

Accurately Measuring UV Sources*

**or What Can Go Wrong Measuring the Output of UV Sources...*

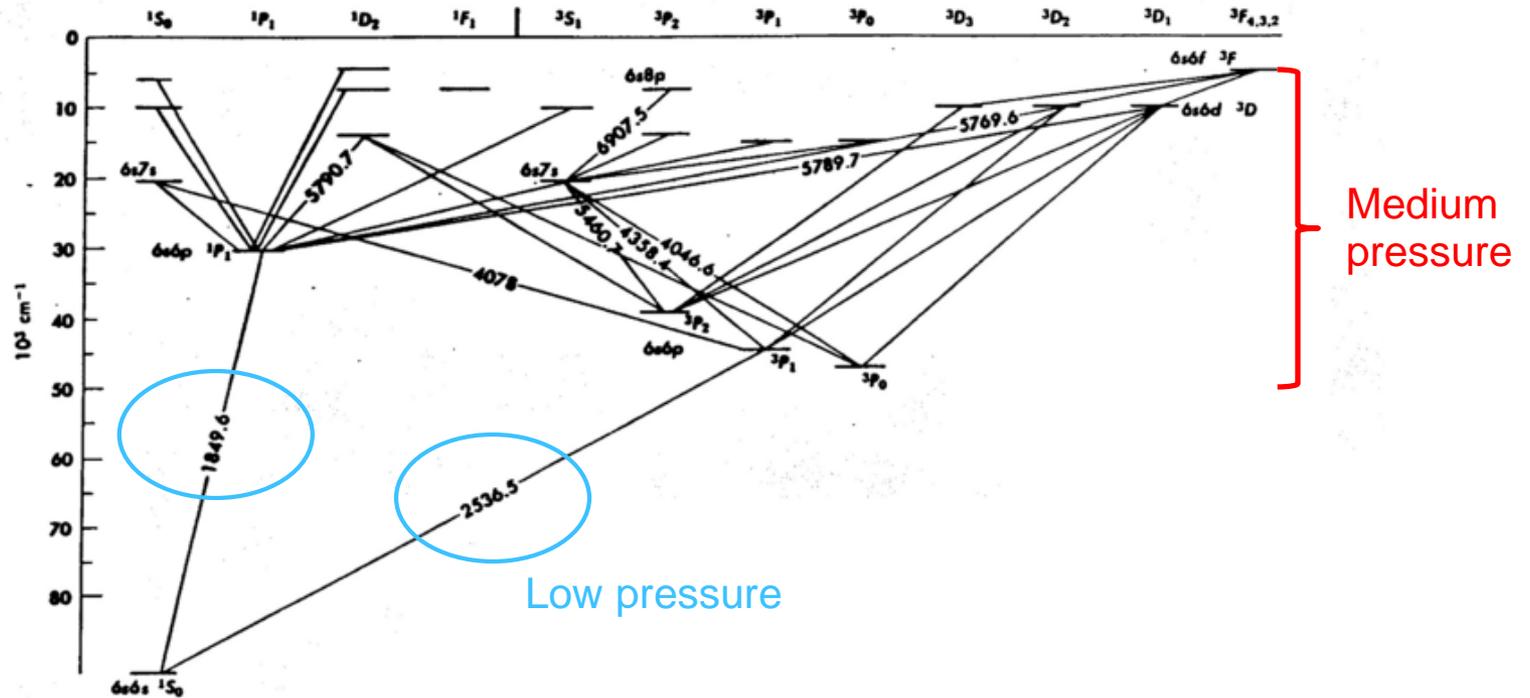
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Agenda

- Introduction to Industrial UV Curing Lamps
- Lamp Types – “Average” Spectral Output of Bulb
 - Low/Medium Pressure
 - The Effects of Cooling
 - Axial Segregation
- Lamp System Output
 - Power supply selection (spatio-temporal effects)
 - Optics
- Non-Mercury Industrial Curing Lamp Types
 - LEDs
 - Excimer
- Summary/Remarks

