



Measuring the Output Performance of UV LEDs

Paul Mills
May 2012

JEOPARDY!

www.jeopardy.com

**UV LED Measurement:
We have the answers,
but what are the
questions?**



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Location,
Location,
Location

On The
Same
Wavelength

Free
Samples

Home on
the Range

Under the
Lens

It's a
Numbers
Game

\$100

\$100

\$100

\$100

\$100

\$100

\$200

\$200

\$200

\$200

\$200

\$200

\$300

\$300

\$300

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\$500

\$500

\$500

\$500

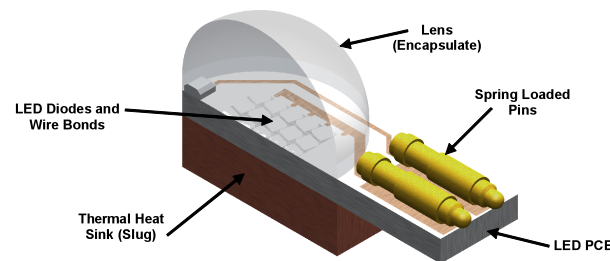
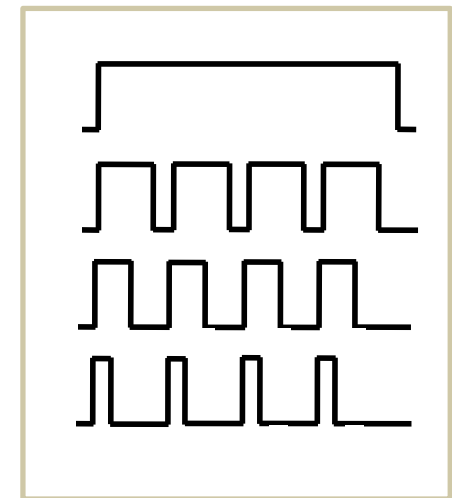
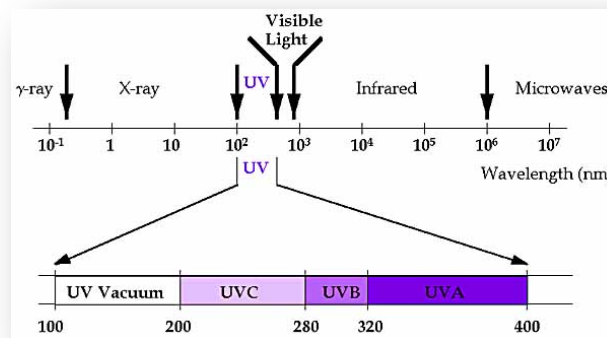
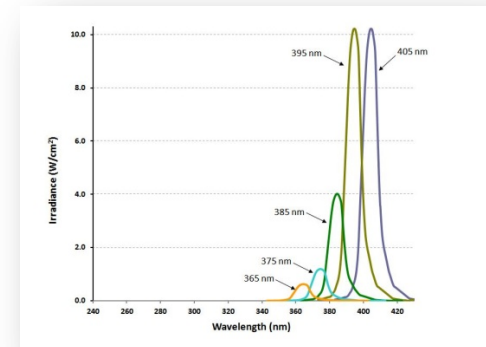
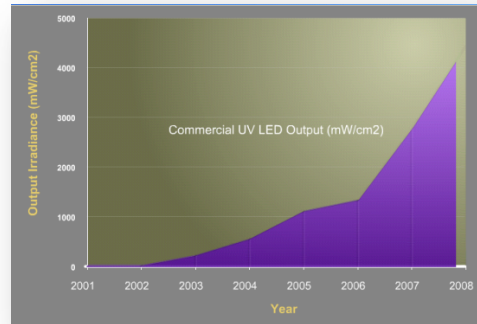
\$500

\$500

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

Trends in UV LEDs

1. Higher Output
2. More Wavelength Choices
3. Broader Spectrum Coverage
4. More Pulsed Control Schemes
5. Increasing use of Optics

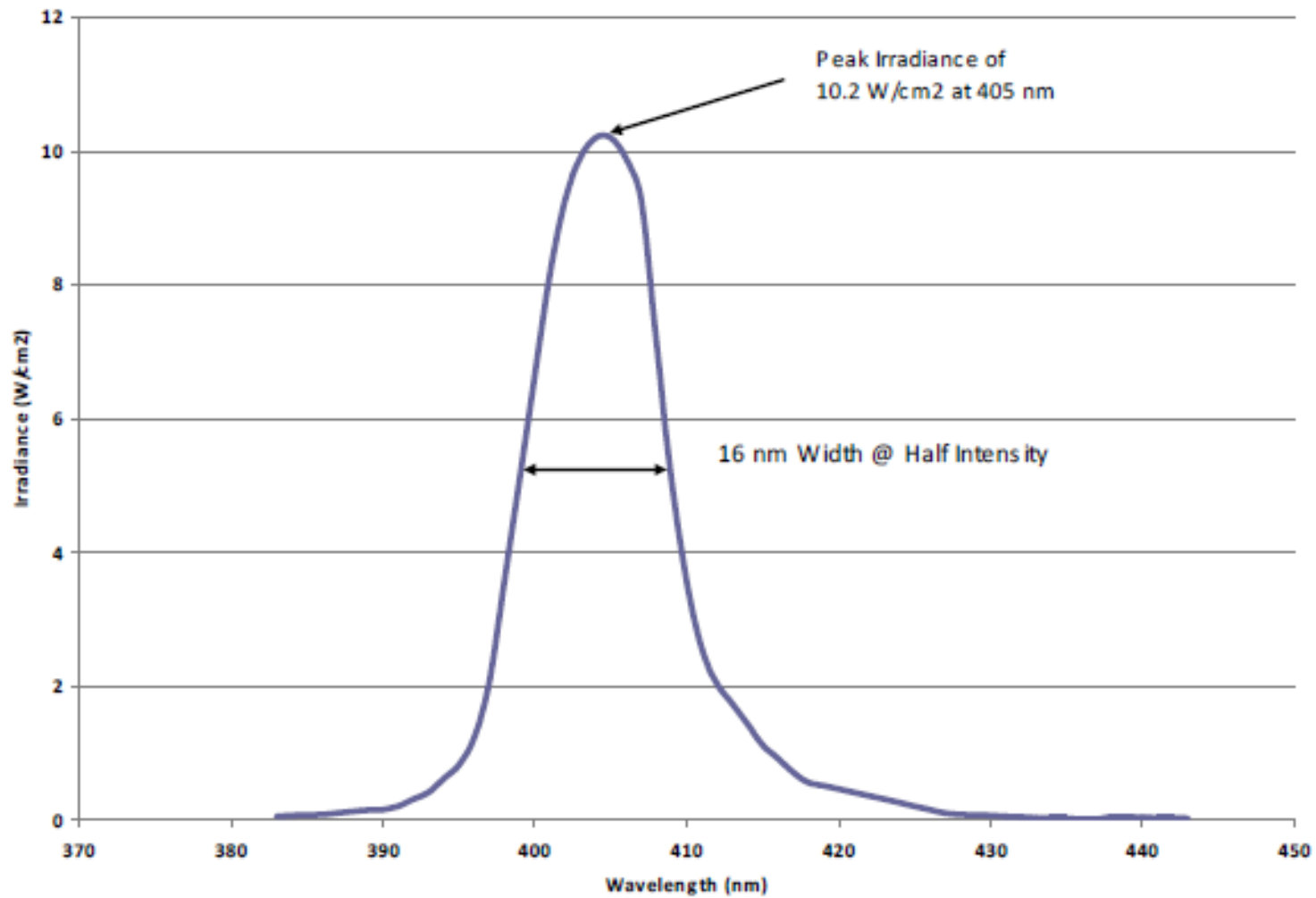


MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

**In 2002
commercial
UV LEDs
Produced about
 $100\text{mW}/\text{cm}^2$**

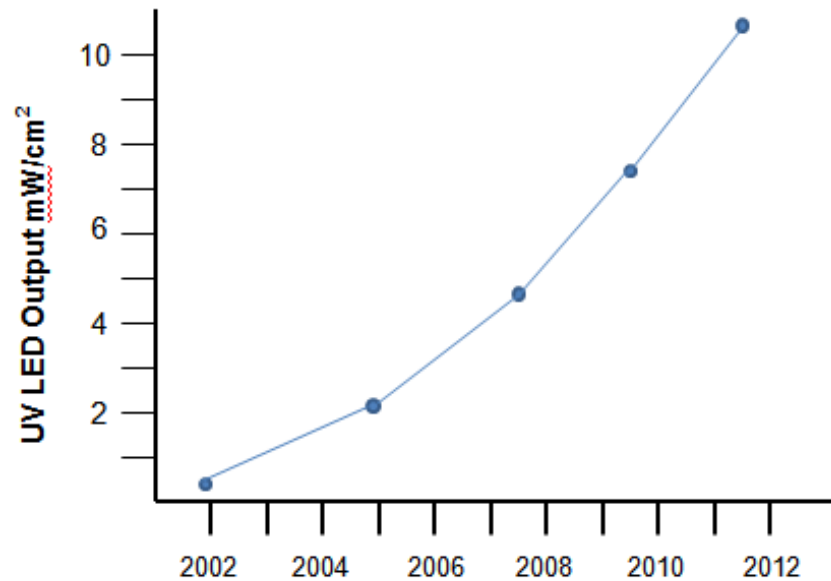


MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



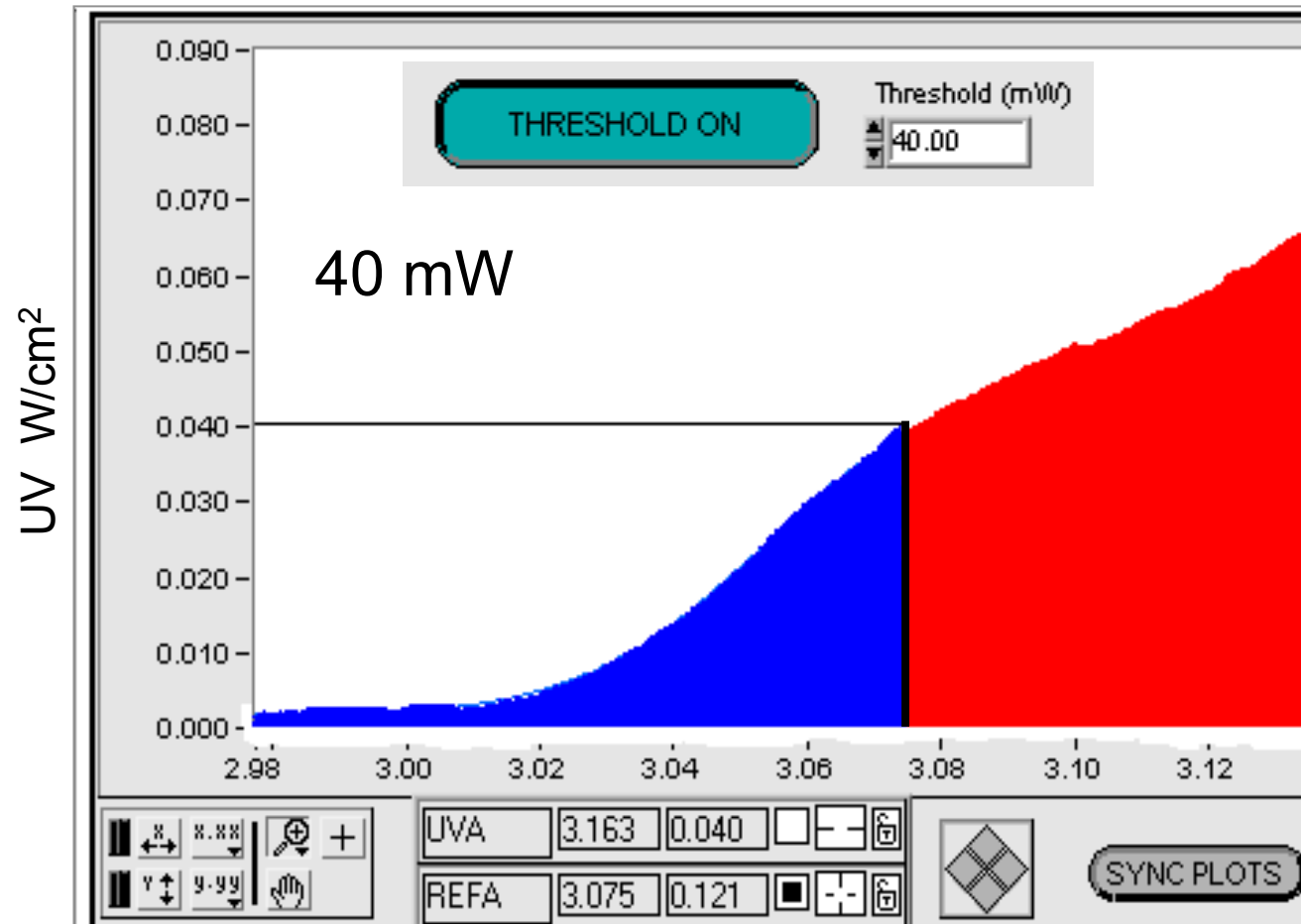
MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

UV LED Output Growth



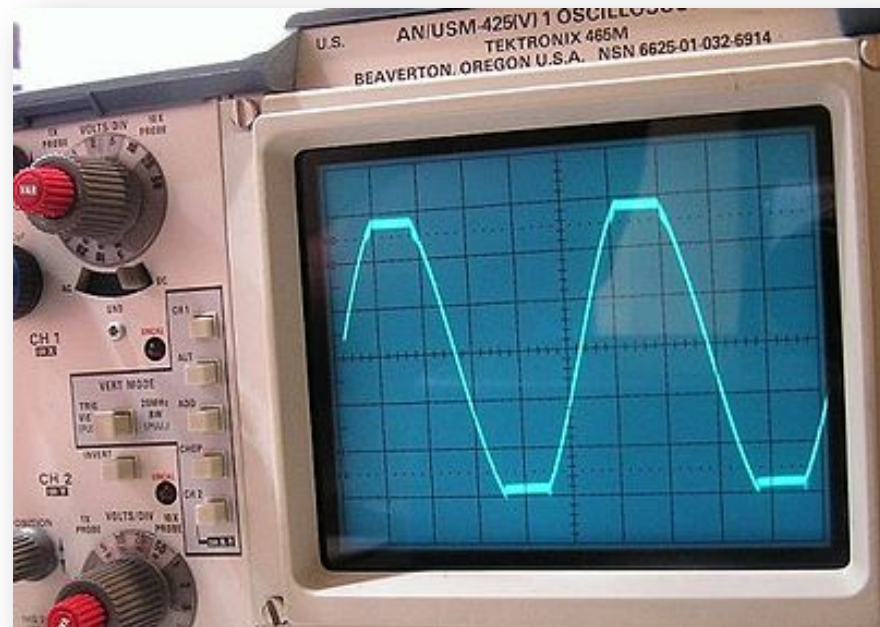
In 10 years
UV LED Output has increased
100-fold from 100 mW/cm²
to over 10W/cm²...

