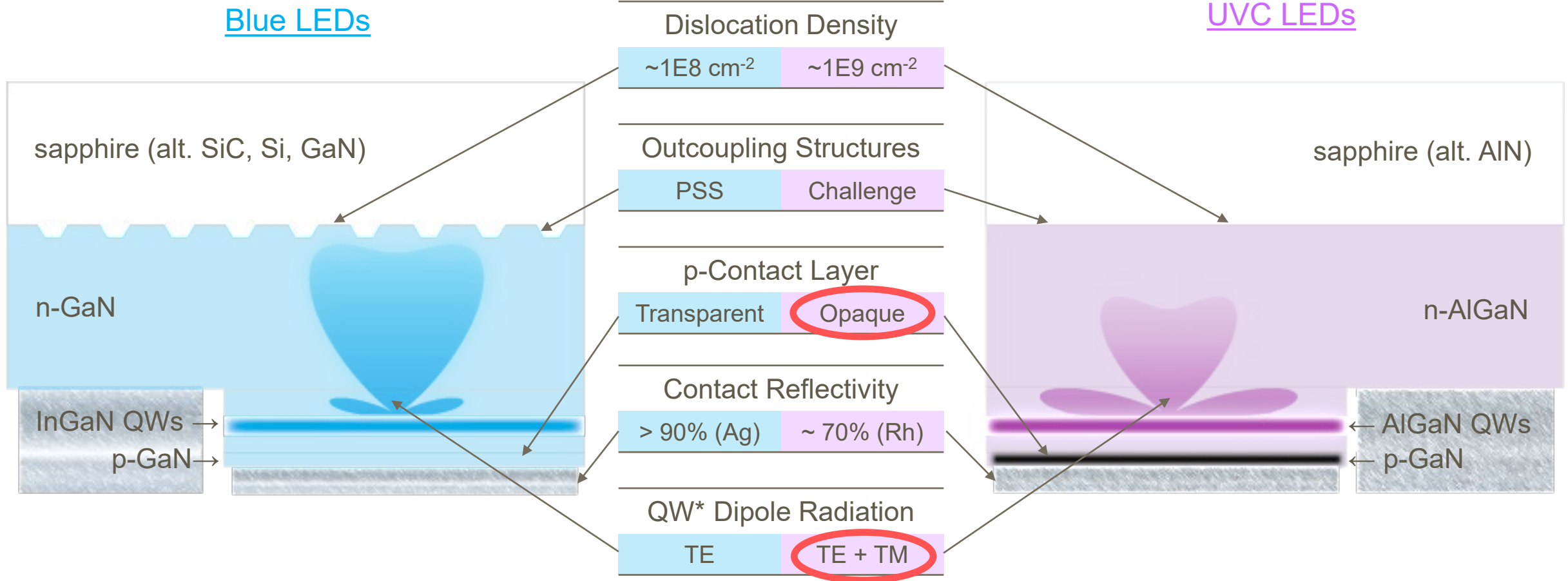


Ultra-Violet C-band (UVC) LEDs for Germicidal / Virucidal Applications

Mike Krames, PhD, FIEEE, FIES

Arkesso, LLC

