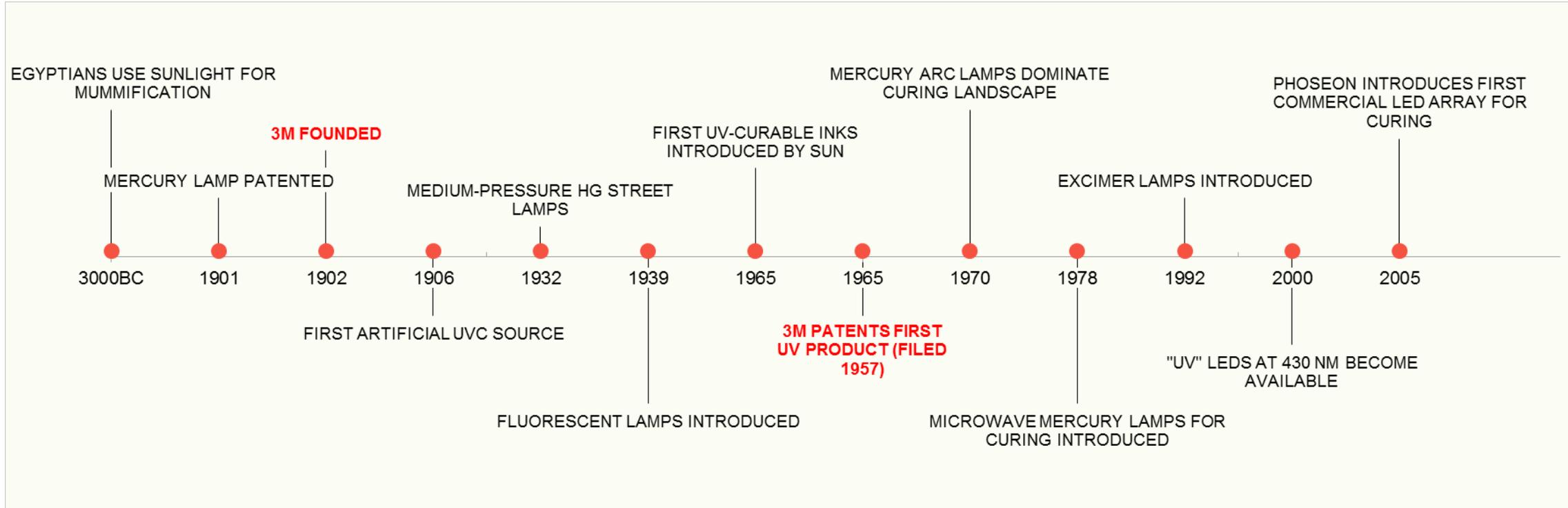


Industry Needs for UV LED Radiometry

Dr. Robin E. Wright

3M Corporate Process Technology Laboratory

History of UV Sources and UV Curing



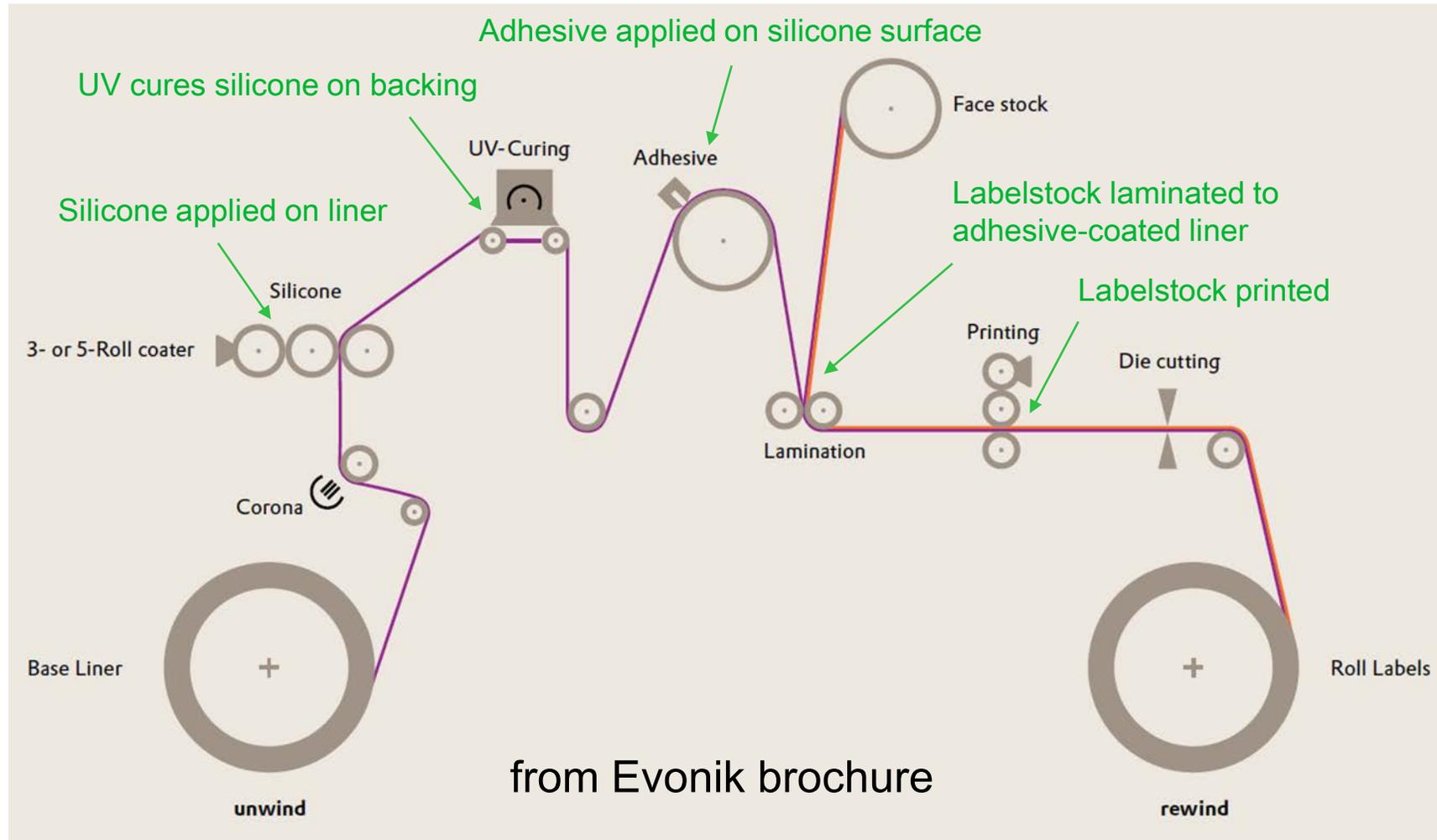
Commercial Impact of UV Processing

UV curing is a multi-billion dollar industry impacting multiple markets -