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

Radiometers must have sufficient dynamic range to accurately measure high-intensity sources without attenuating the measured signal.

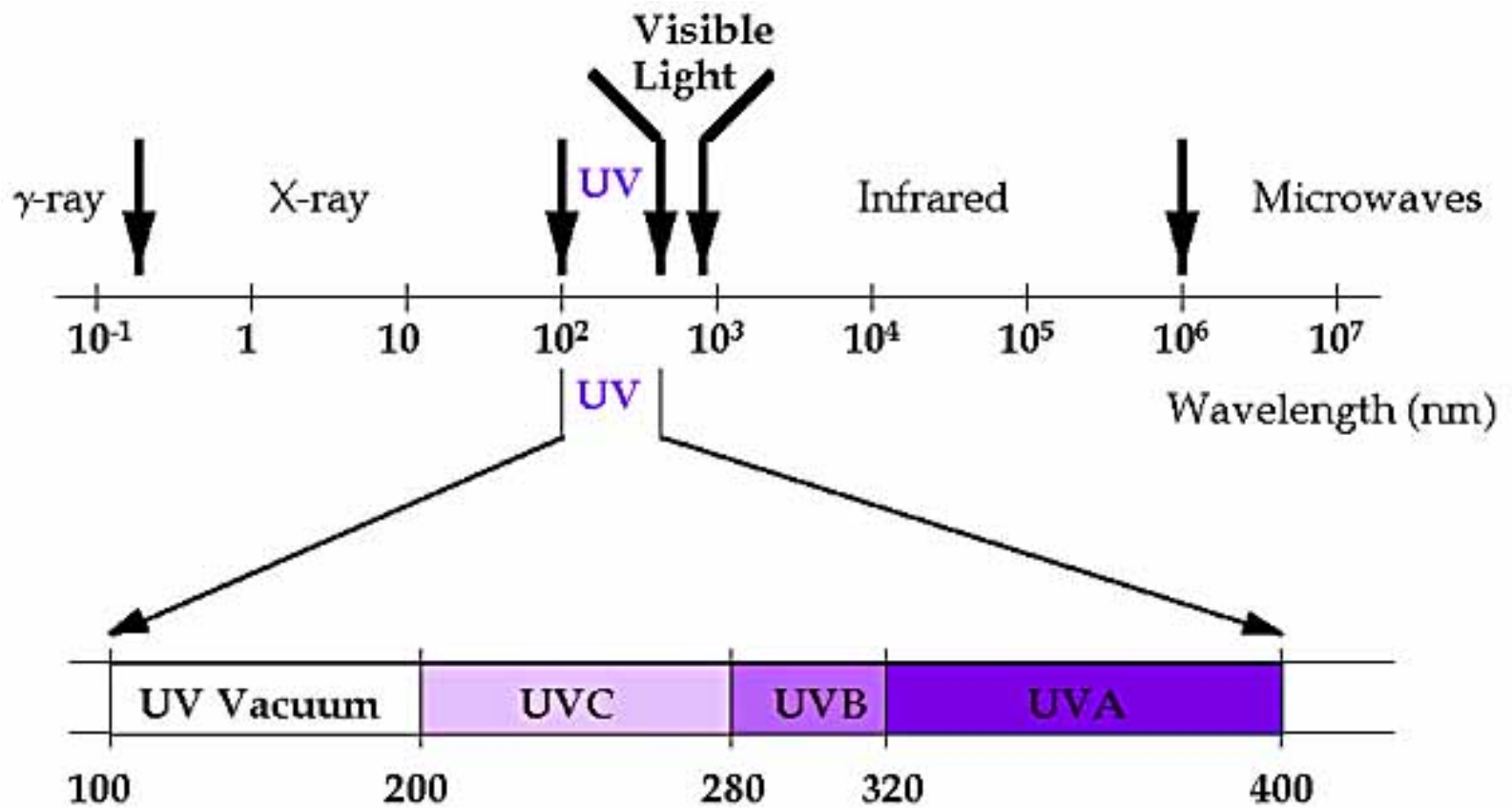


MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

Q: What is the expected irradiance of UV LEDs?