UVC LED Challenges



*Quantum Well

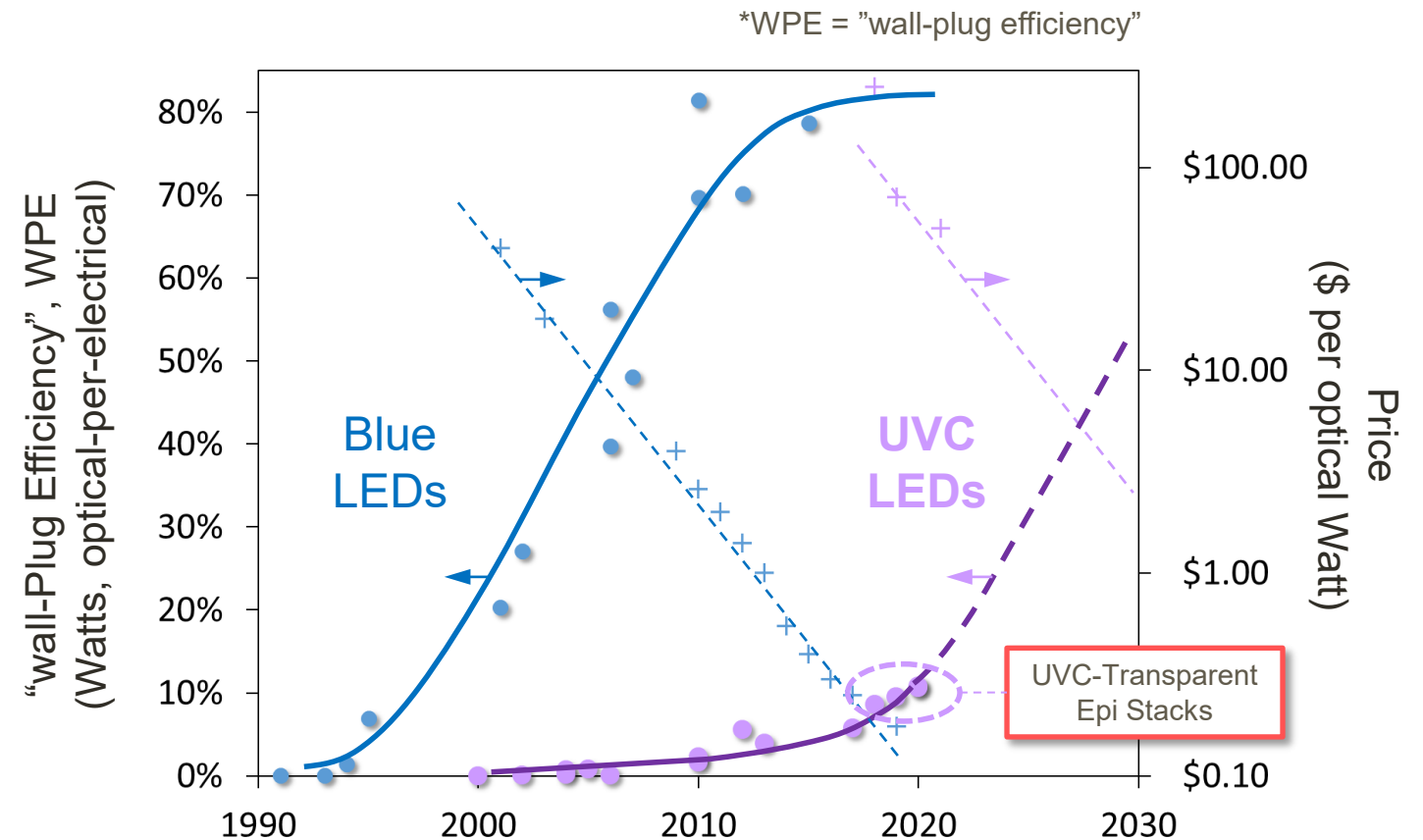
Krames, (2020) LEDs Magazine Vol. 17, No. 6, pp. 36-39

UVC LED Roadmap

- UVC LED entitlement:

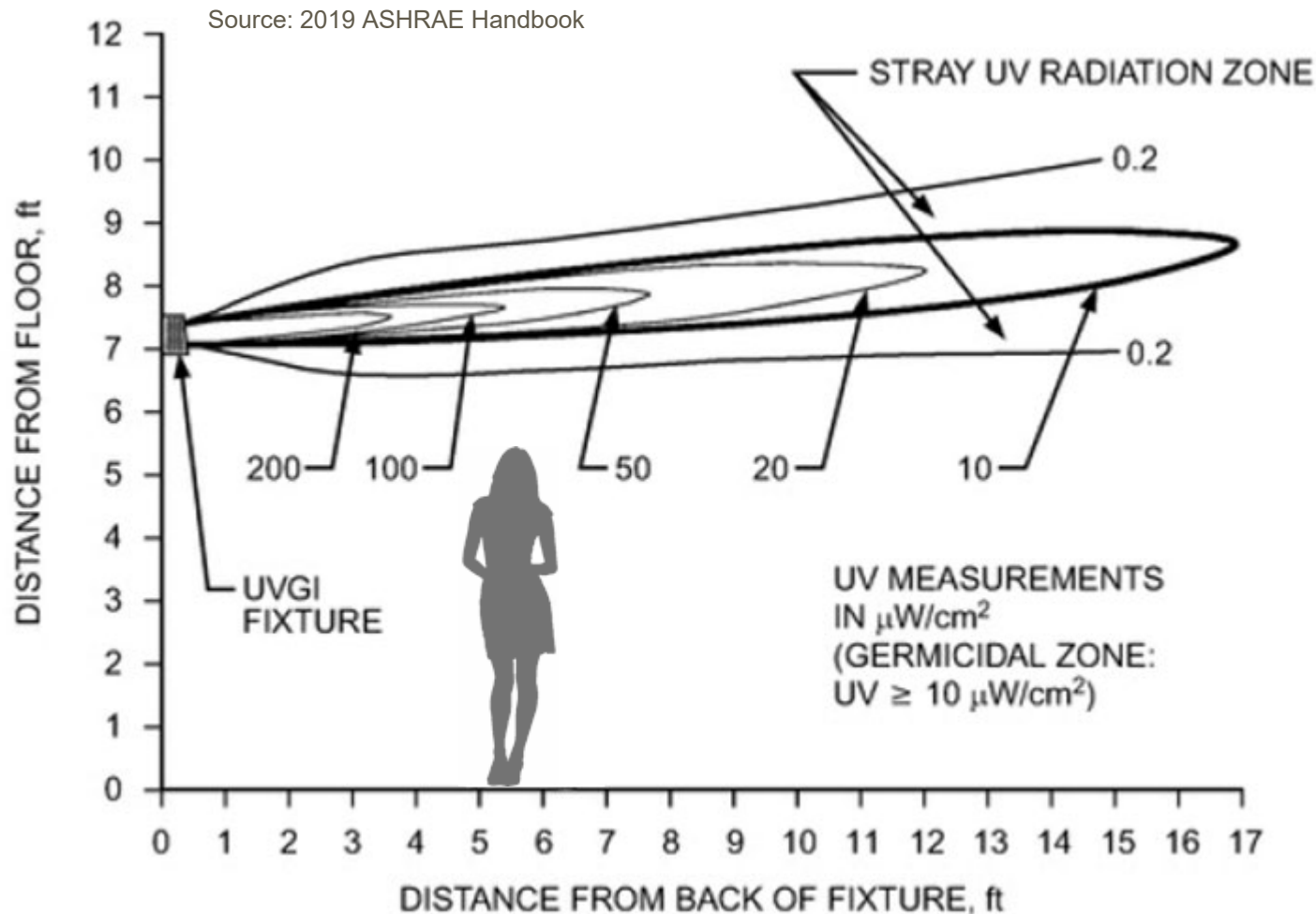
IQE	C_{ex}	Electrical	WPE*
80%	70%	90%	: ~ 50%

- 10x improvement in UVC LED efficiency is entitled
- Rate of progress as for blue LEDs → 50% WPE by 2030
- Approaching ~ \$1 per Watt
- Enables dramatic reduction in both initial and operating costs



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Upper Air GUV using Hg-Lamp Fixtures



Lamp Watts	Lamp UVC (W)	Fixture UVC (W)	Optical Eff.	Total Eff.
36.0	12.6	0.22	1.7%	0.6%
25.0	8.8	0.62	7.1%	2.5%
26.7	9.3	0.60	6.4%	2.2%

Source: CIE TC 6-52



Typical Hg-lamp louvered fixture for upper-room UVGI.

*Hg-lamp Upper Air GUV consumes ~3x more energy than LED lighting!**

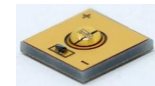
*Using NIOSH guideline for upper air GUV.

Importance of Radiance (“Brightness”): Etendue ($A \cdot \Omega$)