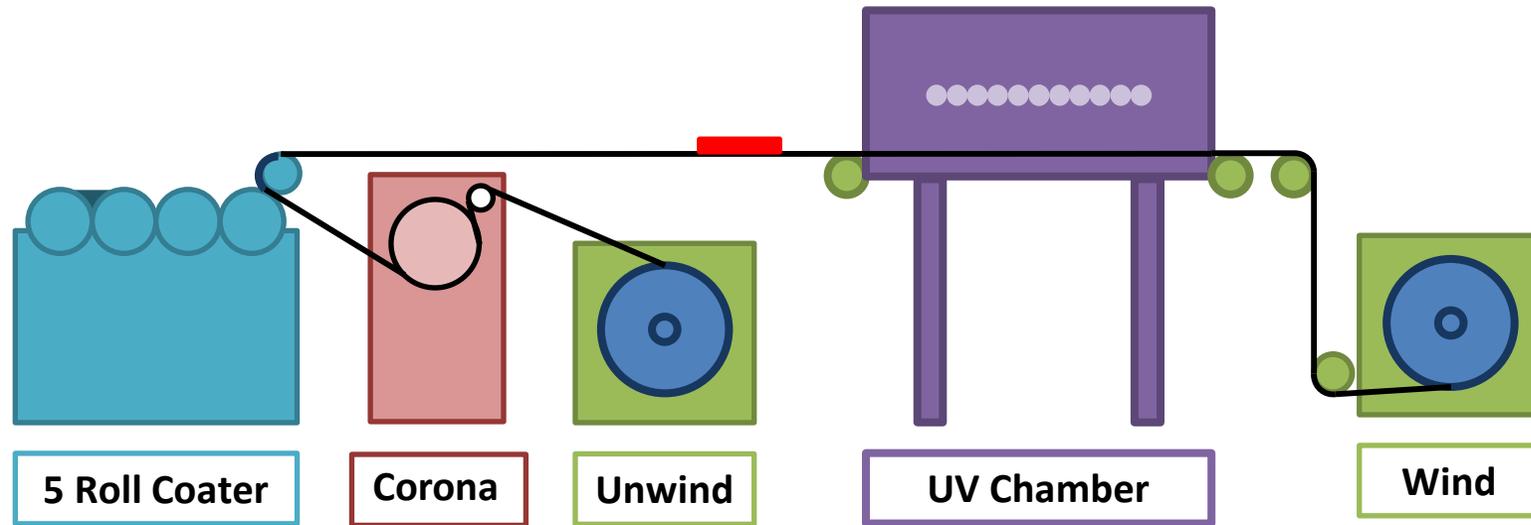
- Abrasives
- Adhesives
- Aerospace
- Automotive
- Dental
- Electronics
- Graphic arts
- Optical
- Functional surface coatings
 - Abrasion resistant
 - Anti-fogging
 - Anti-fouling
 - Primer
 - Release
 - Scratch resistant
 - Seal coats
 - Solvent resistant

