Key Findings from Radiometric Testing of Upper-Room GUV Luminaires

UV Radiometry session of the
joint biennial CNC-CIE, CIE-USNC &
CORM Conference 2023

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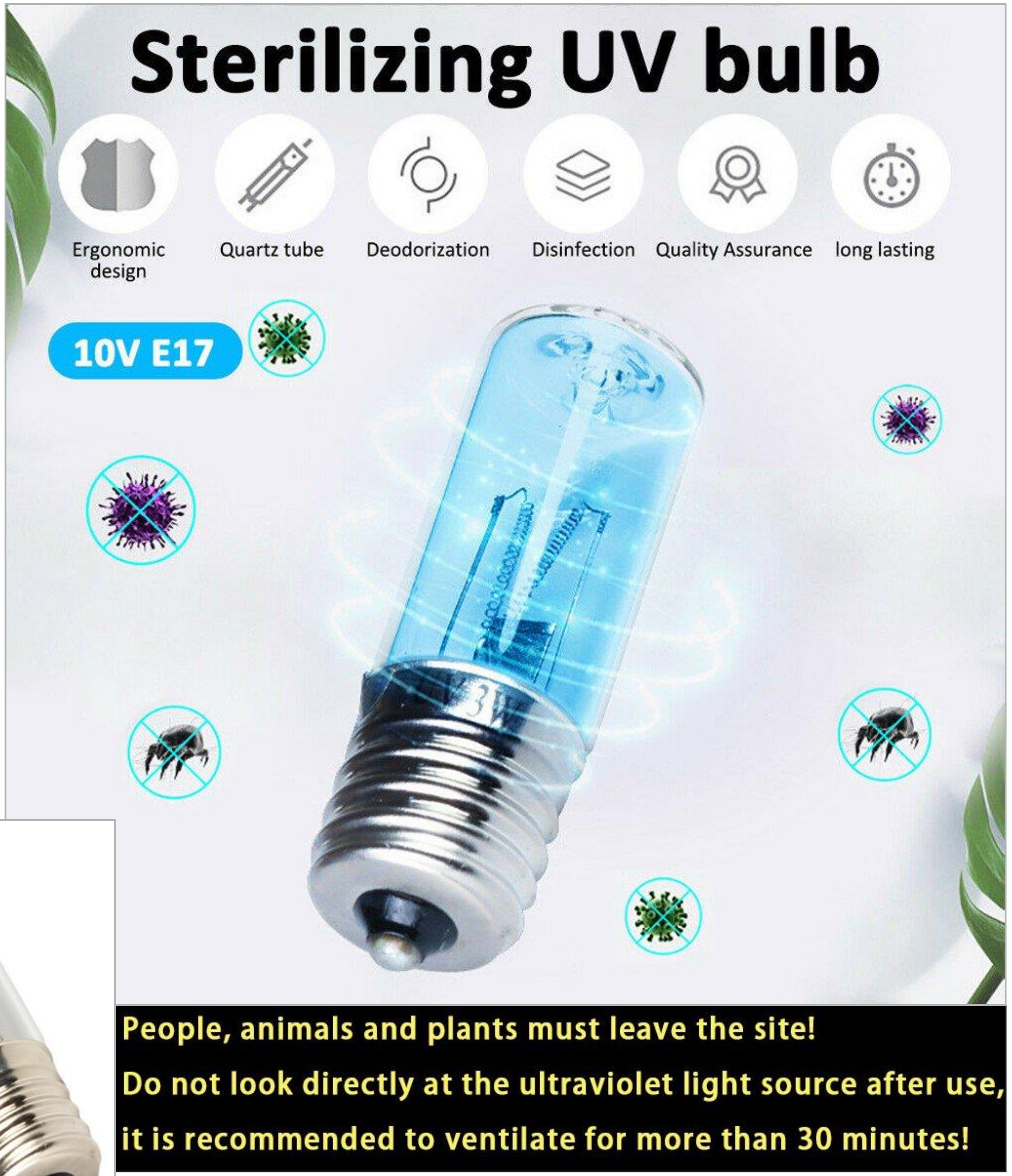
Background

