UV LEDs:
A Measurement Update

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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

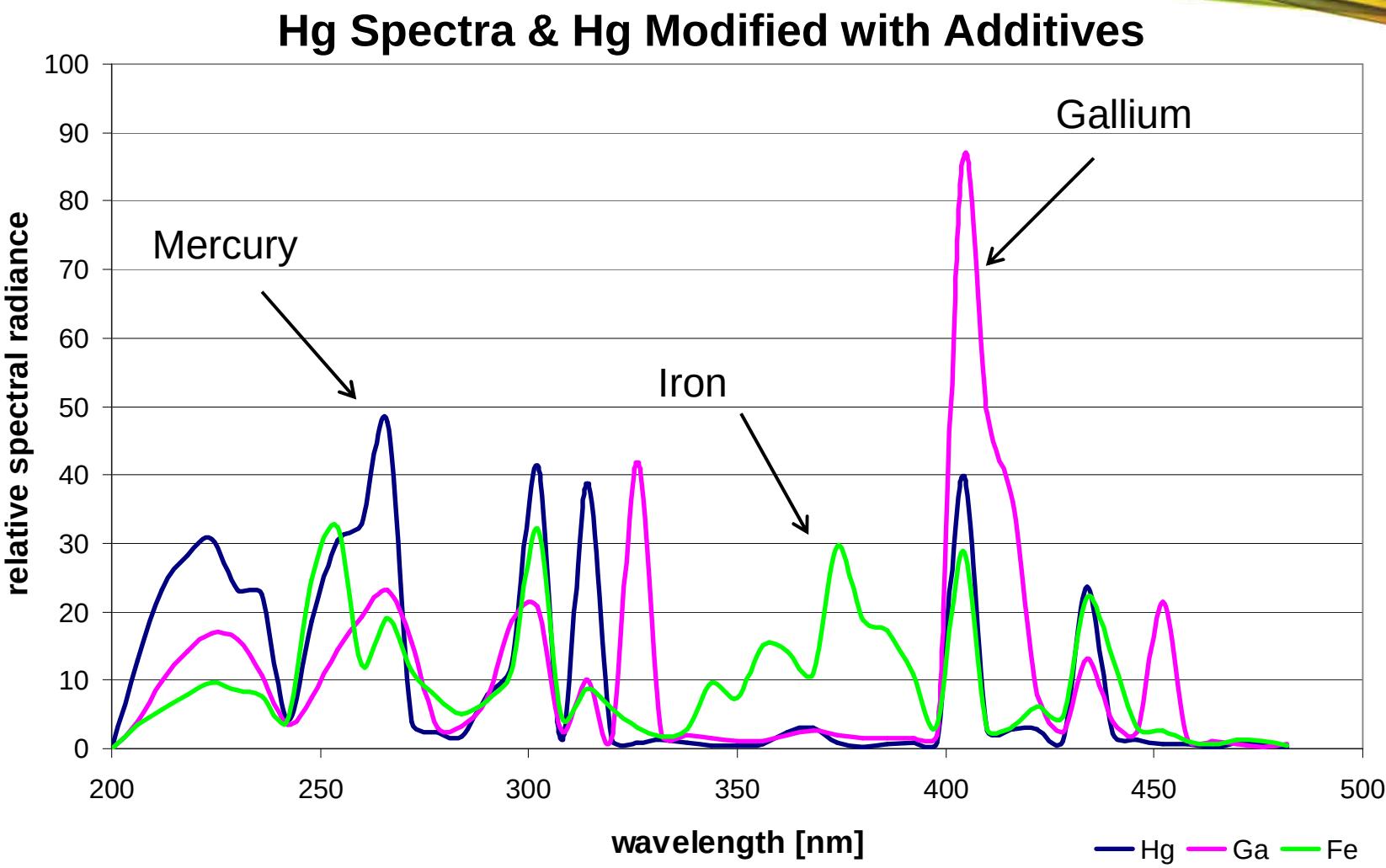
Arc Lamps

Spot Sources

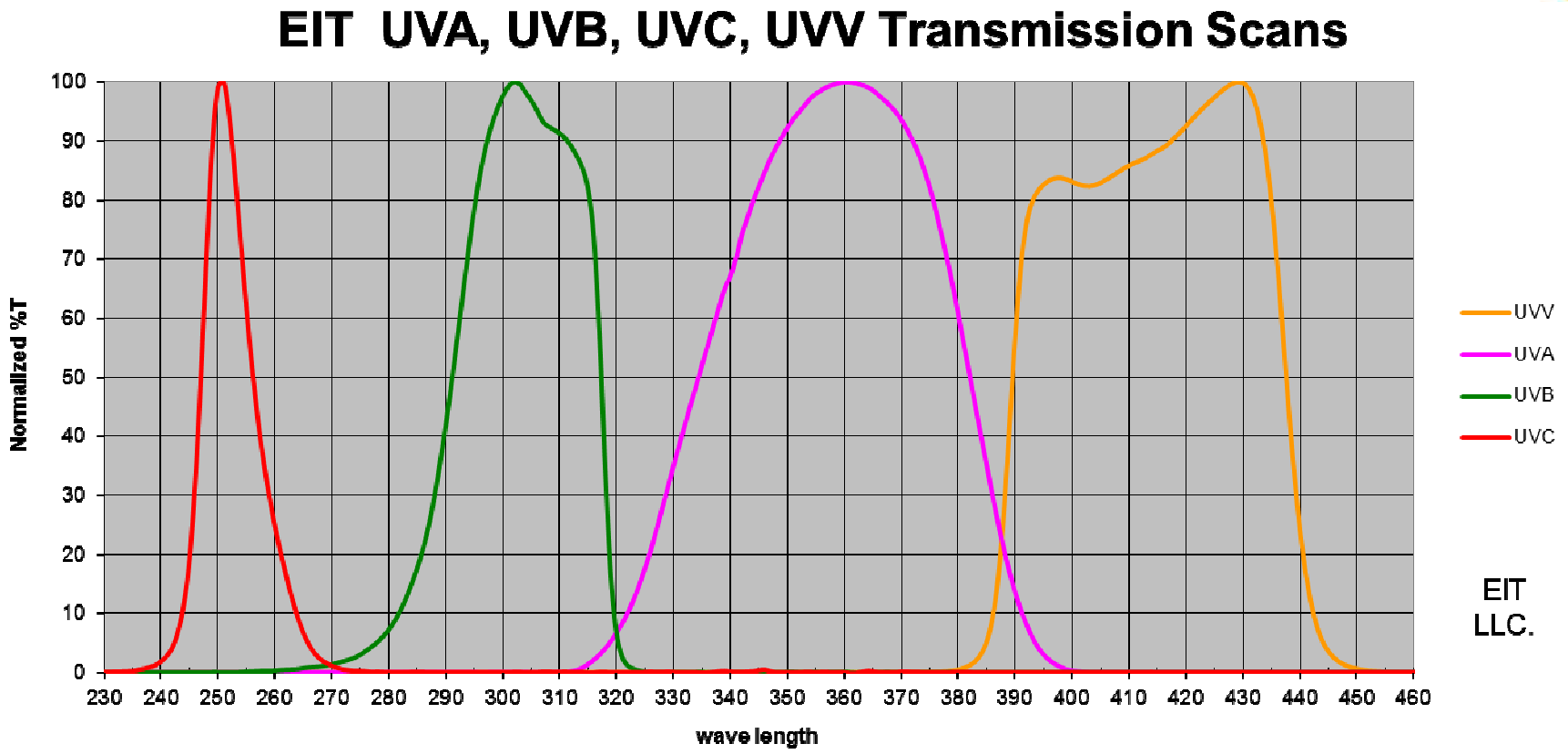
Microwave Lamps

Images Courtesy: Dymax, Heraeus, Miltec, Nordson Corporation

Broadband Spectral Output



Instrument Responses

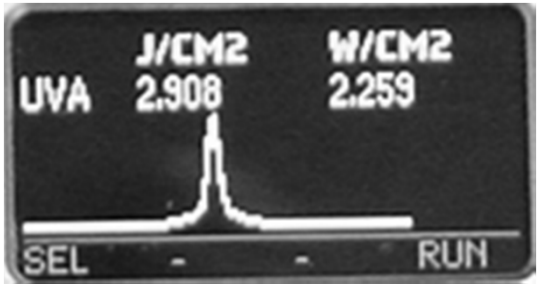


The traditional approach has been to define the band response based ONLY on the filter response

UV Measurement Strategies

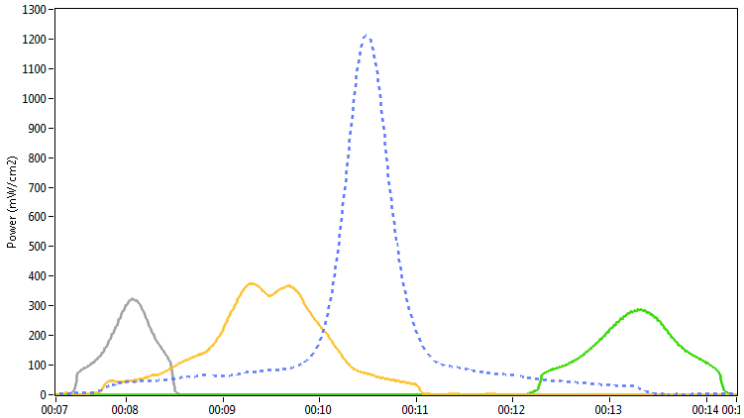
1. Radiometers

- Absolute units
- Want a “number”



2. Profiling Radiometers

