



UV Systems – Design and Control

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Gaithersburg, MD**



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UV CURING

- **Process to cure coatings, inks, adhesives**
- **Polymerization and cross-linking is initiated by UV radiant energy**
- **Coating is converted from a liquid to a solid in a fraction of a second**
- **Replaces solvent-based drying processes**
- **Every existing method of decorating or coating has been converted to UV Curing**



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Benefits of UV curing

- Faster cure speed
 - faster throughput
 - less chance of contamination on the coating
 - fewer parts to re-work
- Reduced floor space for UV installation
- Energy savings in most processes
- Immediate stackability or further processing
- Improved properties
 - high gloss or low gloss or gloss control
 - scratch/chemical resistance
- Solvent free formulations, in many cases



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UV CURING

Key Ingredients of Inks, Coatings, or Adhesives

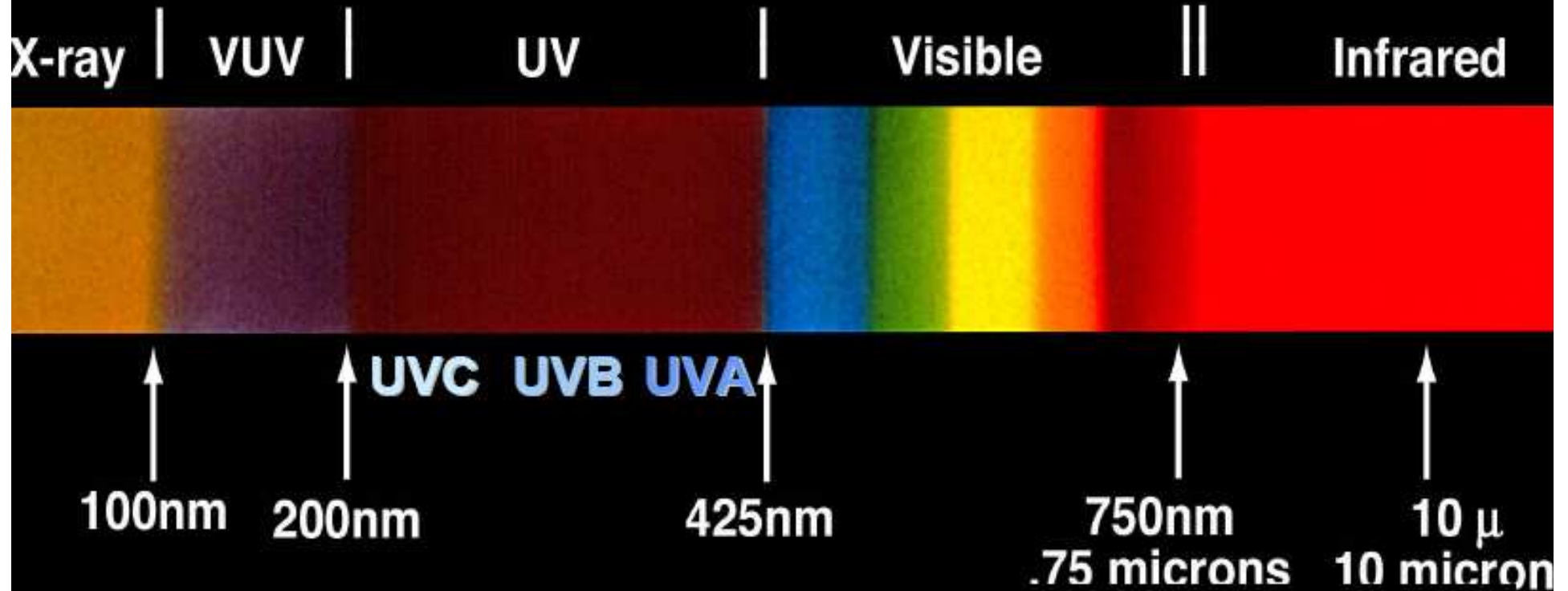
- **Oligomers**
Larger molecules; primarily determine physical properties
- **Monomers**
Smaller molecules; affect viscosity and rate of reaction
- **Photoinitiator(s)**
Respond to UV and initiate reaction; low concentration
- **Additives**
Pigments, surfactants, de-foamers, etc.
Do not enter into crosslinking reaction



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Part of the Electromagnetic Spectrum



Light (*visible* radiant energy) has *color names*, but UV does not.

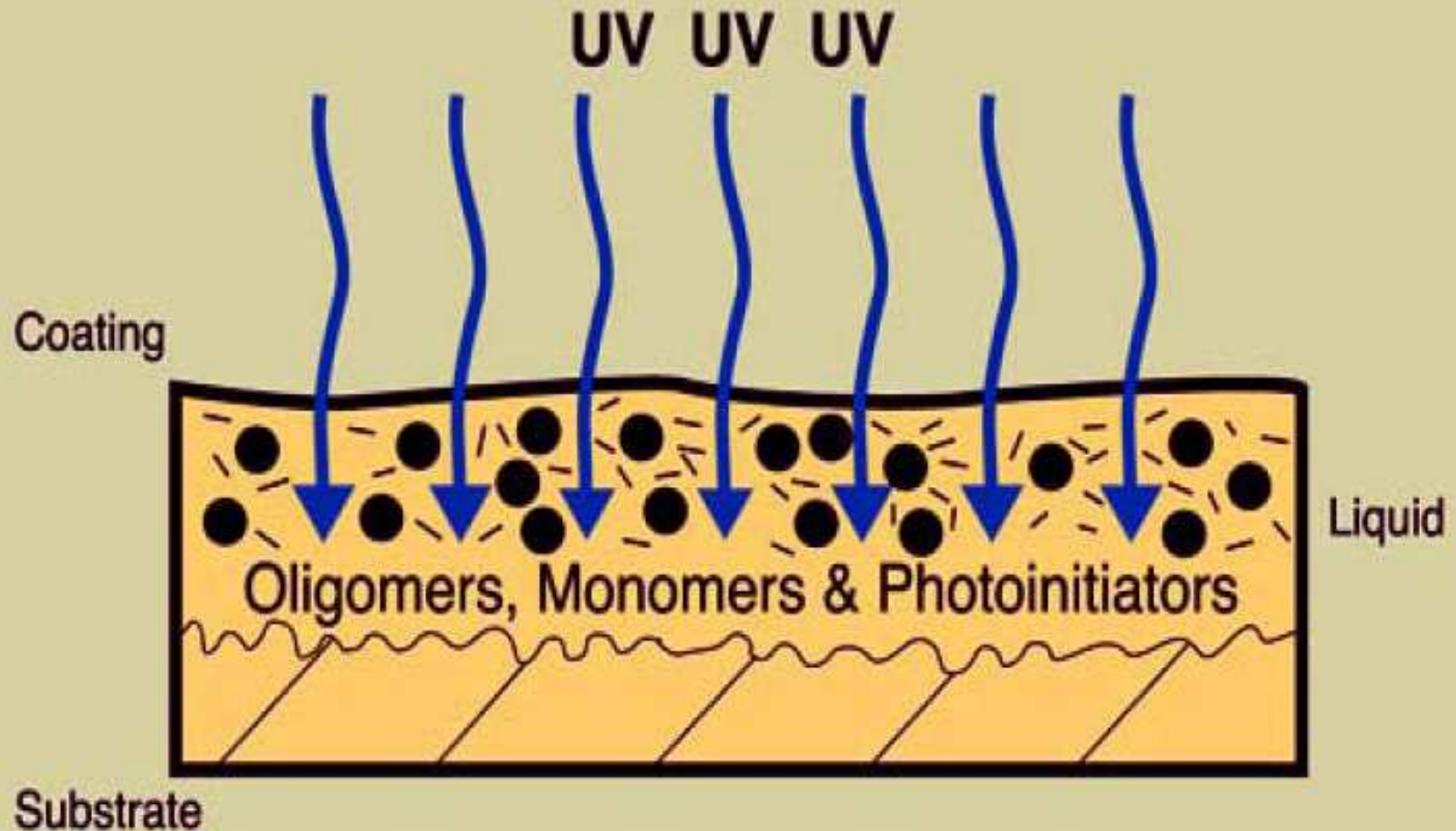
UV is generally divided into three ranges.