Probably little UV from this $6.47 product…

- CALiPER
  - Launched by DOE in 2006 to provide objective test data on solid-state (LED) and benchmark lighting products
  - Expanded scope to include germicidal ultraviolet (GUV) disinfection products in response to the COVID-19 pandemic
  - Published GUV Round 1 reports in September 2023
    - https://www.energy.gov/eere/ssl/caliper



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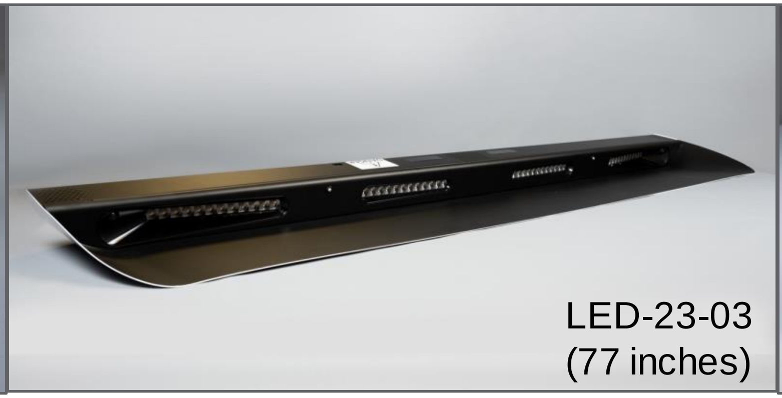
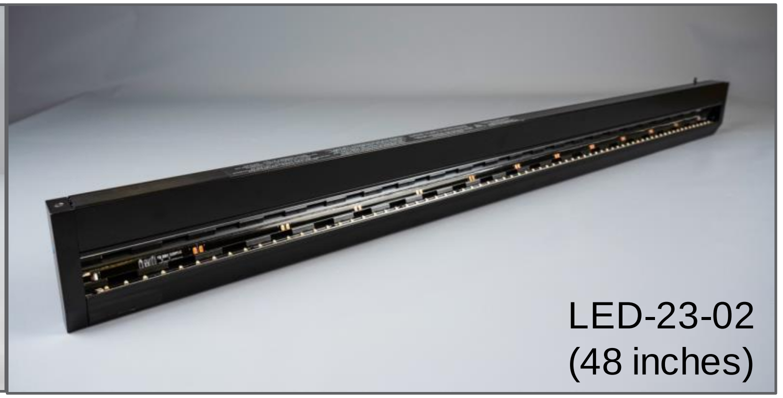
GUV Round 2 scope

- Upper-room luminaires
  - Intended for use in occupied spaces
  - Not designed to generate ozone
  - Rated to produce UV-C
  - Ideally with testable radiometric or electrical performance claims

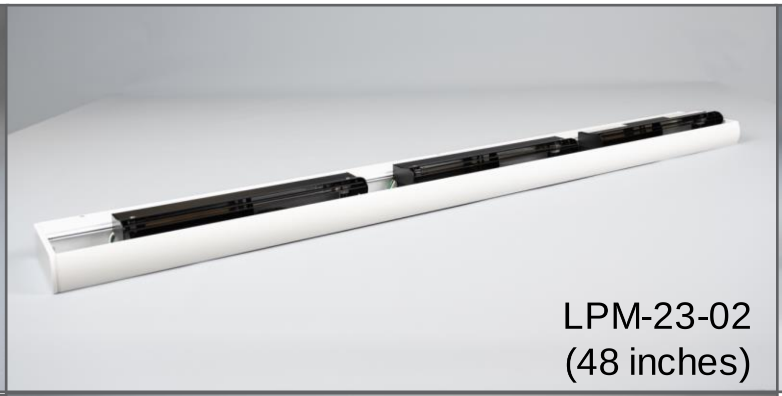
	Towers	Whole-room luminaires for vacant rooms	Whole-room luminaires for occupied rooms	Upper-room luminaires
Kr-Cl excimer • **Peak λ = 222 nm**			Round 3	
Low-pressure mercury (LPM) • **Peak λ = 254 nm**	Round 1	Round 1		Round 2
UV LED • **Peak λ = 255-280 nm**	Round 1		Round 1	Round 2

