INSTRUMENT MARKETS

Healthy UV Curing on Wood

Jim Raymont EIT Instrument Markets

July 20, 2017

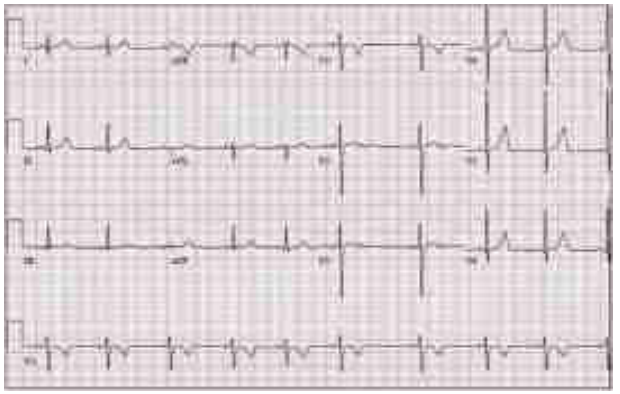
RADTECH INTERNATIONAL NORTH AMERICA

AWFS FAIR VEGAS

Preventative Medicine

"An ounce of prevention is worth a pound of cure"

"You have a rare condition called 'good health'. Frankly, I'm not sure how to treat it."



Physical, Lab Tests, History, Lifestyle Changes, Medicine, Communication, Common Sense

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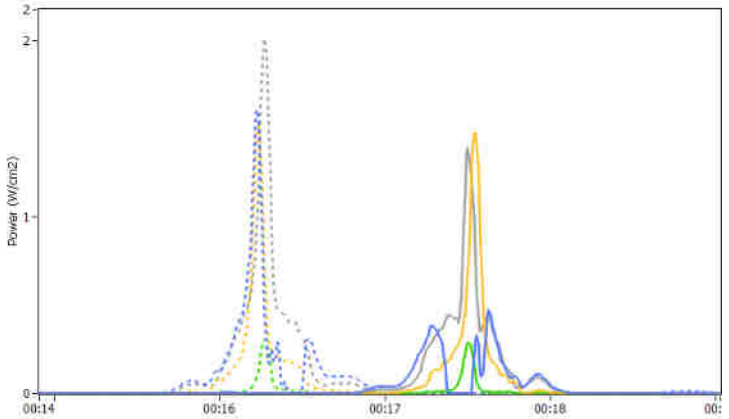
Preventative (UV) Maintenance

“An ounce of preventative maintenance is worth……”



Process Window, Lab Tests, Process History, Maintenance, Communication, Common Sense

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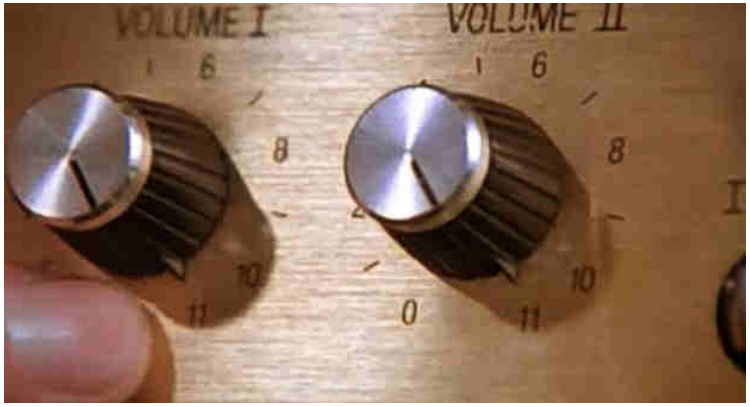
Similarities Between the Medical and UV Worlds

Medical

- Medical History
- Visual Examination
- Diagnosis
- Natural Causes
- Sudden
- Abuse
- Malpractice



UV

- Job History or Job Log
- Visual Examination
- Diagnosis
- Natural Causes
  - Lamp output decays over time
  - Materials have a shelf life
- Sudden
  - Something breaks
  - Changes to settings
- Operator Error
  - Lack of maintenance
  - Changed/Wrong Settings
  - Tinkering with formulas

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Check List of Desired Coating Properties

- ✓ Abrasion Resistance
- ❑ Scratch Resistance
- ❑ Chemical Resistance
- ❑ Hardness
- ❑ Weatherability
- ❑ Non-Yellowing
- ❑ Flexibility
- ❑ Tensile Strength
- ❑ Gloss
- ❑ Coating Viscosity
- ❑ Film Thickness
- ❑ Ability to Over Coat
- ❑ Sandability
- ❑ TBD

What properties are formulation driven?

What properties are process/UV source driven?

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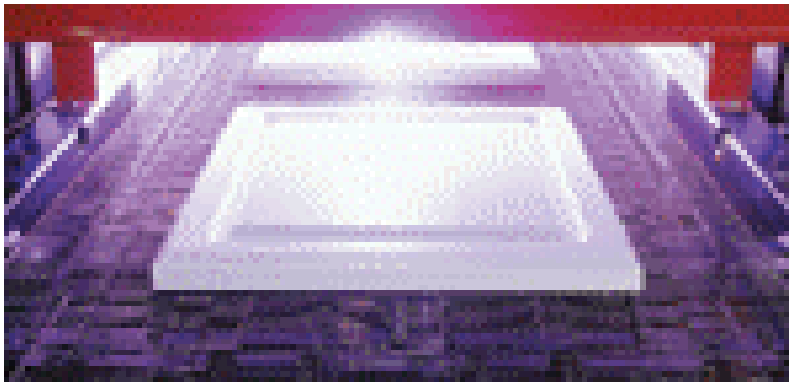
Wood Line Characteristics

- Multiple Lamps
- Multiple Bulb Types: Mercury, Mercury-Gallium, LED
- Varying Lamp Output
  - Station to Station
  - Across the Width of Lamp
- Uniformity of Equipment in a Facility or Company?
- Environment
  - Dust, Dirt, Particles
  - Reflector Cleanliness
- Variable Production Speeds



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Rules of UV: Margaritaville Rule

Rule #1A: Blame the Formulator

Rule #1B: Blame the Equipment Supplier

The UV Process-Analogy

Cake: Bake at 350°F for 30 minutes

Oven Temperature (°F) is similar to Irradiance (Watts/cm^2)

Bake Time (Minutes or seconds) is similar to Energy Density (Joules/cm^2)

Not Specified: Oven Type

Changing the Cake Process Window

- **350° X 30 = 10,500**

Equal Degree Minute Options

- **700°F for 15 minutes?**
- **175°F for 60 minutes?**

What if the cake mix only gave you the time?

Speaking the Same Terminology

Irradiance (Intensity)

- Expressed in watts or milliWatts per square centimeter (W/cm^2 or mW/cm^2)
- Total *radiant power* of (all) wavelengths passing from *all incident* directions onto an infinitesimally small area (cm^2)
- Depth of cure, penetration through pigments and opaque colors, adhesion to the substrate

Energy Density (Dose)

- Expressed in Joules (J/cm^2) or milliJoules (mJ/cm^2) per square centimeter
- Incorporates time as part of the measurement
- One watt for One second = One Joule
- Area under the irradiance curve
- Often the only UV exposure guide number supplied

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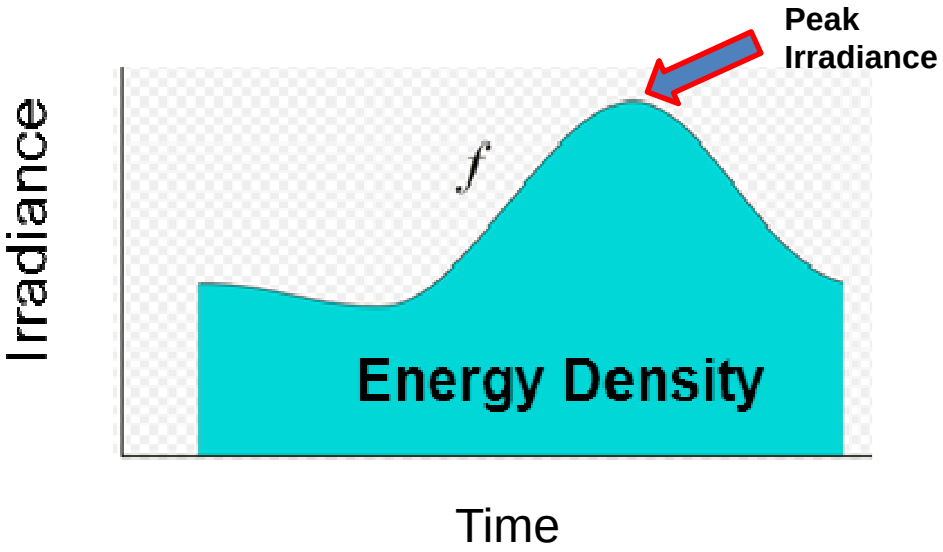
Speaking the Same Terminology



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Impacts To UV Irradiance & Energy Density

- Line speed
- Age of the lamp
- Lamp output settings
- Distance from the lamp to the coating
- The condition of lamp reflectors
- Darkening of lamp electrodes

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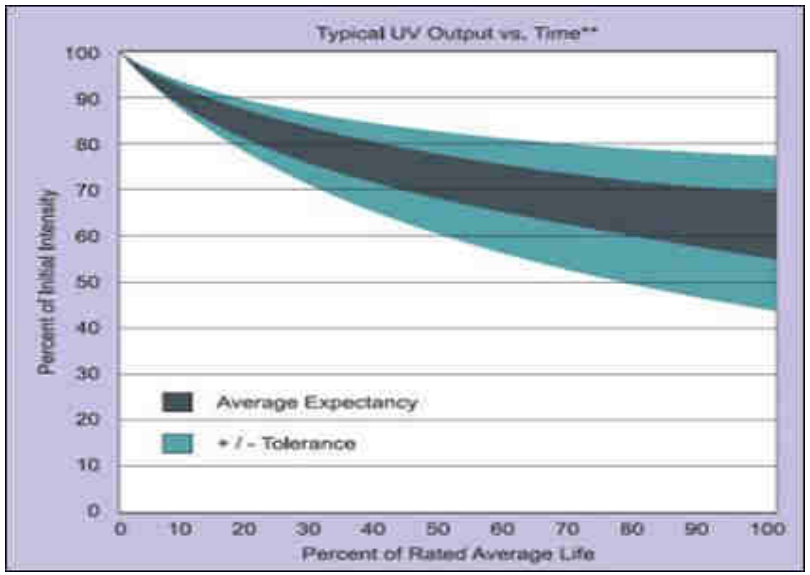
Natural Aging



UV lamps age…

…and so do (opened) coatings.