These ranges are general and not precisely defined, but are useful in distinguishing *long, medium and short* wavelength UV.



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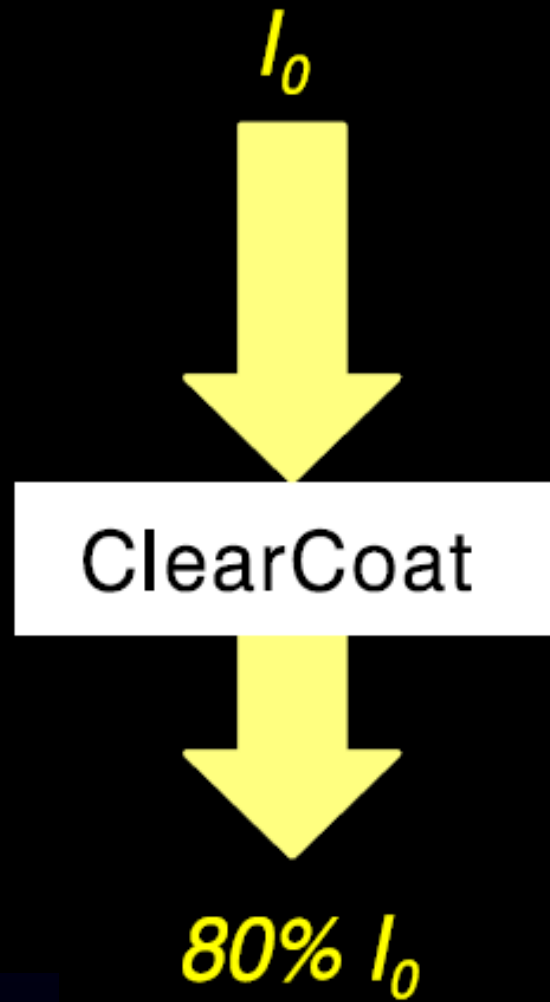
Photoinitiator molecules are evenly distributed within the material – photons are not.



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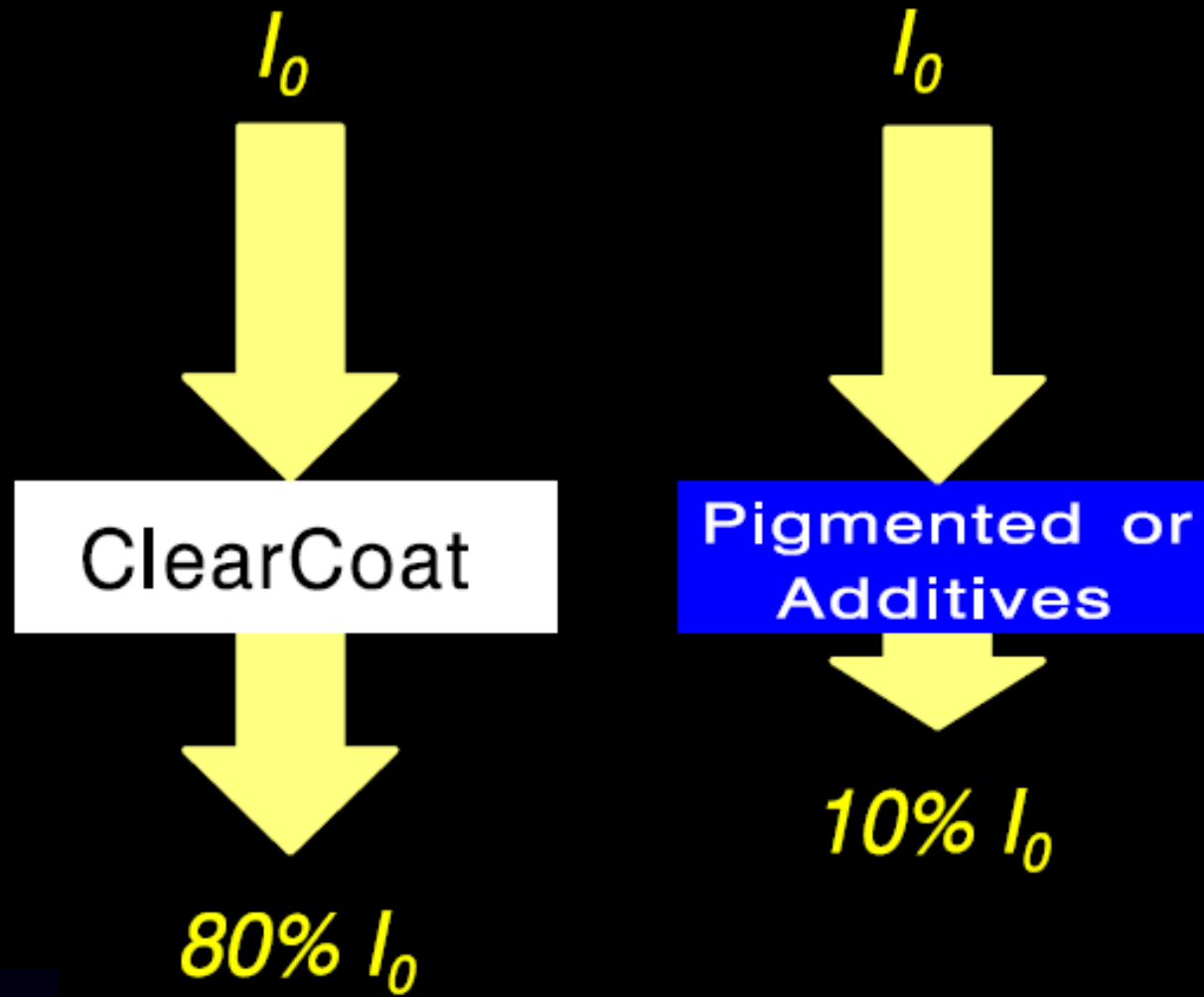
Transmission of Light Through “Optically Thin” and “Optically Thick” Materials



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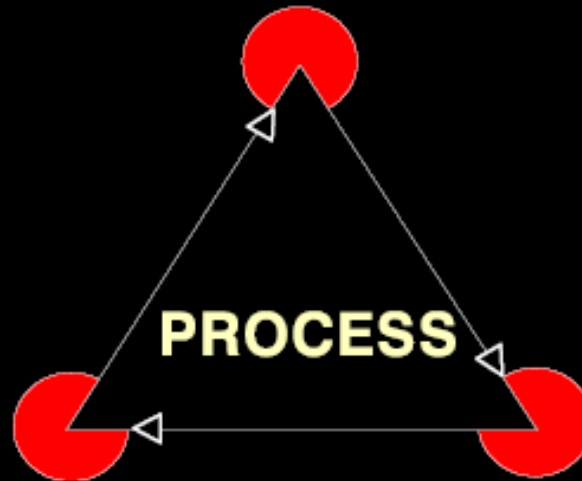