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

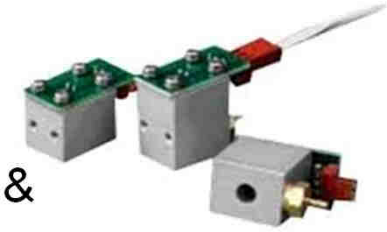


3. Spectral Radiometer

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

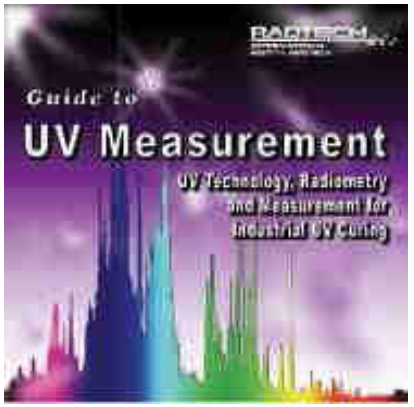
4. Relative Instruments

- 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**

Challenges Measuring Broadband UV Sources

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

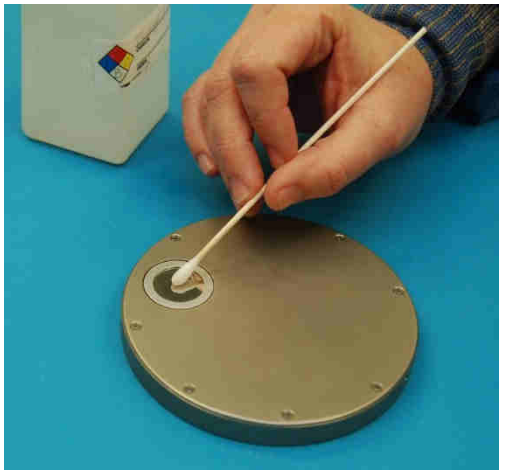
- Fraction of a percent?

UV Measurement Challenges

Instrument Cleanliness

Irradiance W/cm^2			
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/cm^2			
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