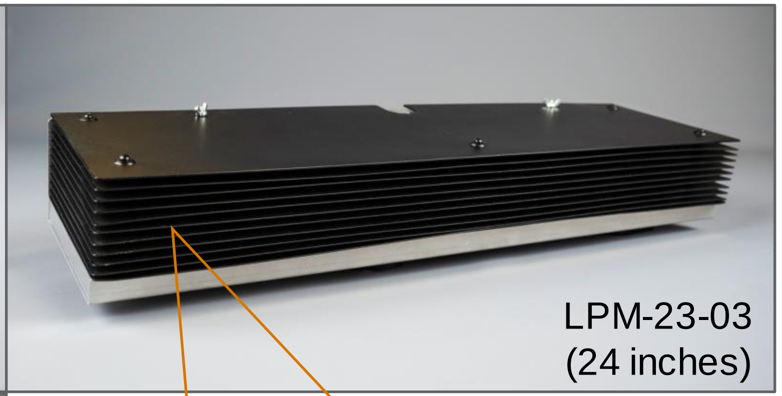
Tested luminaires





Dimensions are lengths along supporting wall





Whereas louvers in the other LPM luminaires were inclined, they were horizontal in this luminaire

Testing

- Key spectroradiometric and electrical measurements
  - For all 8 luminaires
    - Spectral power distribution (SPD) from 200-400 nm
      - In the direction of maximum UV-C (200–280 nm) radiant intensity
    - UV-C radiant intensity distribution
      - Gonioradiometer with mirror (no use of integrating sphere)
    - UV-C radiant flux (i.e., output power) and electrical input power
      - Used to calculate UV-C radiant efficiency
  - For 1 LPM luminaire and all 3 LED luminaires
    - Performance after 100 h and 500 h of operation

Referenced test method	Applied to
ANSI/IES LM-41-20	LPM
ANSI/IES LM-58-20	spectroradiometry
ANSI/IES LM-79-19	UV LED
ANSI/IES LM-84-20	long-term operation

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Preliminary findings: power

- Measured input power differed from claim by > 10% for 3 luminaires
  - LED-23-01 (-23%), LED-23-03 (-16%), LPM-23-01 (-12%)
- Measured output power differed from claim by > 10% for 5 luminaires