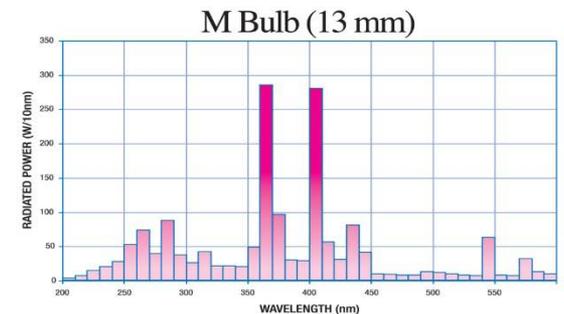
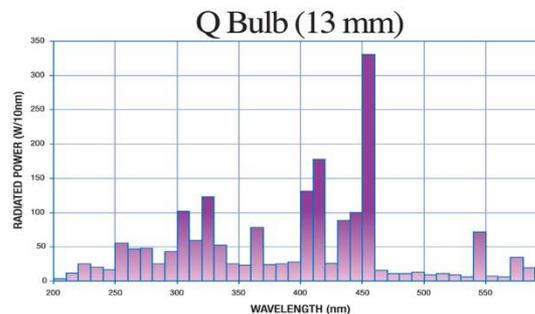
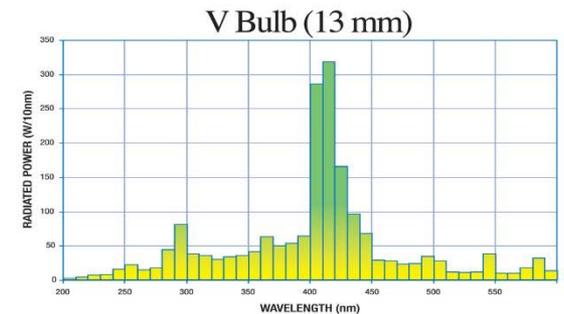
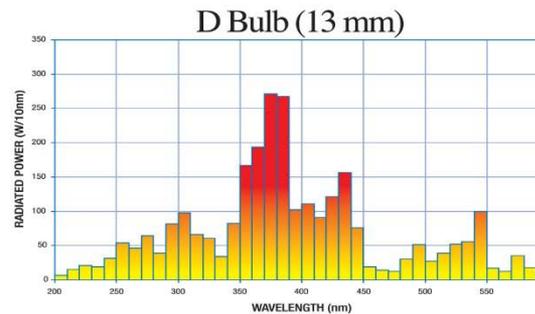
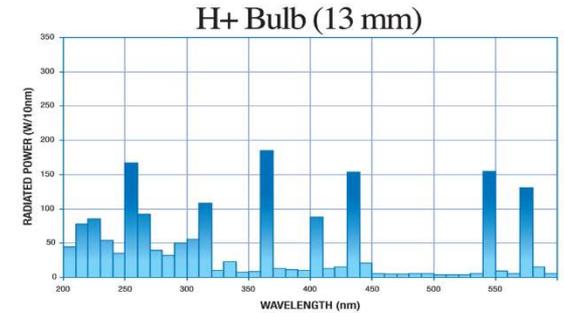
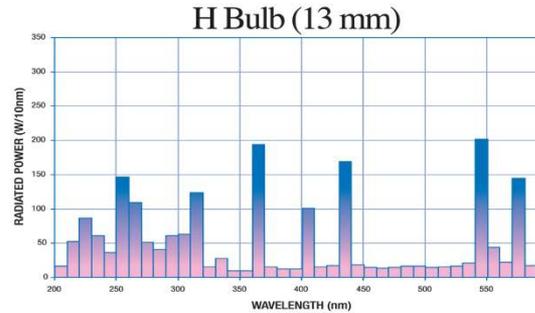
Commercial UV Lamp Systems – Low & Medium Pressure Hg

Mercury Grotian Diagram



Lamp Systems – Medium Pressure Bulbs

- Most gas discharge lamps are based on mercury discharge
- Medium pressure:
 - 1-10 W/cm², + IR
 - Optically thin & thick discharge
- Low pressure:
 - 10-100s mW/cm²
 - Optically thin discharge