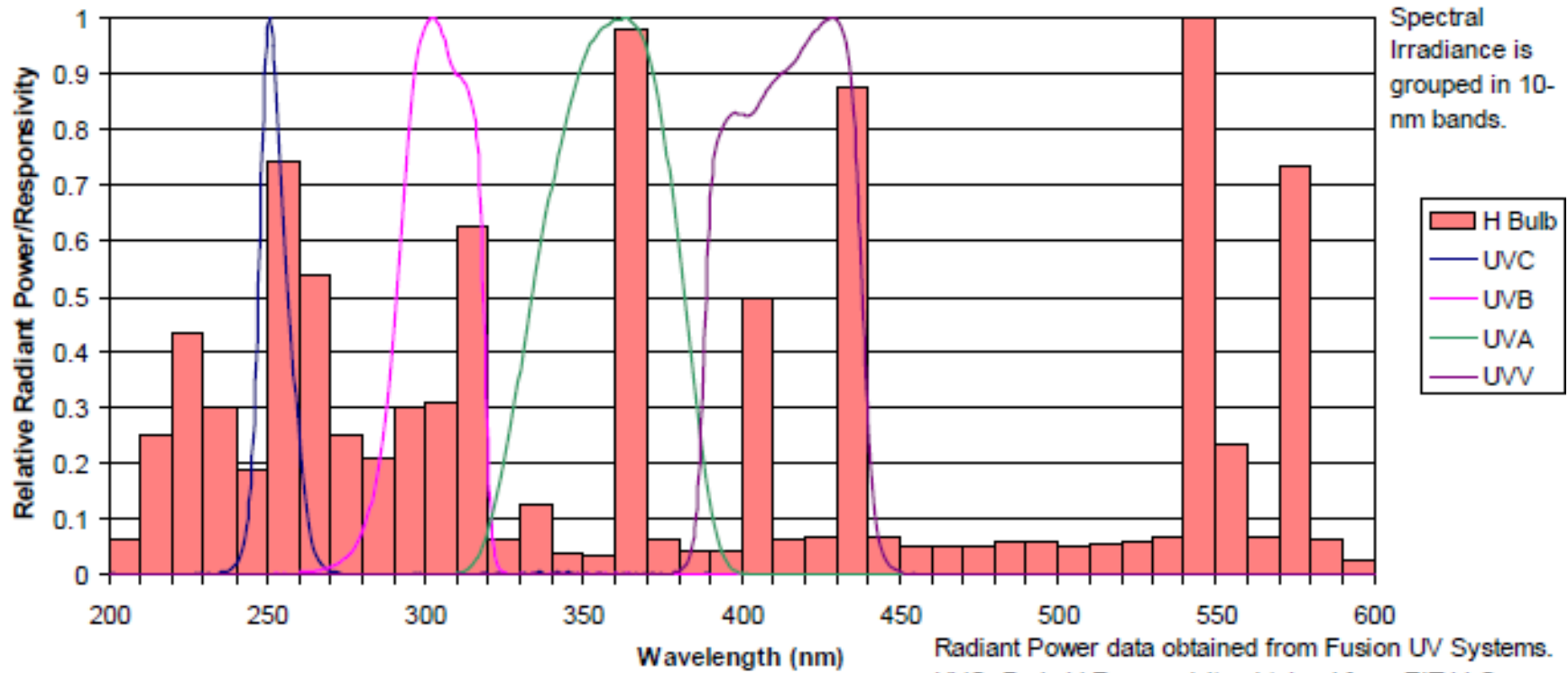


MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

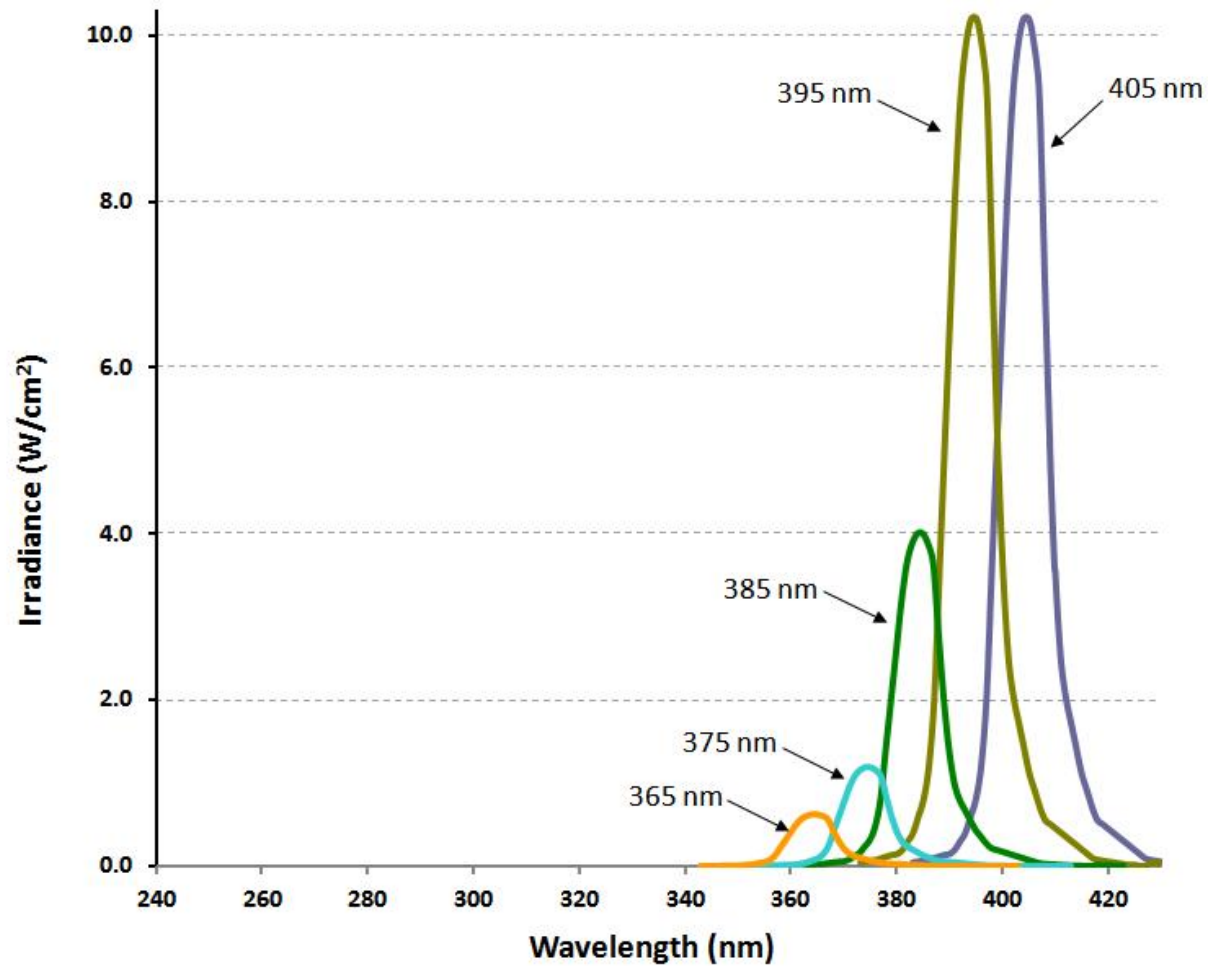


MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

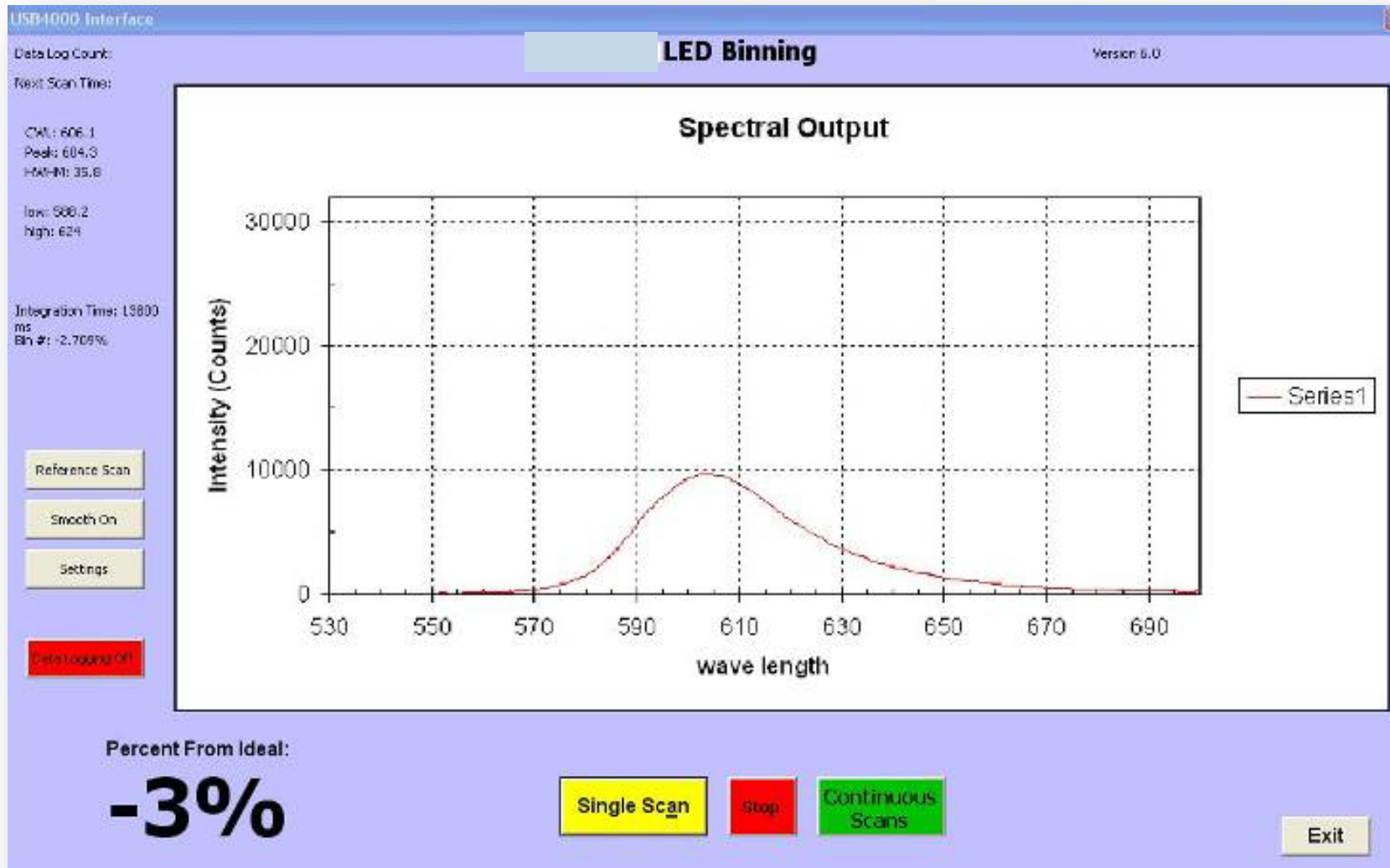
Source Irradiance & UVC, B, A, V Responsivity



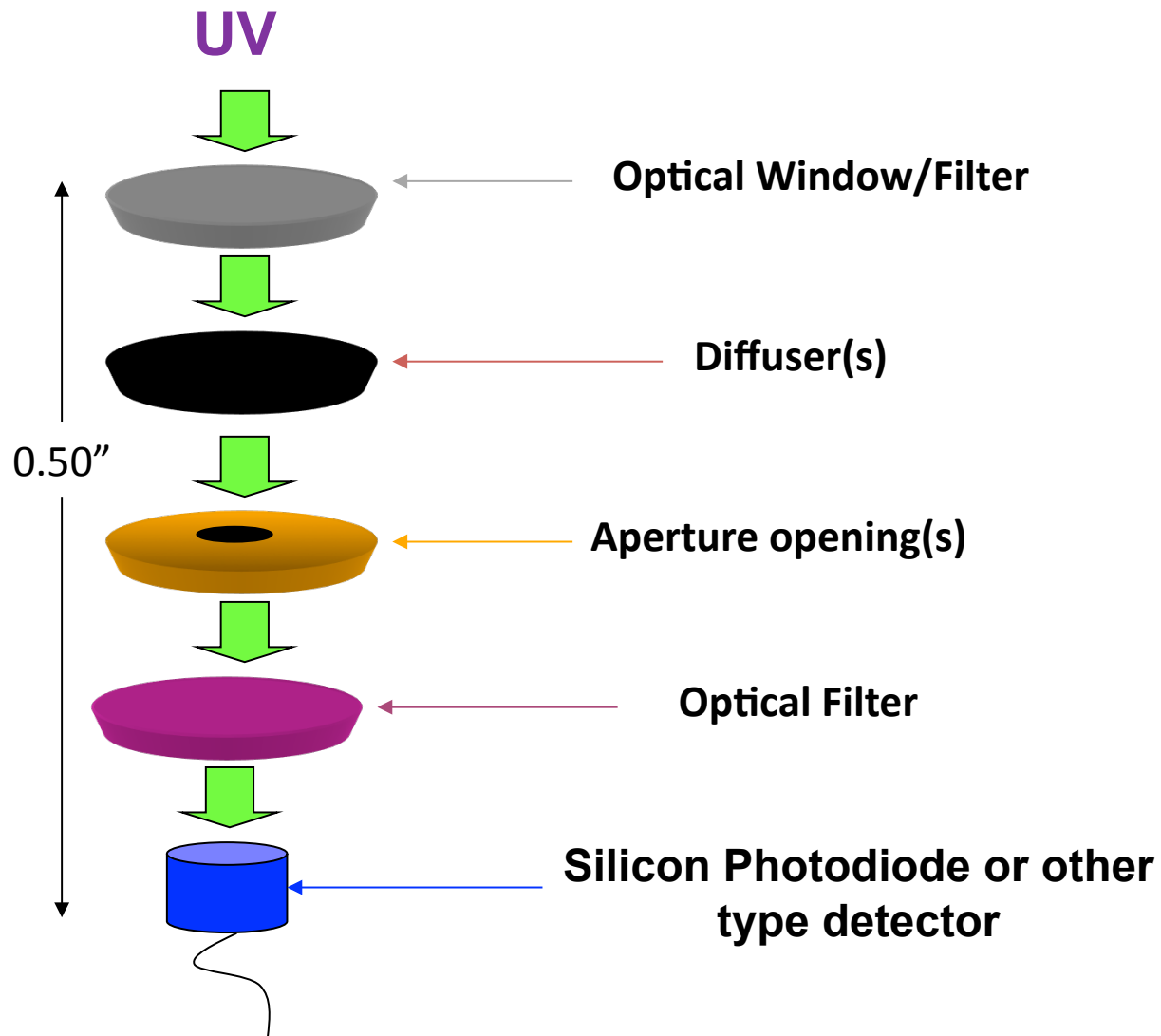
MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

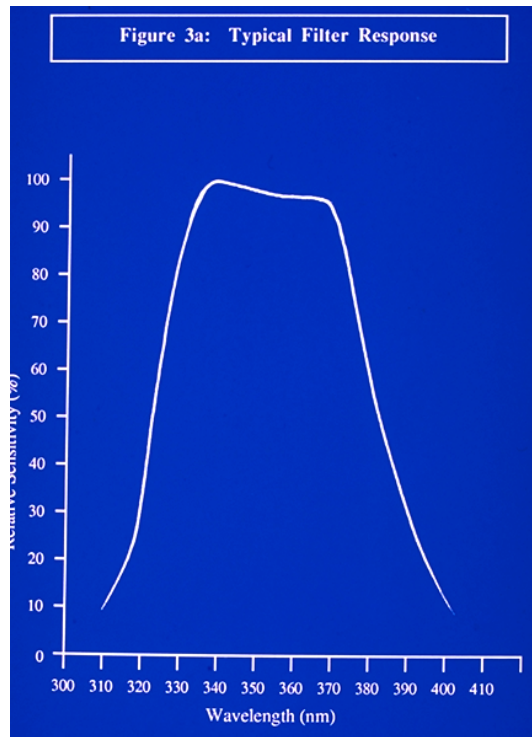


MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

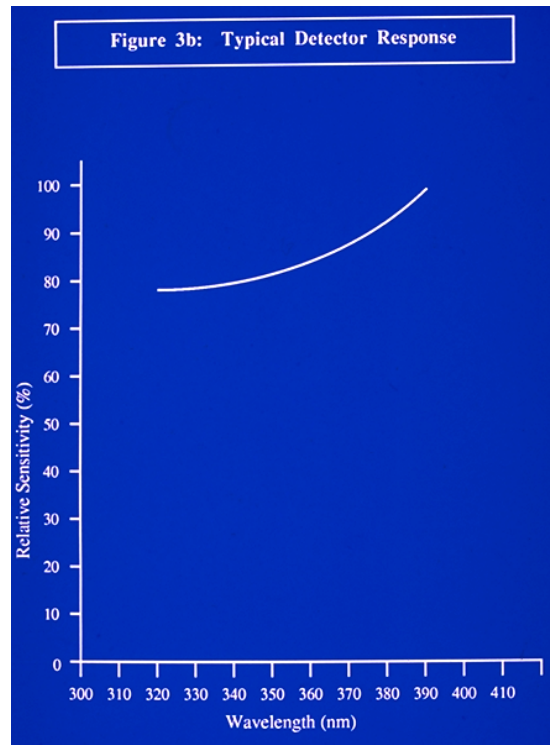


MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

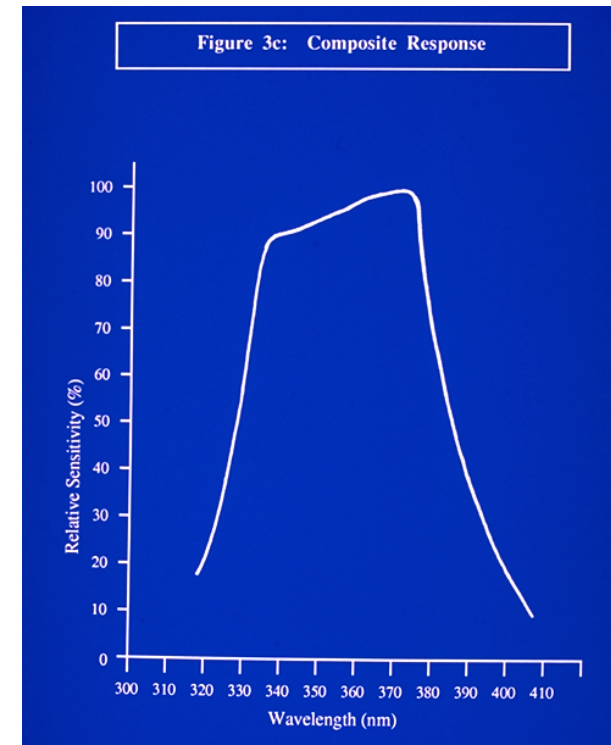
Filter-Detector-Composite Responses optical stacks must be tested



Filter



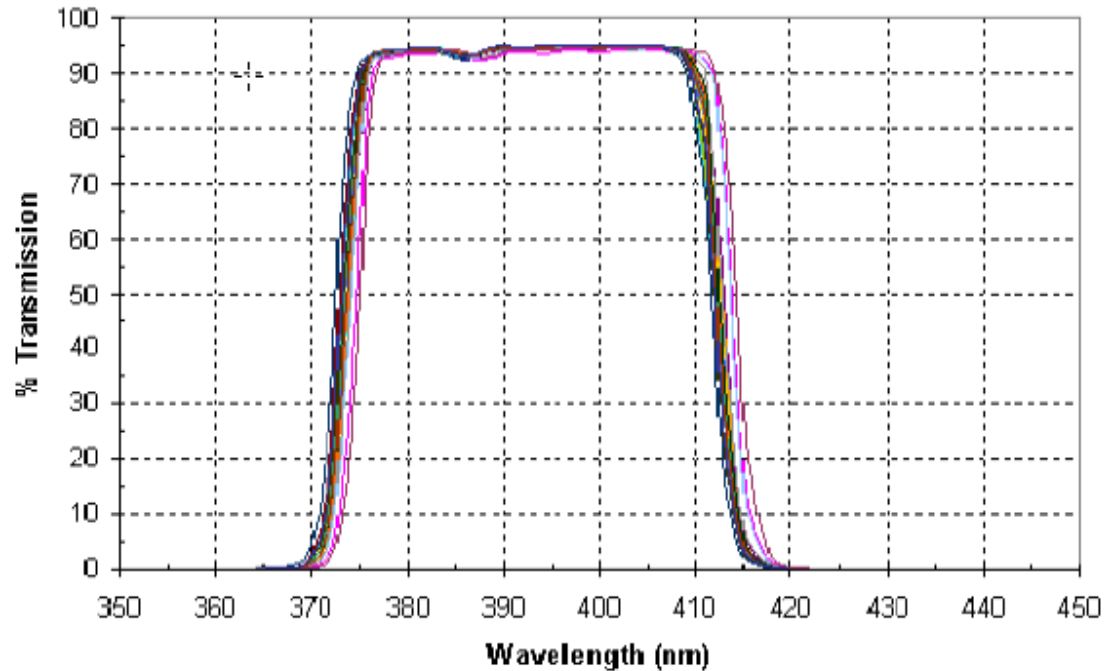
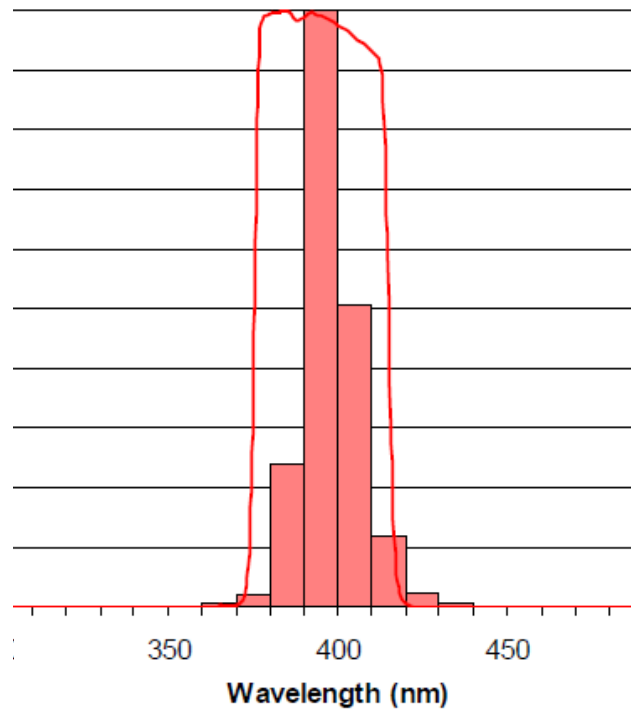
Detector



Composite

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

Source Irradiance & UVA2 Responsiv



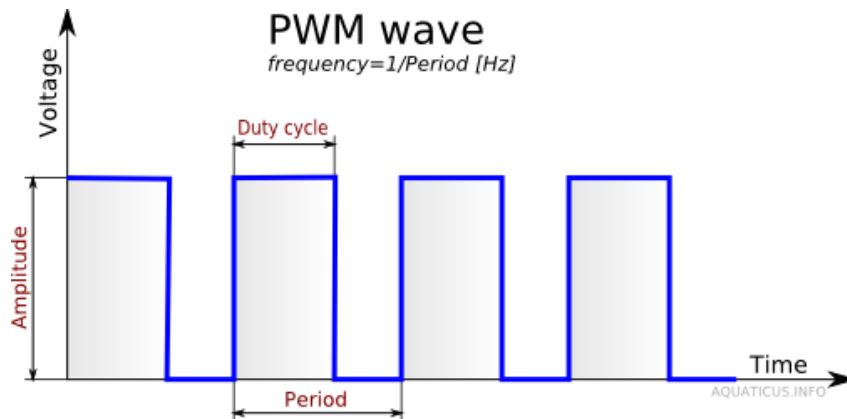
There has been continued improvement in Designing radiometers that are optimized for the wavelengths being supplied by the market.

MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

Q: What wavelengths do we need to measure for UV LEDs?

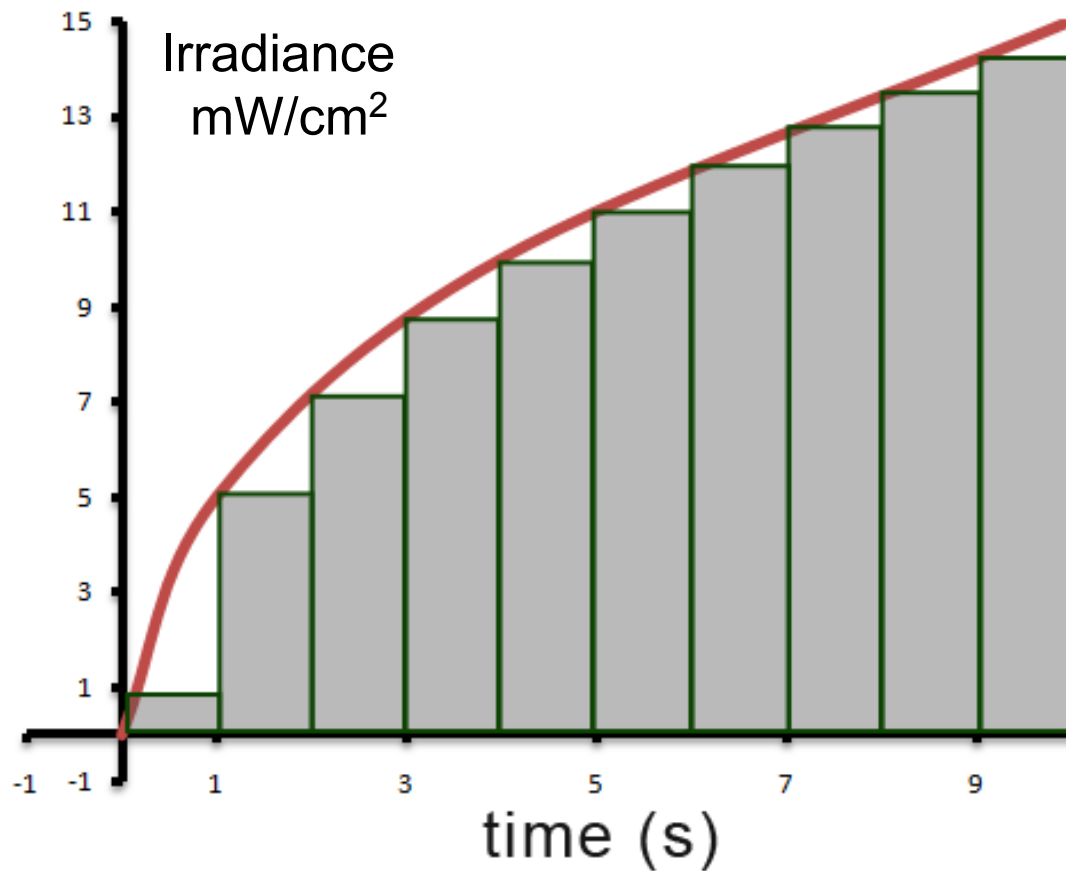


MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



Heat limits how hard LEDs can be driven. Pulsing the diode allows it to be driven to higher output levels by not energizing the die for 100% of the time.

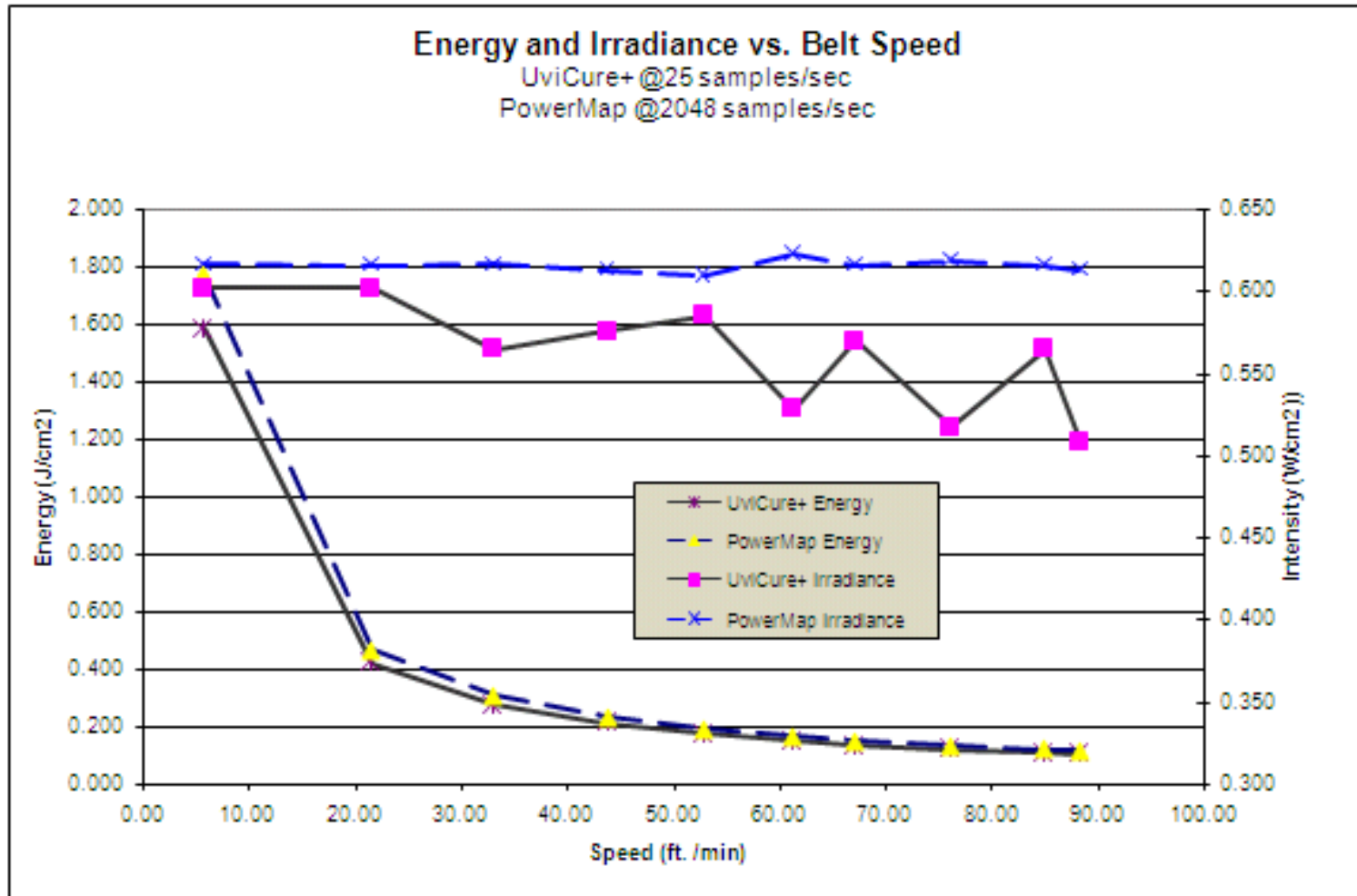
MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



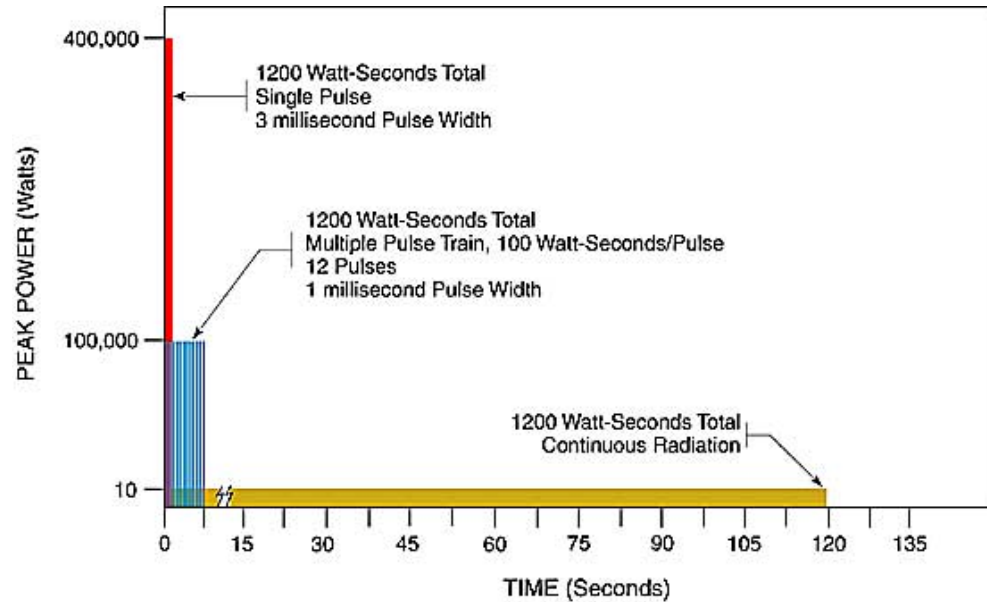
To compute energy density a series of sample irradiance measurements are added together