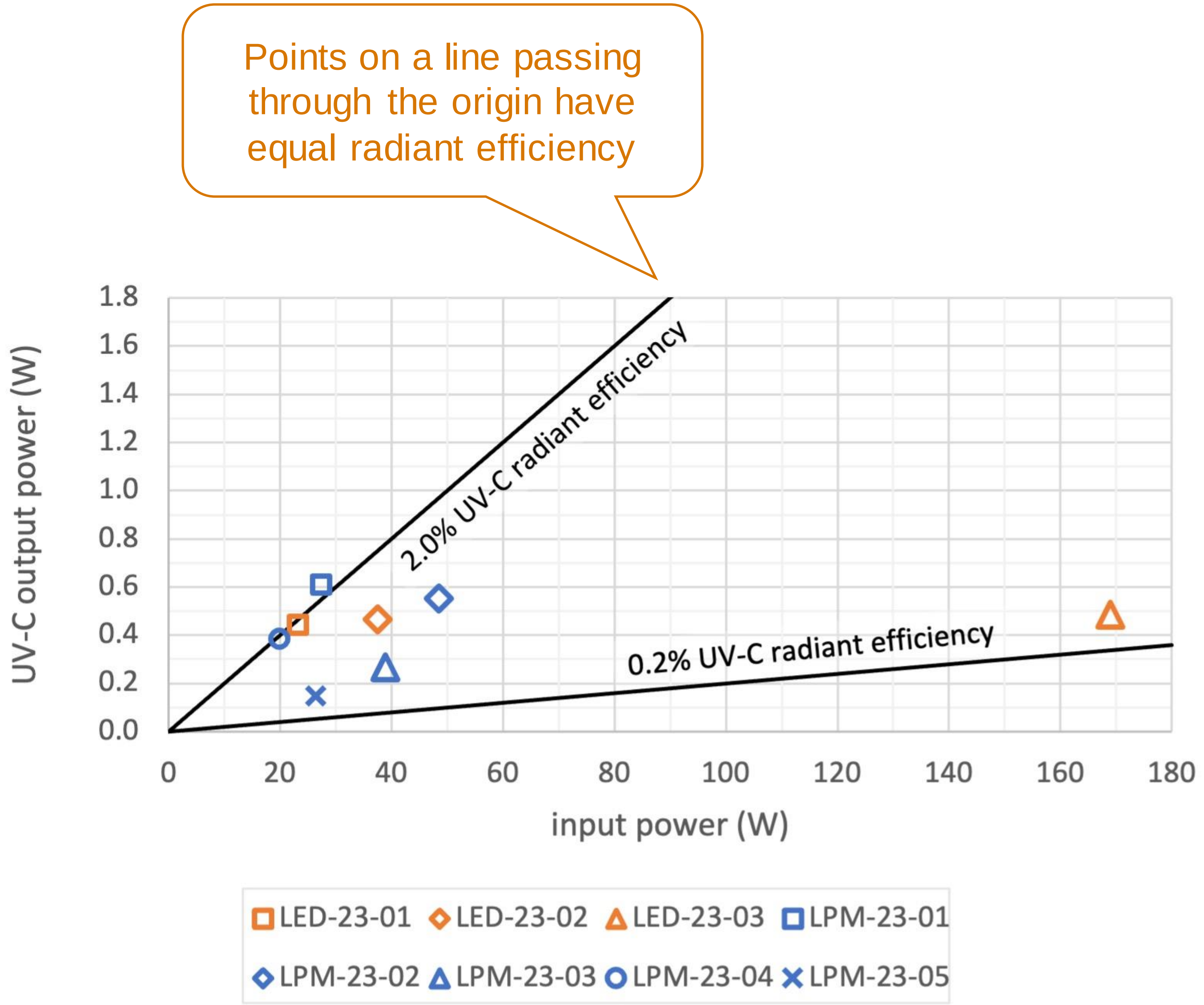
Luminaire	Output power (mW)		UV-C output power (mW)		UV-C fraction
	Claimed	Measured	Claimed	Measured	Measured
LED-23-01*	500	501	-	446	89%
LED-23-02*	652	598	-	467	78%
LED-23-03	-	526	-	489	93%
LPM-23-01	-	658	8,500	614	93%
LPM-23-02*	-	579	396	554	96%
LPM-23-03	12,000	282	-	268	95%
LPM-23-04	556	406	-	387	95%
LPM-23-05	-	161	10,000	152	94%

22% of output from this luminaire was UV-B

* Product documentation stated multiple different values; the value most accurately described as the model’s rating (e.g., on datasheet rather than test report) is shown.