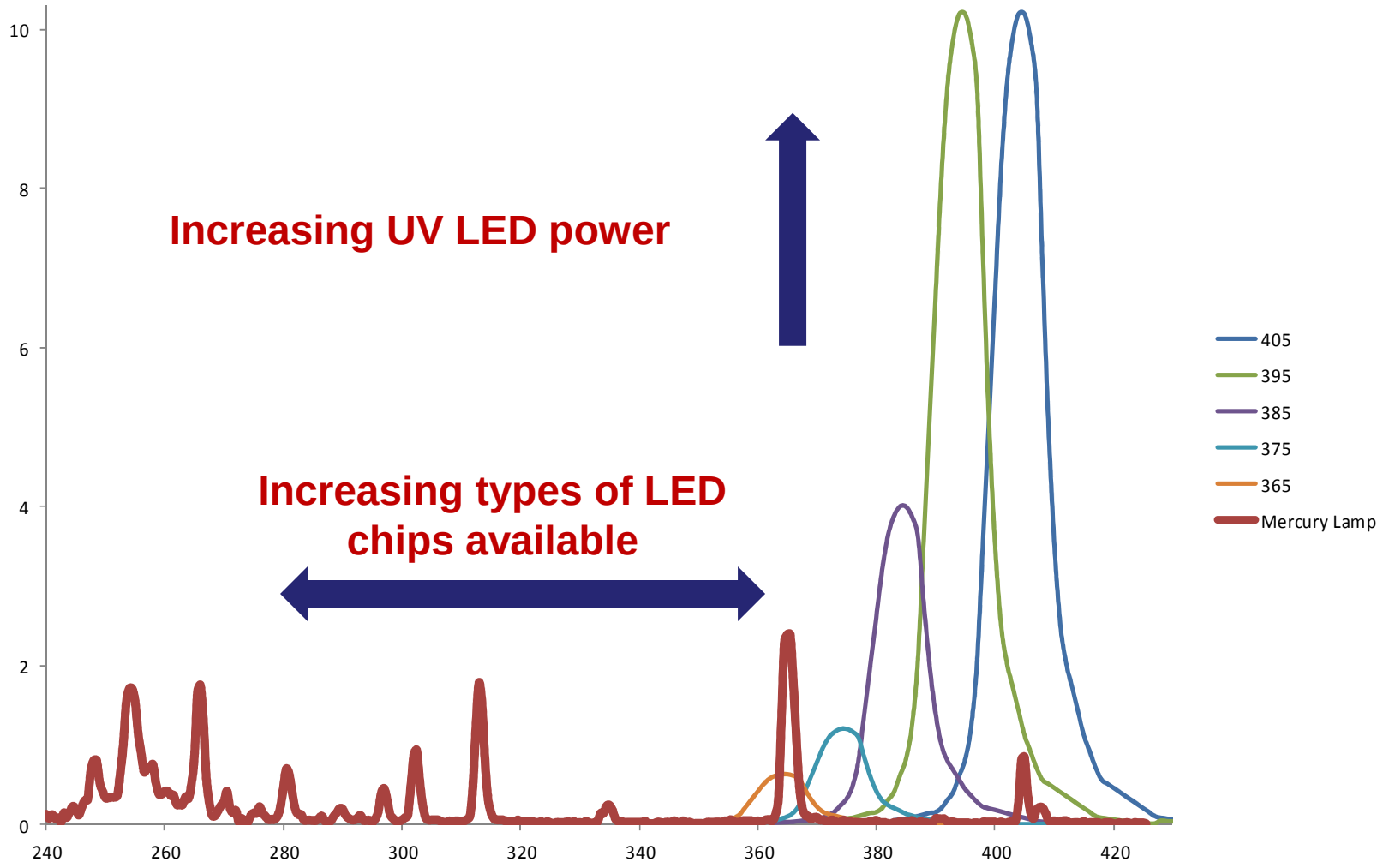
UV LEDs

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

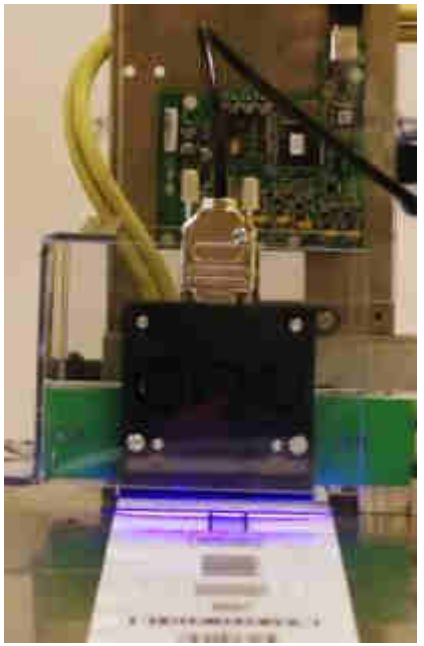
UV LED Power Output vs. Wavelength



UV LEDs: Measurement

What do you want to measure?

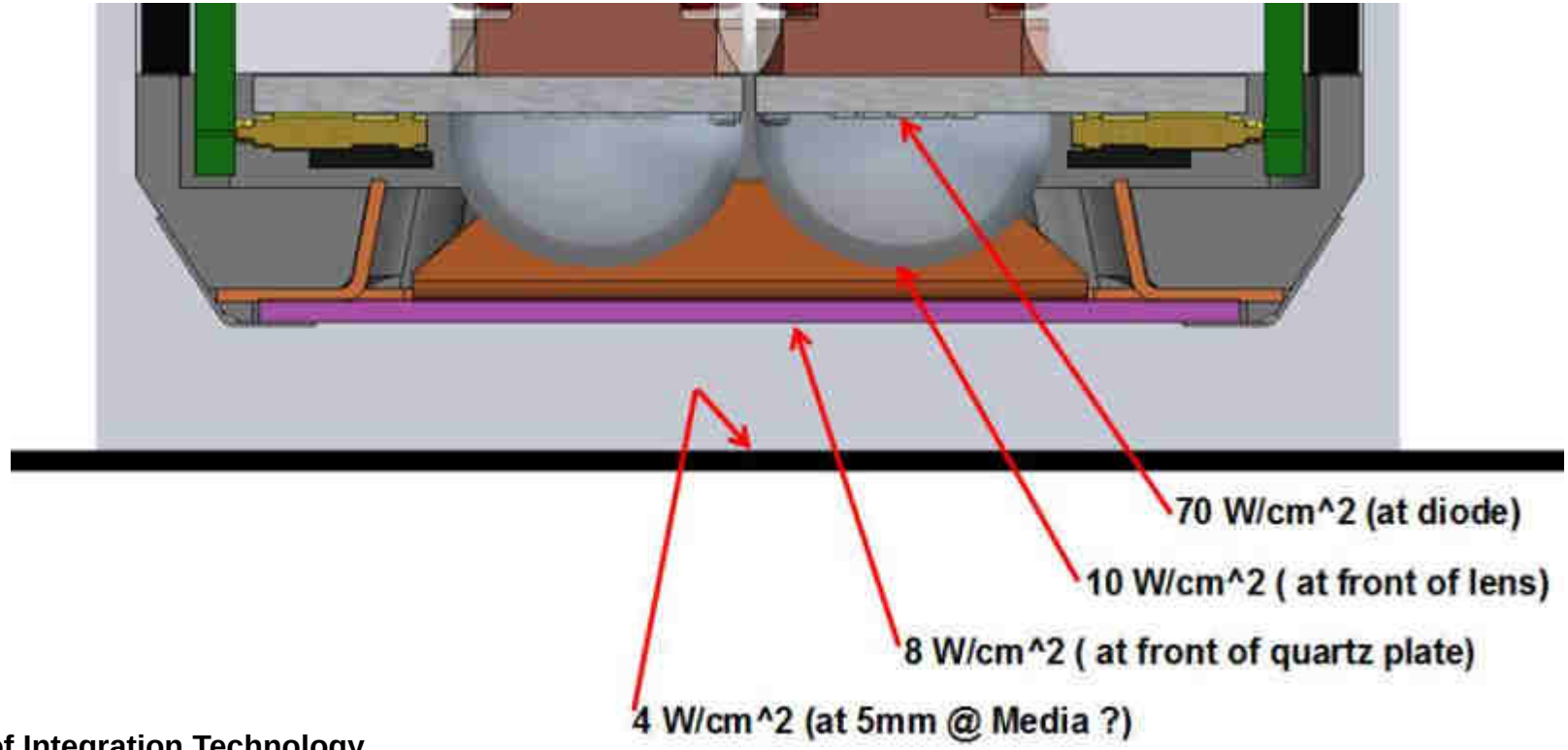
- What do you want to measure?
  - Individual LED
  - Array
  - **Production system**
- What values do you want?
- Industrial UV: W/cm^2 & J/Cm^2
- Visible LEDs: Flux?/Color?



UV LEDs: Measurement

Where do you measure?