*Philips TUV 25W 1SL/25

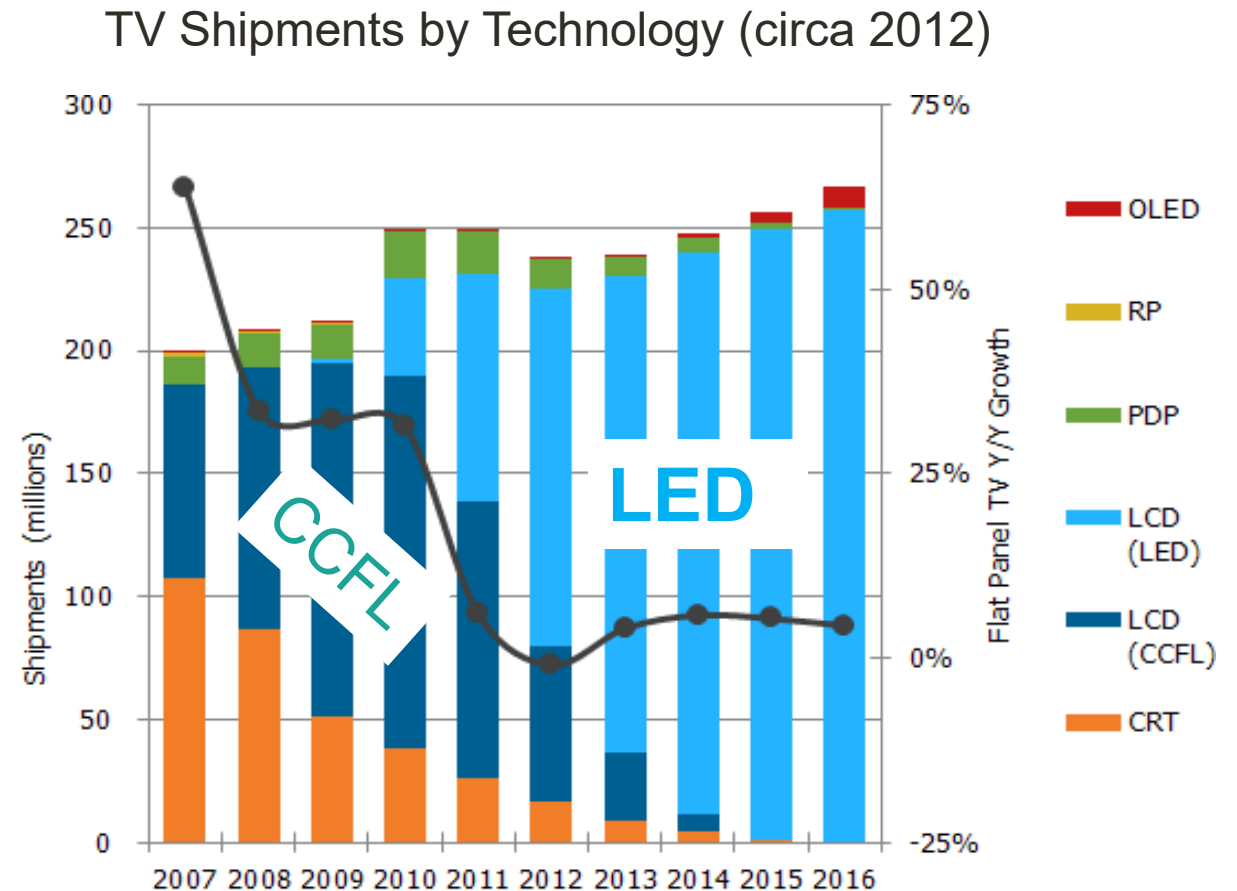
25 W Hg lamp* Fixture	Upper-Air GUV Application	UVC LED** Fixture
	<u>Single fixture, 2020</u>	
2.8%	wall-plug efficiency	5.0%
25	electrical input (W)	14
-	energy savings	44%
1	no. sources	5 (\$\$)
	<u>Single fixture, 2030</u>	
2.8%	wall-plug efficiency	50%
25	electrical input (W)	1.4
-	energy savings	95% ✓
1	no. sources	1 ✓



**6060 SMD UVC LED
Source: Bolb, Inc.

Who Remembers Cold-Cathode Fluorescent Lamps?