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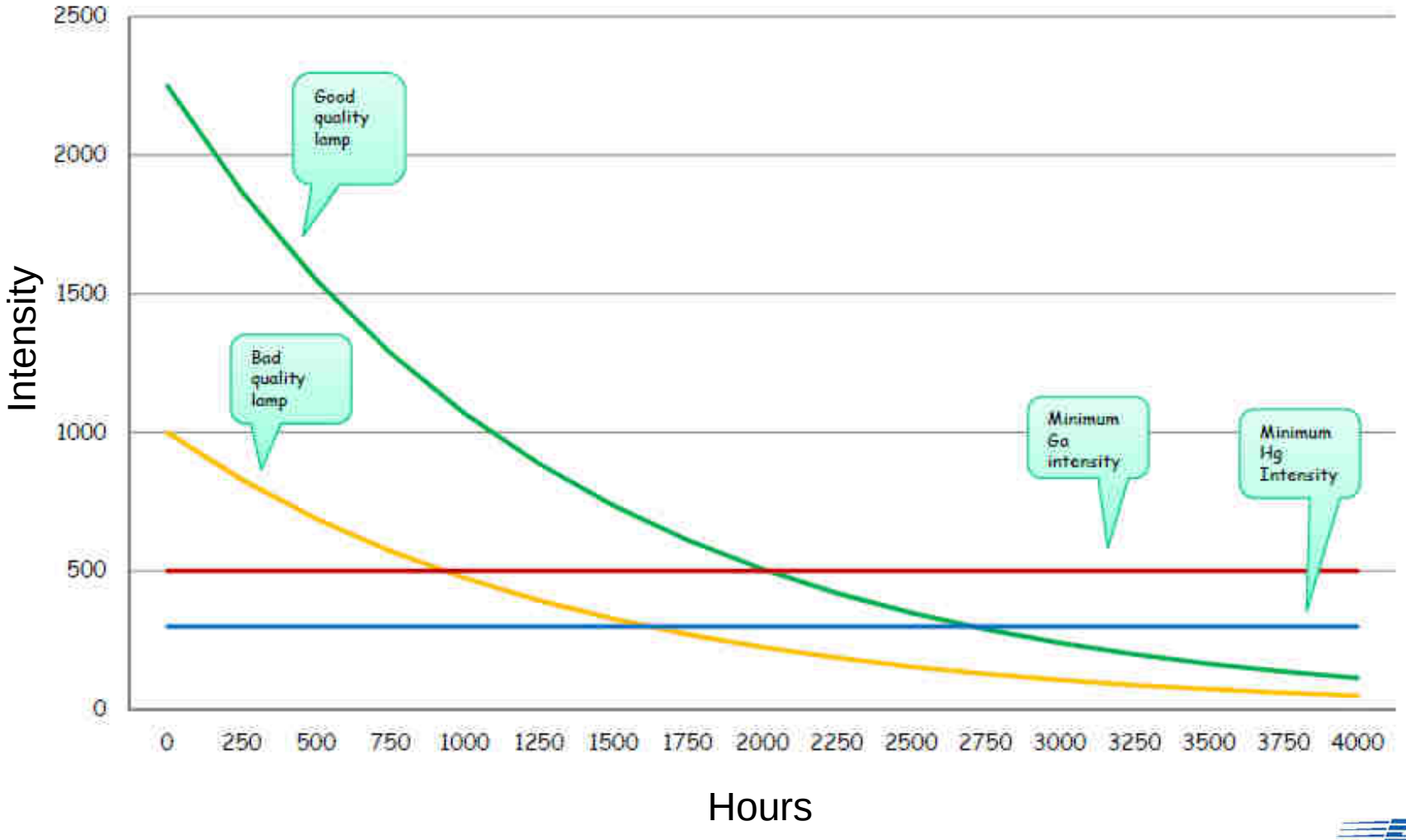
Bulbs: Buy on Value vs. Price



Courtesy Efsen Engineering

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Bulbs: Buy on Value vs. Price

Watch purchasing staff getting 'specials'

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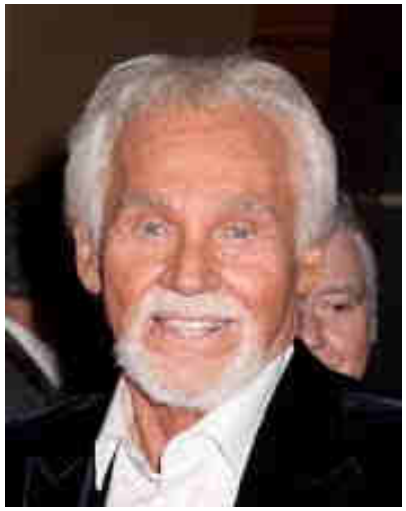
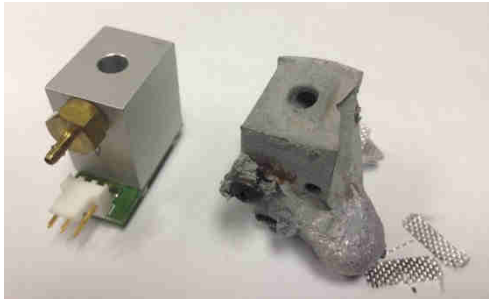
Un-Natural Aging

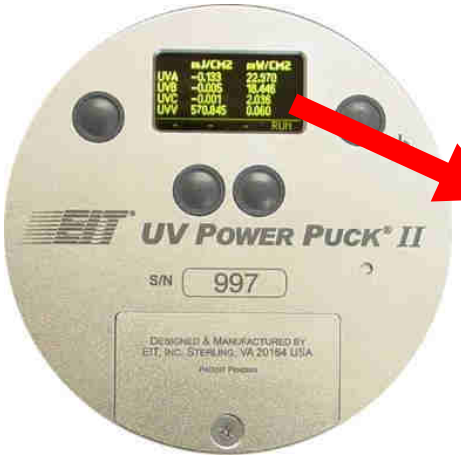




Using Absolute Instruments

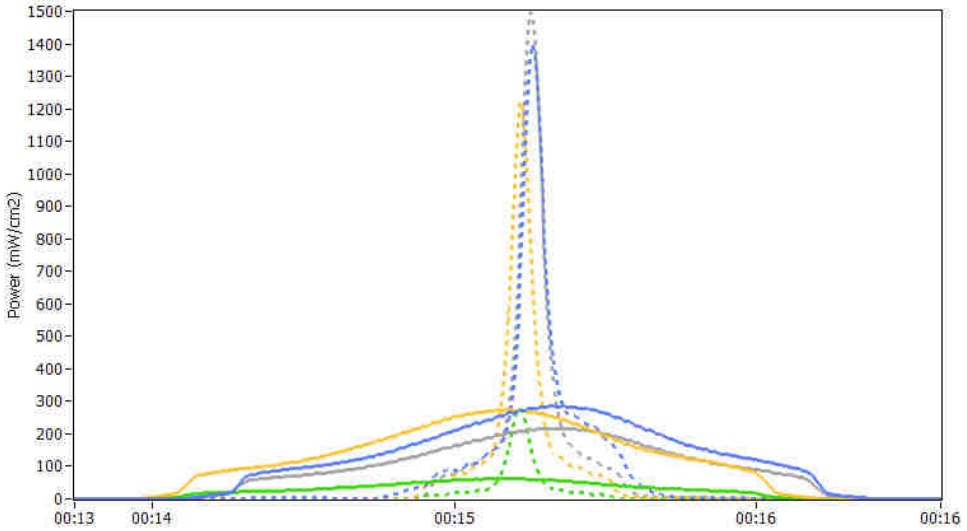
Standard Unit

- Want a “number”
  - Match a specification
  - Troubleshoot
  - Optimize a process
  - Compare lines
  - Communicate data



Profiling Radiometers

- The irradiance as a function of time
- Irradiance profiles useful to:
  - View system over time
  - View lamp focus (Gloss)
  - Determine lamp type
  - Analyze multi-lamp systems
  - Joules/Watt from each bulb
- Targeted Maintenance Approach



Lamp Performance-Numbers

55” (140 cm) bulb

Irradiance mW/cm²	Data collected 3/24/16			
Band	**Left**	**Center**	**Right**	**Highest Delta**
UVA	797	983	635	35.4%
UVB	713	888	573	35.5%
UVC	200	257	167	35.0%
UVV	612	757	492	35.0%
Energy Density mJ/cm²				
UVA	243	282	234	17.0%
UVB	206	239	195	18.4%
UVC	58	68	55	19.1%
UVV	231	264	222	15.9%