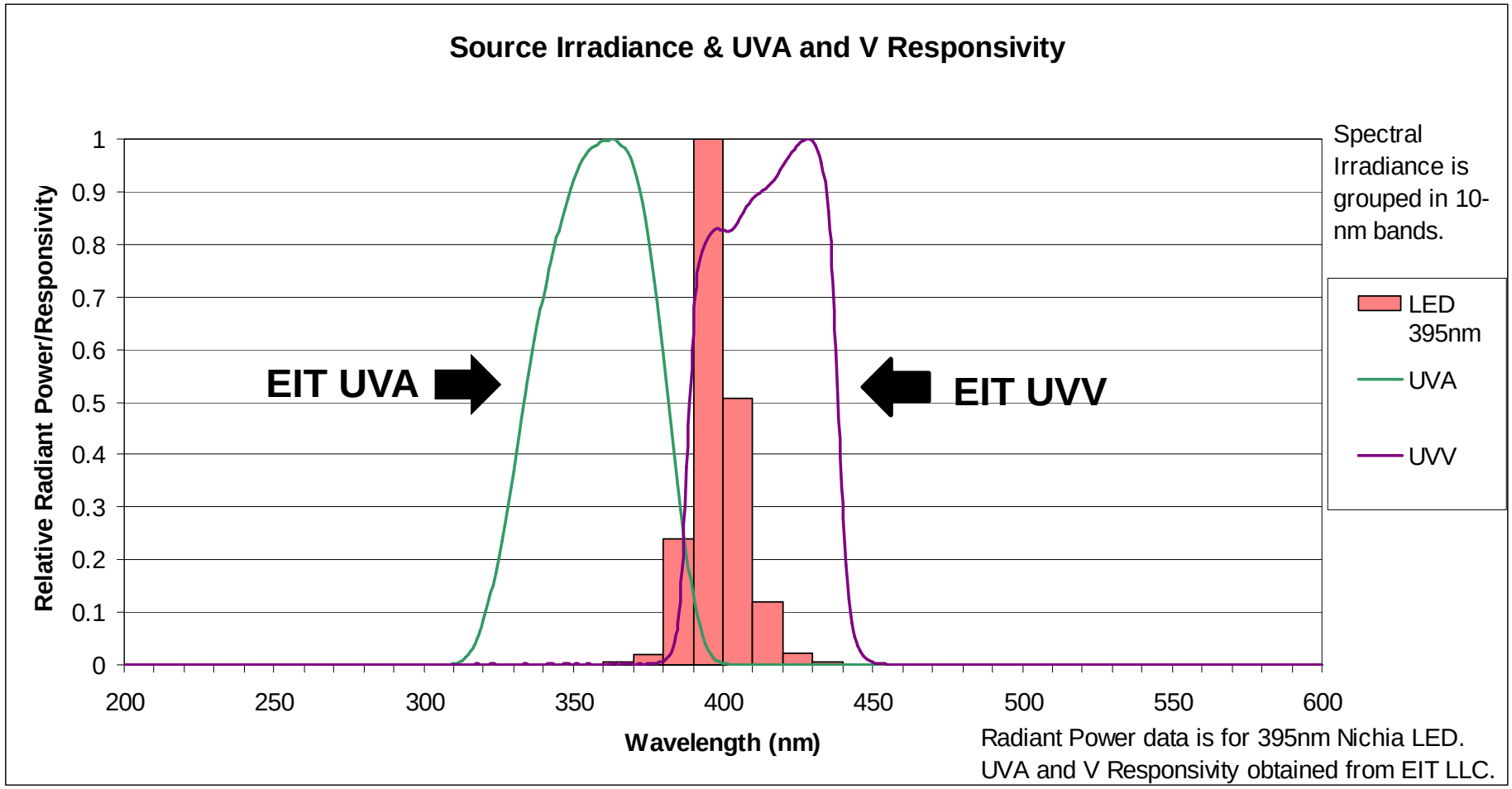
- **Where is the proper location for the UV Irradiance Value?**
- **How do we compare systems and communicate values?**



Courtesy of Integration Technology

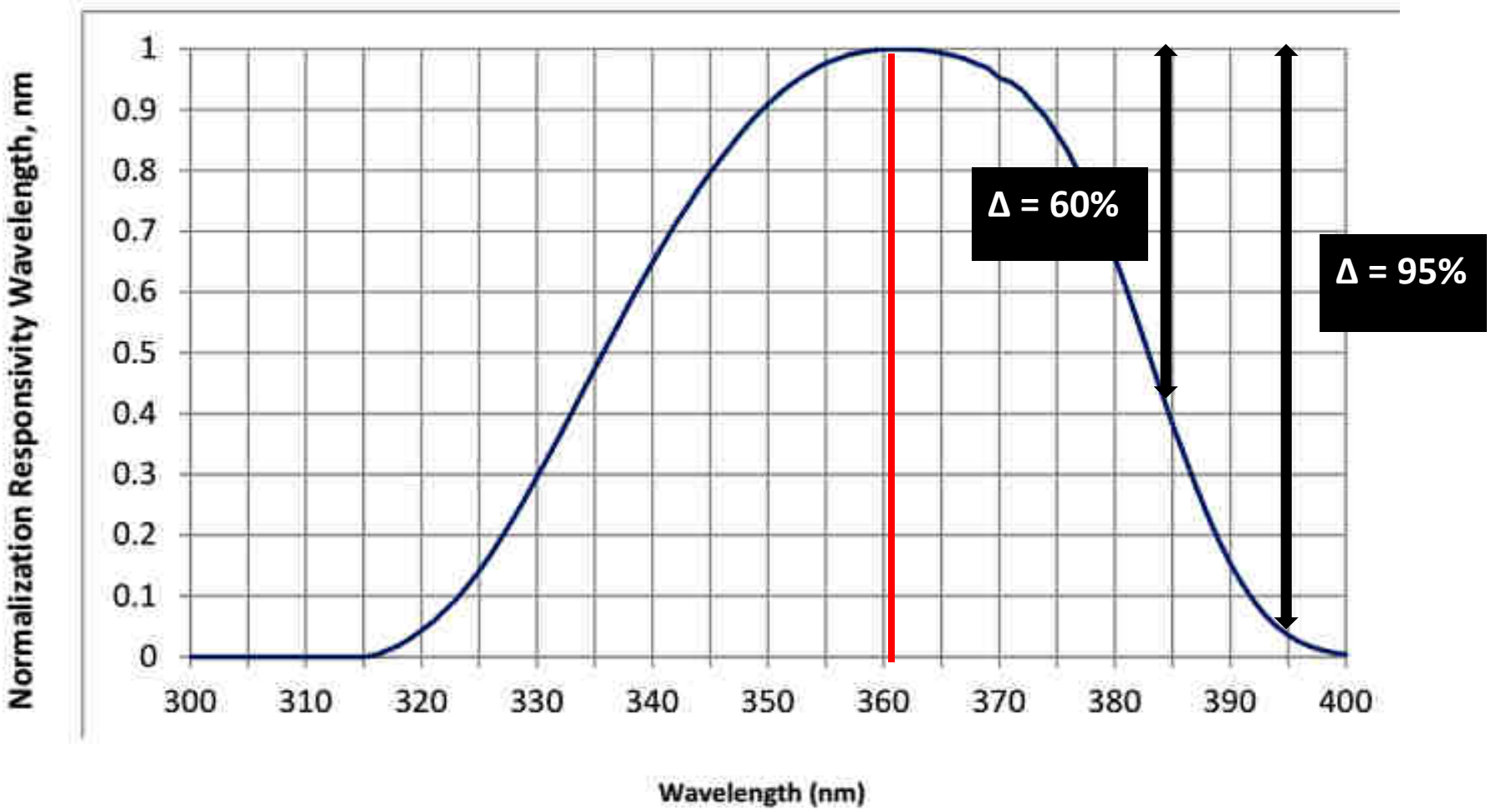
Measurement of 395 nm LED

Is the instrument response matched to the source?