Transmission of Light Through “Optically Thin” and “Optically Thick” Materials



Product

Application Method,
Film weight
Process Speed
Target Properties
Substrate



Exposure

Formulation

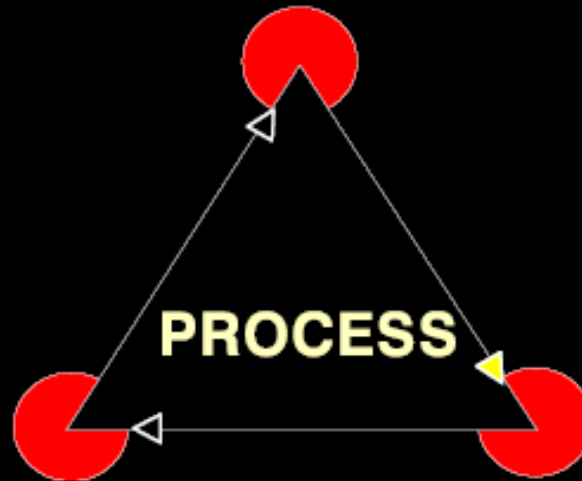


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Product

Application Method,
Film weight
Process Speed
Target Properties
Substrate



Exposure

Formulation

Components
Spectral Absorbance
Spectral Response
Optical Thickness

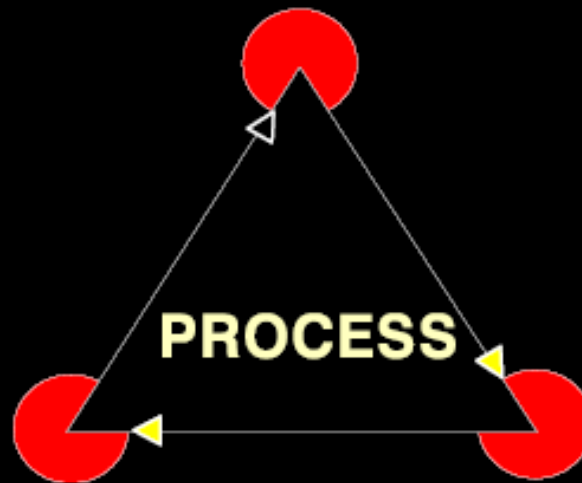


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Product

Application Method,
Film weight
Process Speed
Target Properties
Substrate



Exposure

Spectral Distribution
Irradiance
Effective Energy
Infrared

Formulation

Components
Spectral Absorbance
Spectral Response
Optical Thickness



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IRRADIANCE
and Irradiance *Profile*
(“Intensity” of UV arriving at a surface)

SPECTRAL DISTRIBUTION
(Wavelength of UV)

Spectral Absorbance of Materials

Spectral Emission of Lamps



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**Two types of
medium pressure mercury vapor UV lamp
are commonly used in industry:**

- **Arc (Electrode) Lamp**
- **Microwave (Electrodeless) Lamp**

Other types include:

Excimer Lamps

Flash (xenon) Lamps

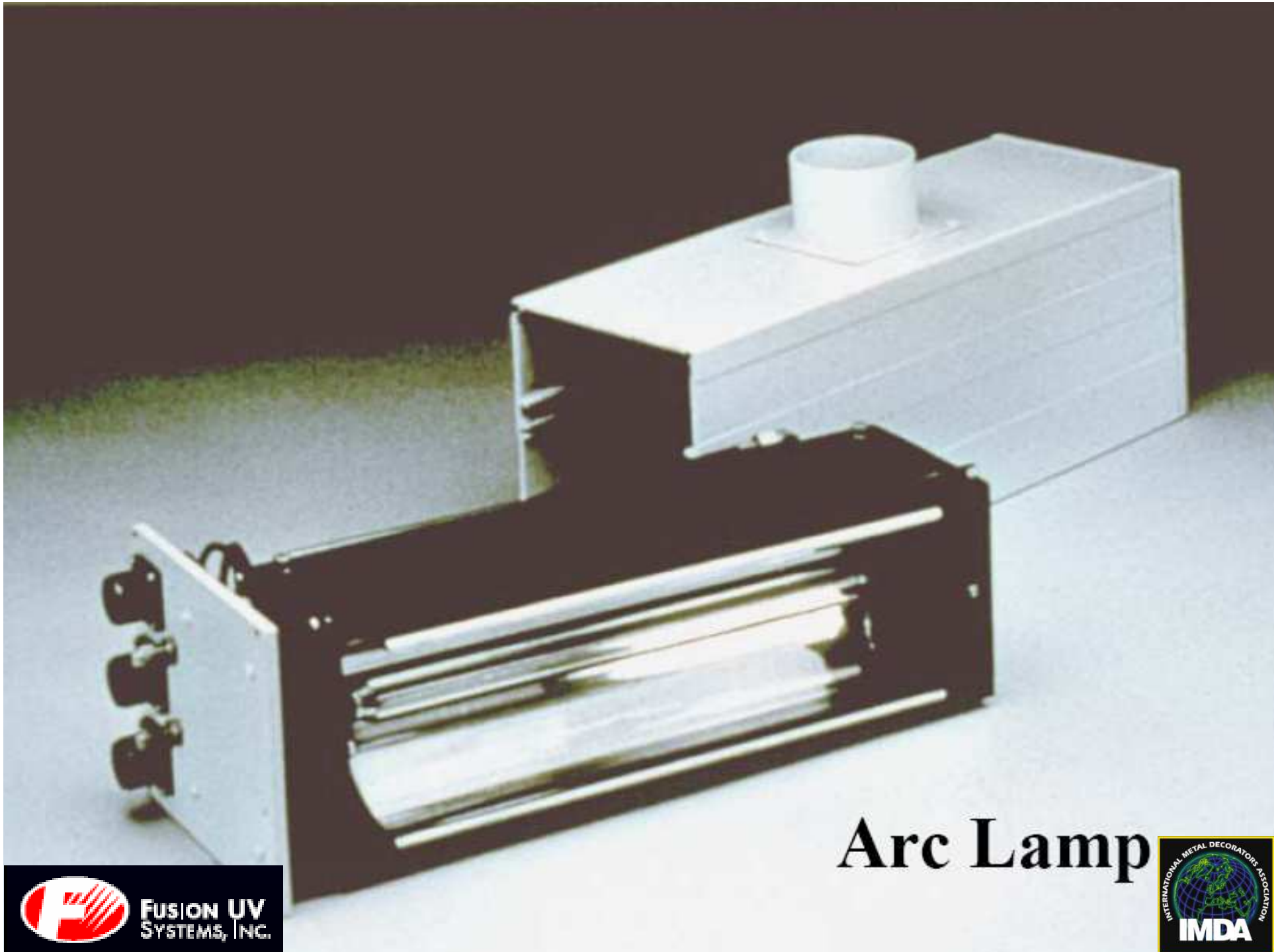
LEDs (Light-Emitting Diodes)

