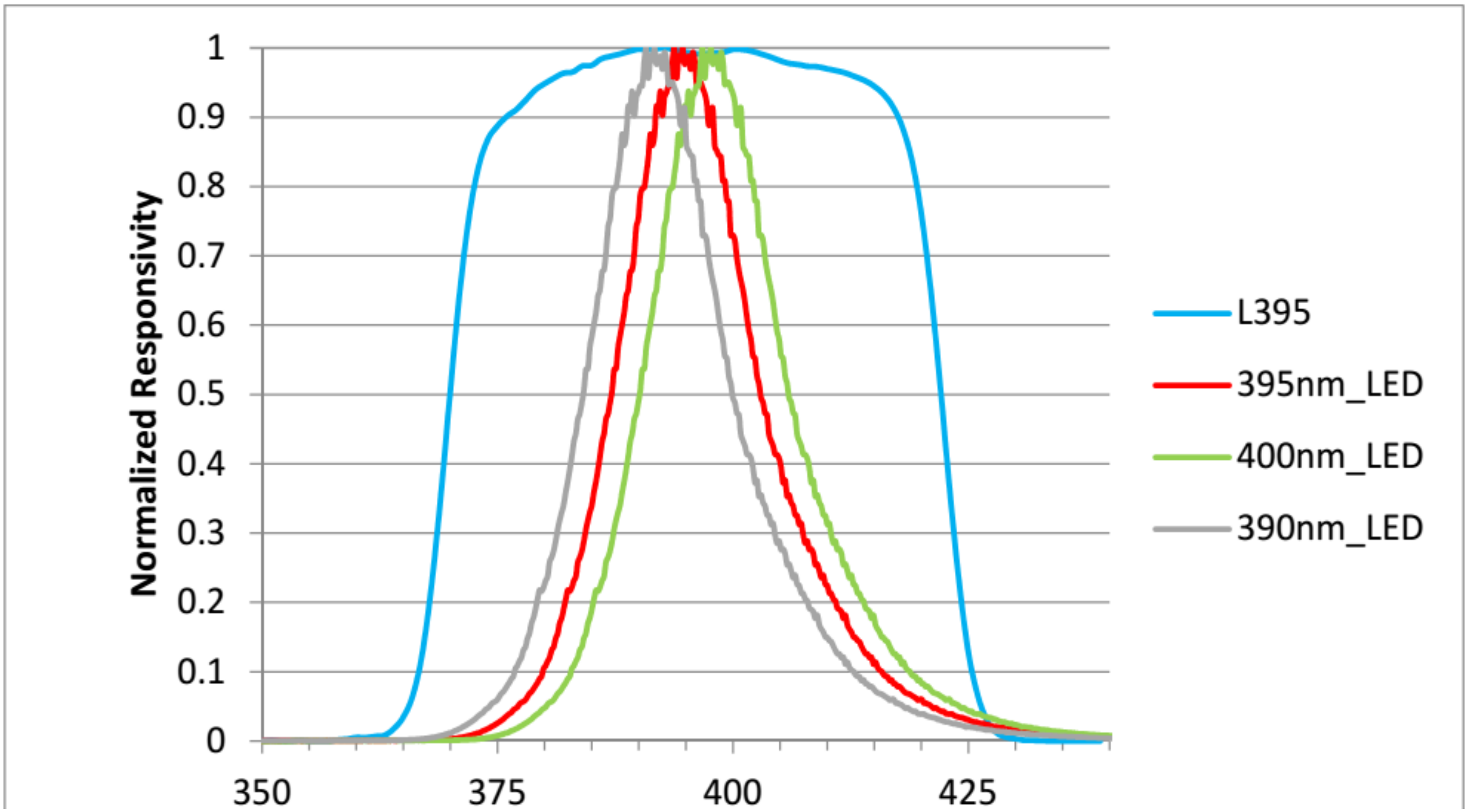


Instrument Response

Total Measured Optics Response

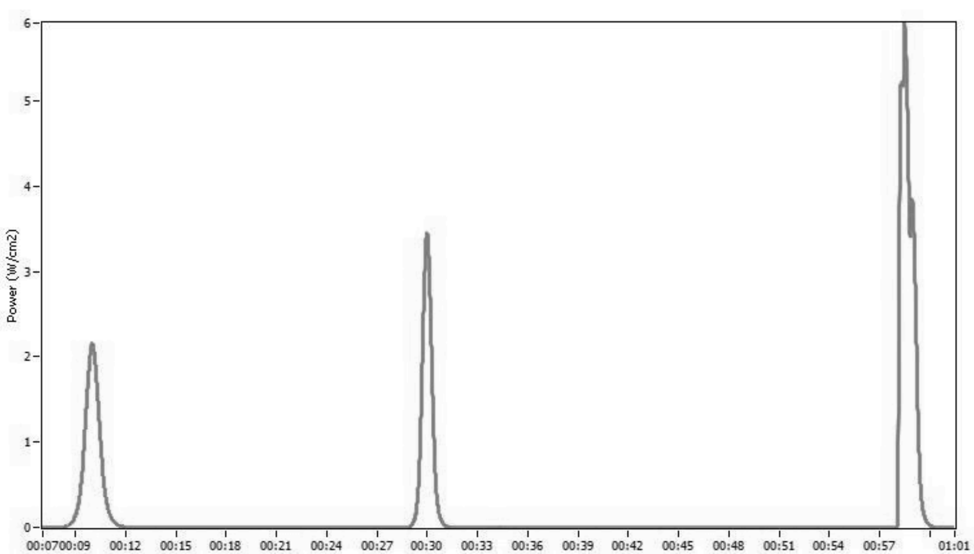


Total Measured Optics Response



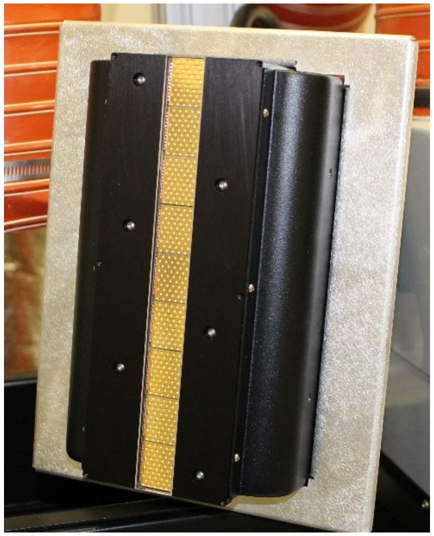
LEDCure™ Profiling Radiometer

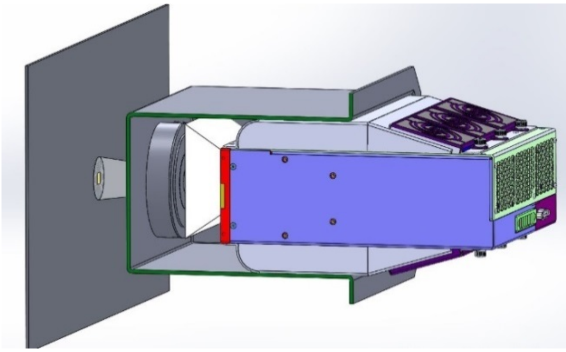
- 40 Watt Dynamic Range
- Display Plus Profiler Option
- L395 Total Optics Response
- Additional L-Bands coming soon



Calibration Challenges

- Industrial LED sources have exceeded **50W/cm^2**
- Typical irradiance levels, sources and standards that NIST has worked with are much lower (mW/cm^2-µW/cm^2)
- Reduce variation and errors introduced in transfer process
  - Fixtures
  - Direct evaluation of EIT master unit by NIST from 220 nm past visible region
- Uniformity of UV LED source used with working standard and unit under test





Instrument Features for LEDs

Desired Instruments Features

- Cover LED Source and natural variations
- High dynamic range
- Easy to use
- Cosine response
- Stable method of value transfer/ calibration
- Other: TBD

Thank You.

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