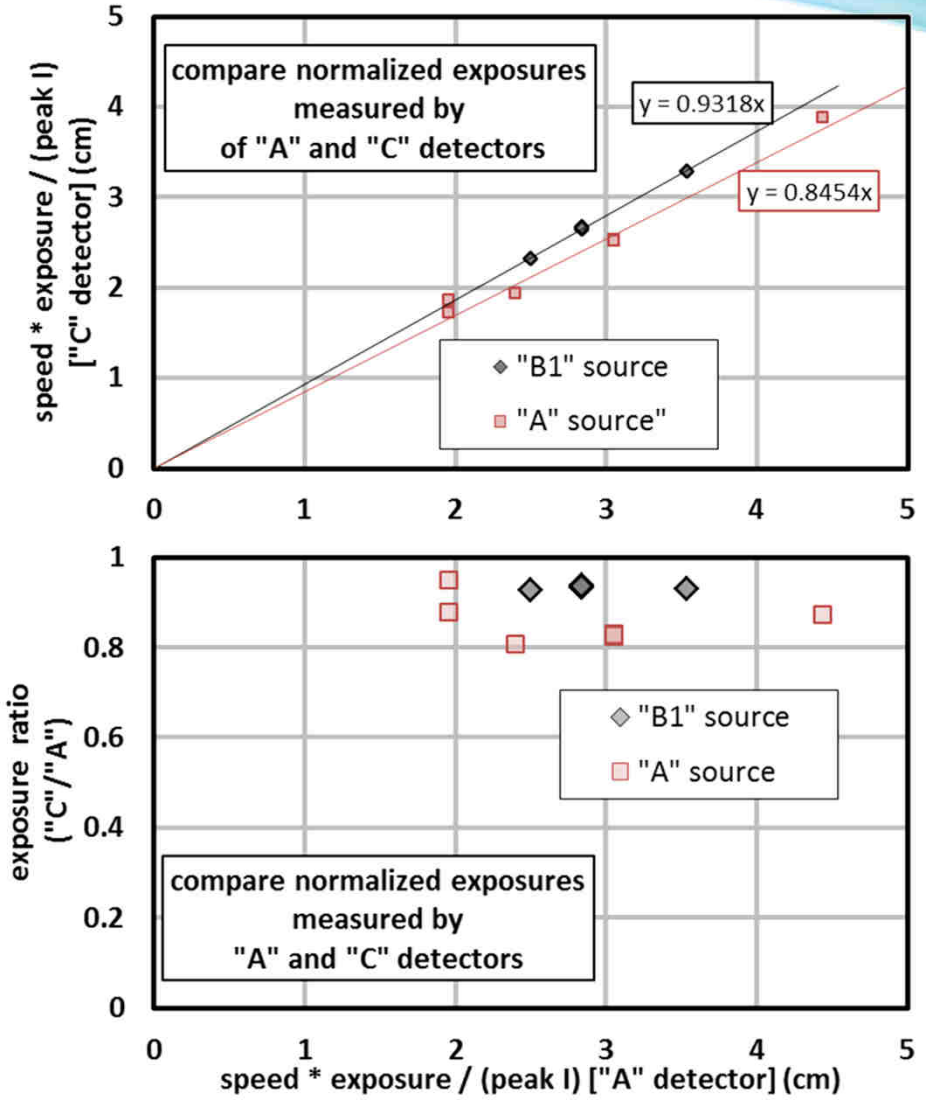


Measurement of 395 nm LED

Using UVA to measure a 385 nm or 395 nm LED



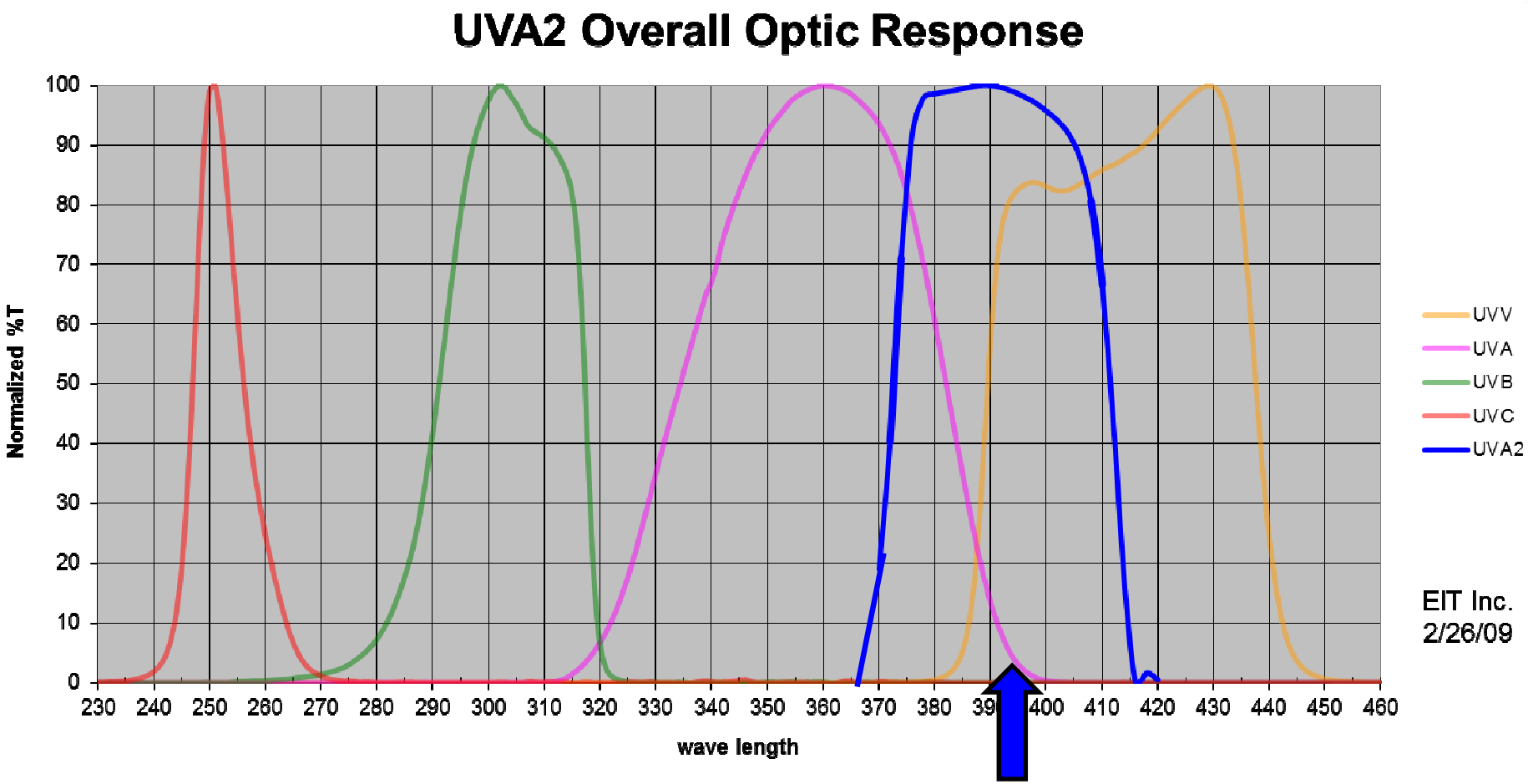
NIST comparison of high power UV LED sources



From NIST report (Figure 9)