Web-based Processing

Schematic of label maker line



Use of Belt Radiometers to Measure I_0 and E

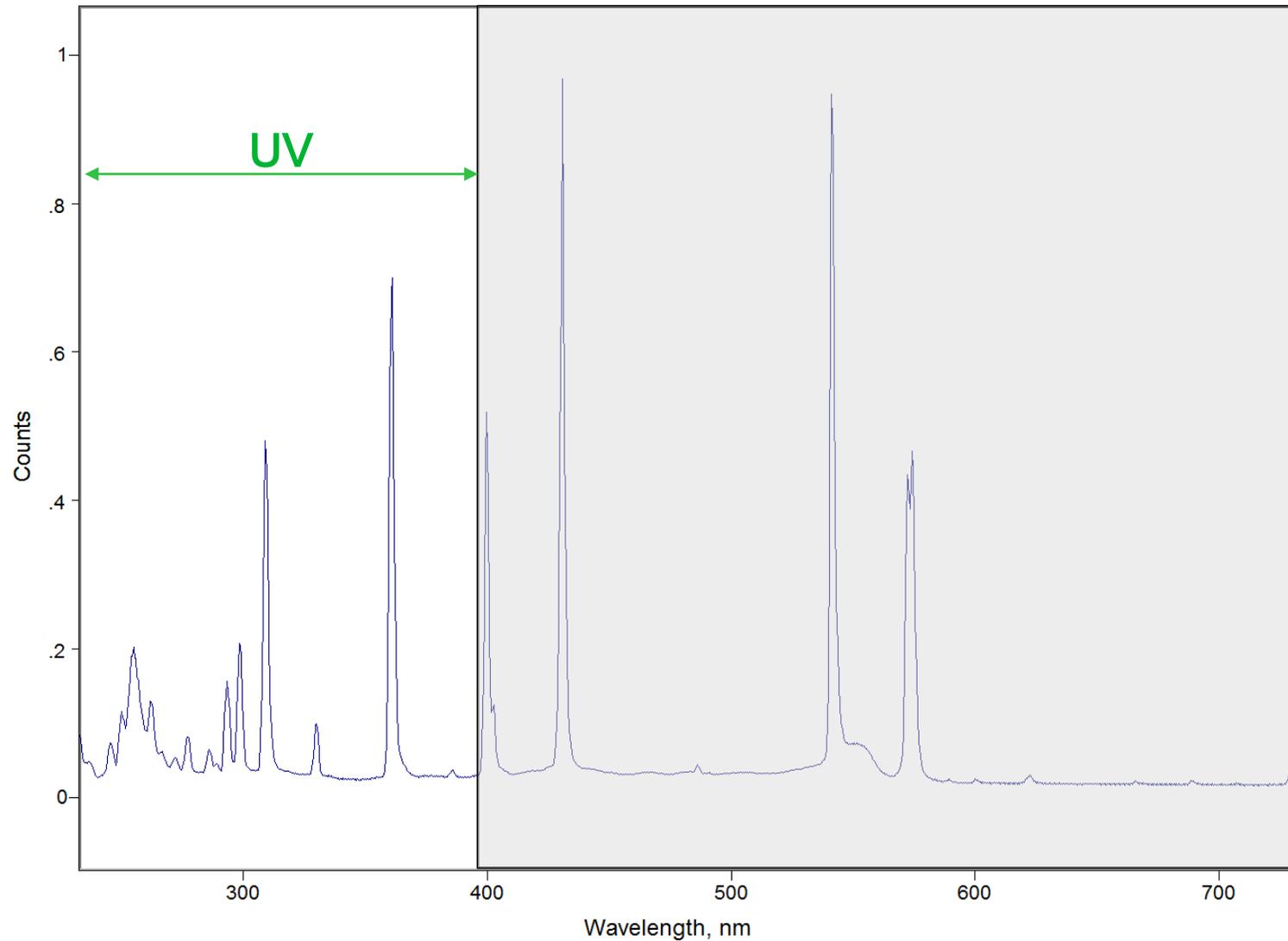


Profile - measure I_0 as a f_{time}

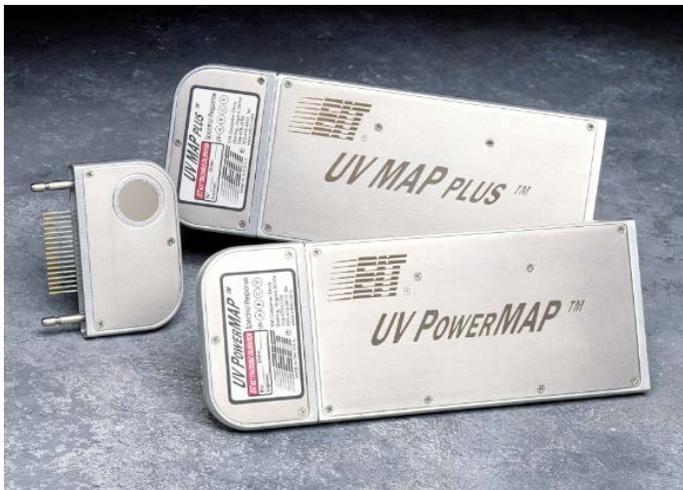
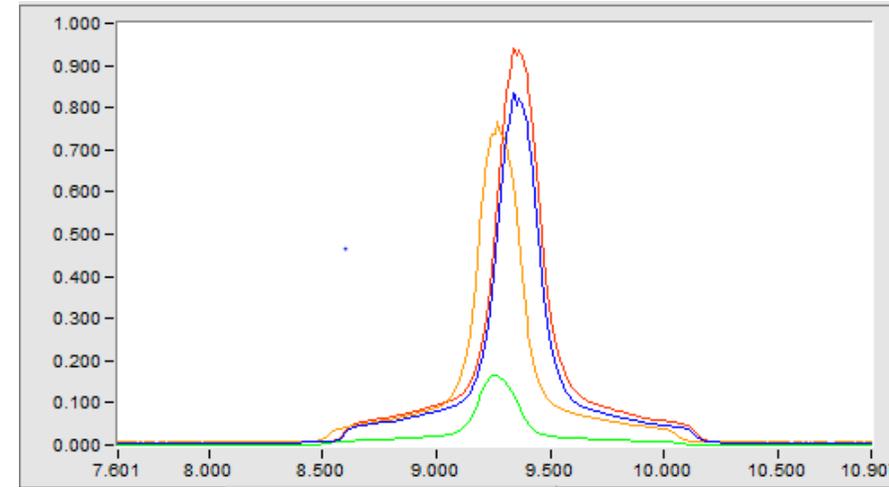
Spectral range selected by bandpass filters