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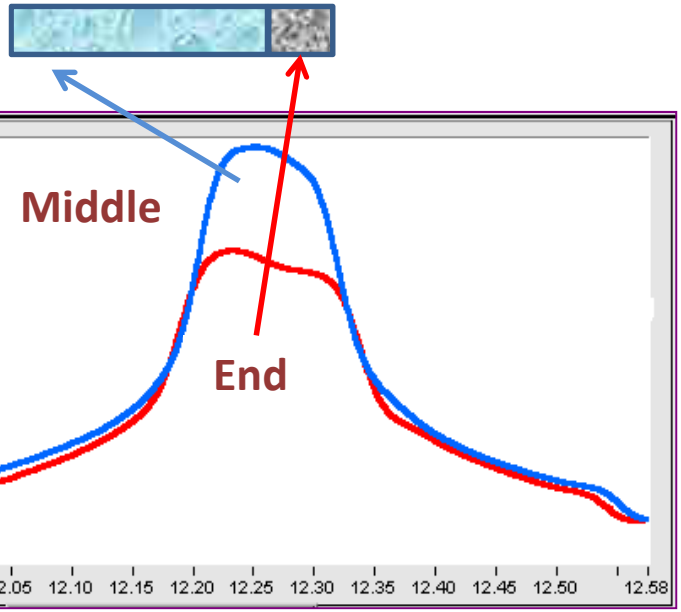
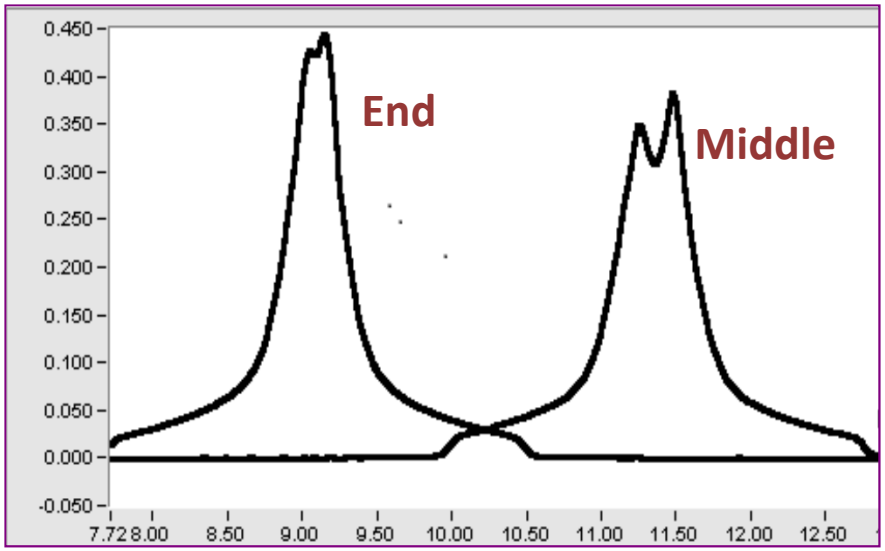
Lamp Performance- Visual





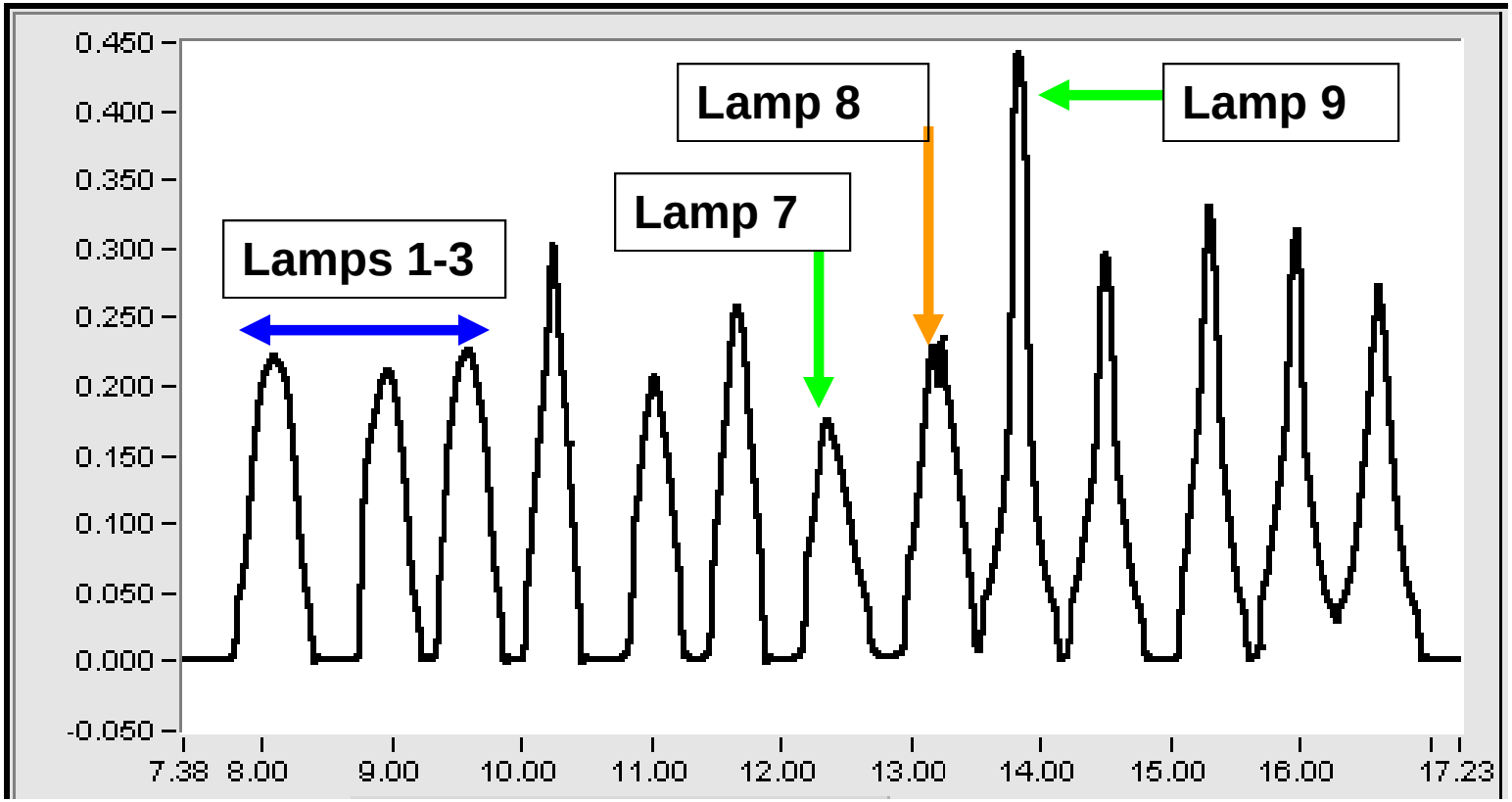
Aged Arc Lamp

- 440mW/cm^2 (Middle)
- 317 mW/cm^2 (End)

Inadequate Cooling Airflow

Multiple Lamps on Production Line

Graphically display and show multi-lamp systems



Lamps 1-3: Parabolic reflectors **Lamp 8: Out of focus**

Lamp 7 to Lamp 9: 173 vs. 440 mW/cm^2 , 58 vs. 93 mJ/cm^2

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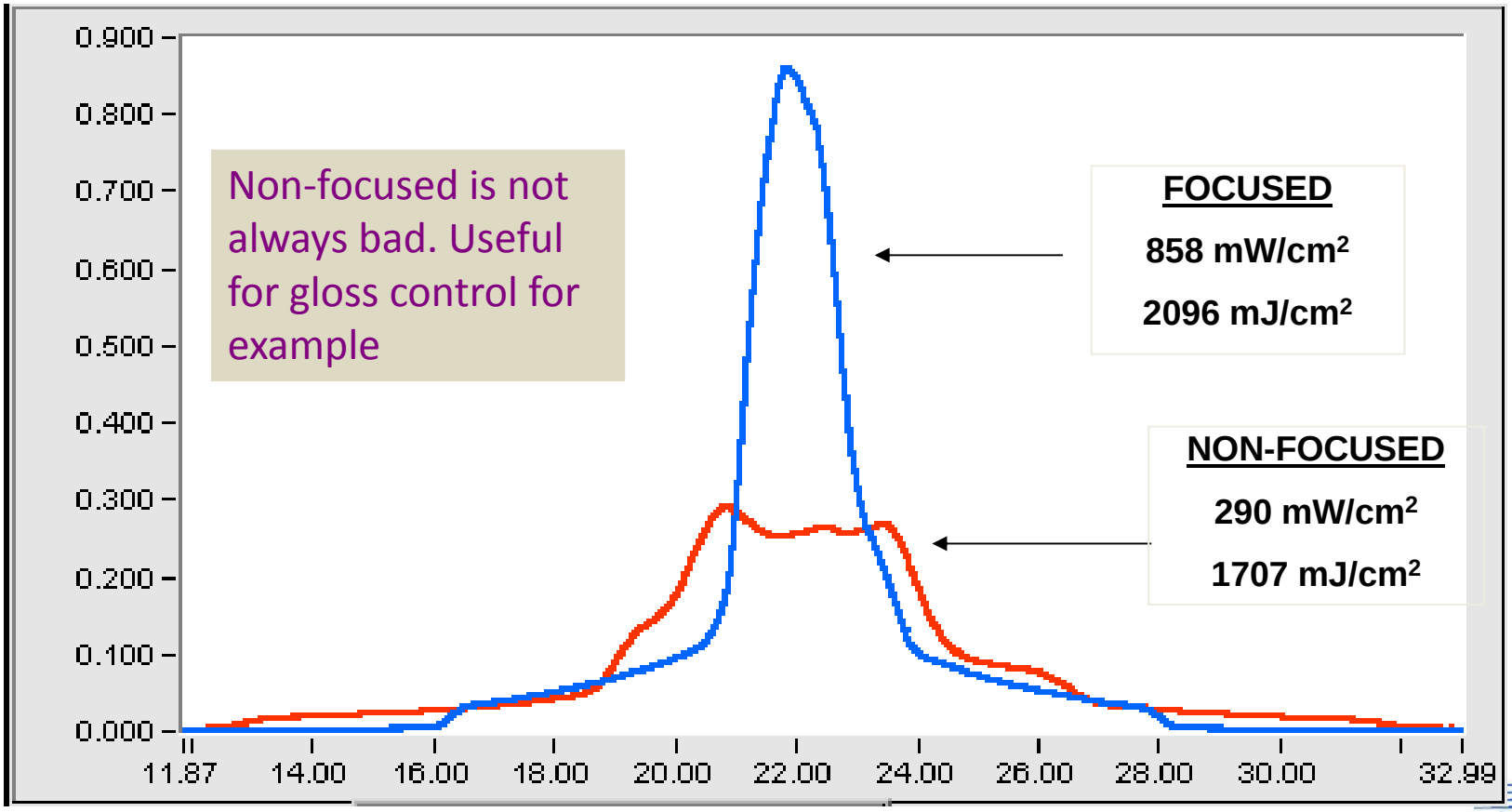
Changing the distance from the UV System to the substrate

- **The effect of moving the UV housing away from the cure surface**
- **Substrate Height?**