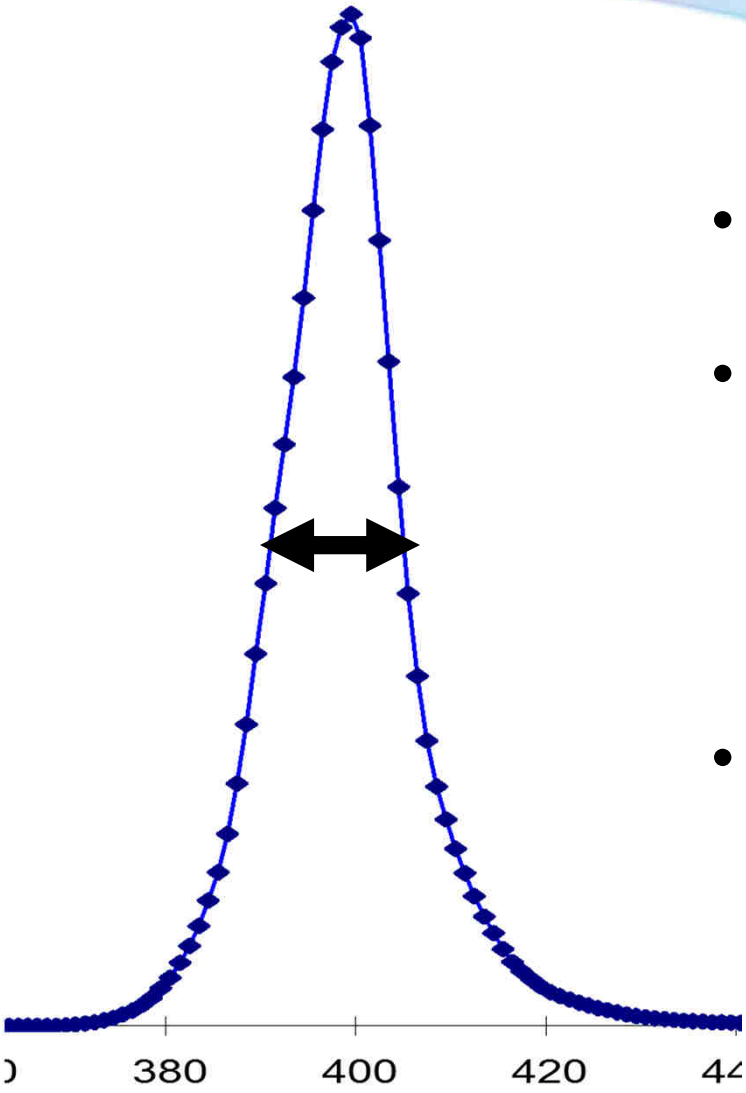
- Study completed by Dr. Robert F. Berg, NIST
- Looked at three LED units with two different radiometers
- No surprise there were differences
- CORM Meeting at NIST on May 18th
- Path forward?

EIT UVA2 Bandwidth Response



Added UVA2 (380-410 nm)

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

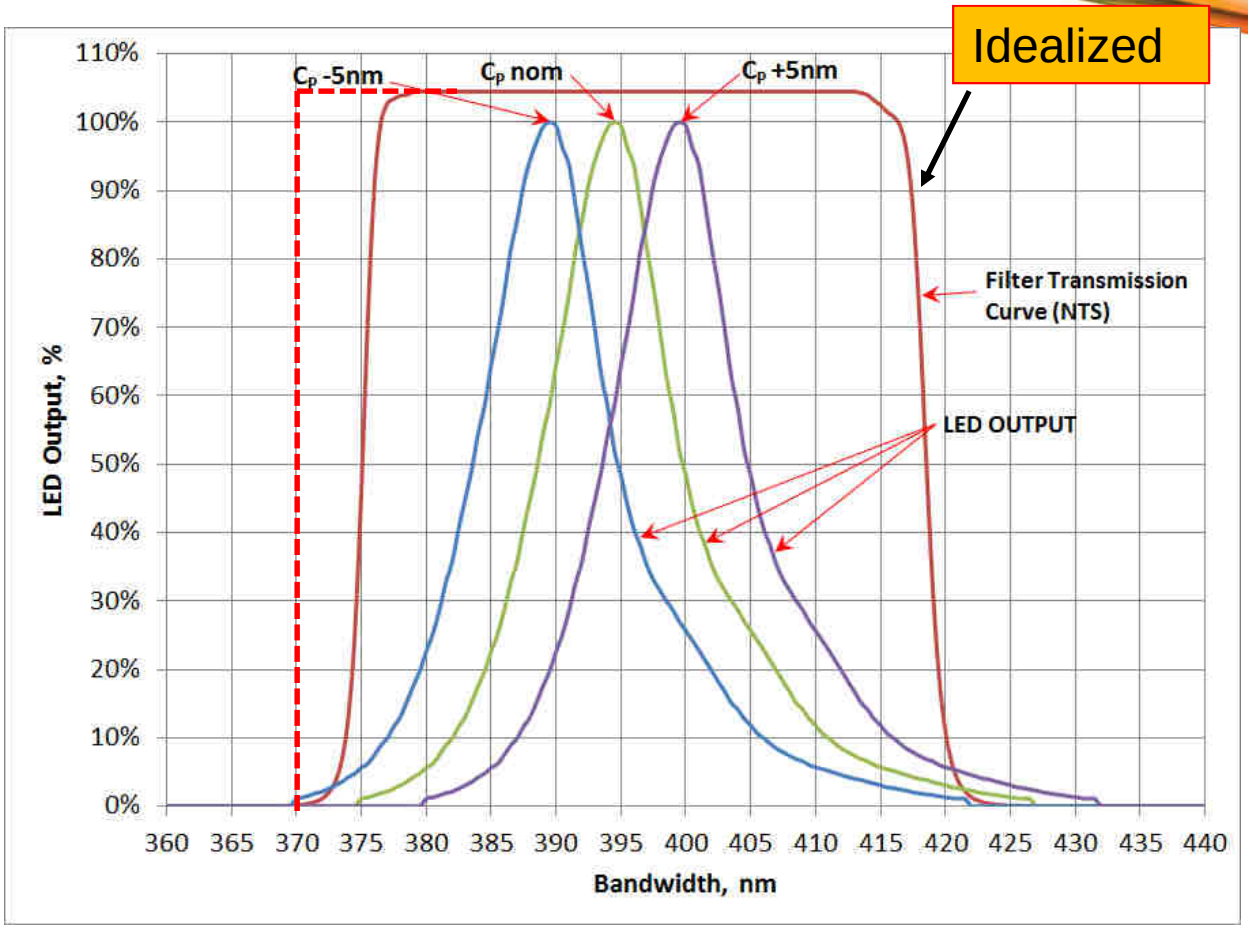
Band Name Identifier	Approximate Wavelength Range
UVA	315-400nm
UVB	280-315nm
UVC	240-280nm
UVV	400-450nm