Integrate - to determine E

Spectrum of a Medium-Pressure Mercury Bulb



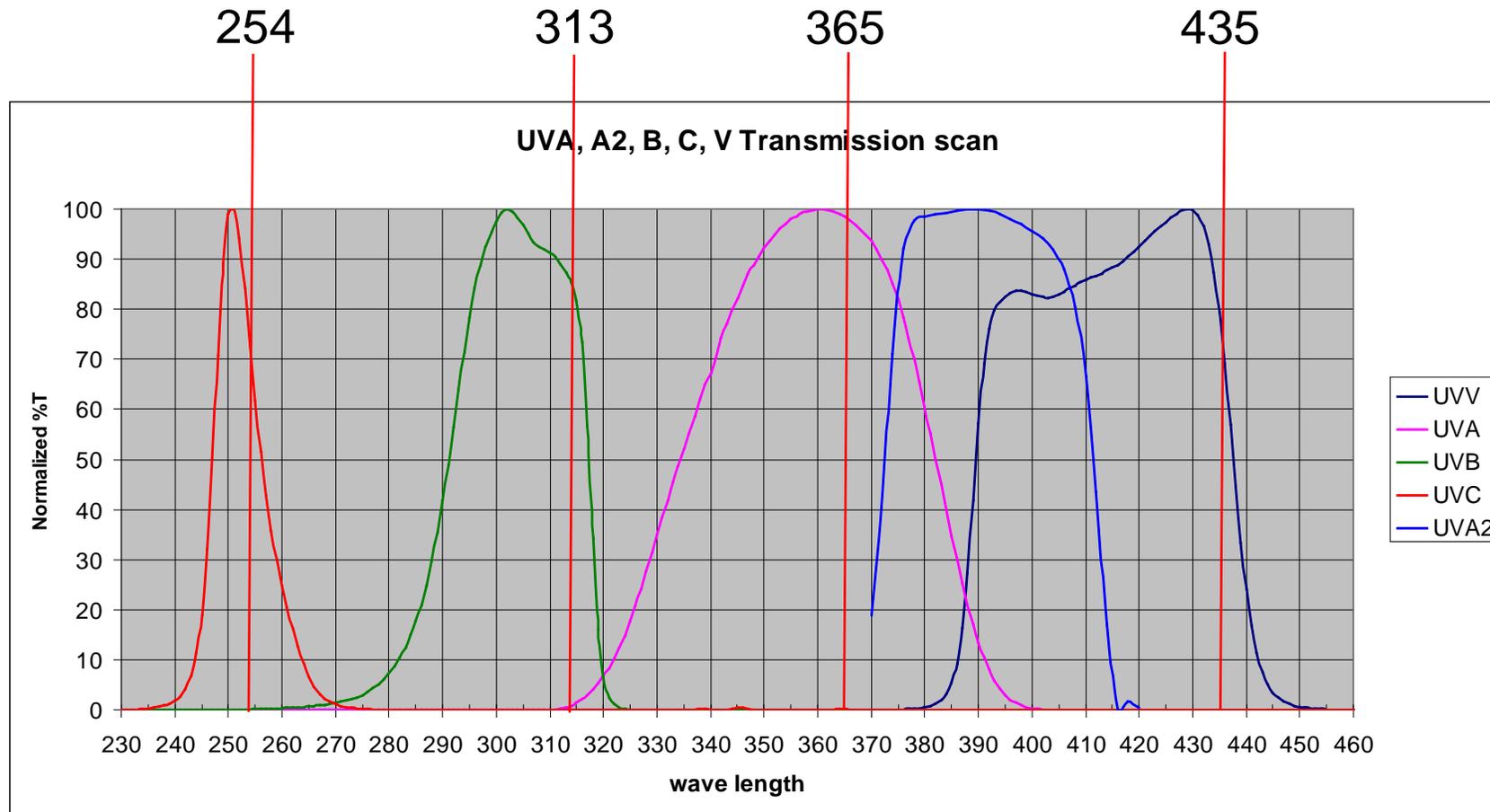
Belt or Profiling Radiometers



Total Energy Density (cm2)					Peak Power Density (cm2)					
		Sample	Reference	Diff.	% Diff.		Sample	Reference	Diff.	% Diff.
UVA	mJ	330.49				UVA	mW	834.74		
UVB	mJ	336.38				UVB	mW	765.06		
UVC	mJ	63.482				UVC	mW	166.45		
UVV	mJ	392.31				UVV	mW	941.41		
Average Temp						Peak Temp				
TEMP	C	21				TEMP	C	23		