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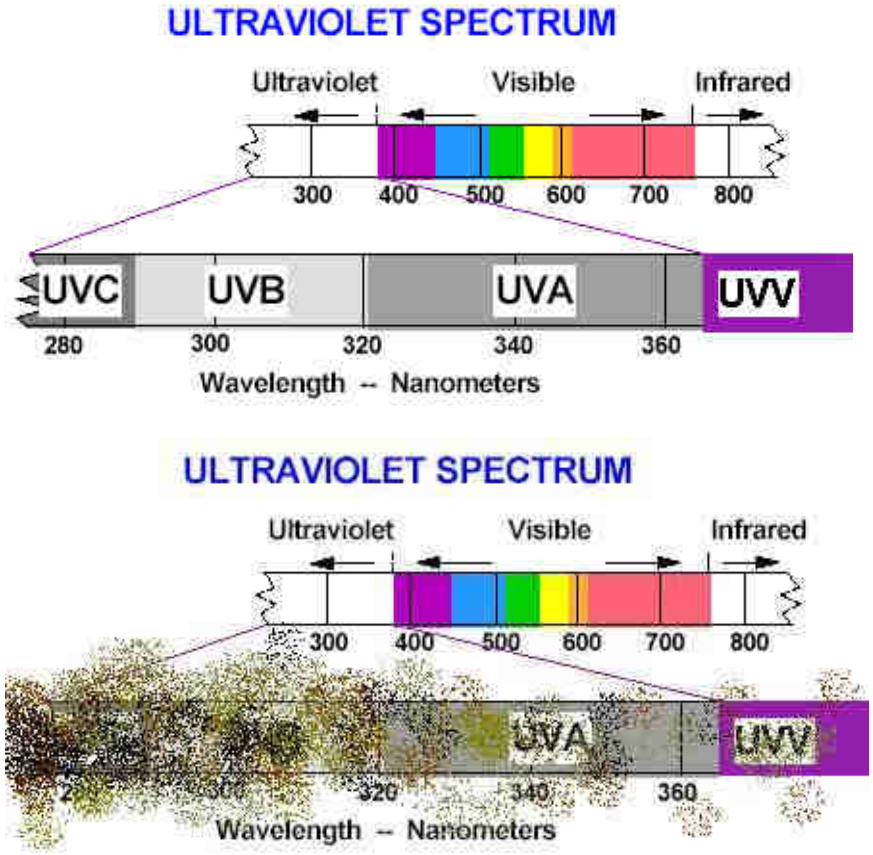
Process Variables-Reflectors



Abrasion Resistance	Toughness	Adhesion	Adhesion & TiO_2 Cure

A CLEAN BULB AND REFLECTOR DELIVERS ALL THE UV SPECTRUM IN THE RANGES OF UVA, UVB, UVC AND UVV

A DIRTY BULB AND REFLECTOR DELIVERS VERY LITTLE OF THE UV SPECTRUM IN UVC & UVB , AND REDUCED AMOUNTS OF UVA AND UVV

A multi-channel radiometer allows you to compare short & long wave ratios and identify changes

UVC: UVA

UVC: UVV

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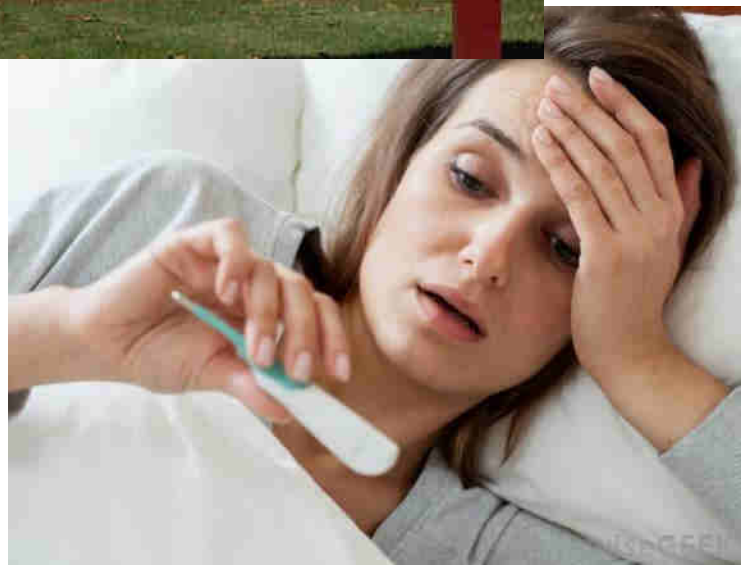
Please Overnight a Radiometer to Us?



Too often, a doctor visit or UV measurement happens only when things go wrong.

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"I am loose and tight

in all the

wrong places"

Process Window

- The range in which a process will work with the desired results
  - Adhesion, hardness, flexibility, gloss, texture, stain or scratch resistance, chemical rub, cross hatch, abrasion rub, color ID, registration
  - Often a compromise (Desired Coating Properties)
- Invest before production & confirm when things are working!
  - Starting guidelines from formulator?
  - Define your lower limits and document the readings
  - Increase line speed/decrease applied power until you undercure, note readings and cushion by 20%
  - Upper limits?
- Monitor your readings by job, hour, shift or day as required to maintain quality
- Establish your process window during the design/development phase and start monitoring from day one in production

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Process Window

Normal Operating Window

Caution 20% Undercure Buffer Range

Stop!Undercure Limit

Over cure or over temperature?

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Starting Point: Formulator Guidelines

Basic Formulator Specification

- 2x Hg lamps 80 W/cm (electrical not UV)
  5 meters/minute, forward feed

Improved Formulator Specification?

- Testing can define a process window
- Lab testing is less expensive than production testing or no process window

Variables:

- Line speed
- Lamp distance
- Lamp output
- Bulb Type
- Source Type
- Coating
- Instrument Type

Organize Your Data

For each UV lamp system

- Hour meter
- Indicated vs. actual process speed
- Power settings (WPI, Amps)
- Irradiance (W/cm^2)
- Radiant Energy Density(J/cm^2)
- Lamp matched to chemistry
- Focus/Reflector condition

Other things to consider

- Date/job number
- Operator signature
- Mesh count
- Formulation type
- Pass/fail on specific QC tests- cross hatch, rub, registration
- Maintenance log of system
- Radiometer type/bandwidths

Date	Line Speed Dwell Time FPM/RPM		UV System: North Line Lamp: 2			
	Ind.	Actual.	Power WPI	Hour Meter	Irradiance (W/cm^2)	Energy Density (J/cm^2)
8/17	25	22	400	780	0.859	1.45

Notes

UV System
Line:
Lamp Number:
Equipment:
Lamp Type:
Power Setting:
Line Speed/Exposure Time:
Reflector Poistion:
Product:
Product Notes:
Maintenance Notes:

Outside the Process Window

- **Panic!!!!!!**
- **Rule 1A/1B: Blame the Formulator & the Equipment Supplier**
- If you have a process window established, relax & breathe deep
- Gradual change towards caution area?
- Which way do you have to go?
- Perform simple routine system maintenance (measure, record, clean, repeat) for your type of equipment
- Adjust user controlled variables until you are back in your process window
- If simple maintenance does not work, look toward major or comprehensive maintenance
- Work and communicate with suppliers in good times and bad times

Get into "predict and perform preventative maintenance" routine vs. a "fix it when it breaks" routine

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UV LEDs

Wide variety of UV LED sources

- Multiple suppliers with wide level of expertise, support, finances
- Match source to your application & process

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

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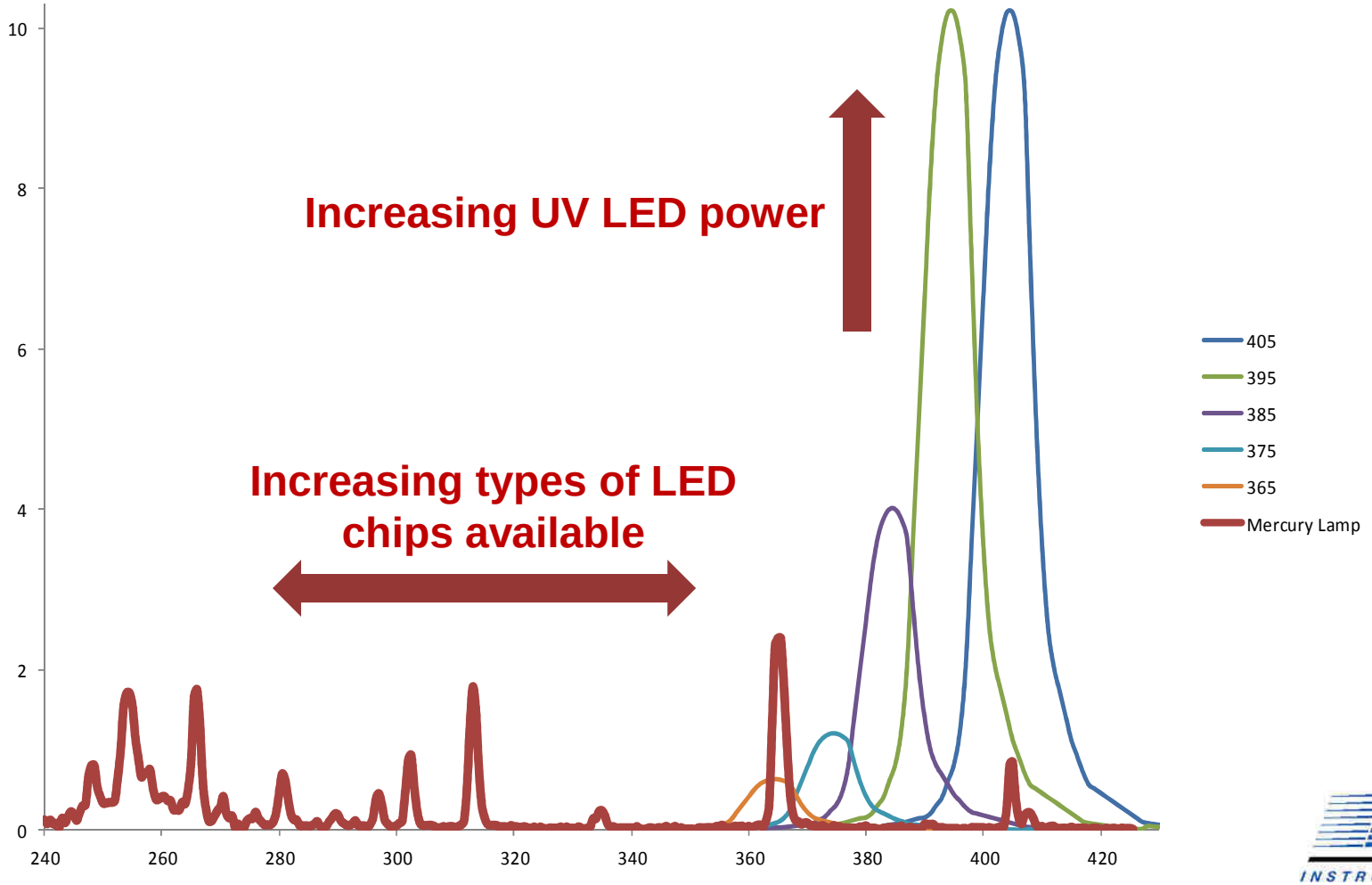
UV LED Power Output vs. Wavelength



