The Evolution of UV LEDs and UV Systems
An Update

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• LED Technology – A quick review

• UVA LEDs Status Update

• UV Systems – two approaches (based on Etendue)

• UV LED customer challenges

• Is LED Lighting predicting the UV LED future?
An electron in the conduction band will relax to the valence band to give off light; this process is called electron-hole recombination.

For (AlGaN)N semiconductors, any wavelength from 250 nm to 650 nm is possible, but...
Group III Nitrides for LEDs

- Same family of materials as used for LED lighting
- Emission wavelength changed by selecting proper alloy composition
- Research continuing to improve efficiency, reduce cost
- UV LEDs riding coattails of Visible LEDs for lighting

Wavelength (from UVC to IR possible)

Complex crystal growth fabrication process determines wavelength and operating efficiency
LED supply chain – (still)changing rapidly

- **Materials**
- **Processes**
- **Devices**
  - **Materials & Subsystems**
  - **Full Systems Integration**

- **Semiconductor Crystal Growth**
  - Increasing number of players for both UVA and UVC LEDs
- **LED Device**
  - Power designs operate at high current
- **Packaging**
  - Chip Scale packaging developing for lighting can now be used for UVA curing
- **Integration**
  - New design capabilities driving greater modularity

**2013 versus 2015**

- More companies entering UVA due to lighting competition | Slowing down
- UVC companies increasing, focused on germicidal apps | Greater interest in curing
- Increasing UVC makes true Hg lamp replacement possible | More true than ever, but...
# UVA Chip Design Summary

## UVA LED CHIP Tech. (365~400nm)

<table>
<thead>
<tr>
<th></th>
<th>Chip form</th>
<th>350mA</th>
<th>1000mA</th>
<th>Output Power</th>
<th>Vf</th>
<th>Current spreading</th>
<th>Rth</th>
<th>Reliability</th>
<th>Overdrive</th>
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* Chip Irradiance Maps

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* When properly designed
** Close working distance – easy to make custom designs

Taiwan, May 2015
Most UVA die suppliers don’t offer 365 nm devices (because they are harder to make)

Irradiance goes down with decreasing wavelength

Note range in source irradiance due to LED binning (variation in manufacturing yield)

Several companies offering very good 365 nm devices (but they are pricey)

4 LED 365 nm package from Seoul Viosys with circuit layout
**Etendue** or étendue (/eɪtændu/) is a property of light in an optical system, which characterizes how "spread out" the light is in area and angle.

**Low Etendue**
- High irradiance at source
- Can use optics to focus

**High Etendue**
- Lower irradiance at source
- Much harder to focus
- Subject to the Inverse Square Law

![Diagram showing the difference between low and high etendue with examples of irradiance levels: 1W/cm², 0.25W/cm², 0.11W/cm².](image)
High Entendue source:

- Lots of space between die
- Close working distance needed for high irradiance
- Development of flipped chip UVA LEDs (like LumiLEDs UV die) simplifies design/construction

No Wire Bonds:

- Significantly increases design freedom
- Many design houses can make “custom” cure systems
- Easier for end users to “own their designs”
Low Entendue source:

- Close packed large LED die
- Simple reflective optics
- Larger working distances possible
- Better for mixed wavelength systems (UVA + UVC)

High LED packing density in “arc” direction
UV LED Curing Challenges

• Formulation optimization versus LED Wavelength
  (*Power, wavelength, chemistry all play a role in curing*)

• Highly segmented UV curing market
  (*web width, line speed, chemistry, power levels*)

• Absence (to date) of adequate UVC LEDs
  (*but they are currently in development*)

• UV LED system price
  (*sticker shock for the uninitiated*)
For the future of UV LED curing, look at LED Lighting

LEDs replace High Power HID lamps

LED Power going up, LED prices coming down

LED module customization getting easier

Government Incentives(?)

Superbowl 2015 – 100% LED Lighting!!

How long will the Mercury exemption be available?
Summary

- UVA LEDs getting better, easier to use

- UVA LED curing systems still riding the coat tails of LED Lighting systems

- Pricing for UVA LED curing hardware will continue to come down as new business models evolve

- UVC LEDs getting better, will see them in curing applications soon (but look out for sticker shock)

THANKS!  SOLID UV the LED cure