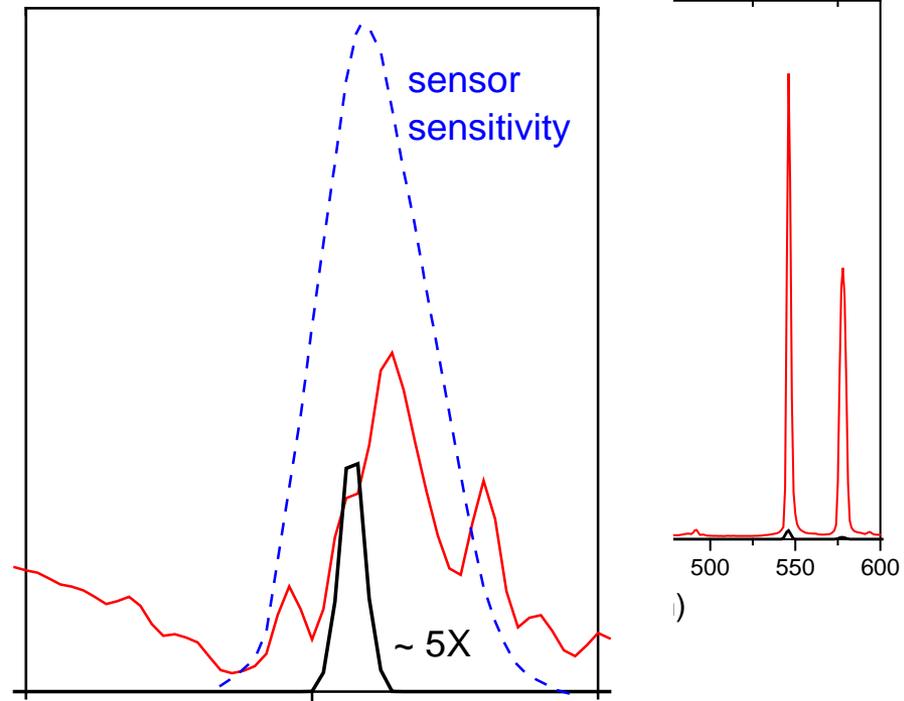


NOTE:

Lamp Systems – Low & Medium Pressure Bulbs

- Different spectral signatures
- Self-absorbed 254 nm line in medium pressure lamp
- Detector sensitivity matters

(relative scales)



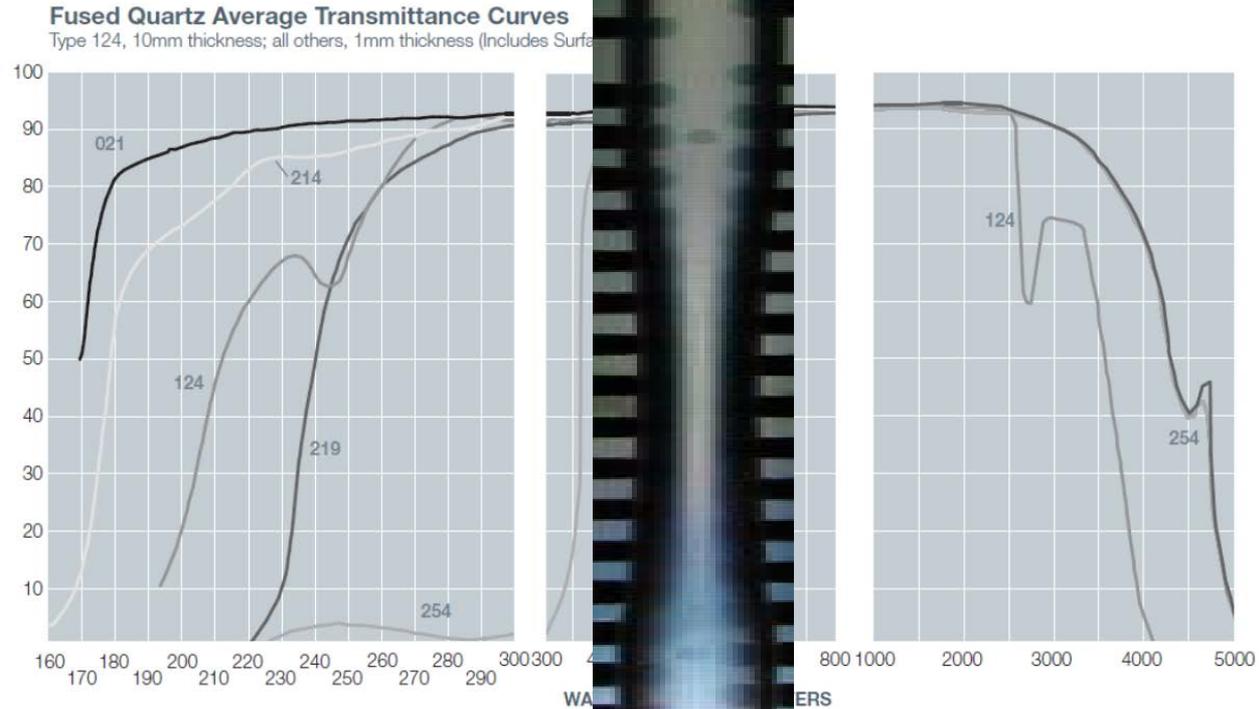
“Environmental” Effects (Bulbs)