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

Fast vs. Slow Sampling Instruments

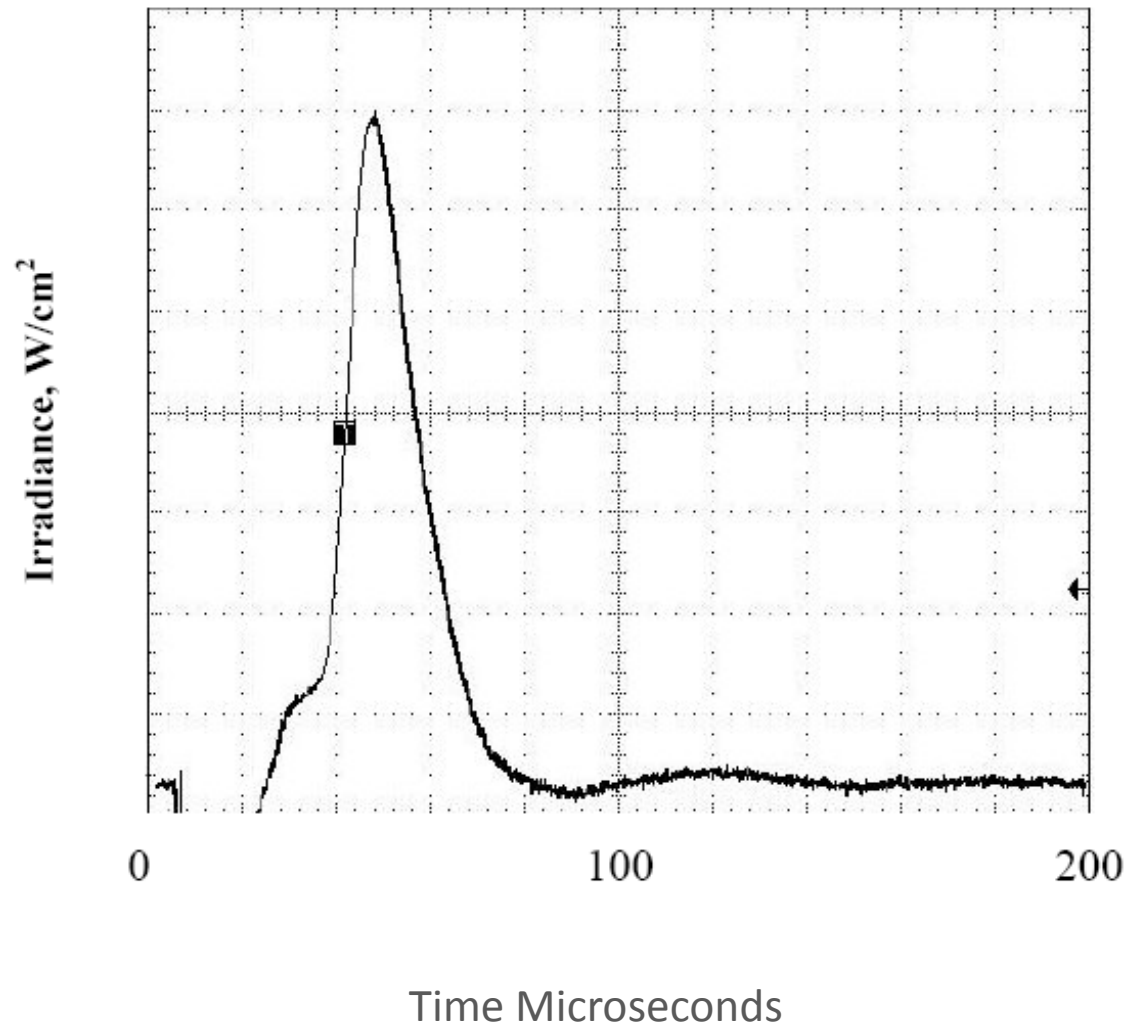


MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

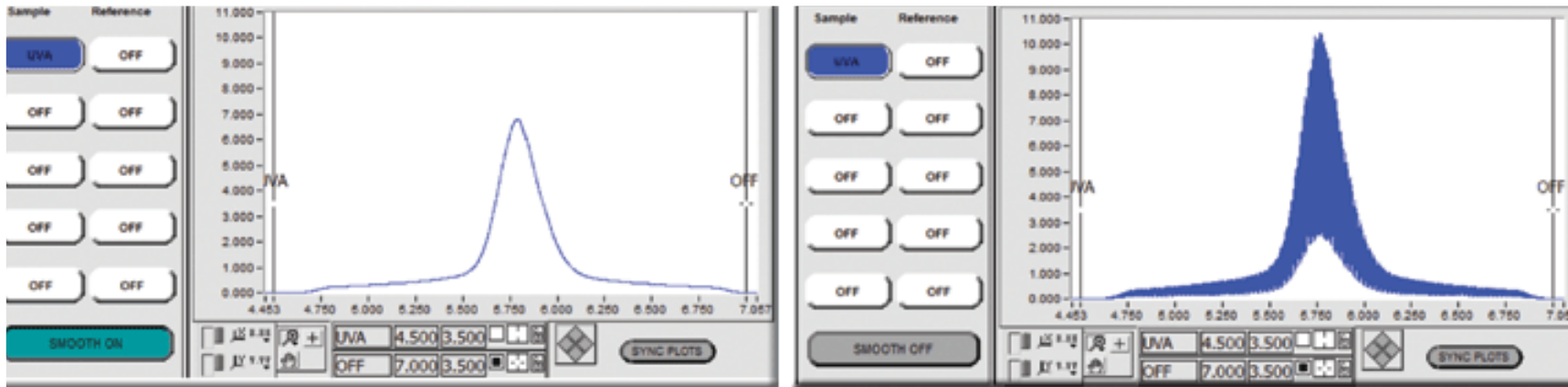


Some UV light sources, like pulsed Xenon lamps require extremely fast sampling to accurately capture the lamps emission.

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



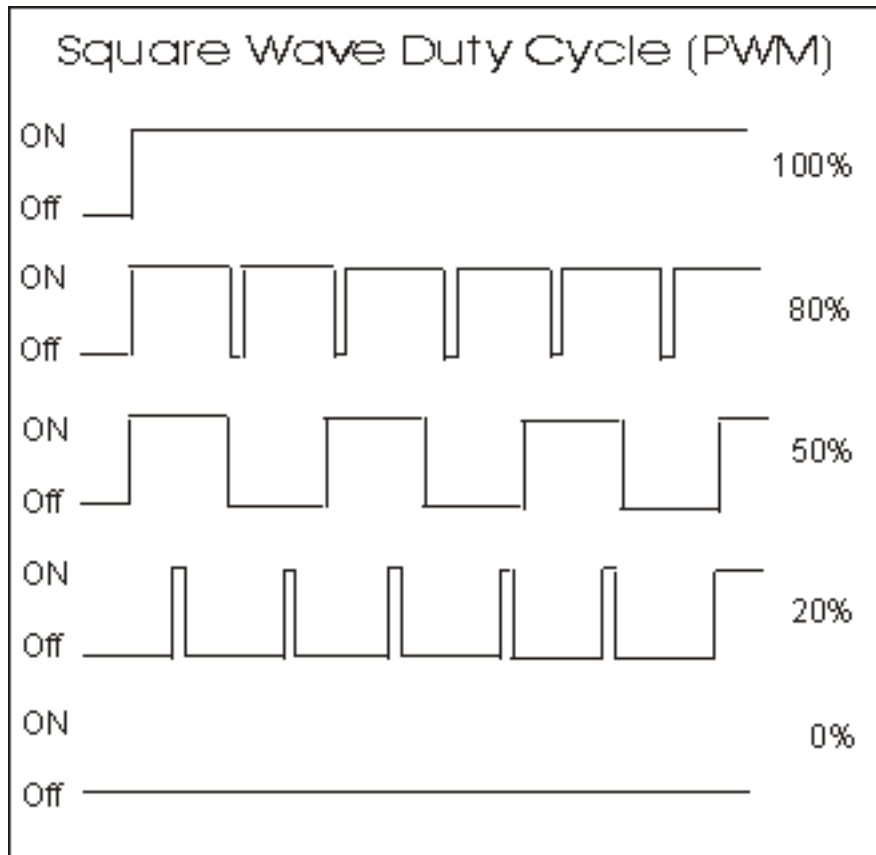
Smoothing On = 6,795 mW/cm²

Smoothing Off = 10,459 mW/cm²

Energy Density = 2,568 mJ/cm²

Fast sampling can capture variations in lamp intensity with power supply changes.

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



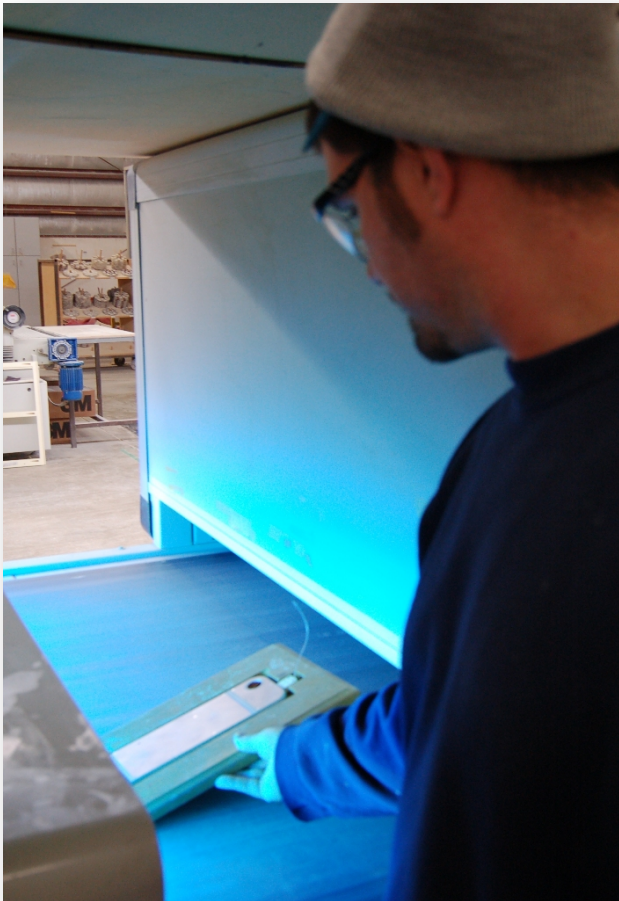
Pulsing the LED light source directly affects actual energy density compared to the instruments calculat

MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

Q: What is the control scheme for LEDs and should measurement instruments compensate for them?



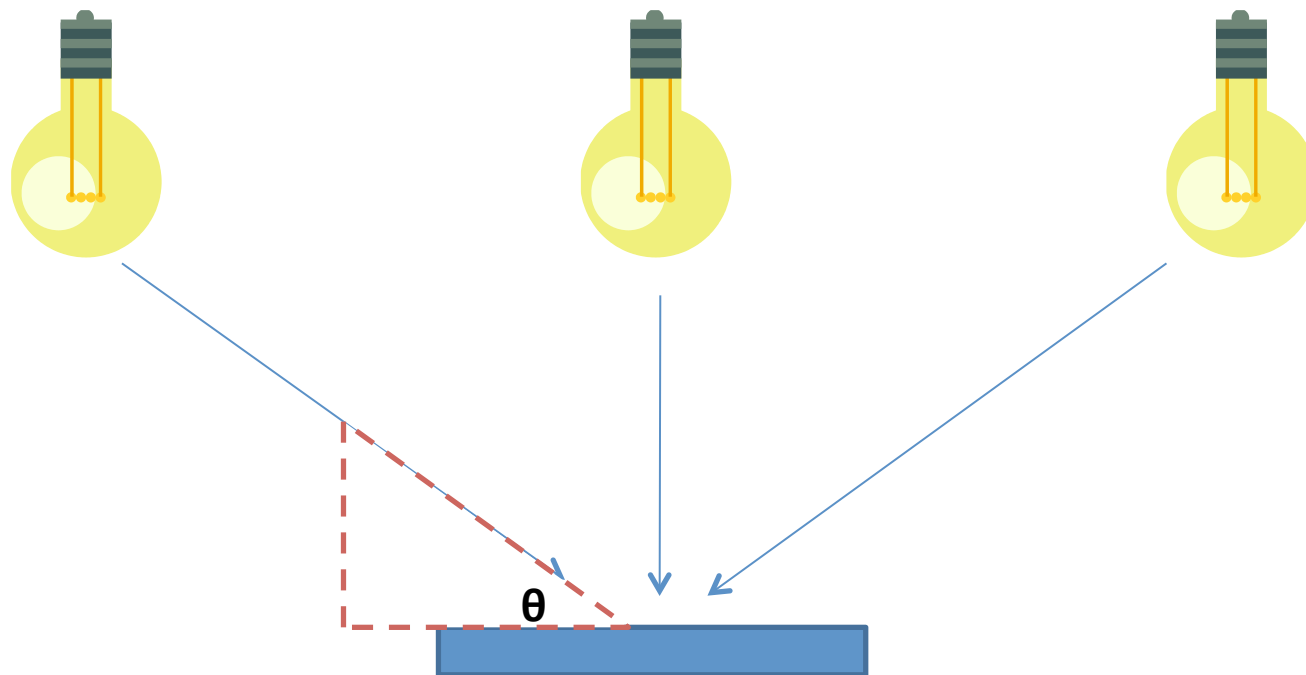
MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



The measurement device is intended to simulate the part surface in a production environment.

MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

$$E_{\theta} = E \times \text{Cos}\theta$$

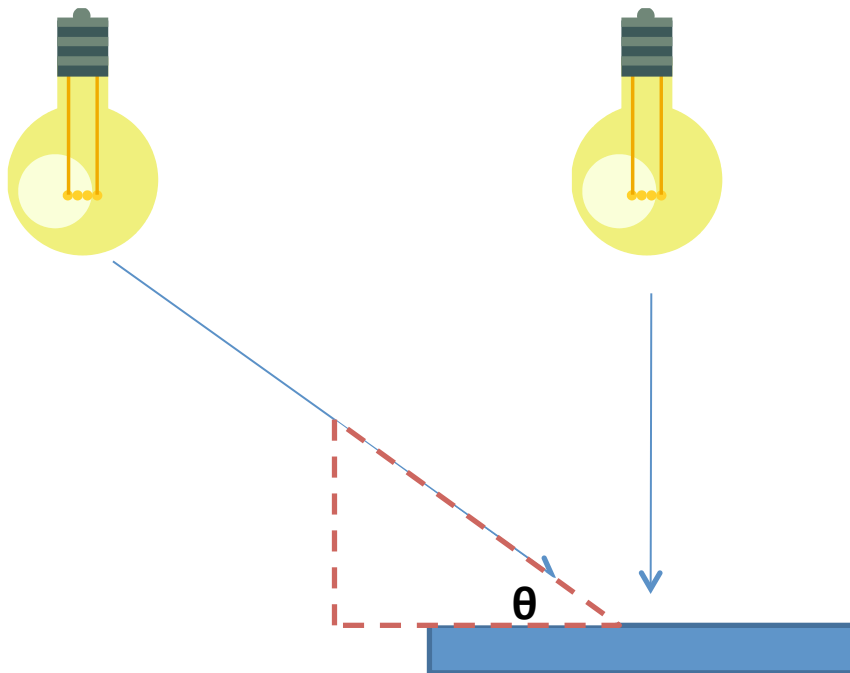


Cosine Error in Measurement

MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

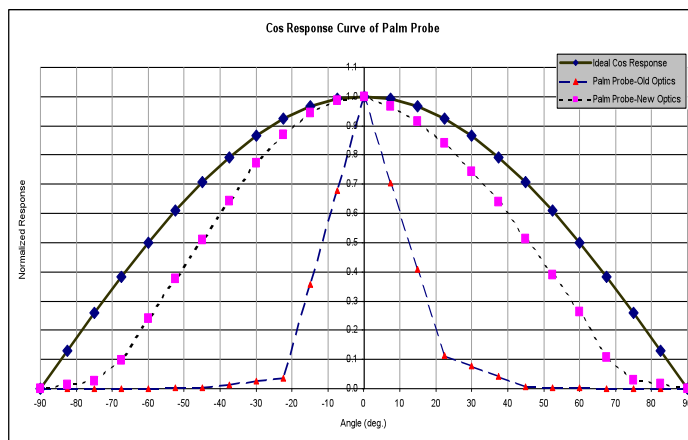
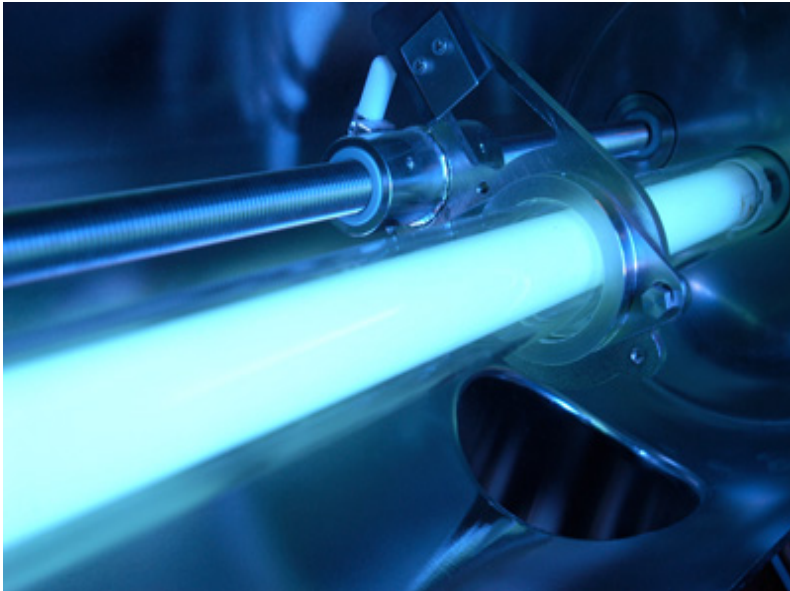
$45^\circ = .7 \text{ Watt}$