PowerMAP™ data for Hg bulb

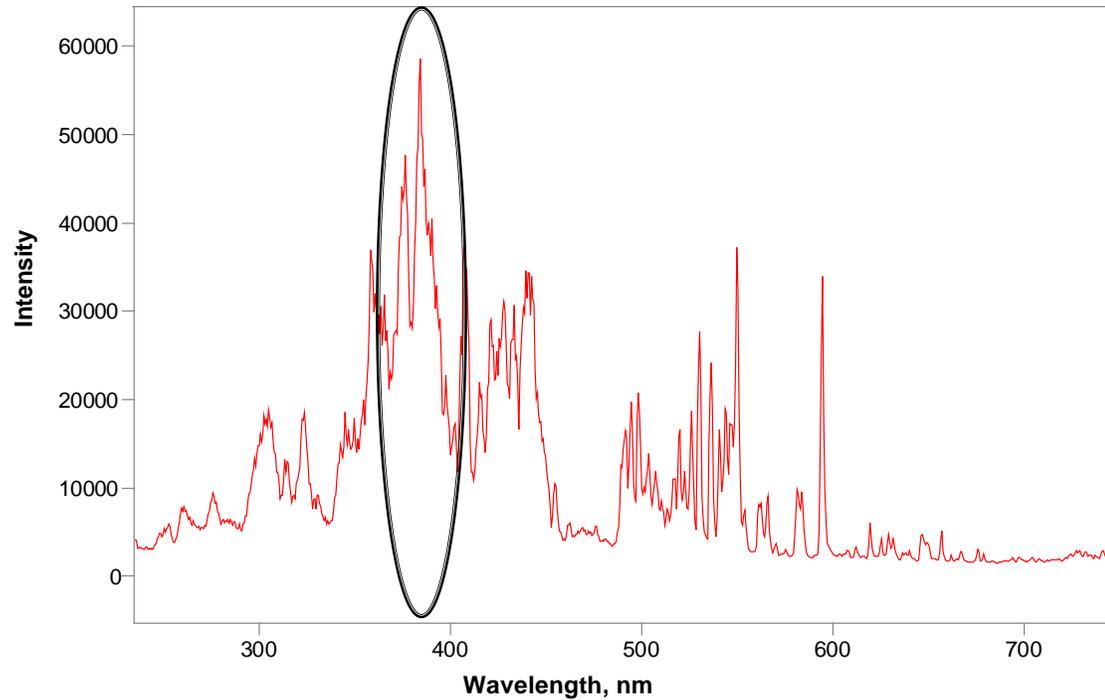
Filter Transmission Curves



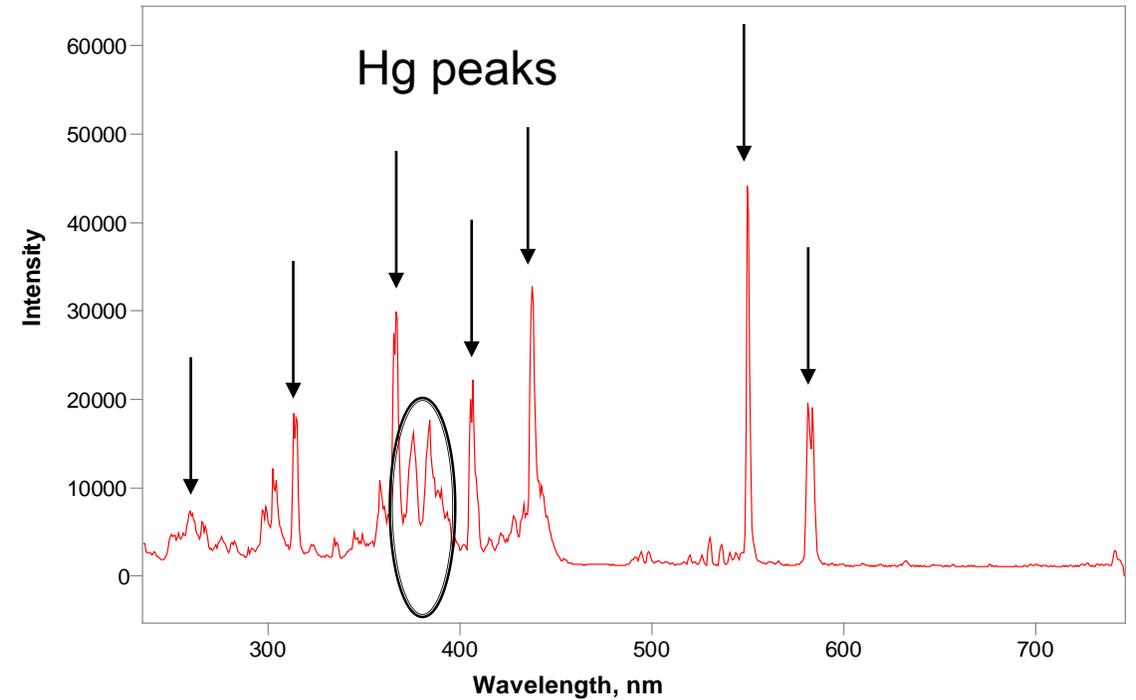
Radiometry Issues using MP Mercury Bulbs