RF-Powered Lamps



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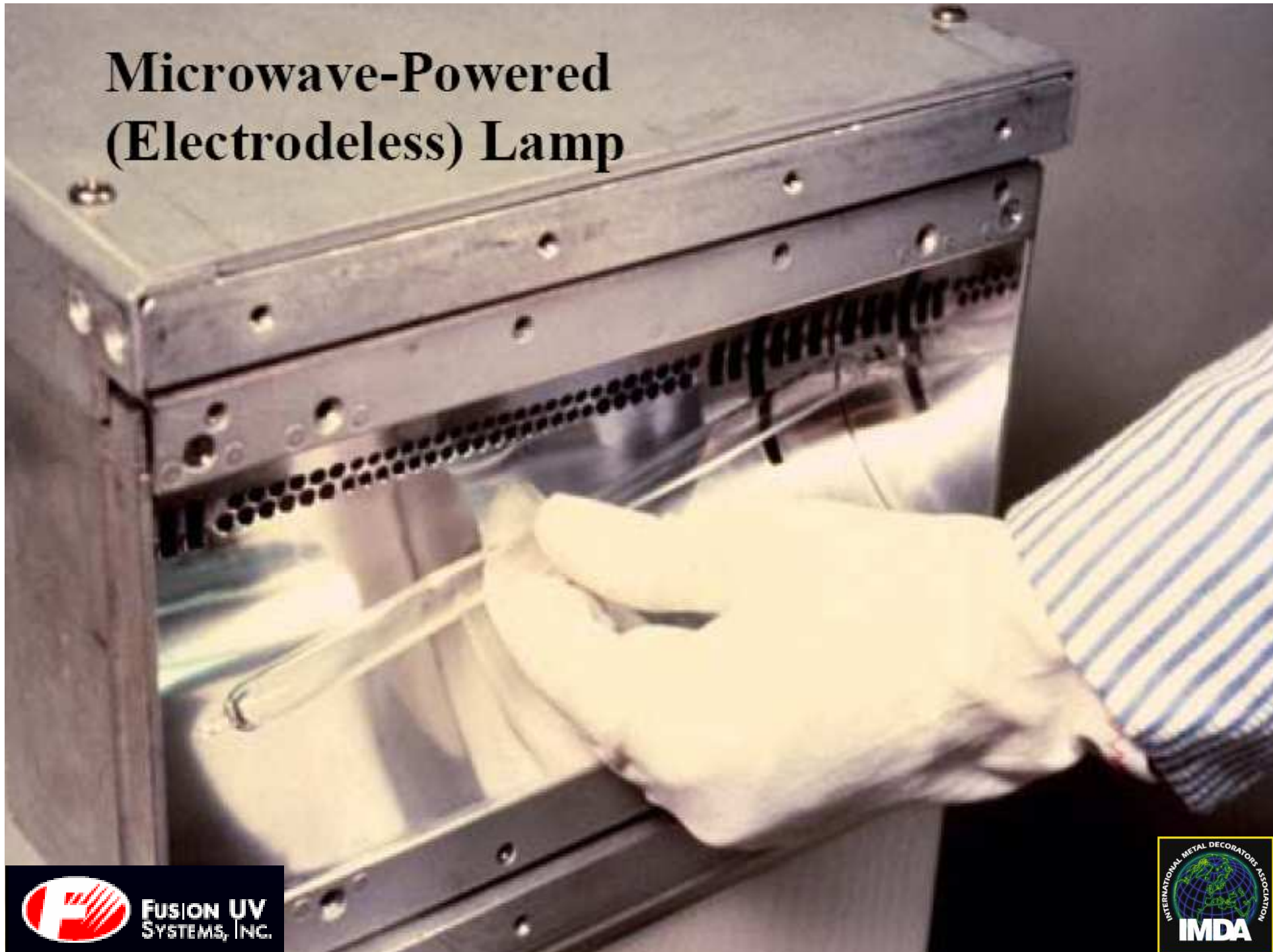
Arc Lamp



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Microwave-Powered (Electrodeless) Lamp

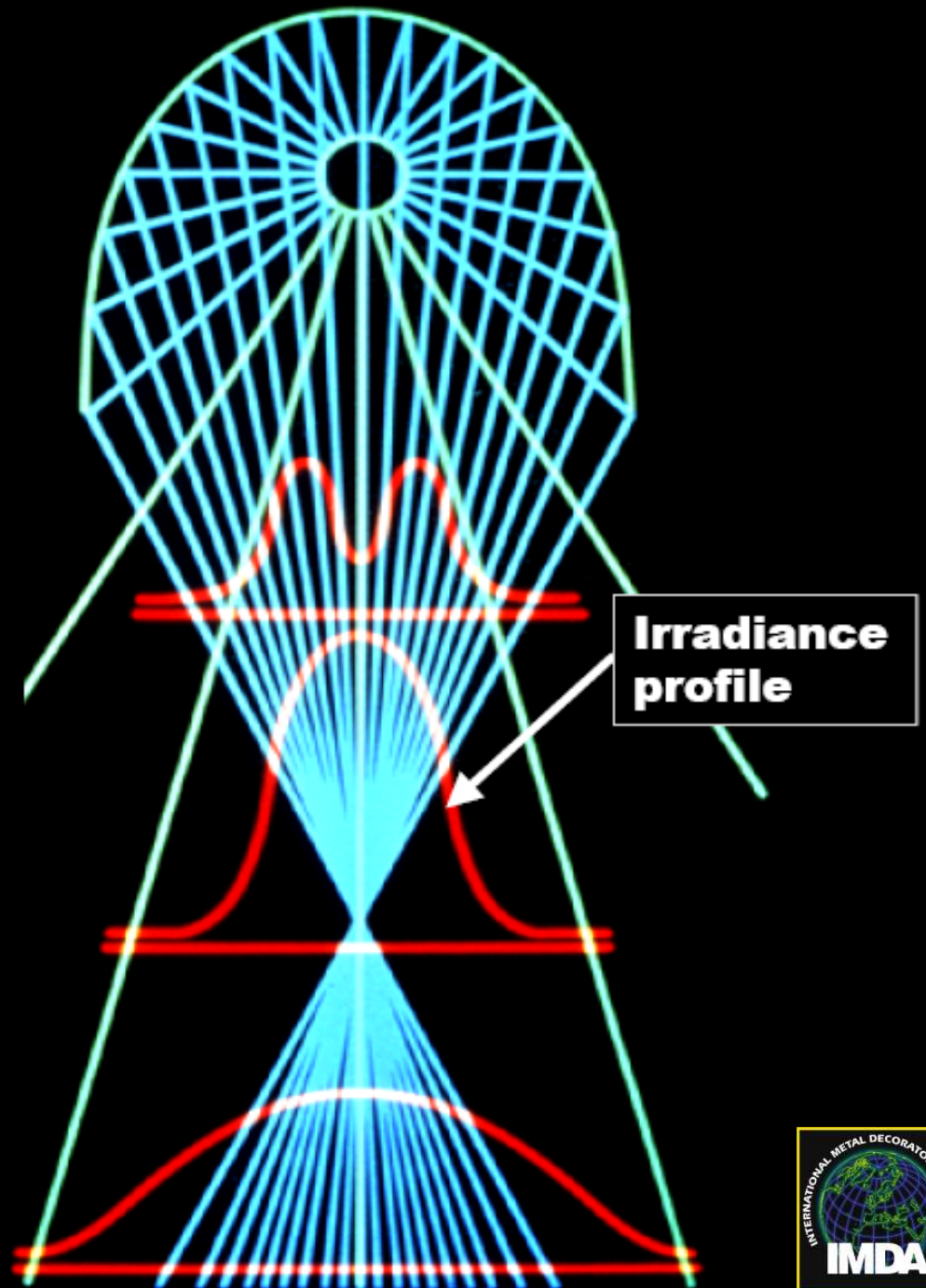


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LAMP DESIGN FACTORS AFFECTING IRRADIANCE

- Power Input (watts)
- Bulb Efficiency
- Bulb Diameter
- Reflector Shape
- Reflectivity