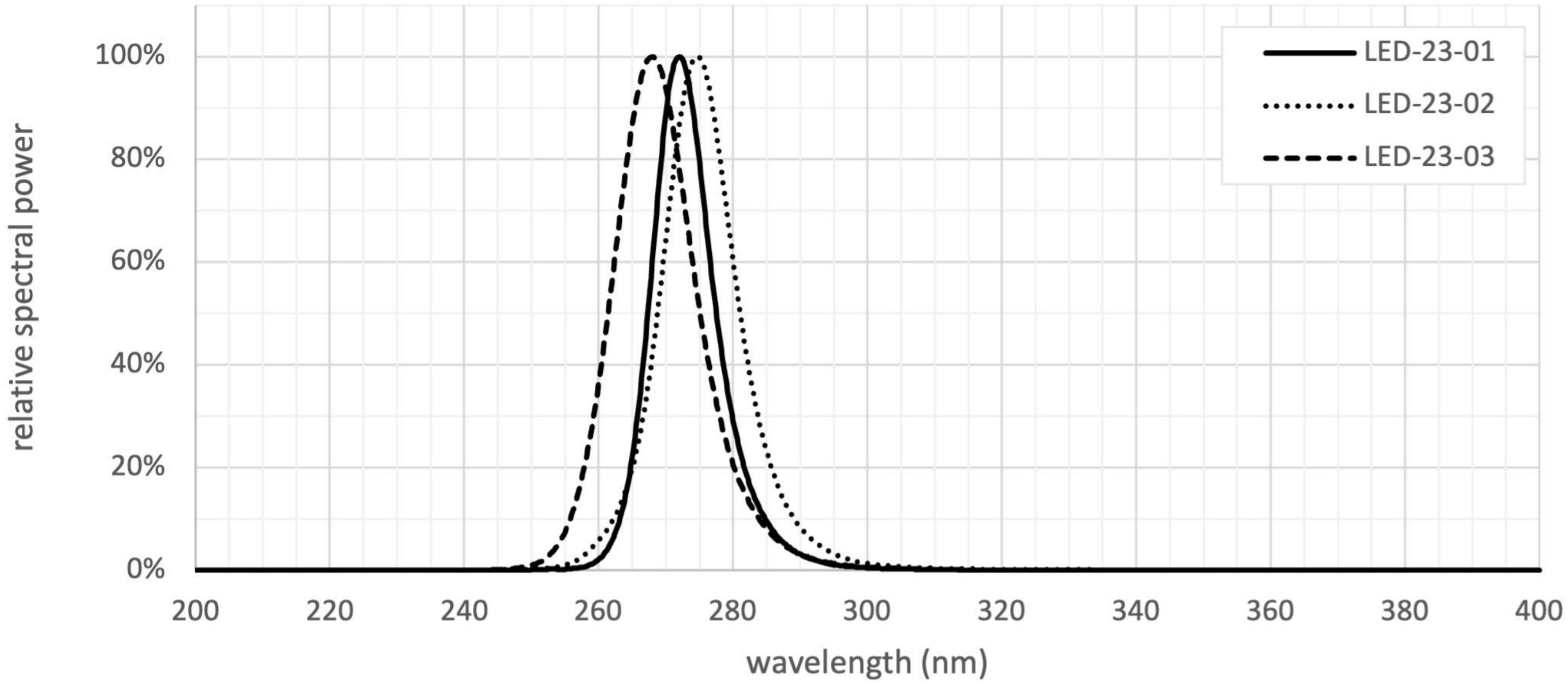
Preliminary findings: radiant efficiency

- UV-C radiant efficiency
  - Was slightly better on average for LPM than for LED
  - Was lower for LPM luminaires with no reflector or a reflector that was not aligned with louver pitch
- Ranges were small but meaningful
  - 4 units of LPM-23-05 (0.6% efficiency) would be needed to match the UV-C output power of 1 unit of LPM-23-01 (2.3% efficiency), and the LPM-23-05 system would use 4 times the amount of electrical energy