- No consensus on spectral band definitions
- No “standard” calibration – many claim “NIST traceability”
- No “standard” medium-pressure mercury bulb spectrum
 - Arc vs microwave lamps
 - No standard bulb fill recipe
 - No design specifications (e.g. quartz type and thickness, etc.)
- Known temperature effect on some bulb emission spectra
- Filter selections not optimal for all bulb emission spectra

Effect of Power on Iron Halide (D) Bulb Spectrum



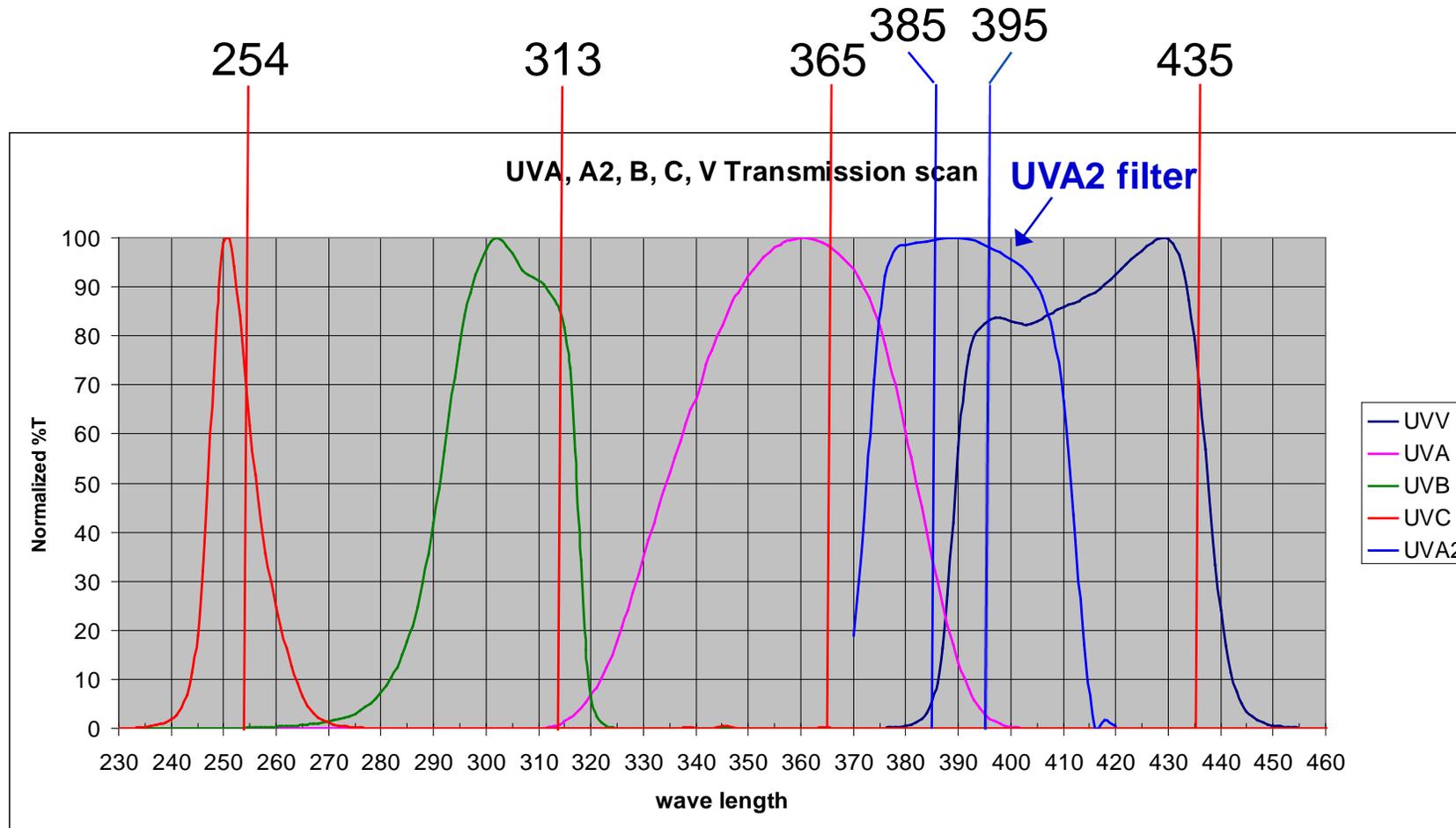
100% power



50% power

Introduction of LEDs Created a Need for a New Filter

UV-A2 covers both 385 and 395nm LEDs (and, fortuitously, the iron halide Hg bulb)