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Irradiance Profile

Peak



Energy



Time or Distance



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Energy (mJ/cm²) is the time-integral of the irradiance profile (mW/cm²) over a specific wavelength band

$$E = \int_{\lambda_1}^{\lambda_2} \int_{t_1}^{t_2} f(I) dt$$

Fortunately, we have instruments and devices that will do this integration automatically over defined wavelength ranges

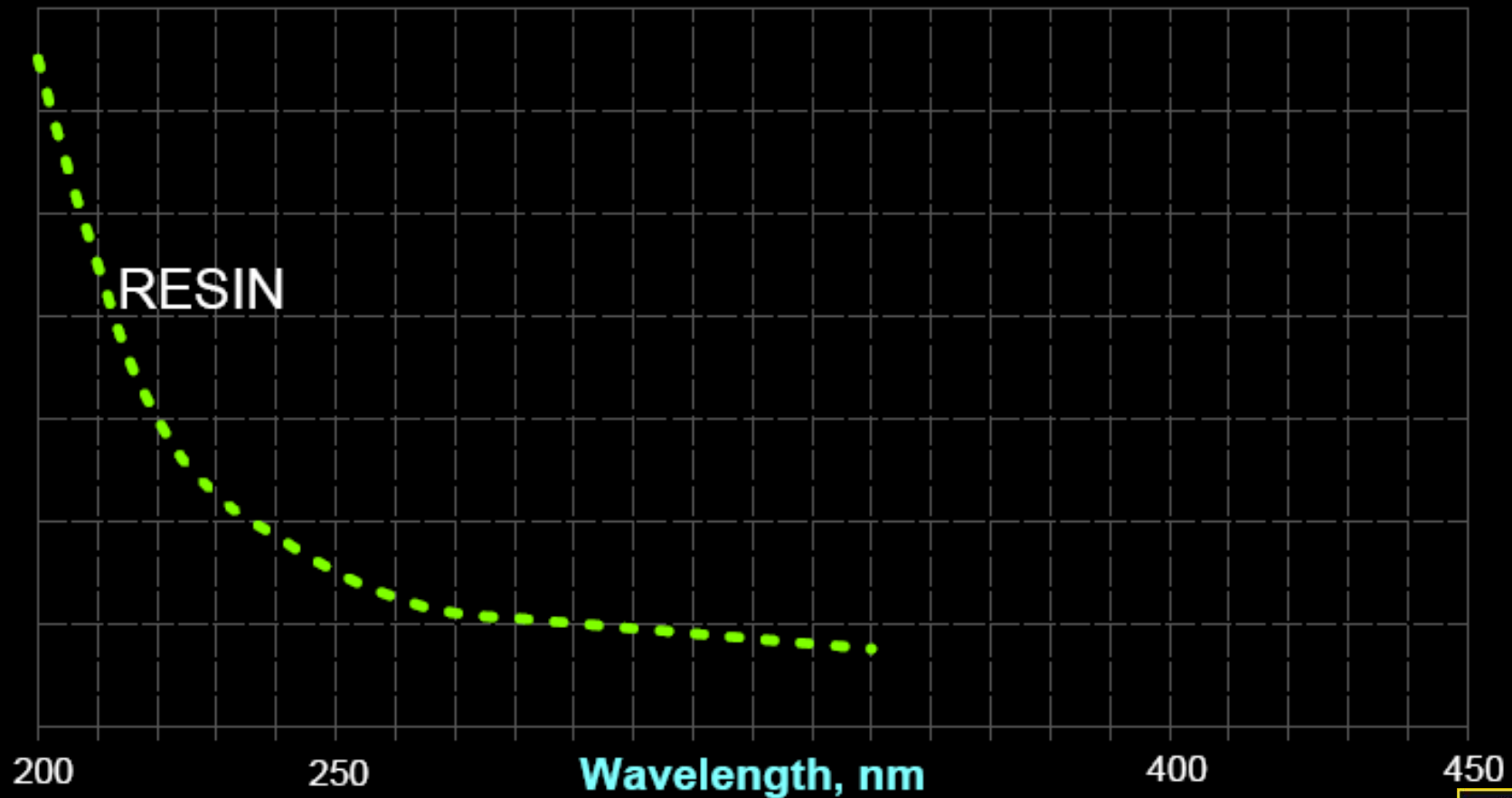


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UV ABSORPTION of COMPONENT MATERIALS

Relative Absorption, %

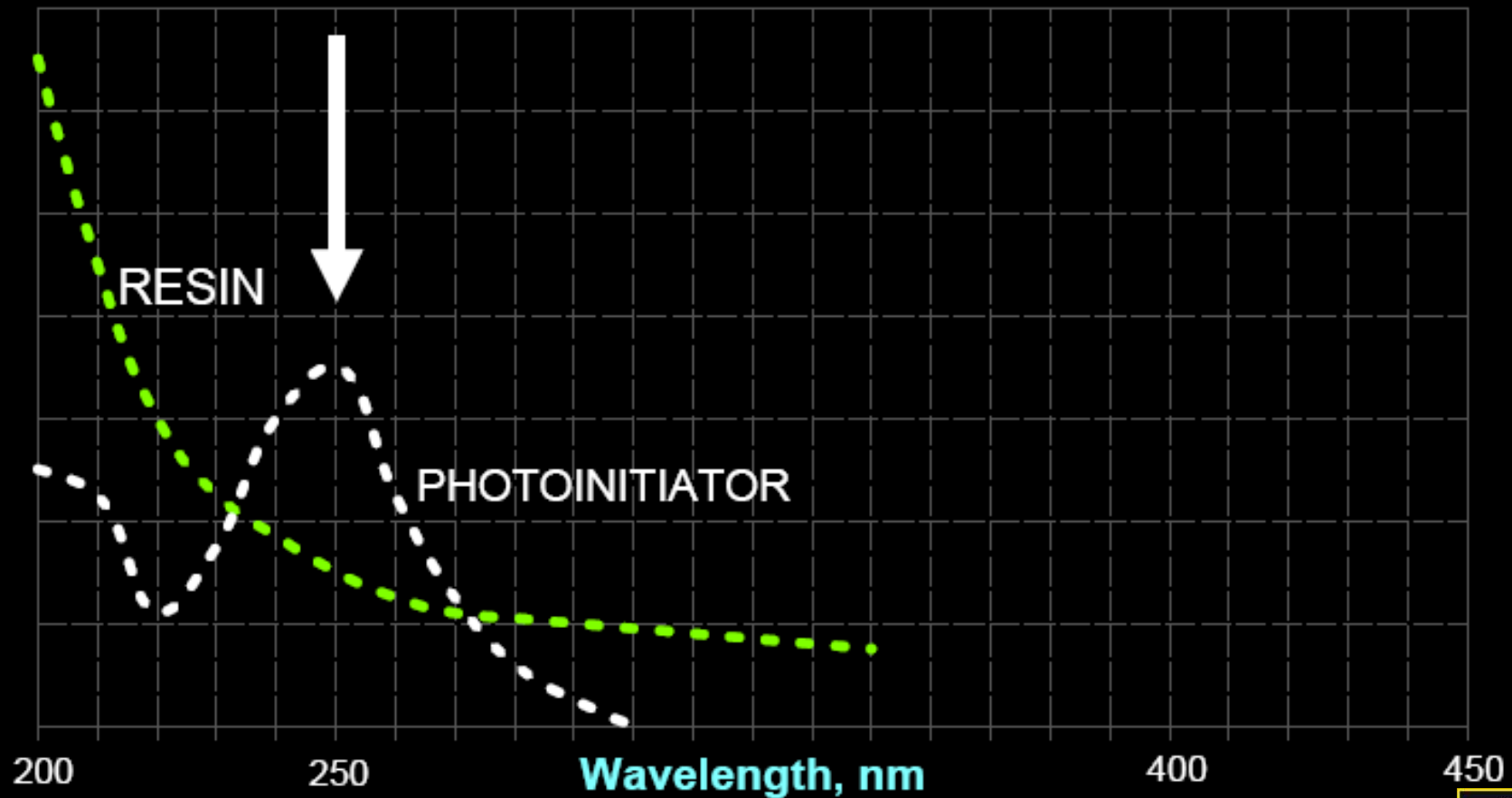


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UV ABSORPTION of COMPONENT MATERIALS