Cooling

- Bulb additives have lowest vapor pressure
- Bulb temperature and quartz transmission
- Integral feedback loop control

Orientation

- Power coupling → Color separation



Lamp Systems – Power Supply Dependence

Irradiance measured under lamp (on conveyor)

- Non-static exposure
- Simulates customer process

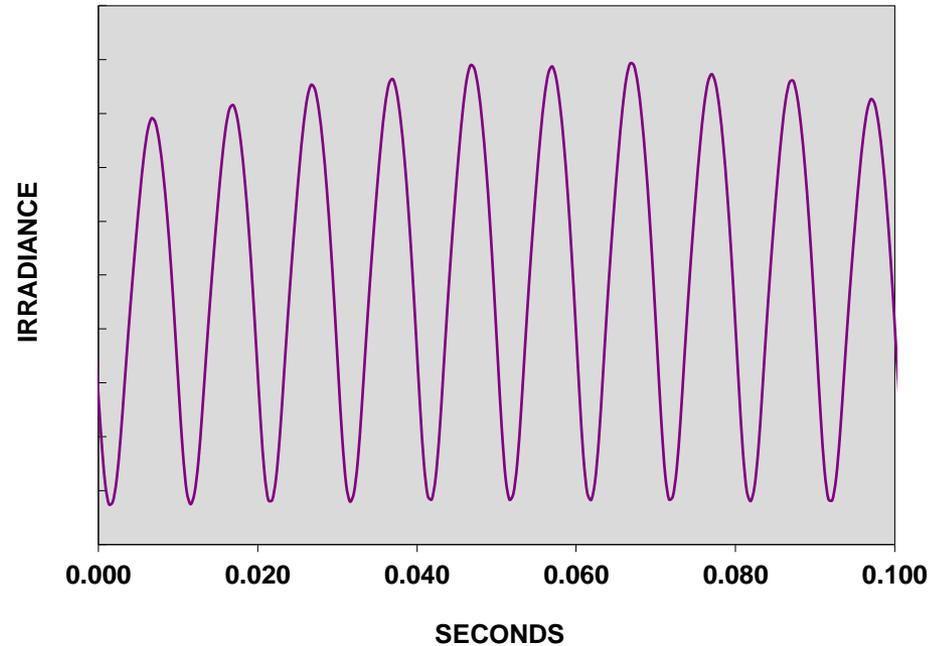
AC vs. DC power delivery

Also varies:

- Location on bulb wrt power coupling
- Modulation depths



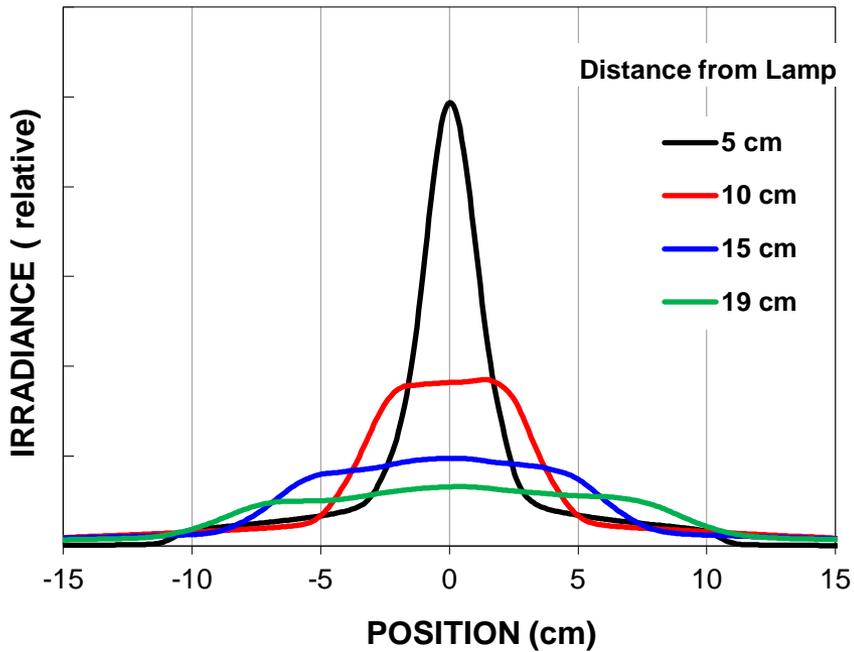
100Hz UV Output Ripple
(50Hz AC Line)



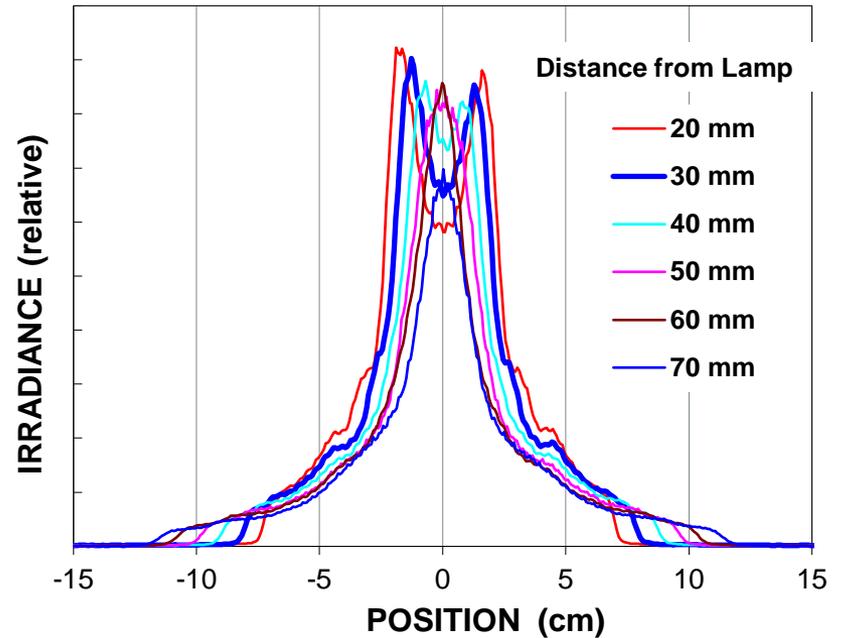
Lamp Systems – Optics

Irradiance measured on conveyor

FOCUSED

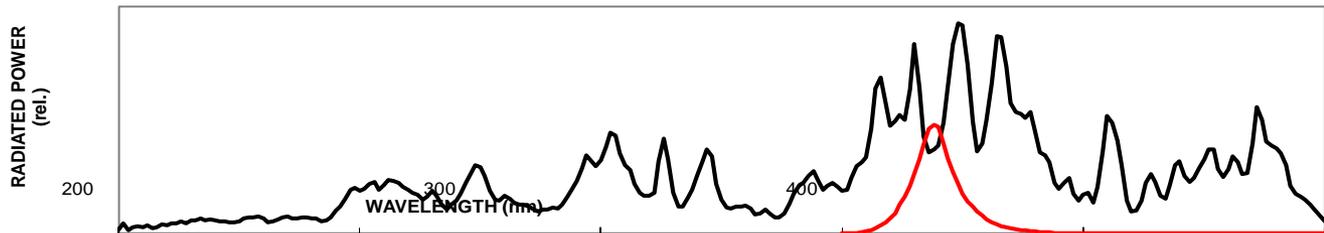
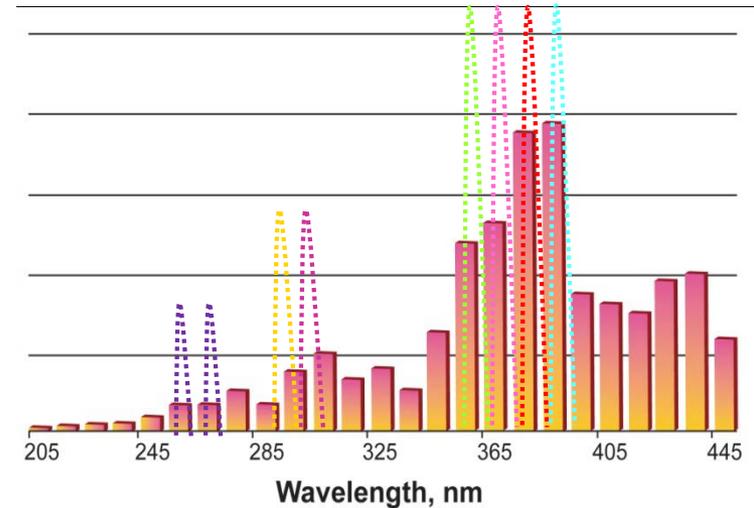