Preliminary findings: spectral distribution

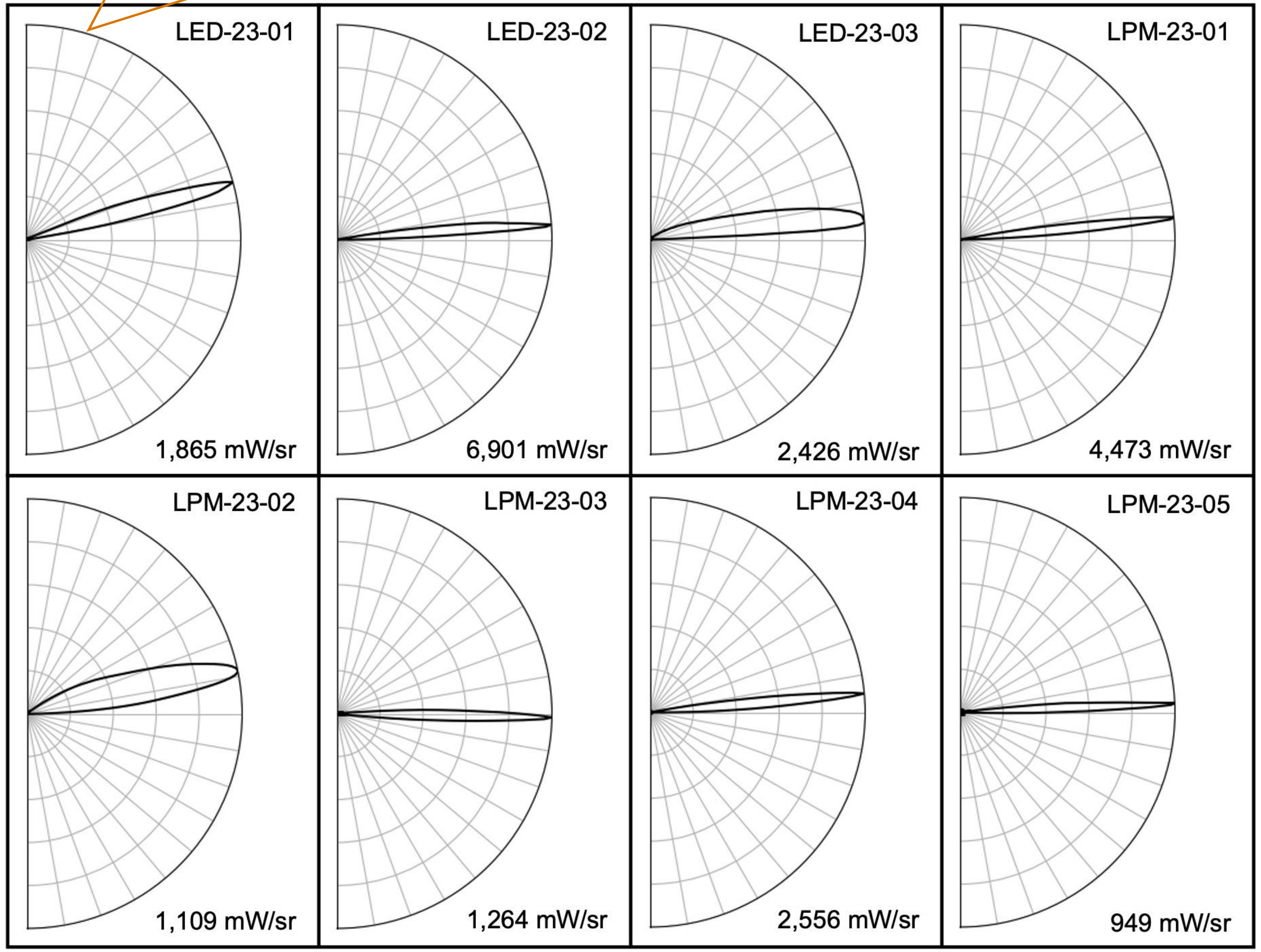
- Measured peak wavelengths were consistent with claims
  - Largest differences were for LED-23-01 (2 nm) and LED-23-03 (3 nm)
- UV-B (280–315 nm) content was 3–4% for LPM and 7–22% for LED
- UV-A (315–400 nm) content was ≤ 3% for all tested luminaires



Preliminary findings: spatial distribution

- Product documentation
  - 4 luminaires had IES LM-63 data
    - 3 had polar plots of claimed radiant intensity distribution
- Test results
  - Measured max radiant intensity values were 10–31% below claims
    - LED-23-01 max was 75° from wall
    - LPM-23-03 max was 1° below horizontal
  - Luminaires had 2–6% of output power below horizontal, with 2 exceptions
    - LPM-23-03 (63%) and LPM-23-05 (23%)
  - Lateral beam angles were 41–83° for LED and 89–110° for LPM

Vertical half-plane in the direction of maximum UV-C radiant intensity



Preliminary findings: photobiological safety

- UL 8802* results estimated by CALiPER (no testing yet)
  - Initial calculations predicted that *even with no downward tilt* only LPM-23-02 would pass, but max irradiance was typically in the near field…