Relative Absorption, %

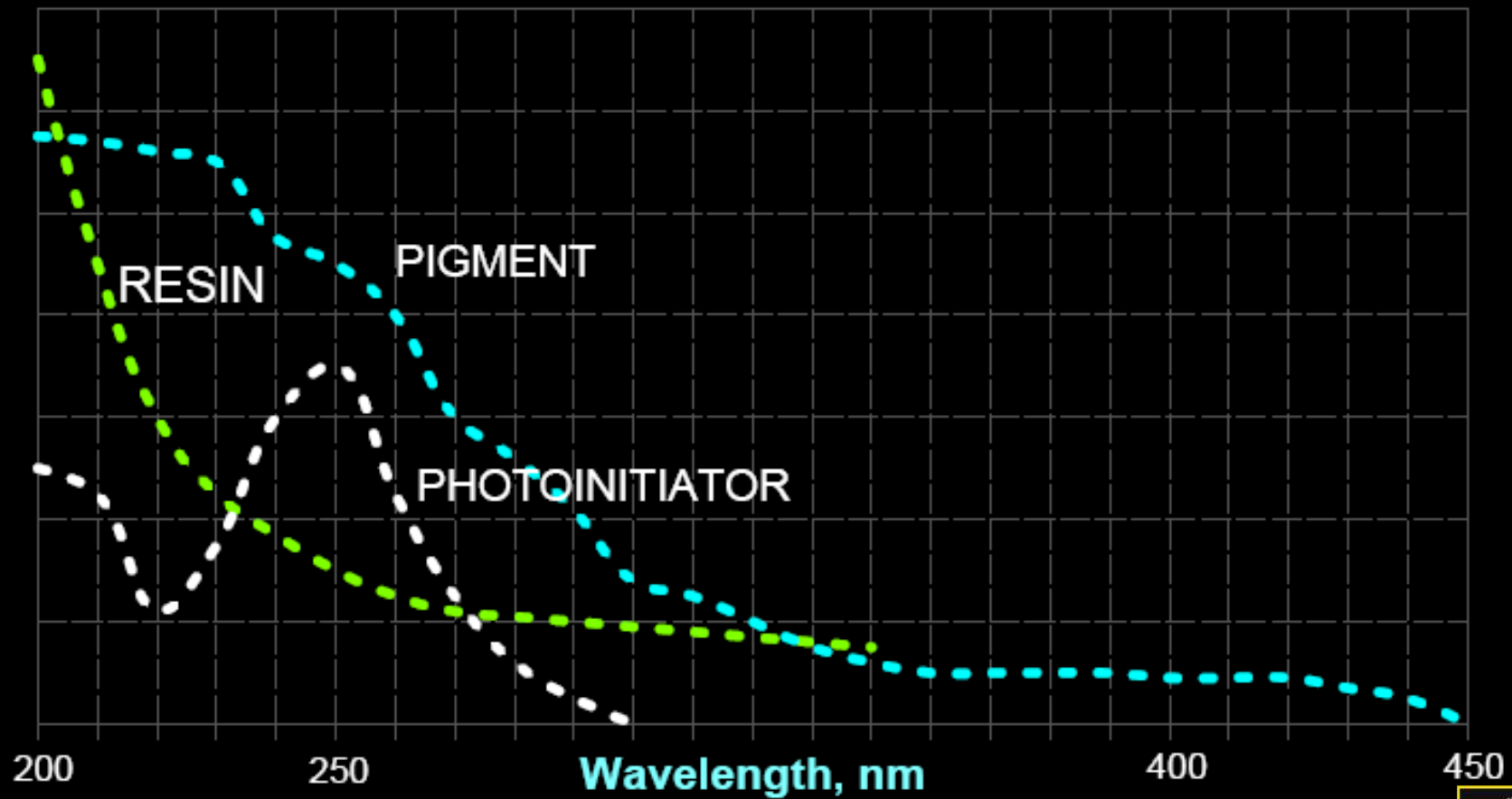


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UV ABSORPTION of COMPONENT MATERIALS