FLOOD-LIKE



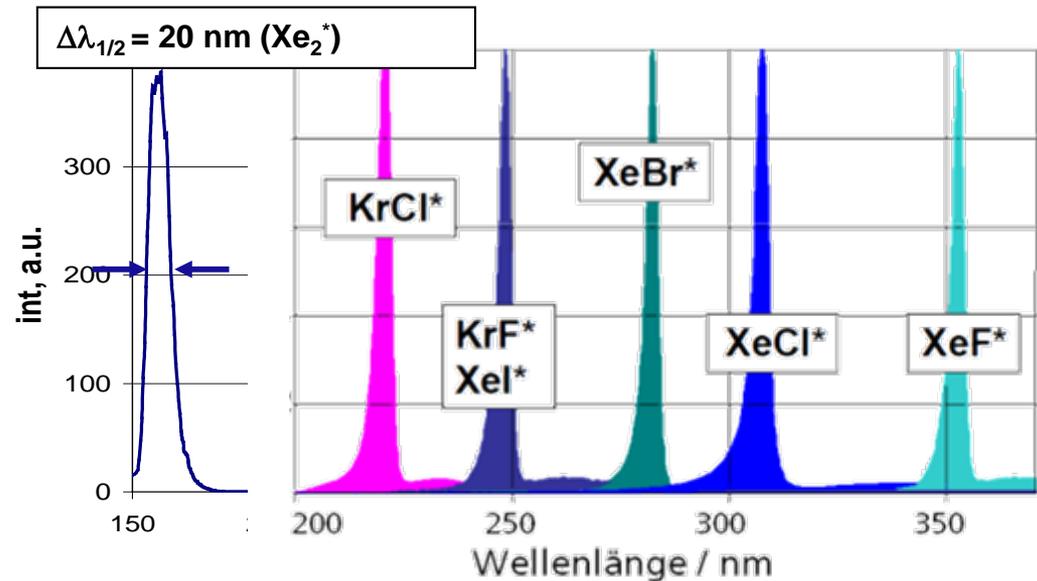
LEDs

- UVA (≥ 365 nm) output powers extremely high
- UVB, “UVC” available @ much less power output
- NOT well-measured by Hg lamp based radiometers
- Single-sided point source
(or array of point sources)
- Driving and
 - PWM vs I
 - Some terr



Excimers

- Molecular transitions (fairly broad spectral distribution)
- Optically thin discharge
- VUV, UVC, UVB ranges
 - O₂ absorption (O₃ production)
- SOME customer radiometers available (for each band)
- Typically RF-driven (HV)
- All shapes and sizes
- Lower output powers (10-100 mW/cm²)



Summary/Remarks

- Not all UV systems are created equal
 - Pressure
 - Power delivery
 - Additives
 - Operating conditions
 - Optically thin/thick sources, distributed sources, point sources
- UV curing systems are rough environments for most analytic tools
- More precise and robust measurements needed
- Lamp suppliers putting more diagnostics (optical, thermal, etc..) in systems to ensure performance/process control