$90^\circ = 1.0 \text{ Watt}$



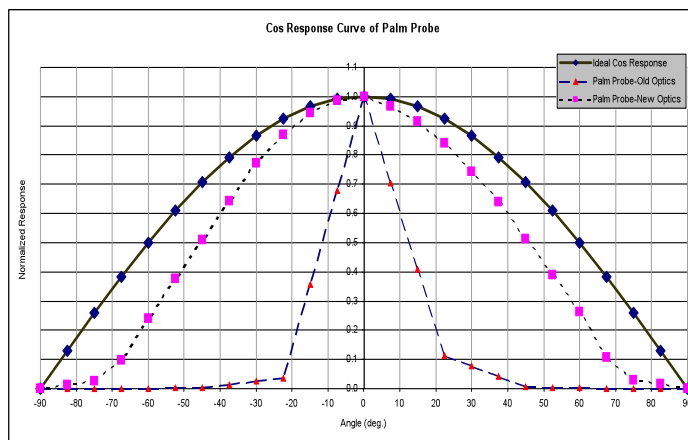
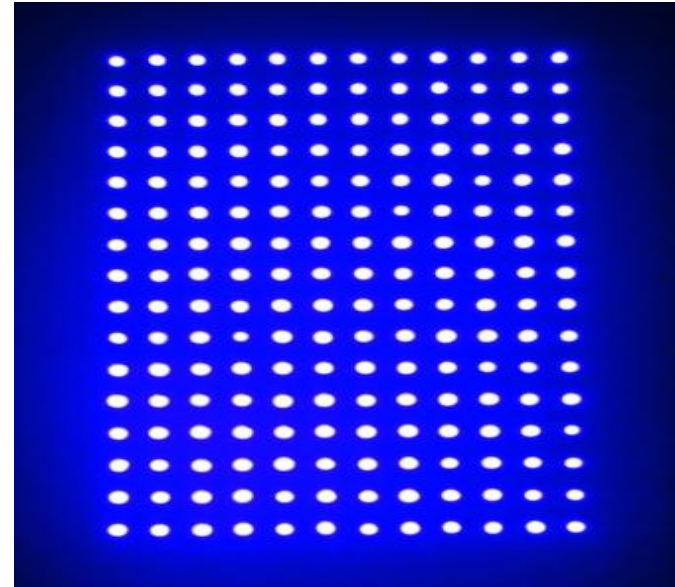
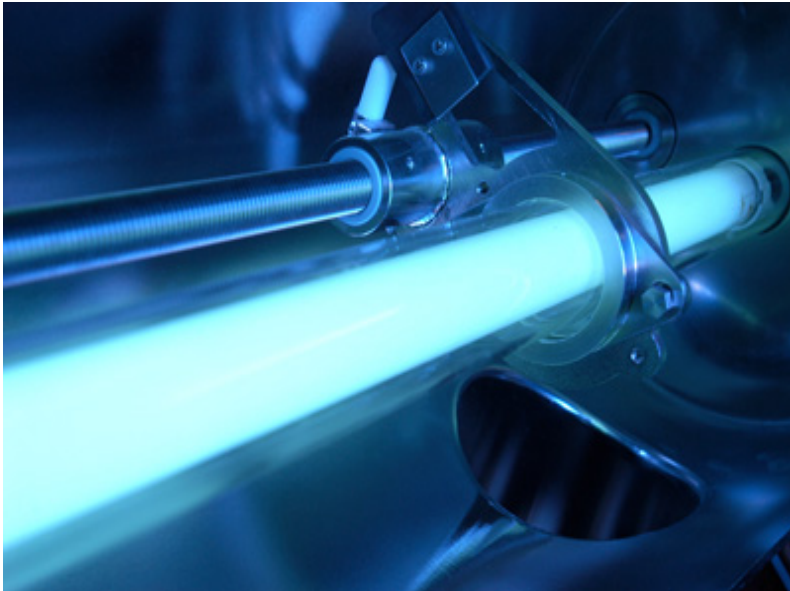
Cosine Error in Measurement

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



We have learned to design Instruments that accurately simulate conventional light sources...

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



But LED arrays are being supplied in a wider range of configurations

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

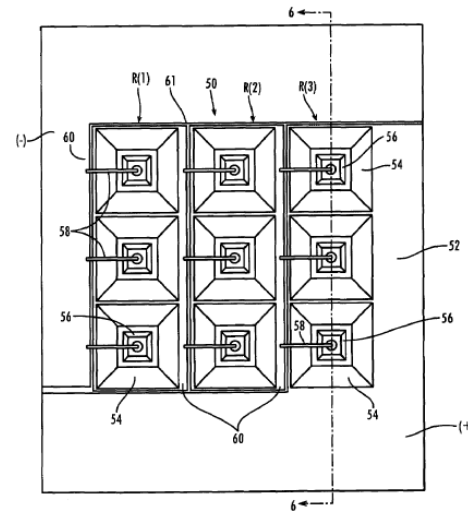
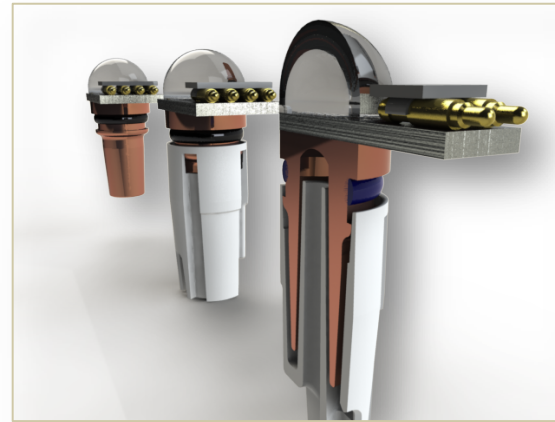
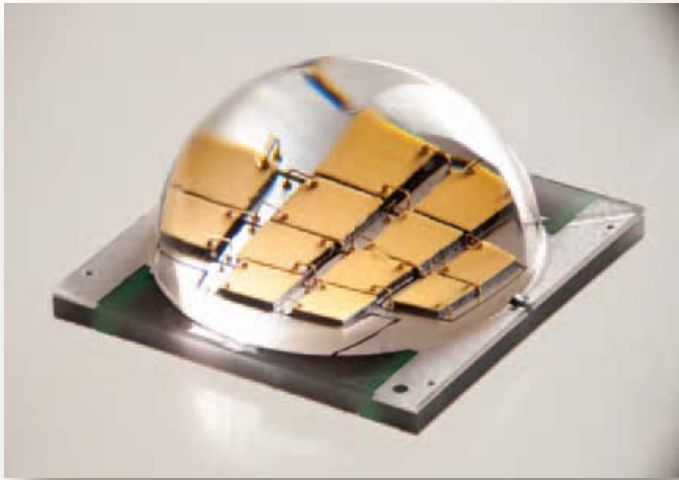
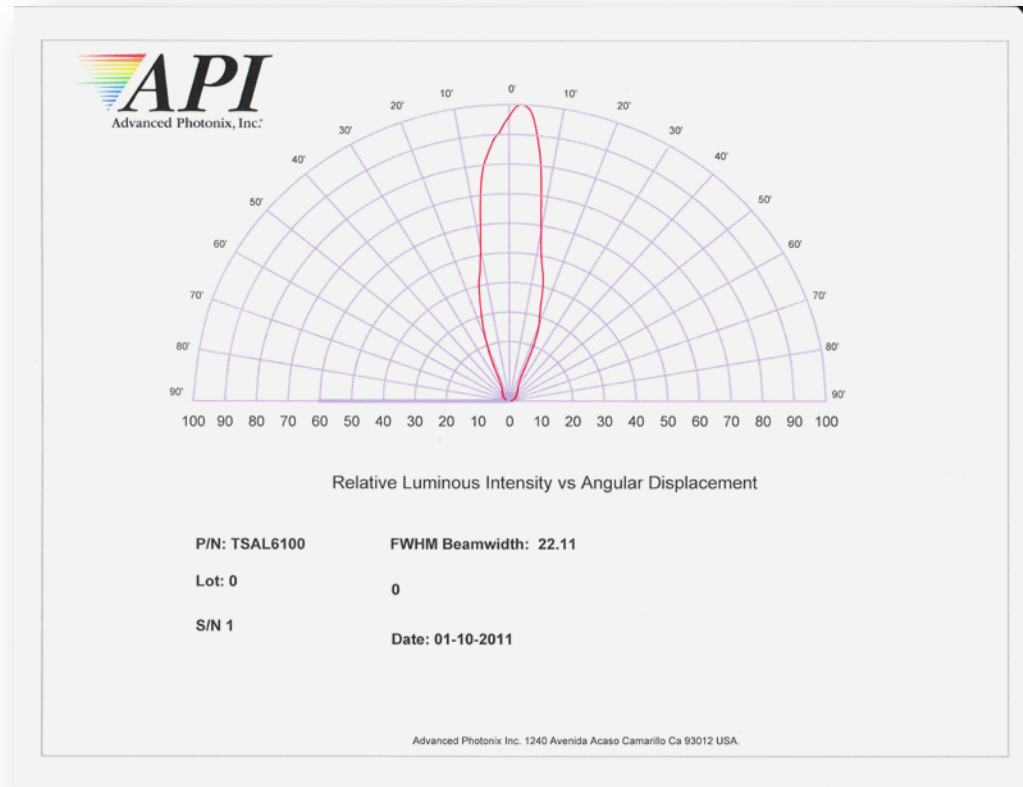
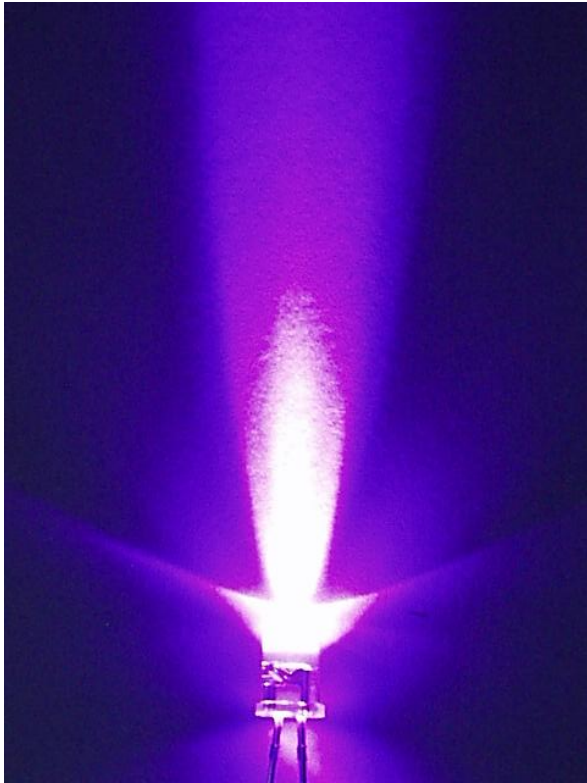
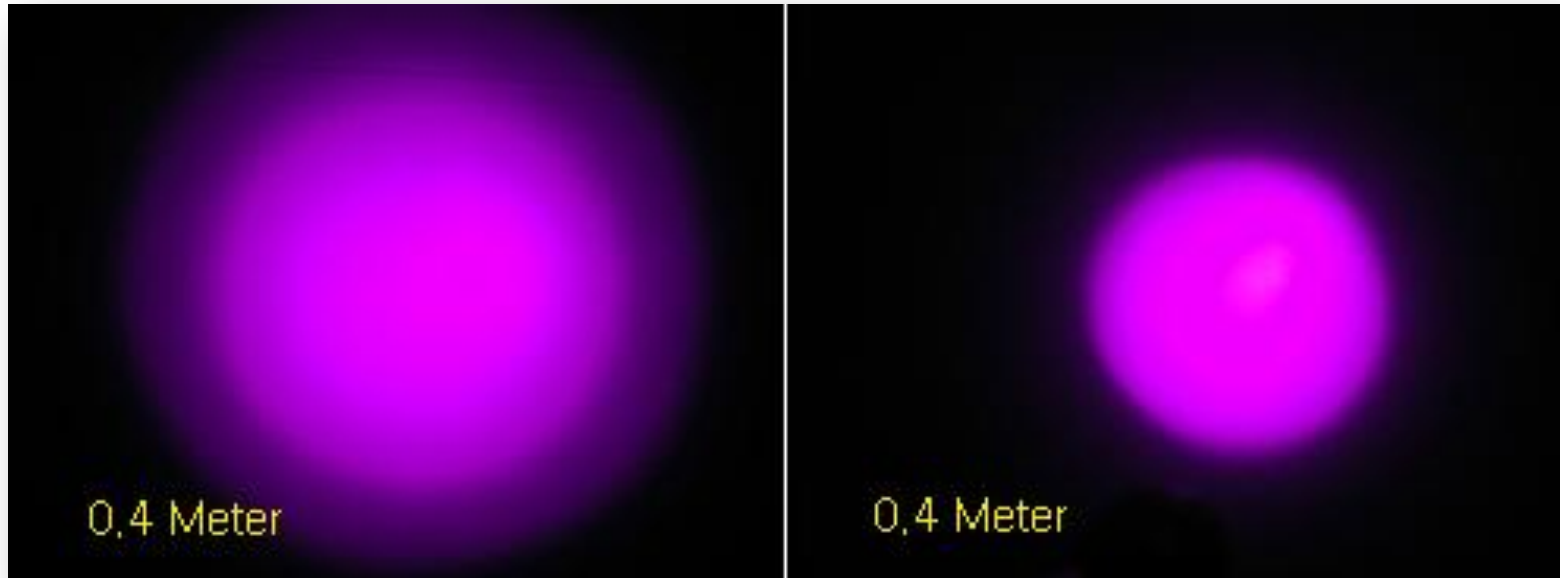