Relative Absorption, %

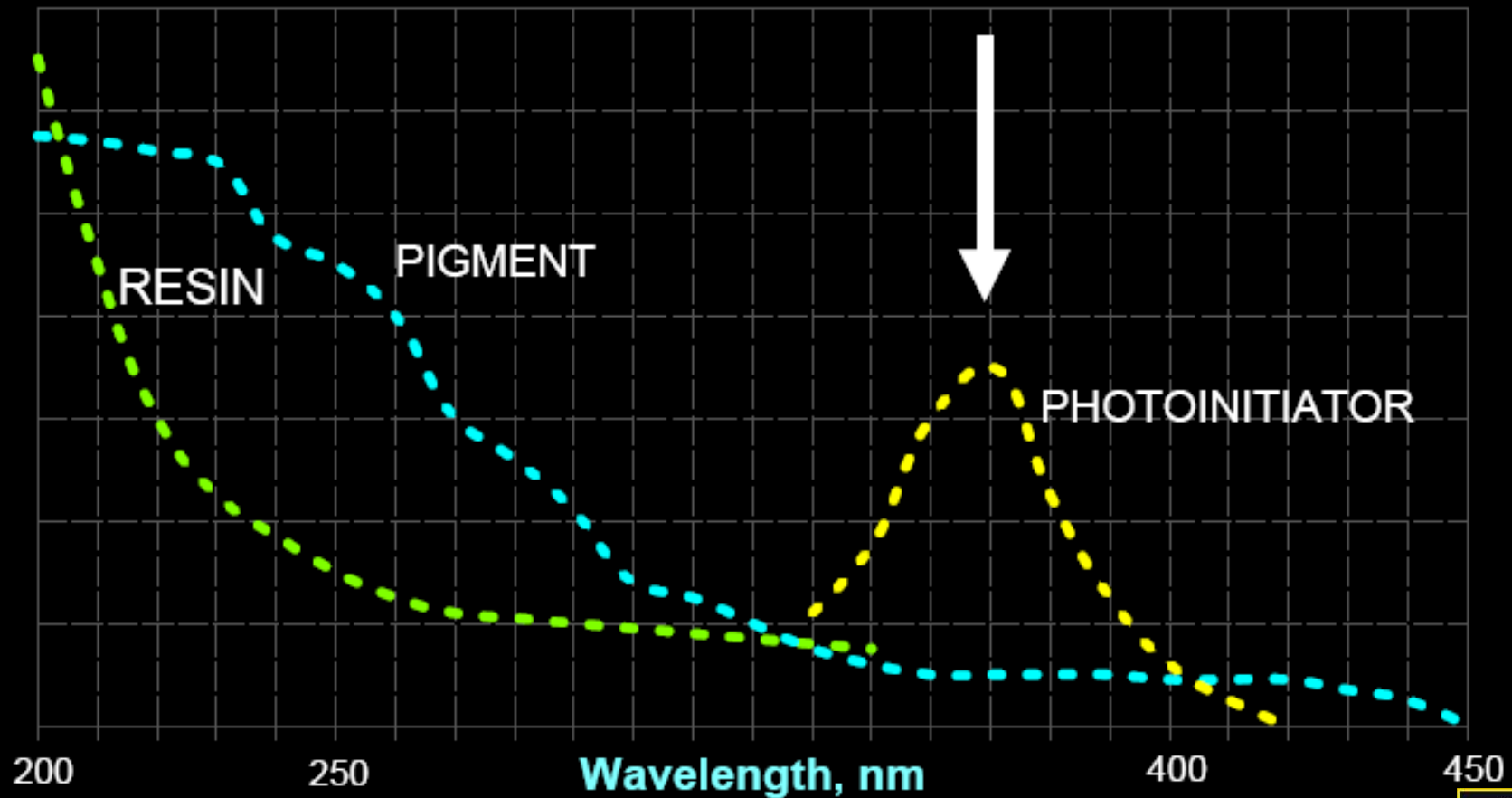


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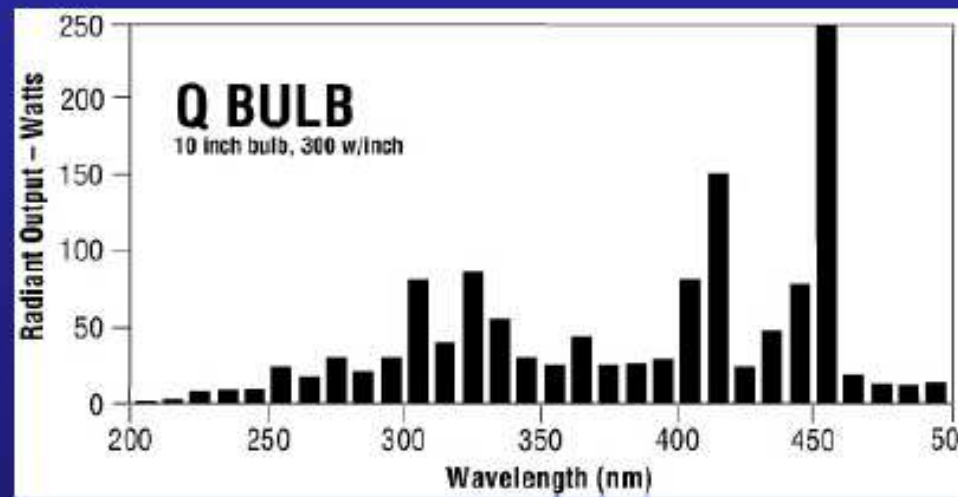
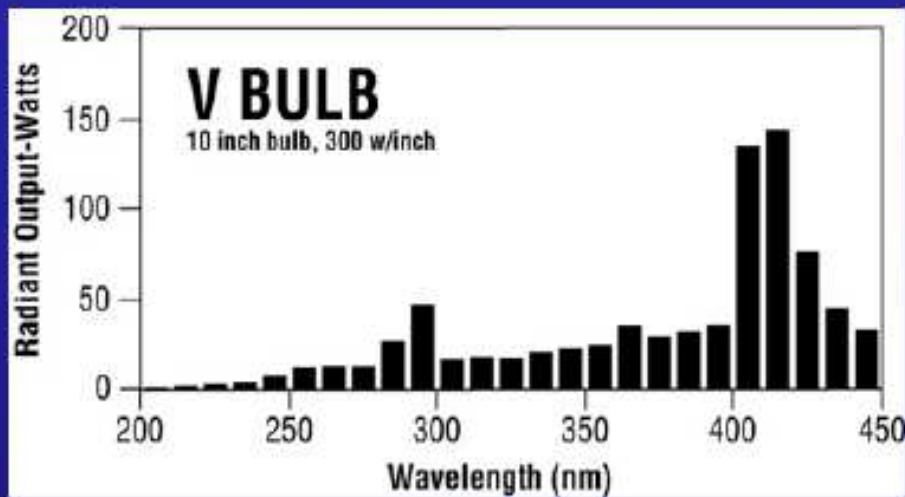
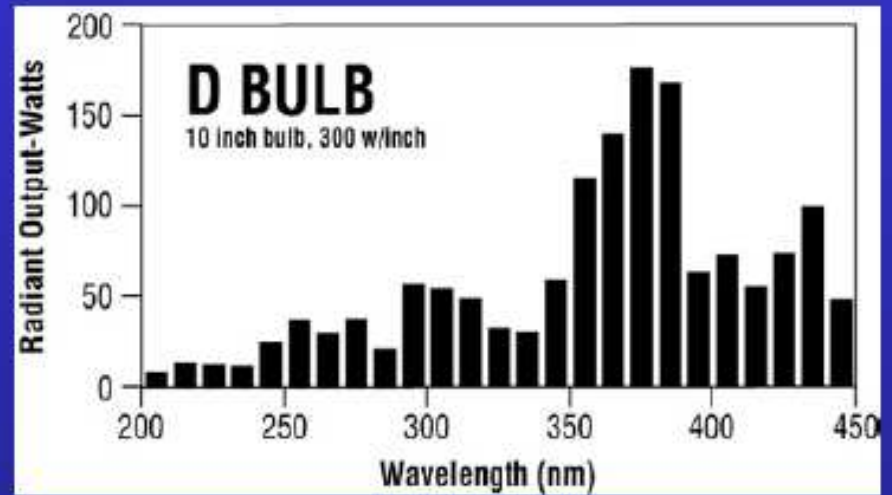
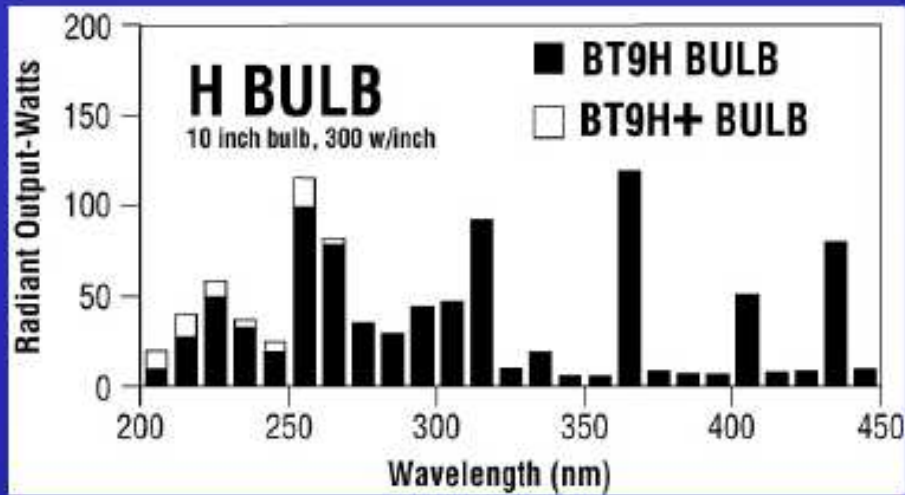
UV ABSORPTION of COMPONENT MATERIALS

Relative Absorption, %



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The spectral output of UV lamps can be expressed in 10-nanometer bands – this integrates the effects of line and continuous spectral emission. It makes calculation easy by reducing the UV lamp spectra to 25 data points.



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Radiometry is used to evaluate the optimum exposure required for a photo-curable material to develop its ideal properties.

Radiometry is used to specify the minimum exposure condition required in process design.

Radiometry is used to verify the process design.