Why Medium-Pressure Hg Lamps are Used Today

Pros

- Broad spectral output
- Ability to “dope” bulbs
- Good UV power
- Availability
- Low cost
- Long bulb lifetime

Cons

- Regulatory pressure on Hg
- Heat management; fire hazard
- No “recipe book” for bulb fills
- Spectra are temp sensitive
- Unclear which λ 's are doing work
- Poor radiometric traceability
- OEM replacement bulbs

UV LEDs – A Paradigm Shift

- UVA LEDs (385, 395nm) are changing the landscape
- Printers are shifting from mercury lamps to LEDs
 - Low heat
 - High power
 - Long lifetime
 - Better energy efficiency
 - Narrow emission band
- Use of LEDs is expanding to broader industrial coatings
 - Number of wavelengths is expanding (365nm is available)
 - Shorter wavelengths being developed (down to 265nm)

Current Status of UV LEDs

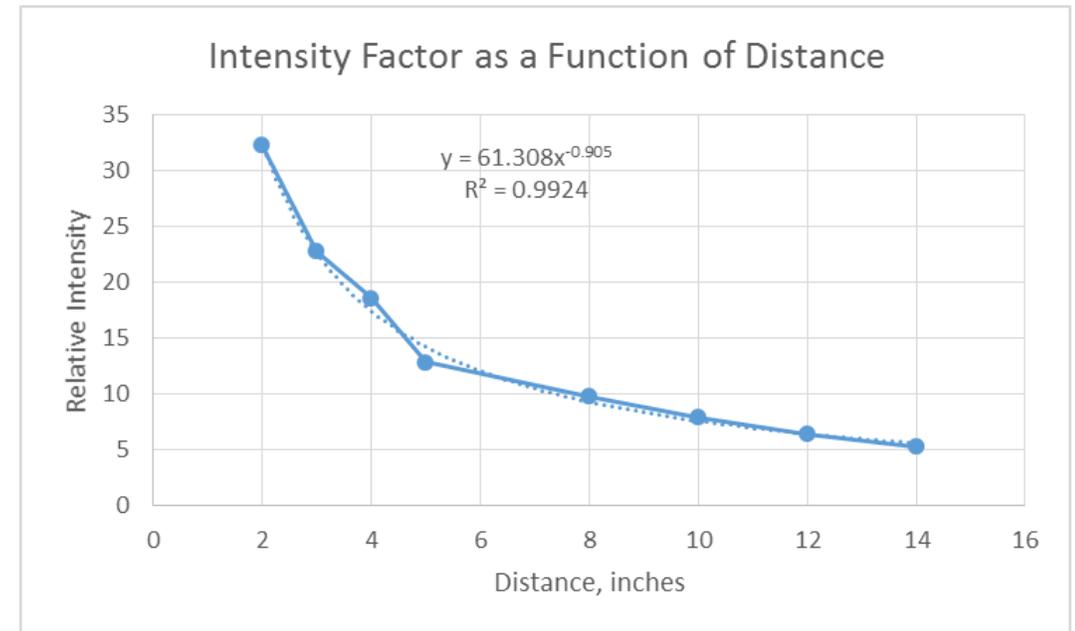
λ , nm	Hg	395	385	365	340	320	300	285	265
Maximum Power*, W/cm ²	2	20	12	12	?	?	?	0.05	0.05
Cooling (Air, Water)	A	A/W	A/W	A/W	?	?	?	W	W
Lifetime, hrs	8k	>20k	>20k	>20k	?	?	?	8k	8k
Cost per foot, est.	15-25k	20k	?	20k	?	?	?	?	32k
Industrial viability	Y	Y	Y	Y	?	?	?	N	N