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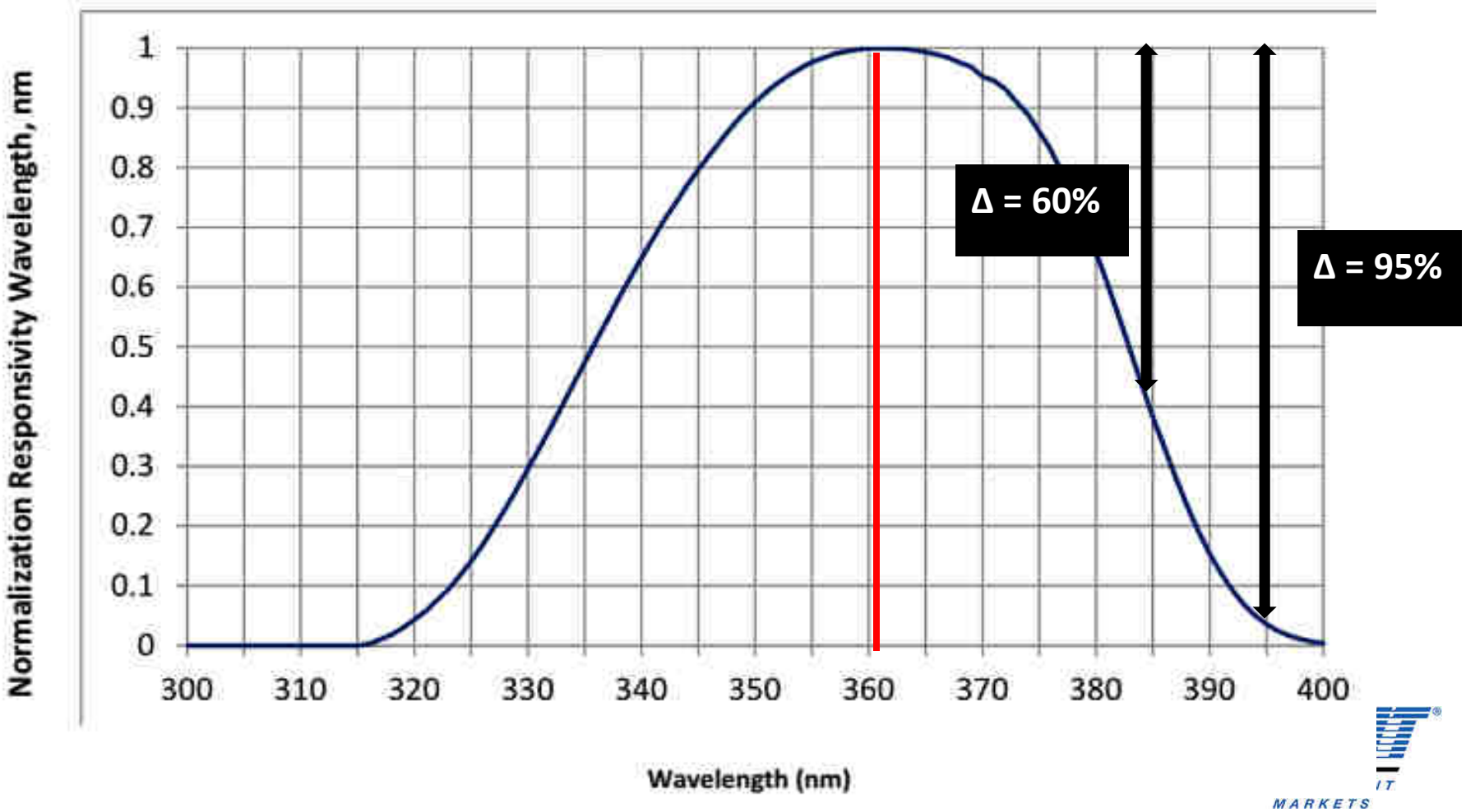
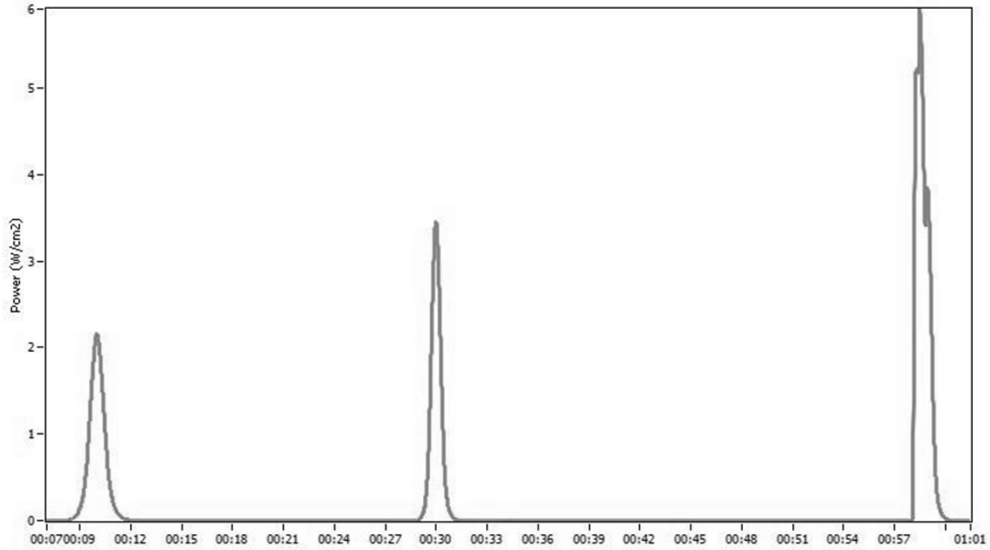
Measurement of 395 nm LED

Using UVA to measure a 385 nm or 395 nm LED



LEDCure™ LED-R™ L395 Series

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



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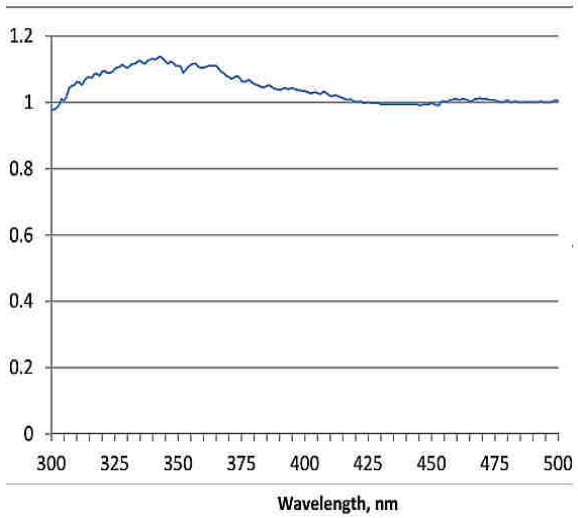
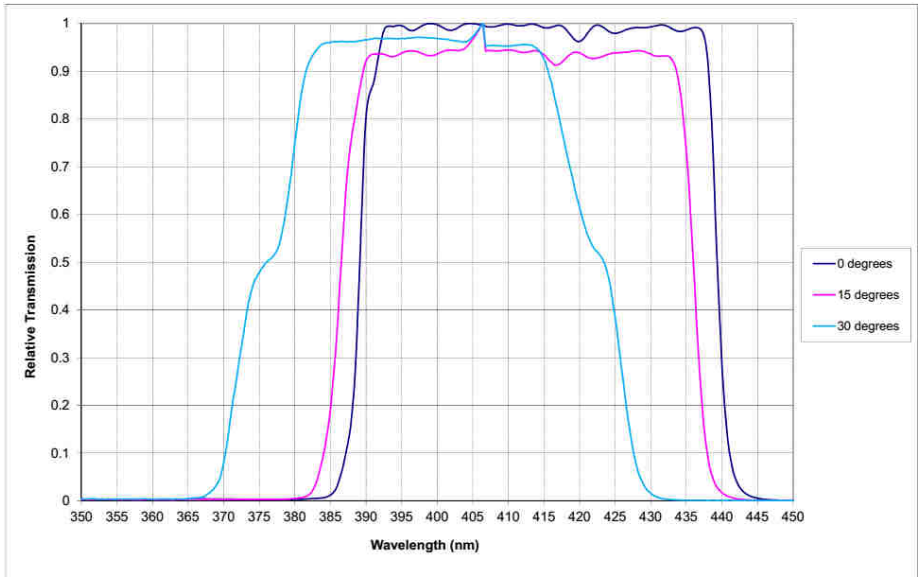
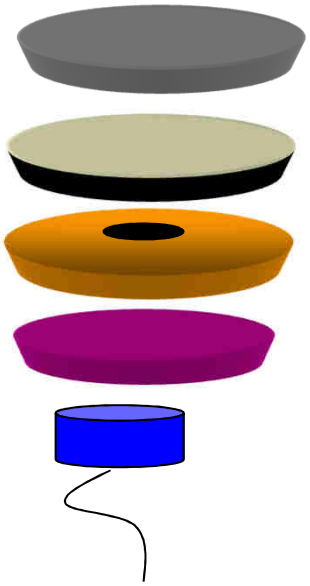
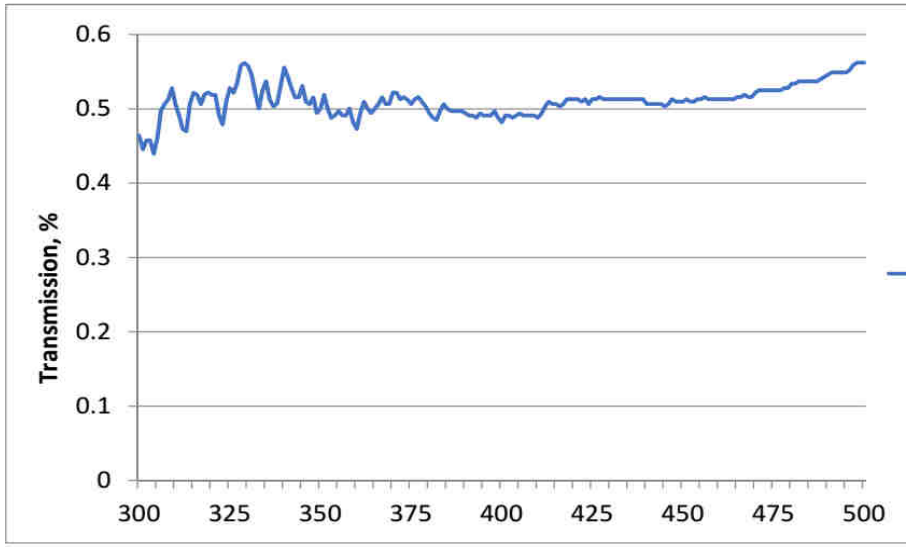
EIT Patented Optics Design