Radiometry is used to monitor the process over time



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Portable, or Dynamic Instruments



Radiometry and Quality Control

- The instruments we use to measure and quantify UV exposure are called *radiometers*.
- They measure:
 - Wavelength in several different UV bands
 - Irradiance and peak irradiance
 - Exposure (energy) in those bands
- Radiometry is used by ink and coating manufacturers to **specify** the exposure required by their materials.
- Radiometry is used by lamp providers to **select** the proper lamps and bulbs, and to **verify** that the lamp systems are providing the proper exposure
- Radiometry is used to **verify** that the lamp systems provide and **maintain** the proper exposure



O.K., but what about places
where radiometers can't go?



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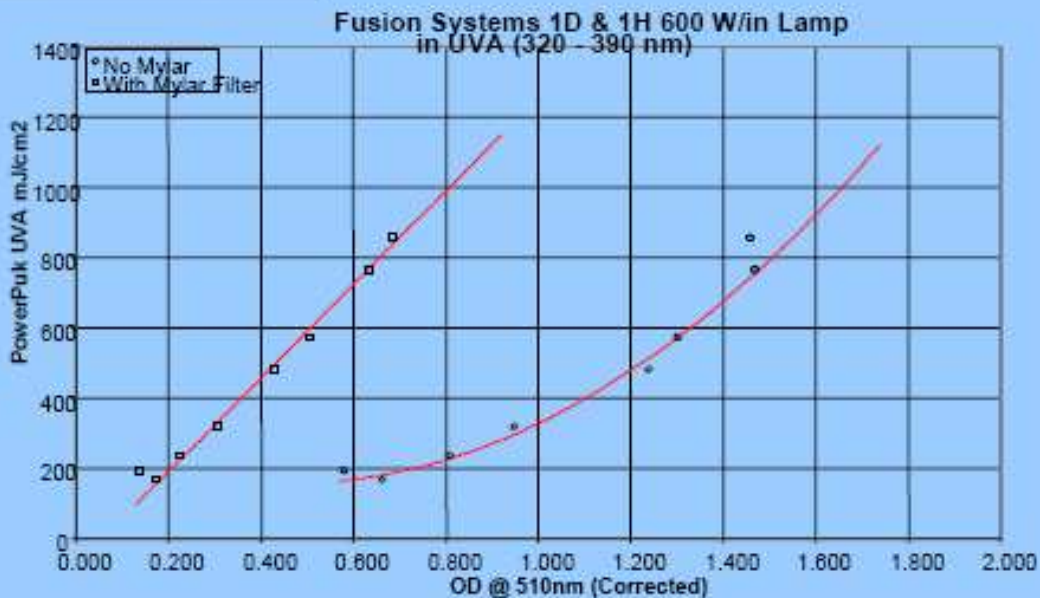




Radiachromic films measure *energy* only.

Radiachromic films can be useful, but only when correlated with a radiometer and specific UV lamp or lamp set.

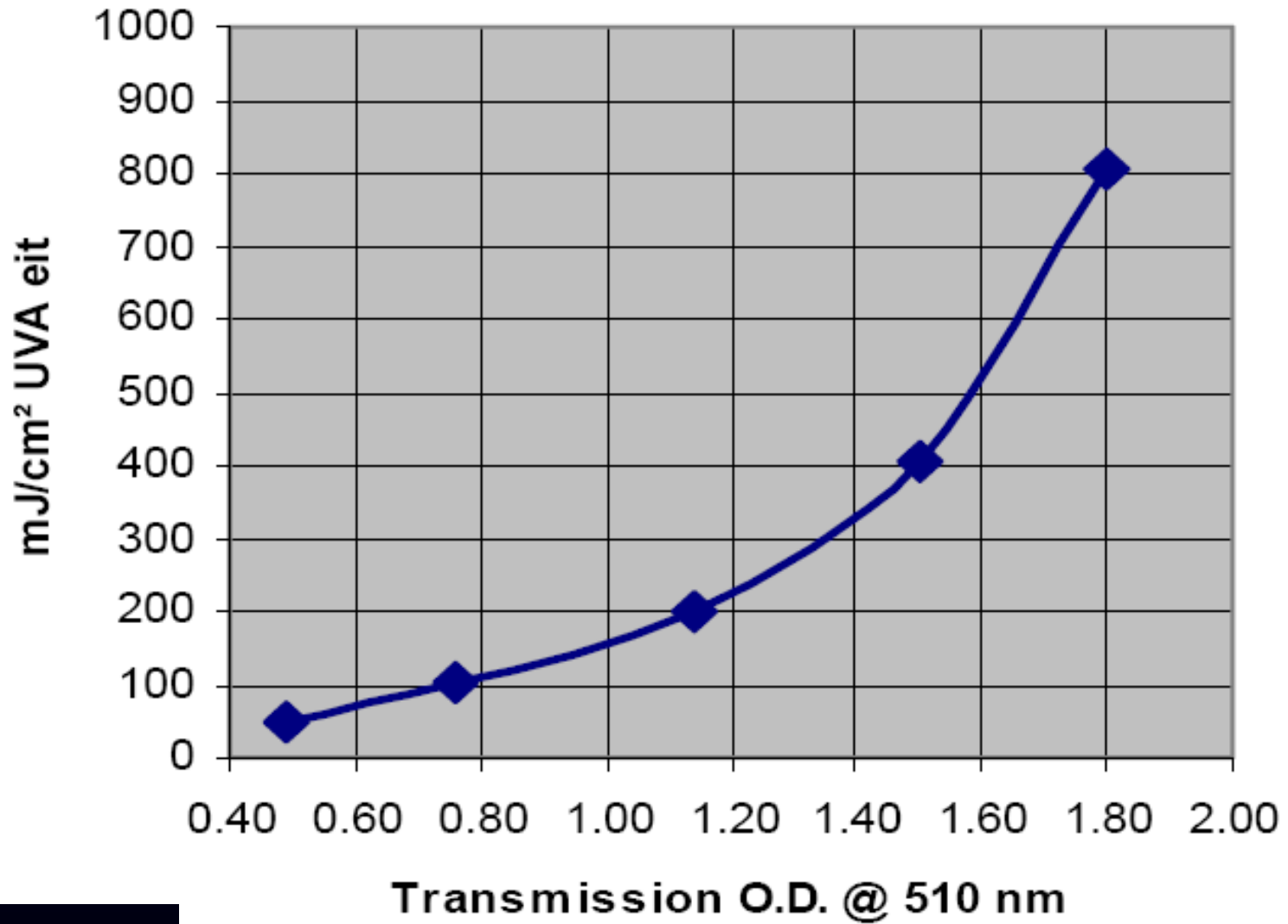
Interpretation by instrument is preferred over visual interpretation



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**FIGURE 4 Correlation of FWT-60 Film
with "H" Bulb Exposure**



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OBSERVATIONS

Radiachromic films can be interpreted with reasonable accuracy with relatively simple instruments – color densitometers.

This requires only a simple correlation with the appropriate radiometer of choice, by exposure to the *specific* UV lamps to be used in the process.

This correlation is valid *only* for the specific type and spectral distribution of lamps to be monitored.



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Summary

- Ink or coating manufacturers incorporate specific photoinitiators
- Select bulb spectra to match the absorption profile of photoinitiator
- Longer wavelength UV for improved depth of cure
- Short wavelength UV for improved surface properties
- For inks, higher irradiance (intensity) will increase cure speed and increase efficiency (energy required to cure)
- For inks, higher irradiance improves depth of cure and adhesion



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Thank You



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