* Assumes room surface reflectances are zero

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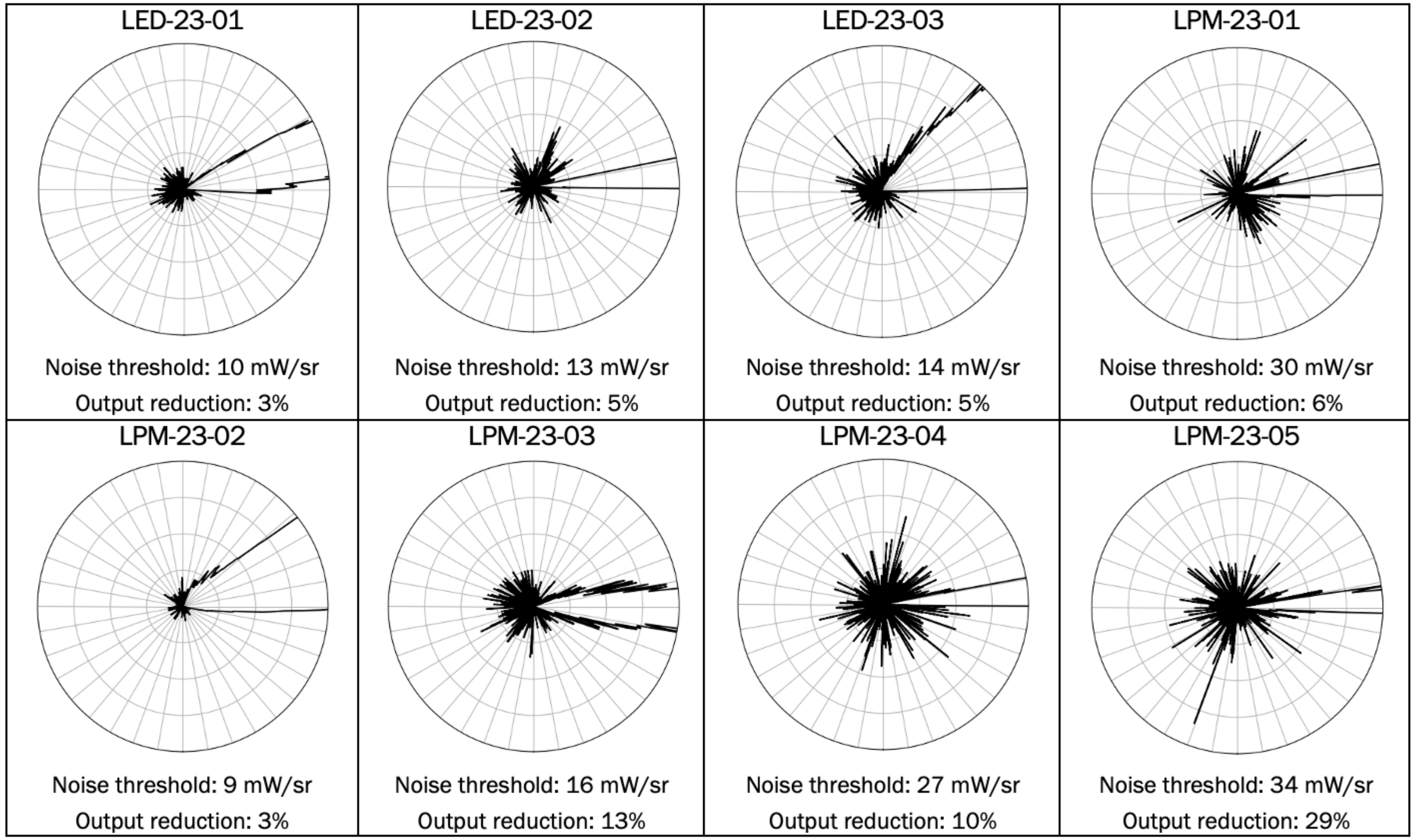