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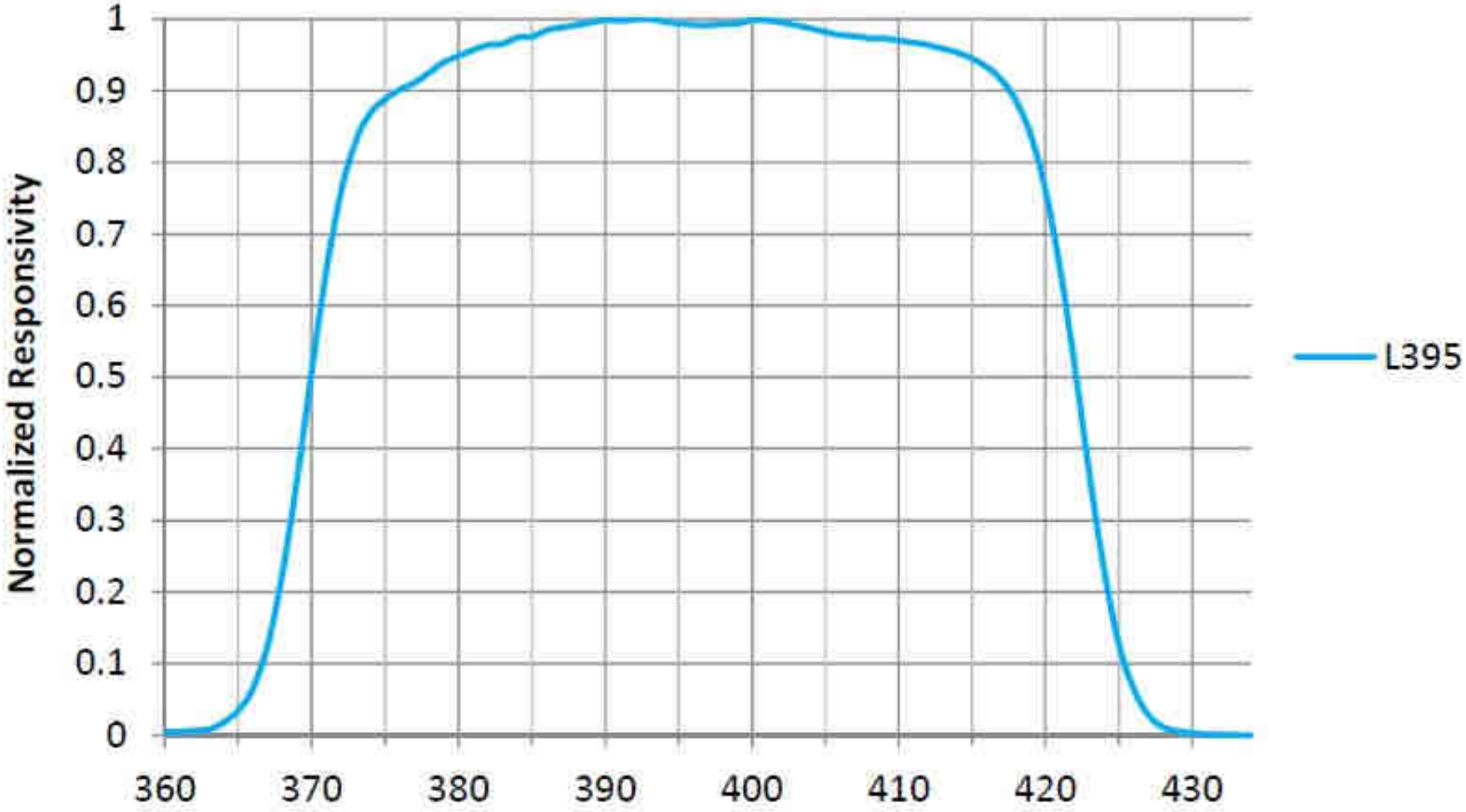
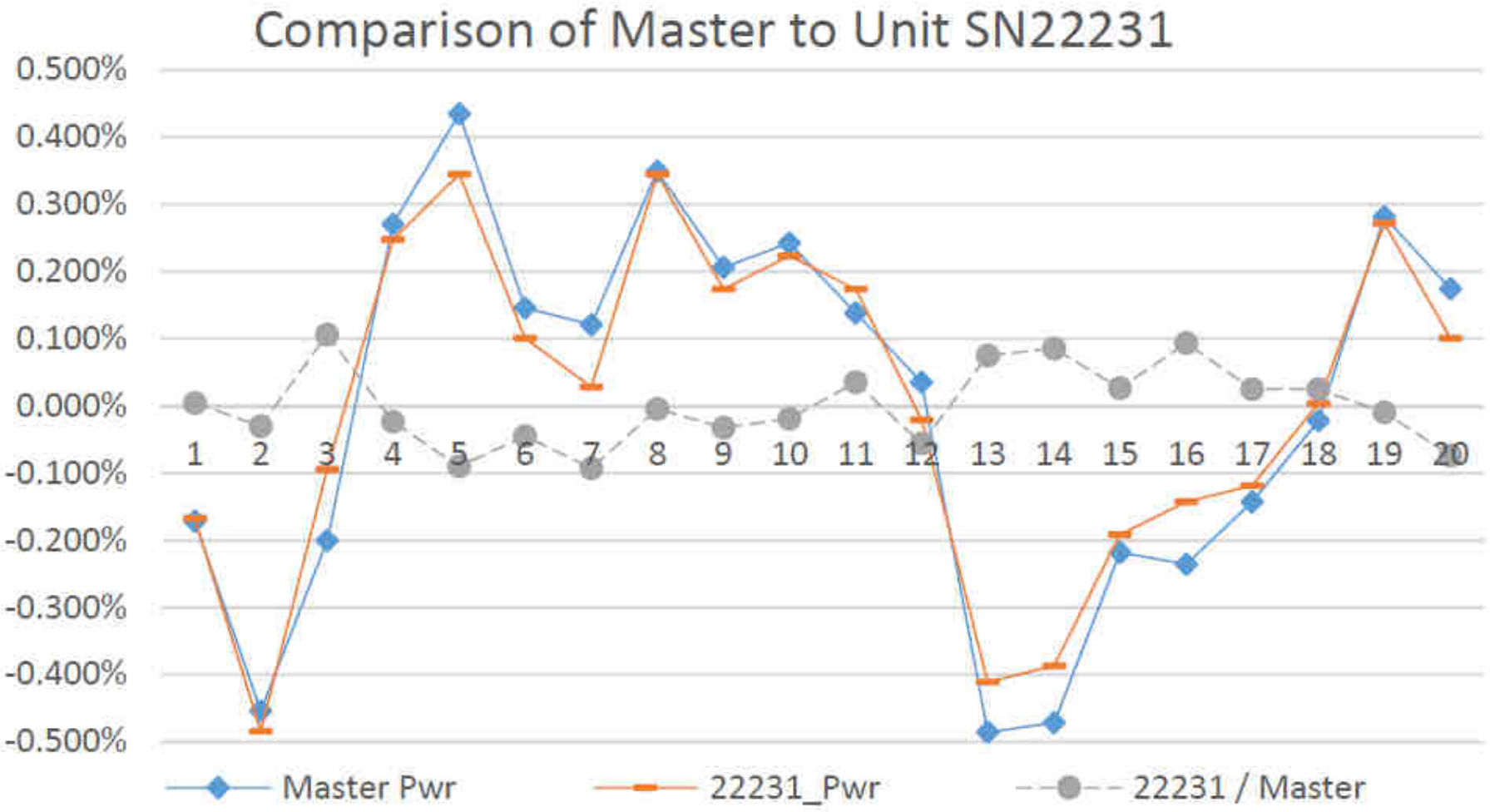
LEDCure™ L395 Instrument Response