Fig. 5

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



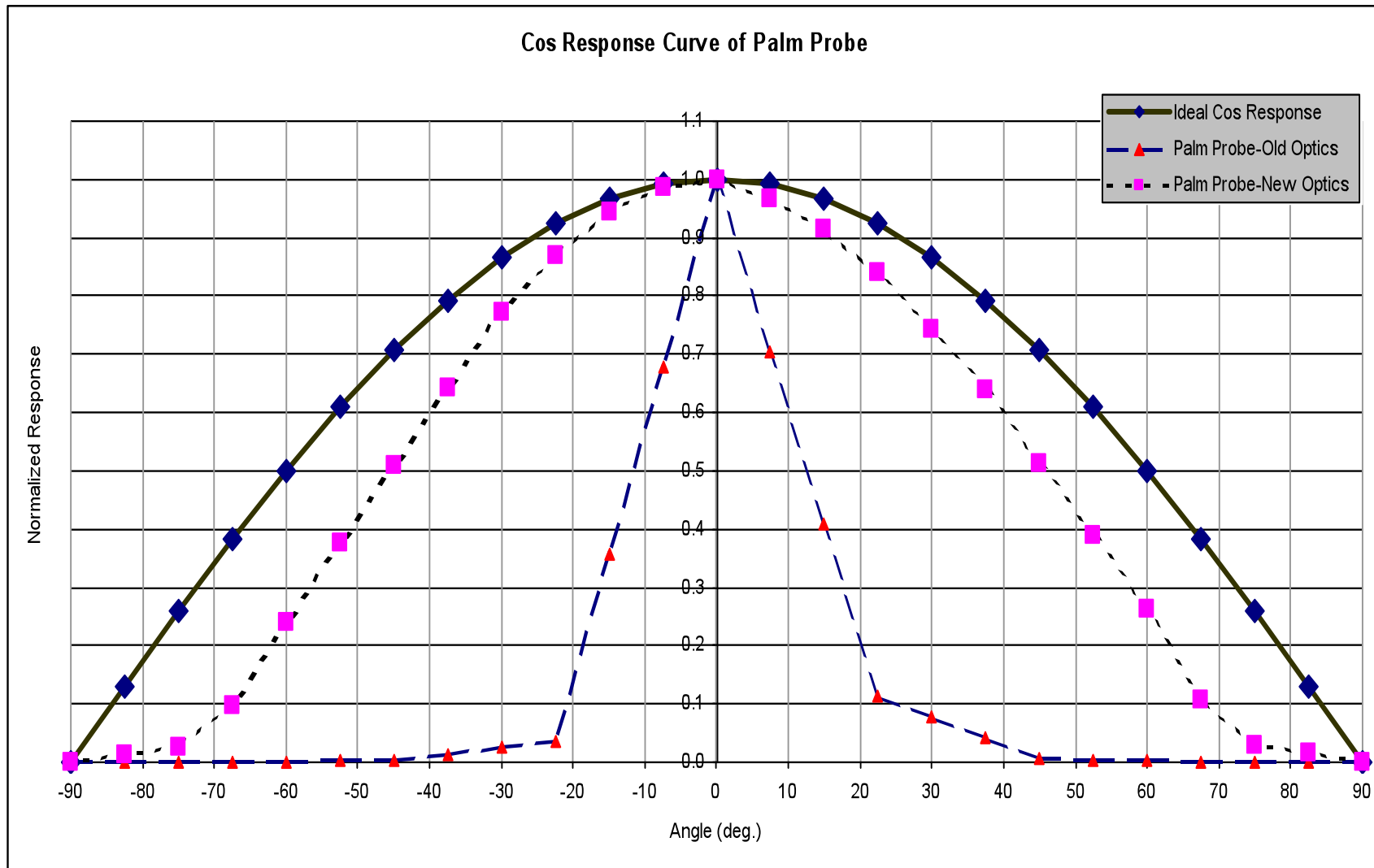
MEASURING THE OUTPUT PERFORMANCE OF UV LEDS



Optical diffusers and lenses on dies and arrays could significantly affect the radiant footprint of the light source and change the proper spatial response.

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

Spatial Response of Instruments Goal: Cosine Response

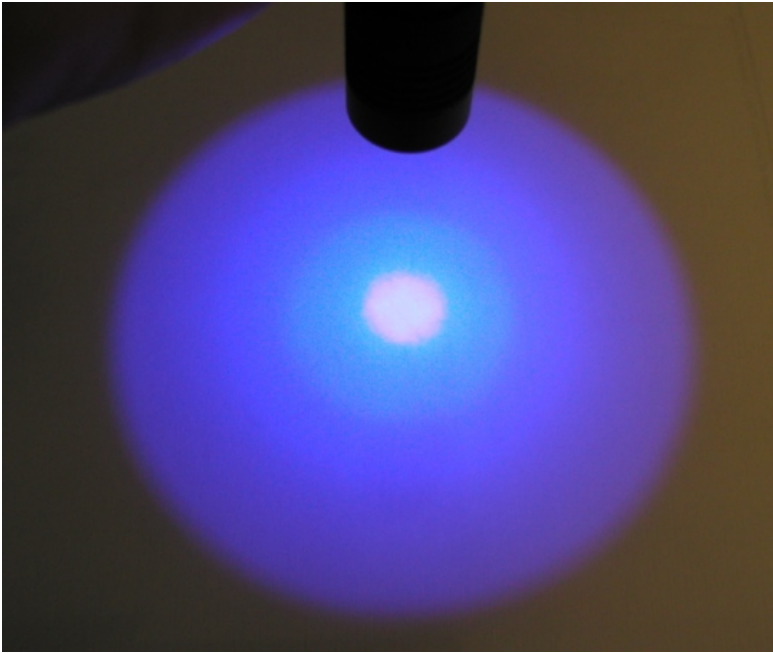


MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

Q: What is the proper cosine response for LED arrays?



MEASURING THE OUTPUT PERFORMANCE OF UV LEDS



Irradiance falls off quickly as we move away from the source in any direction.

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

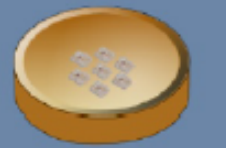

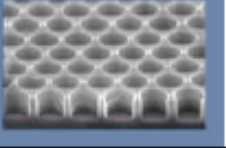

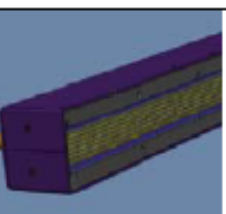
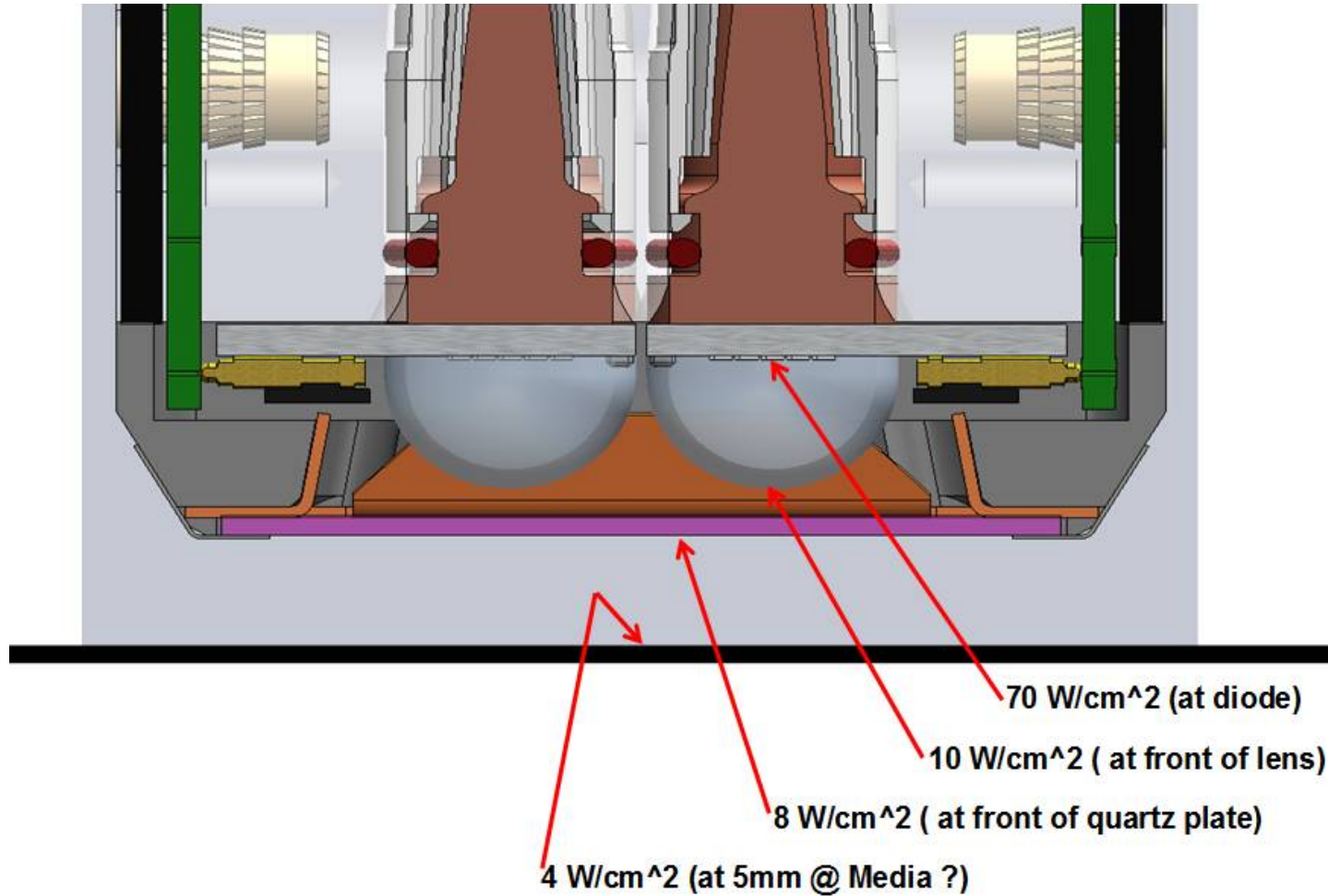
Optics	Pros	Cons	
Macro – LED array inside reflector optic	High peak irradiance over small area.	LED array cannot be scaled uniformly.	
Micro – Each packaged LED has an individual optic	Can be scaled uniformly.	LED to LED spacing and therefore maximum UV output limited by packaged LED size.	
Integrated Optic – Optic part of LED formation process	Increased optical efficiency.	Expensive and array is hard to scale uniformly.	
Directional Optic	Increased peak irradiance over narrow band.	Optics configuration limits number of LEDs that can be configured in system, limiting total available UV output.	
Scalable micro optic	SLM module can be scaled uniformly while maintaining high peak irradiance.	Light is not focused and diverges over distance.	

Table Courtesy of Phoseon Technology

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



Courtesy of Integration Technology

MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

Q: Where should UV LED measurements be made?