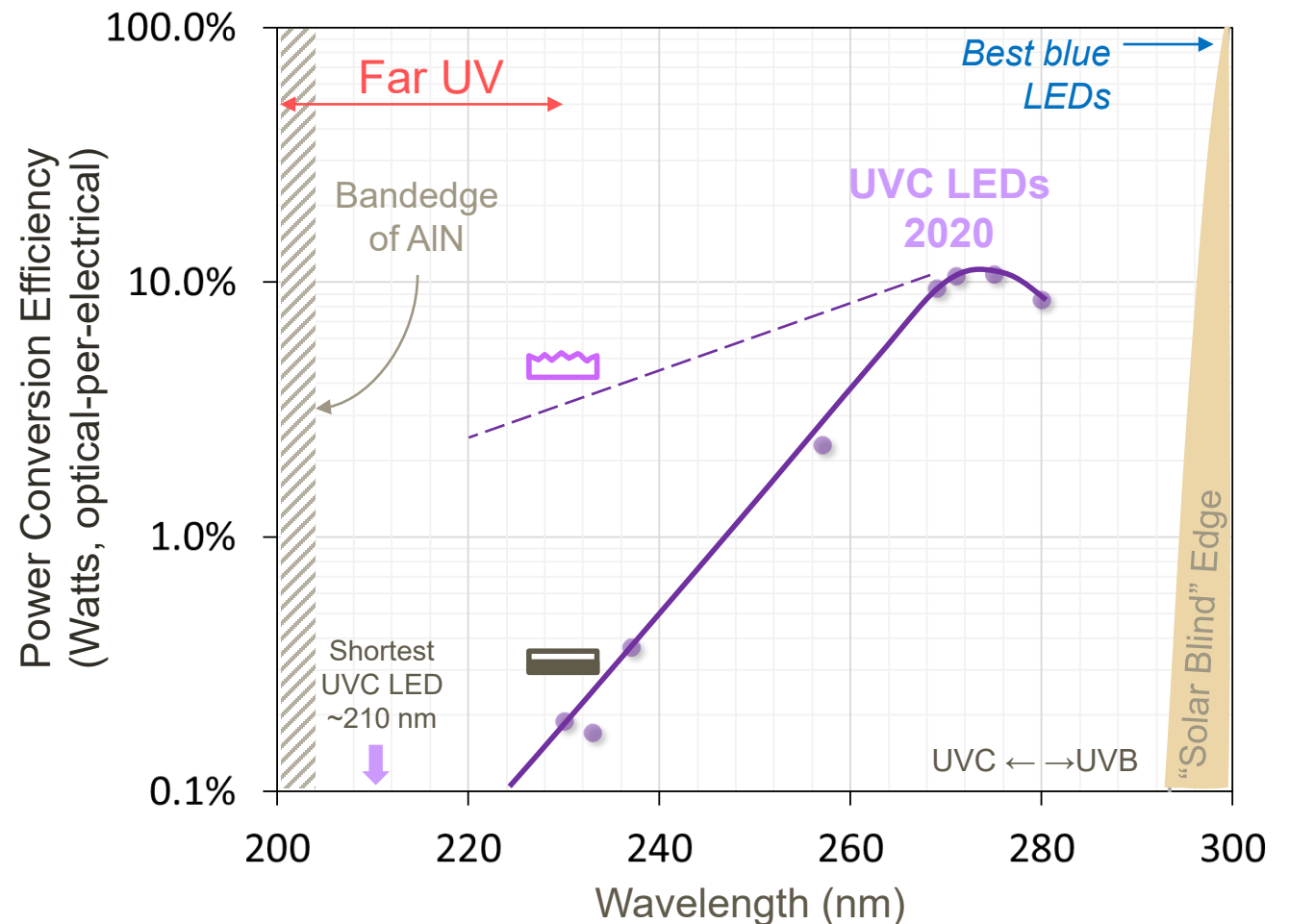
- White LED cost in 2010:
 - \$20 per klm
 - \$6 per Watt
- Hg-based Cold-Cathode Fluorescent Lamps (CCFLs):
 - < \$1 per klm
 - < 30¢ per Watt
- Conclusion: a 20x cost advantage could not save CCFLs from LEDs



<https://www.digitaltvnews.net/?p=21931>

Wavelength Dependence and “Far UV”

- Best “Far UV” LEDs now ~0.2% WPE
- Light extraction modeling shows >10x can be attributed to opaque p-layers
- Due to TM vs TE dipole radiation pattern (bandgap driven)
- In the future, 222 nm UVC LED WPE ~ 25+% may be possible, and would exceed KrCl lamp performance



after Krames, (2020) LEDs Magazine Vol. 17, No. 6, pp. 36-39

Questions?

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Disclosure: Client companies of Arkesso include those active in the UV-C LED space.