Total Measured Optics Response



LEDCure L395 Performance



Data collected at EIT February 9, 2017

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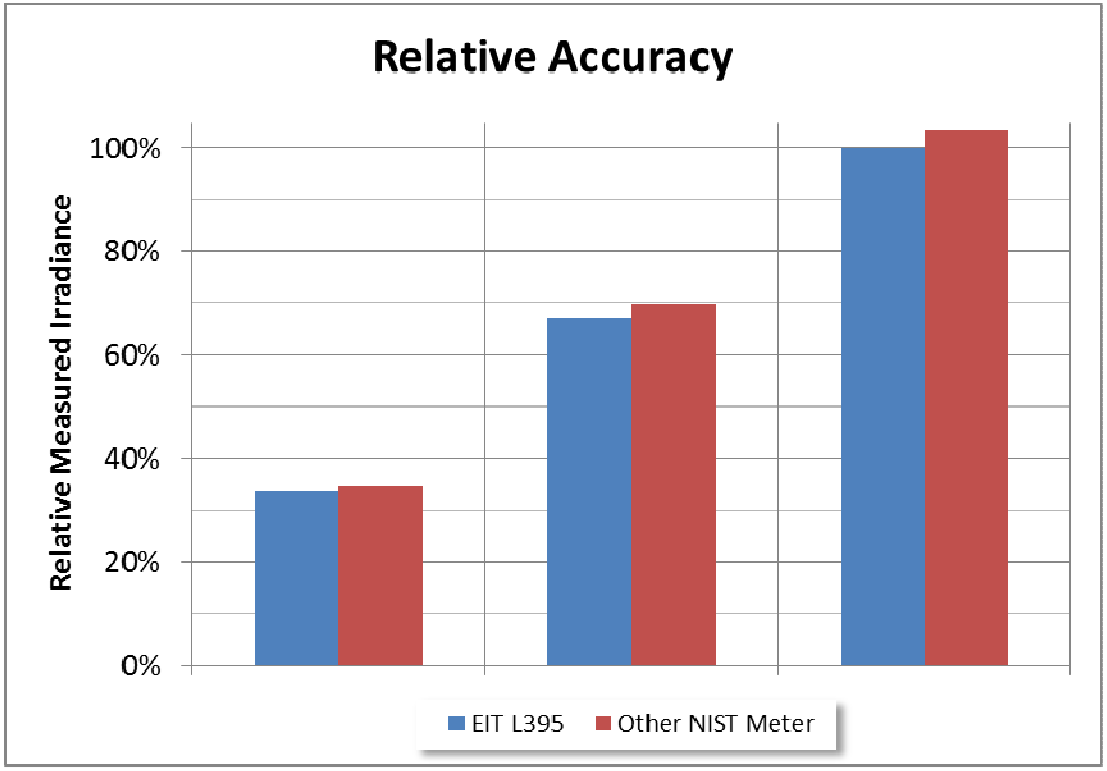
LEDCure L395 Feedback



- A 395nm UV LED source was calibrated to 16W/cm² using the EIT L395.
- The UV LED source was then measured with another NIST traceable radiometer.
- The two radiometers matched to within 4% at different irradiance levels.

Data Courtesy of Phoseon Technology

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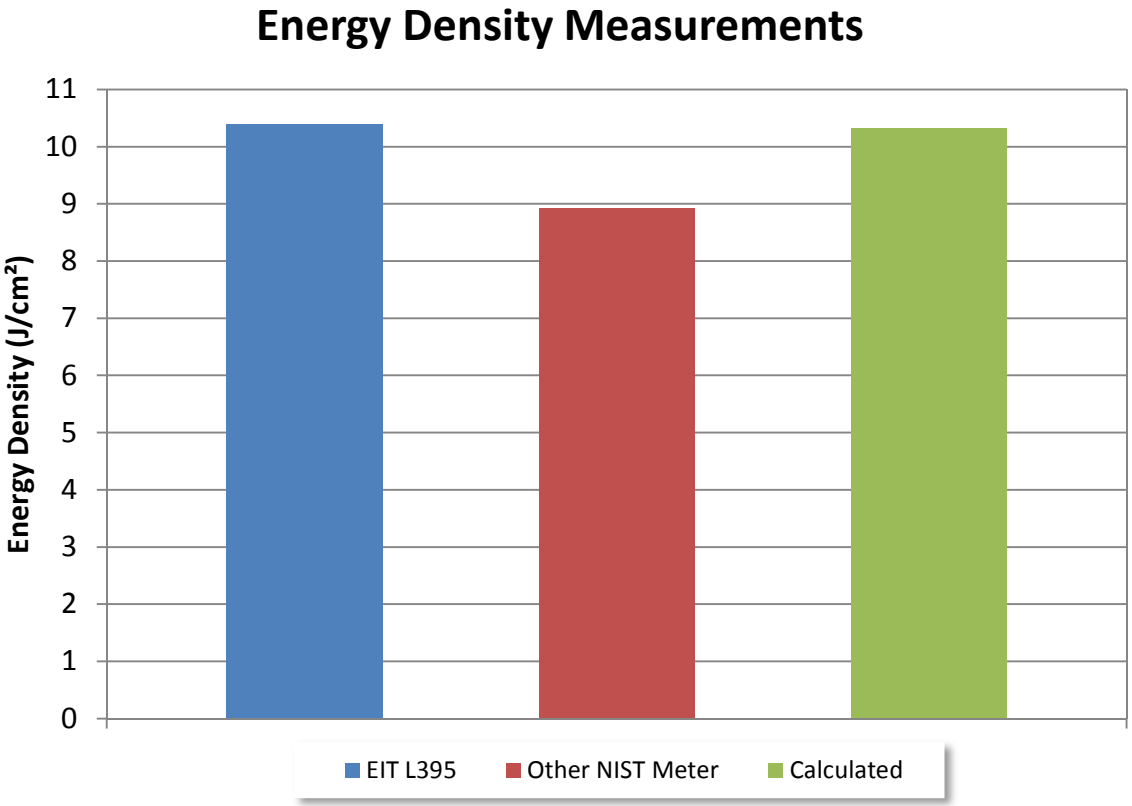
LEDCure L395 Feedback

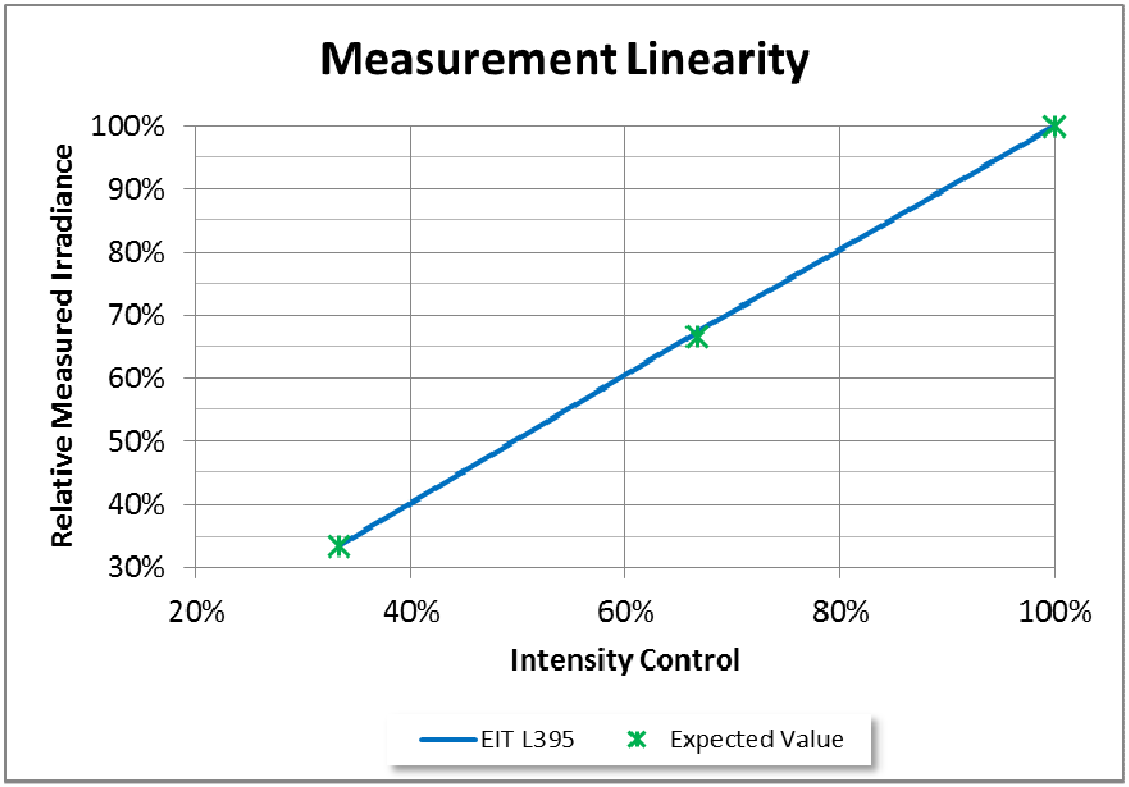


- Energy Density (Dose) measurements were taken at a speed of 20mm/sec (1.2m/min) and compared to the calculated value based on the short axis spatial response.
- The EIT measurement differed from the calculated value by less than 1%.
- The other NIST traceable radiometer differed from the calculated value by more than 13%.

Data Courtesy of Phoseon Technology

EIT INSTRUMENT MARKETS

LEDCure L395 Feedback



- Measurements at different irradiance settings were made with the EIT L395 radiometer, and compared to the expected values.
- The L395's linearity across a 3:1 dynamic range is excellent.