* There is usually no information on how or where the power was measured

Relative Intensity as a Function of Working Distance

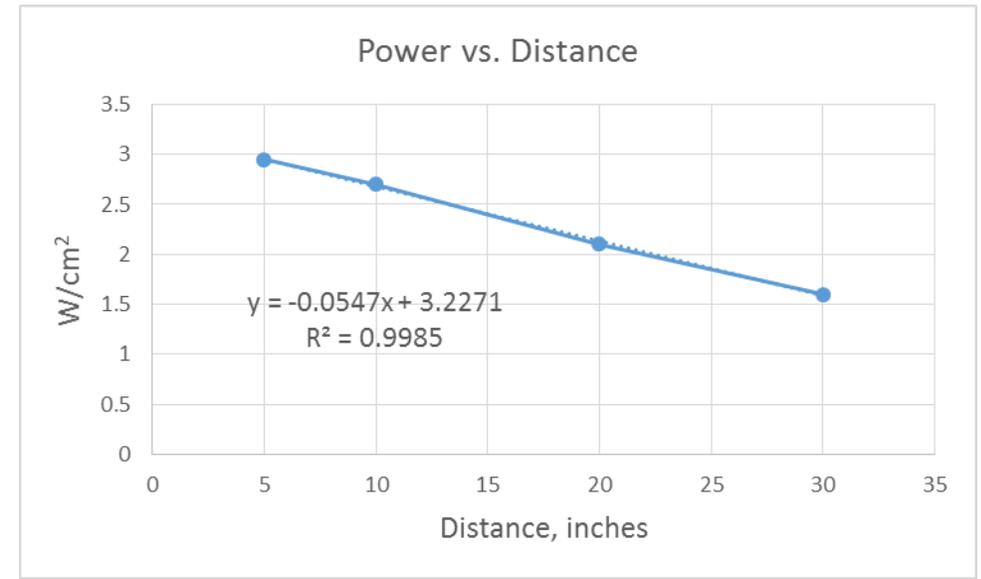
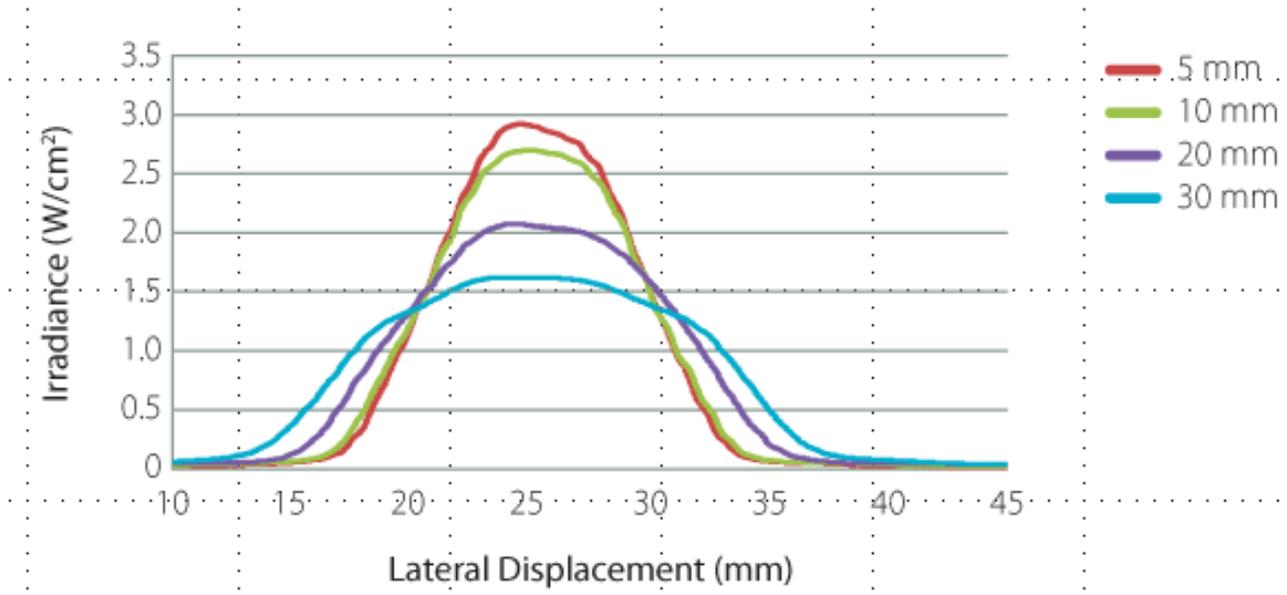
Philips fluorescent bulb

Distance from Lamp (inches)	Intensity Factor	Distance from Lamp (inches)	Intensity Factor
2	32.3	24	2.33
3	22.8	36	1.22
4	18.6	39.37	1.00
6	12.9	48	0.681
8	9.85	60	0.452
10	7.94	80	0.256
12	6.48	100	0.169
14	5.35	120	0.115
18	3.60		



Irradiance as a Function of Working Distance

Direct Dynamics* 395nm LED array with redirecting optics



* no information on measurement device – power meter or profiling radiometer



Importance of Radiometric Measurements

- How do you verbally specify a manufacturing process to someone that does not speak your language?
 - A common language is required – for curing, it is radiometry
 - For companies like 3M, global standards are critical
 - Measuring dimensions in units of hands or weight in units of stones is still acceptable; we know how to translate them into common engineering units
 - How do you transfer mW/cm^2 or mJ/cm^2 specifications if there is no commonality between devices used or no knowledge of the geometry in which a measurement was made
- LEDs are narrowband so radiometry should be much easier

Problems with LED Radiometers

- There are currently no established standards
 - Detector responsivity curves are not flat
 - LED lamp manufacturers are selling radiometers under their label
- There is no distance specification as to where to measure
- There is no standard LED array configuration
 - Some arrays use optics for far-field (>10 mm) applications
- Peak powers exceed conventional lamp calibration powers
- Multi-wavelength LED arrays will soon become available

Radiometry “Dream Team” Established

LED Array Radiometry Task Force			
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CORM members are also invited to participate!

Moving Forward

- Propose that members share past and ongoing efforts
- Use forums like CORM and/or CIE to come together and discuss various scenarios
- Needs:
 - Agree on detector(s) selection
 - Agree on calibration procedures
 - Consistency on how to measure and report output
 - Implementation remains with OEMs

Thank you!

Questions?