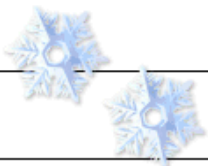
MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

My Christmas Wishlist



Name: _____

1. Better dynamic Range
2. Fast sampling & Smoothing
3. All wavelengths
4. Perfect cosine response
5. Inexpensive as Possible!



www.celebrating-christmas.com

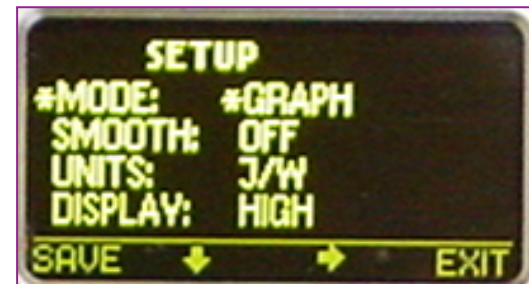
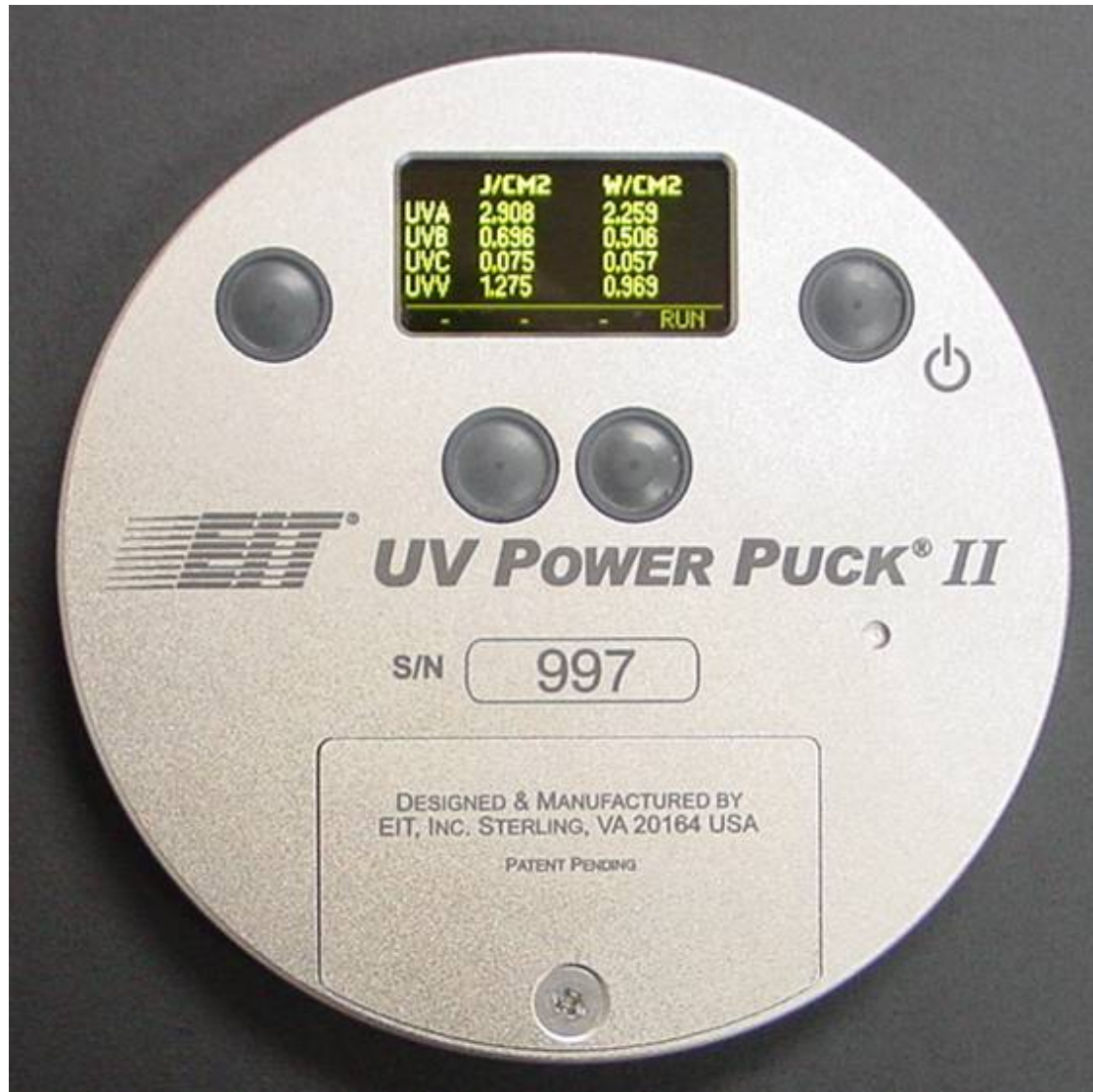
The right instrument needs to address a wide range of desirable features.

MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

Q: How much should a radiometer cost?



MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



Quantitative, routine
maintenance

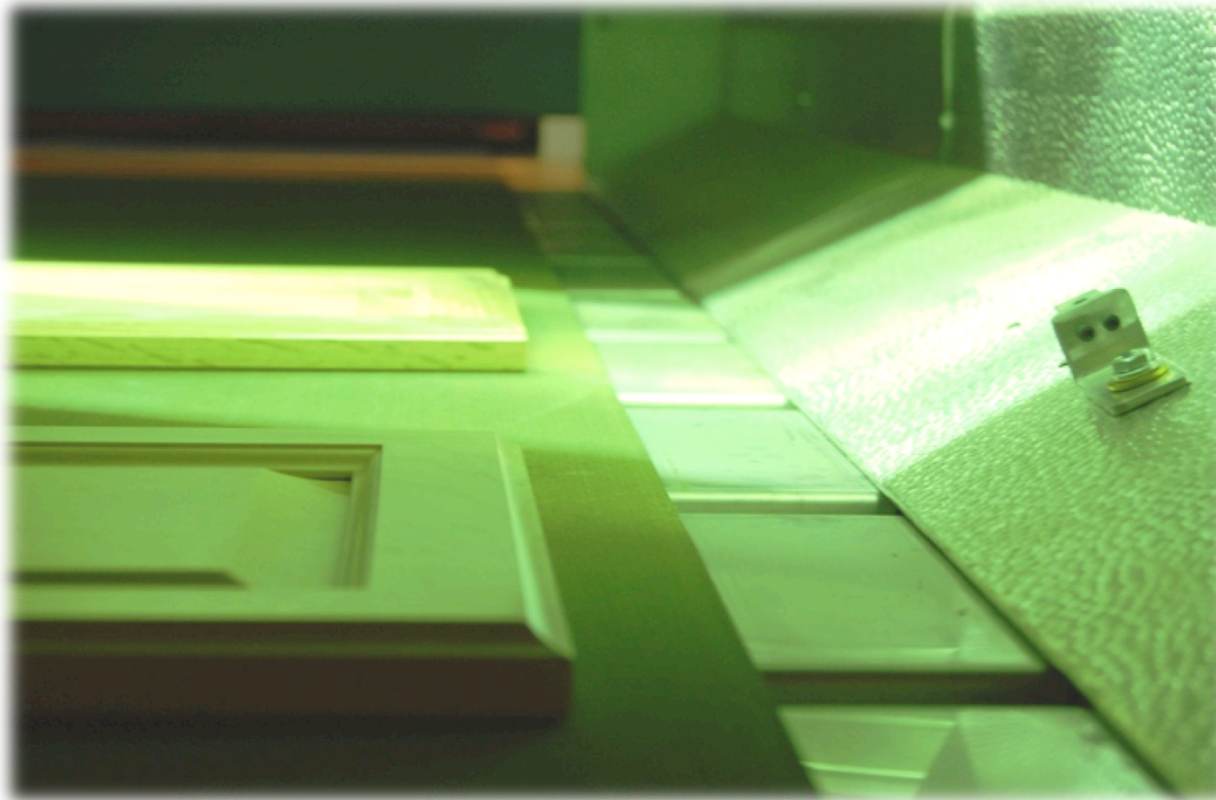


Real-time
status monitoring

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



MEASURING THE OUTPUT PERFORMANCE OF UV LEDS



A sensor in the process chamber detects changes in UV irradiance

Two kinds of UV measurement

Absolute Measurement

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

Relative Measurement

- **Want to compare**
 - UV changes with time
 - Alarms
 - Constant monitoring
 - Simultaneous readings

MEASURING THE OUTPUT & AREA BREADBREAD OF UV LEDS



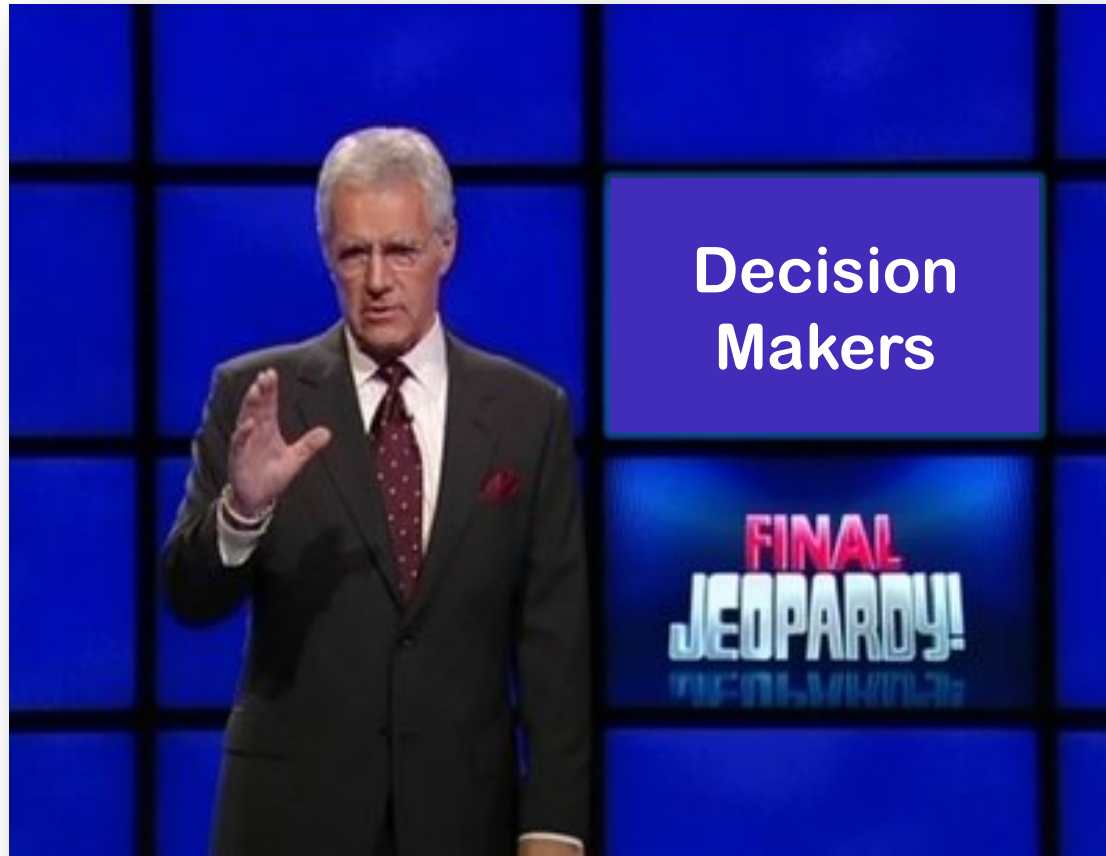
“Off-the-Shelf” Standard Interface Solutions

MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

Q: What is the purpose of your measurement?
What is “the number” used for?



MEASURING THE OUTPUT PERFORMANCE OF UV LEDS



MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

INTEGRATION
TECHNOLOGY



LOCTITE

Phoseon
TECHNOLOGY



American
Ultraviolet®



BALDWIN

hönle
uv technology

MEASURING THE OUTPUT PERFORMANCE OF UV LEDS

**UV LED CURING
ASSOCIATION**

Committed to UV LED Curing Education

RADTECH
THE ASSOCIATION FOR UV&EB TECHNOLOGY

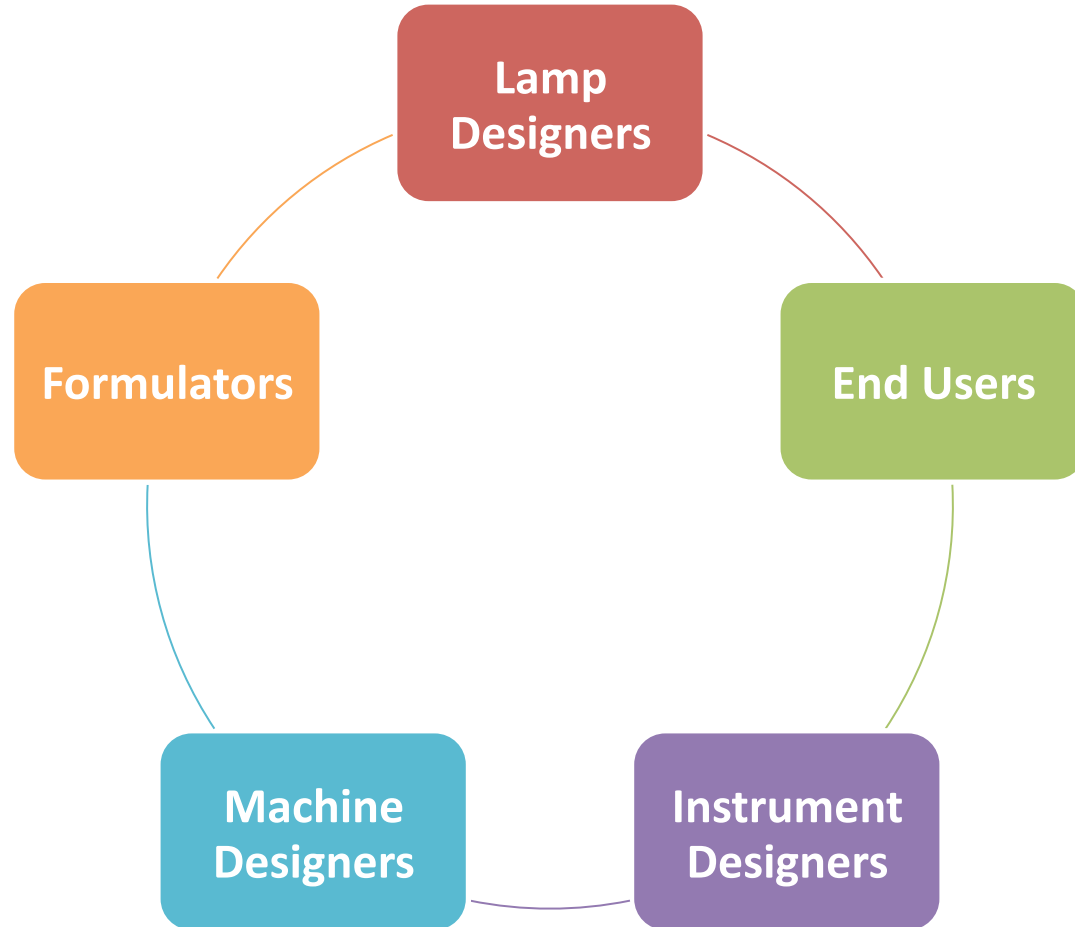
RADTECH
RADTECH
RADTECH
EUROPE

MEASURING THE OUTPUT PERFORMANCE OF UV LEDs



“Someone calling themselves a customer says they want something called service.”

MEASURING THE OUTPUT PERFORMANCE OF UV LEDS



MEASURING THE OUTPUT PERFORMANCE OF UV LEDs

Q: Who will lead the discussion that will shape how LEDs are measured?



MEASURING THE OUTPUT PERFORMANCE OF UV LEDS



Thank You !

Paul Mills
pmillsoh@aol.com
EIT LLC
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