Data Courtesy of Phoseon Technology

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LEDCure L395 Performance

LEDCure vs National Standard

Working Distance (mm)	Primary Standard: Integrating Sphere (W/cm^2)	LEDCure L395 (W/cm^2)	Difference
5	9.01	9.23	2.4%
10	7.74	7.74	0.0 %
15	6.66	6.63	- 0.5%
20	5.74	5.83	1.6%
25	5.04	5.08	0.8%

Data Courtesy Lumen Dynamics/Excelitas

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Continuous On-Line UV Measurement

- 1.3 meter (51”) wide wood processing LED line
- Multiple LED heads
- 52 individual sections over 1.3 meter (51”) wide line

- Supplier requires contractor to confirm UV output at the start of each 8 hour shift

Photo courtesy Efsen Engineering

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Continuous On-Line UV Measurement

- Rail placed under LED Array with Sensor
- Measure perpendicular to the conveyor direction

Photo courtesy Efsen Engineering

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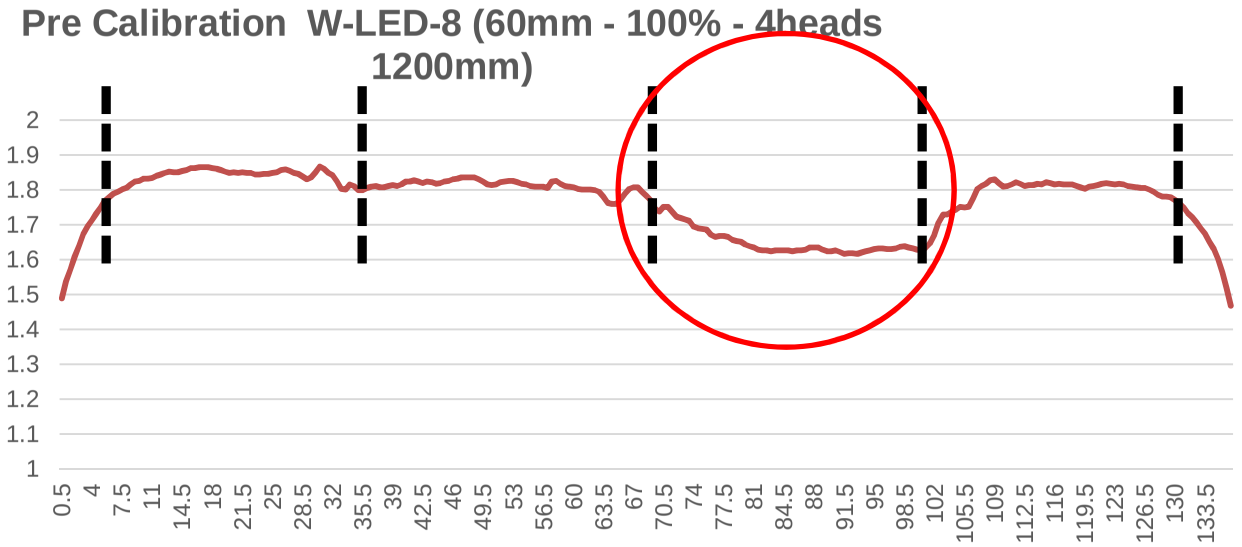
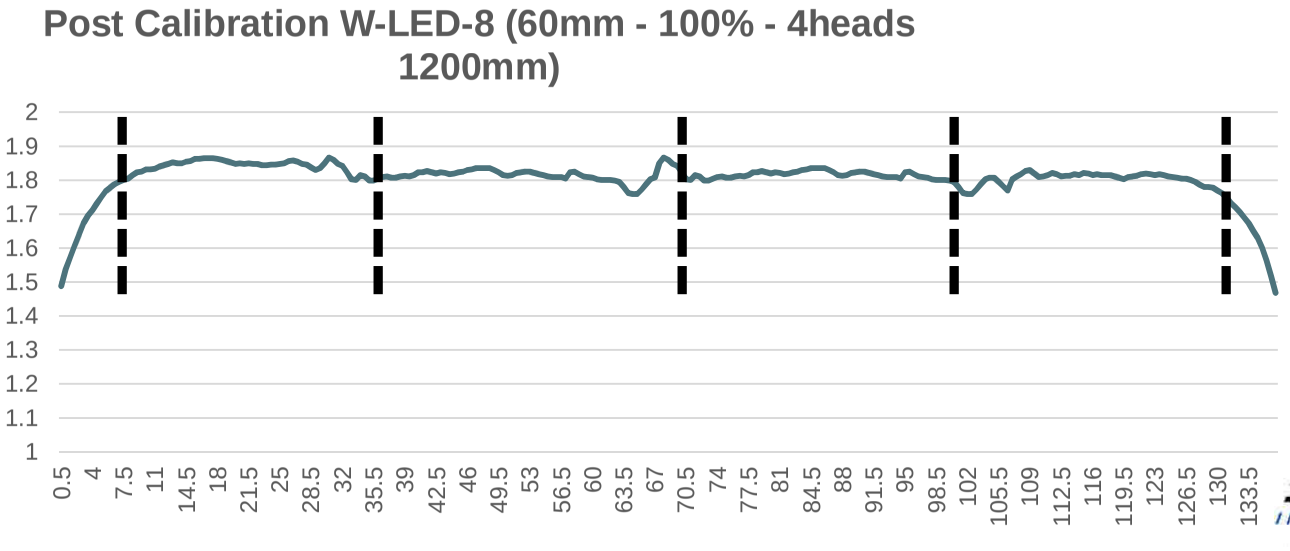
Continuous On-Line UV Measurement



-16%



-5%

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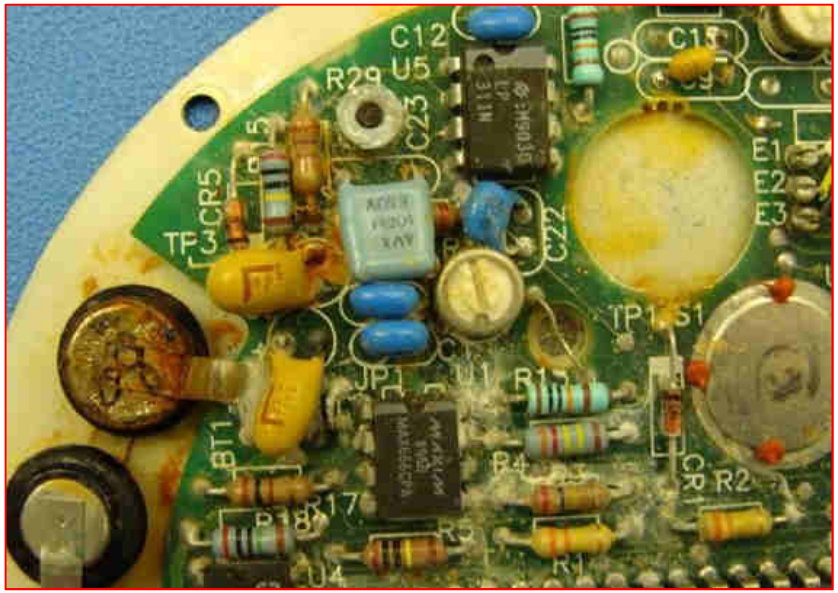
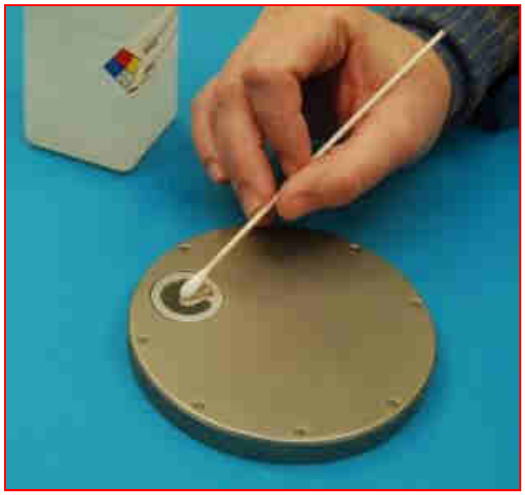
Calibration & Service

- Radiometers work better when properly maintained



Calibration & Service



- Two recommended methods:
    - Lint/detergent free wipes or IPA with cotton swab
- Advantages and disadvantages to each method
- First do no harm
- Avoid shirt sleeve, shop towel, etc.
- Avoid ‘dry’ cleaning instrument
- You Tube video on cleaning

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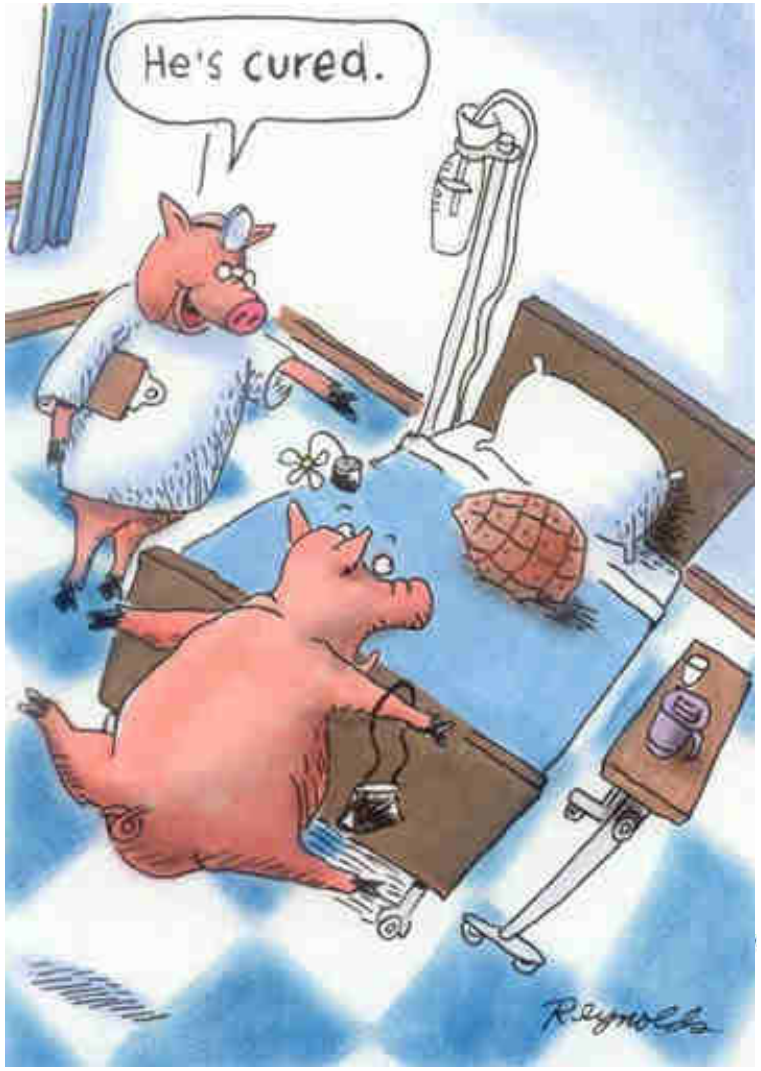
Prescription for Profit

- ✓ Establish a baseline.
- ✓ Establish a process window.
- ✓ Make measurements routinely.
- ✓ Measure consistently. Same location, speed, device
- ✓ Document test procedures
- ✓ Label & mark equipment
- ✓ Use the right radiometer
- ✓ Calibrate all of your tools
- ✓ Communicate



Thank You

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