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

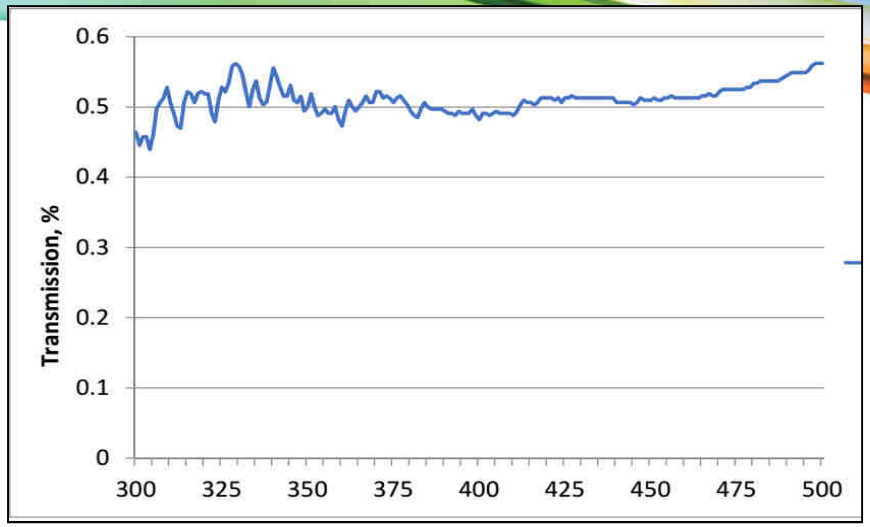
- "Wide" (+/- 100 nm) vs. "Narrow" (+/- 50 nm) Approach
- Advantages & Disadvantages to each approach
- **Goal: Flat Response**

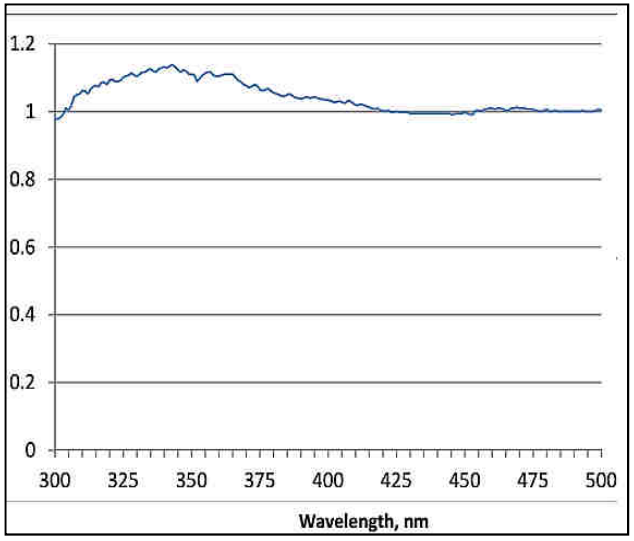


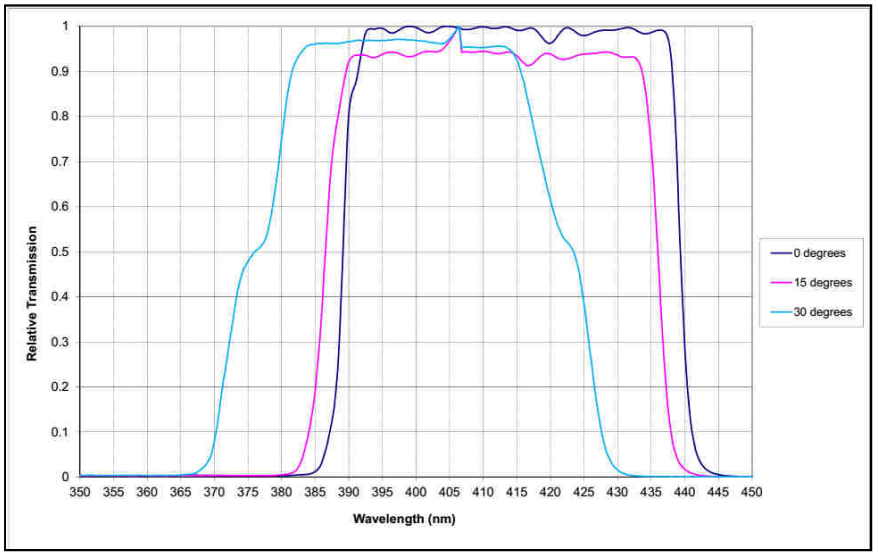
L395 LED Output Spectra Showing ± 5nm Spread of Cp Along with Required Filter Response to Obtain 2% Measurement

Total Instrument Response

- Control of overall optics to flatten **OVERALL** response of instrument
- **ALL Optical Components NOT just the filter**

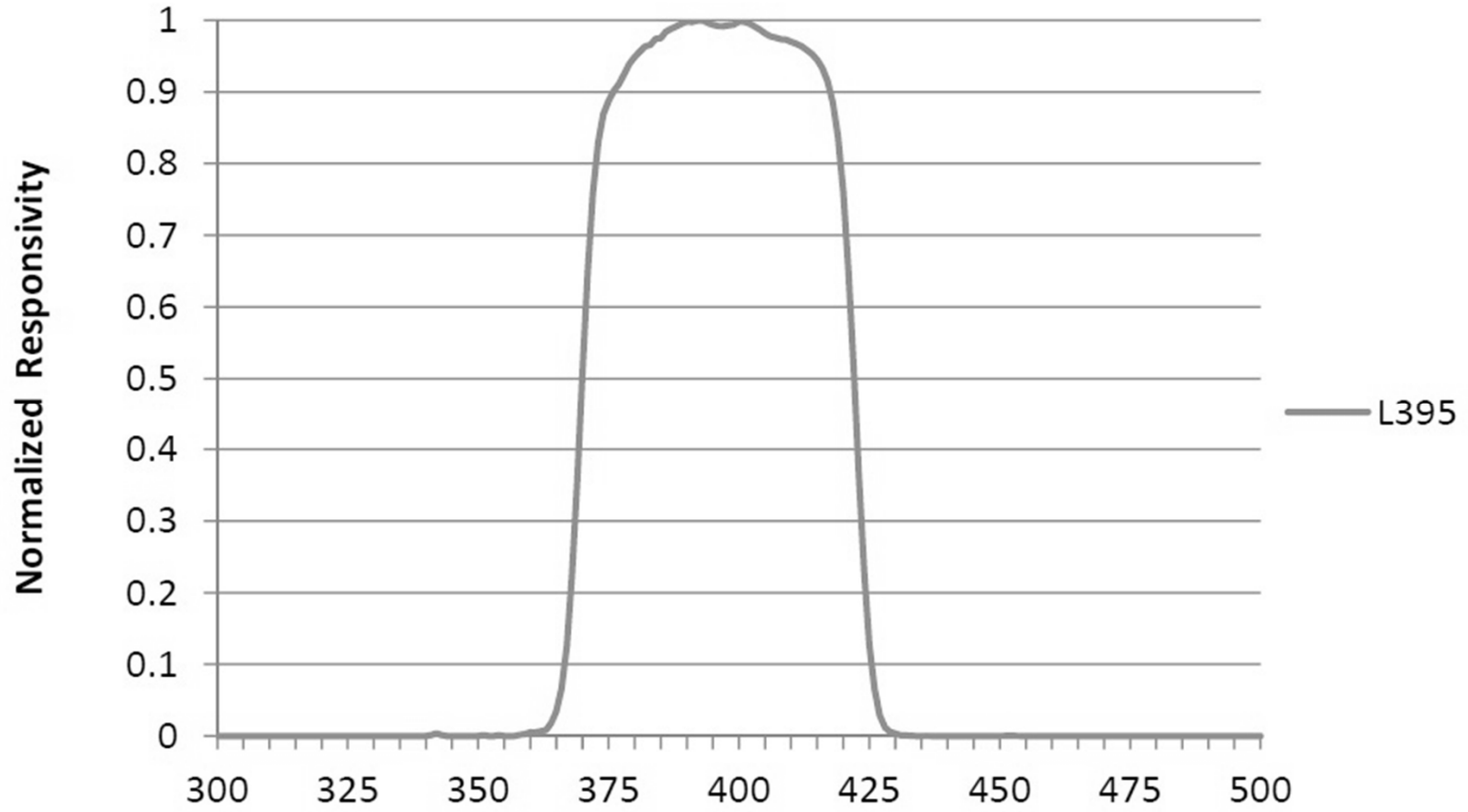






Instrument Response

Total Measured Optics Response



Instrument Response

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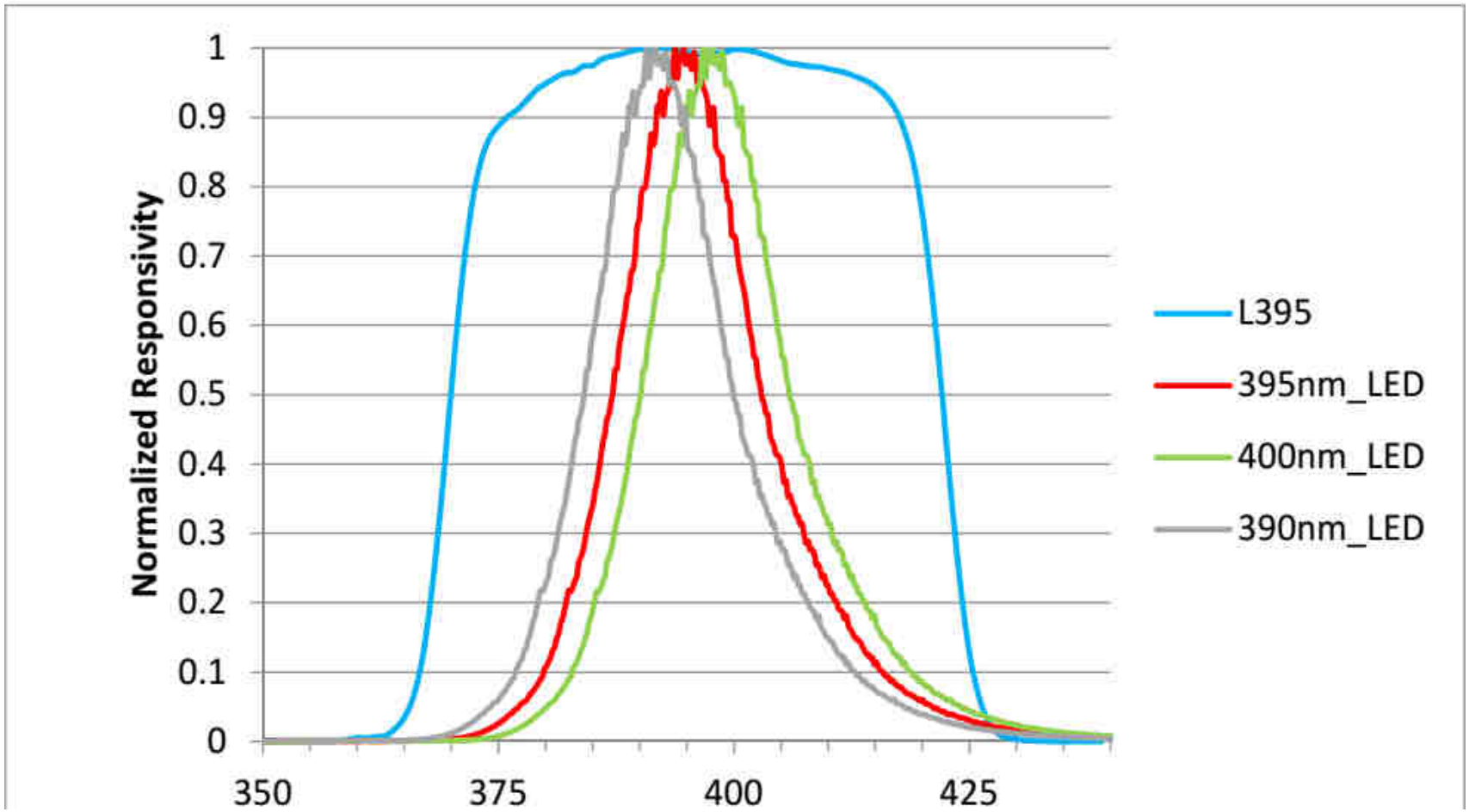
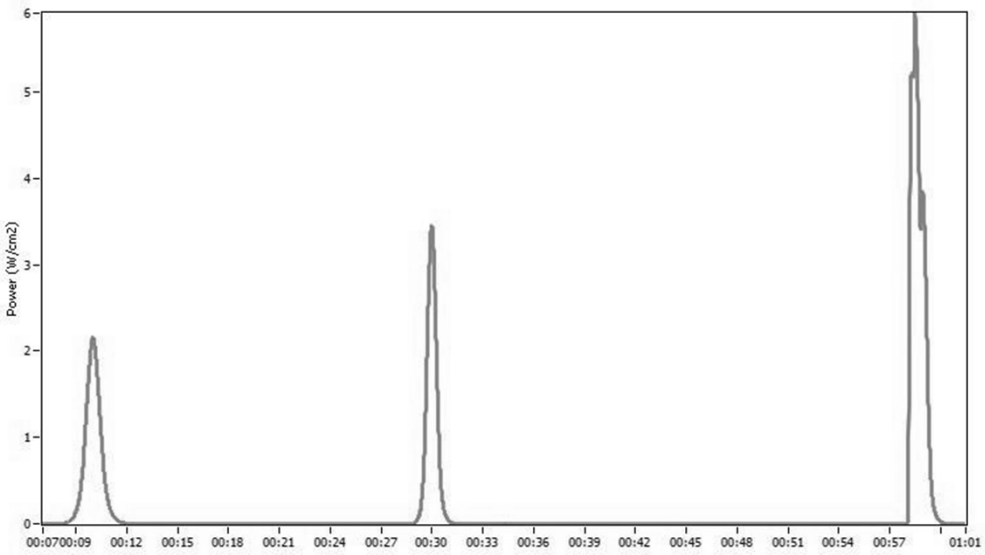


LED-R™ Series

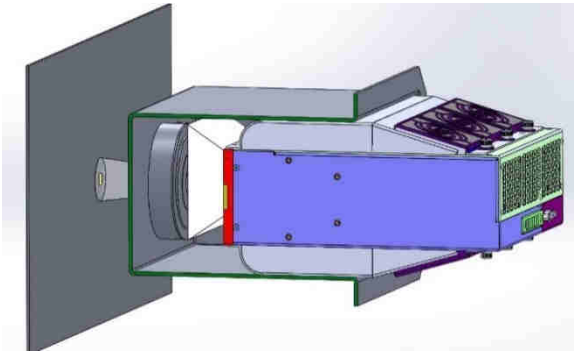
LEDCure™ Profiling Radiometer

- 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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