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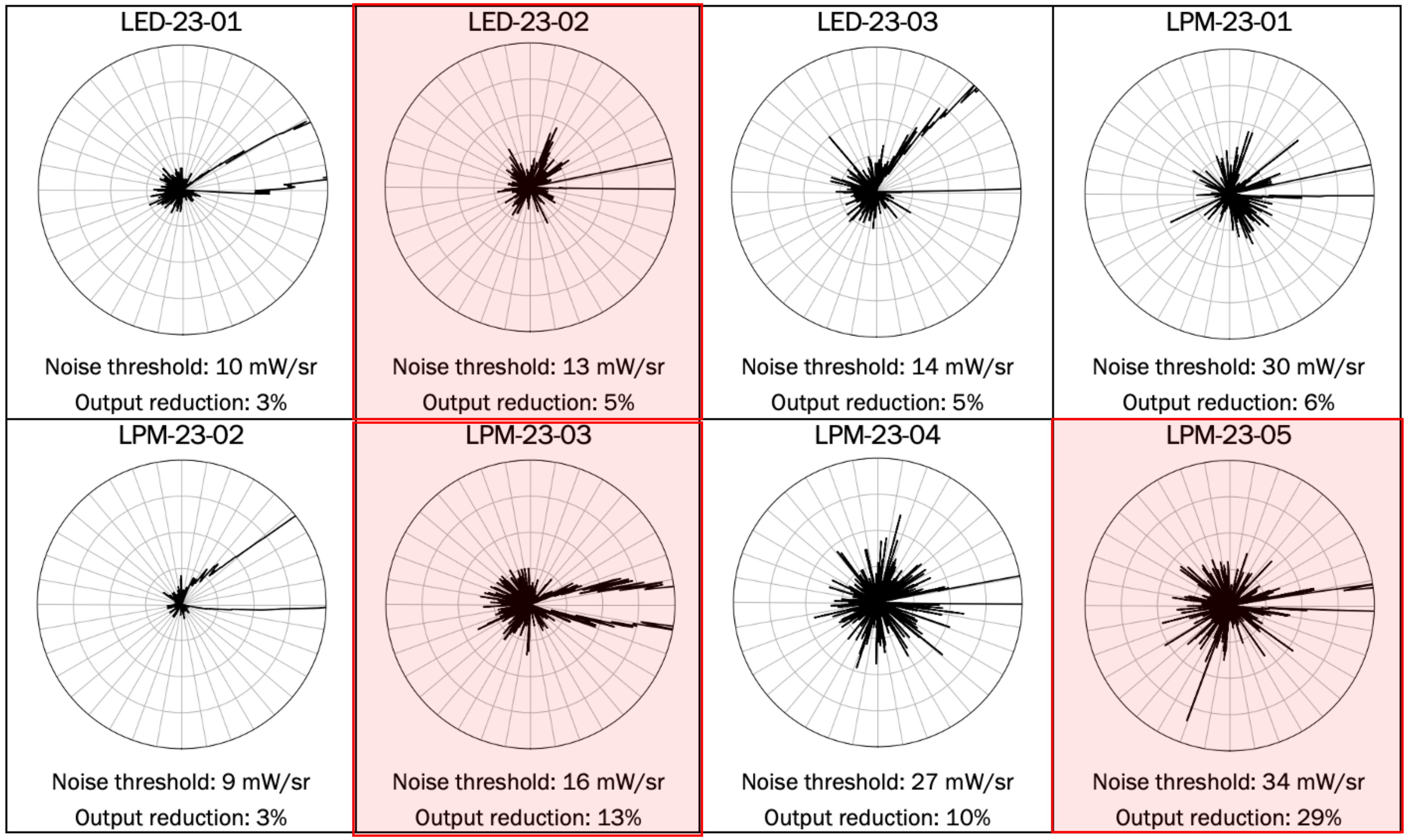
  - Noise in the IES files was identified as the culprit, and removed below luminaire-specific thresholds
    - Calculations then predicted 5 luminaires would pass even after being tilted 1° downward
    - But output power was reduced by 3–29% in so doing

But the nearest point predicted to exceed eye safety threshold for LED-23-02 was 56 feet out from luminaire!



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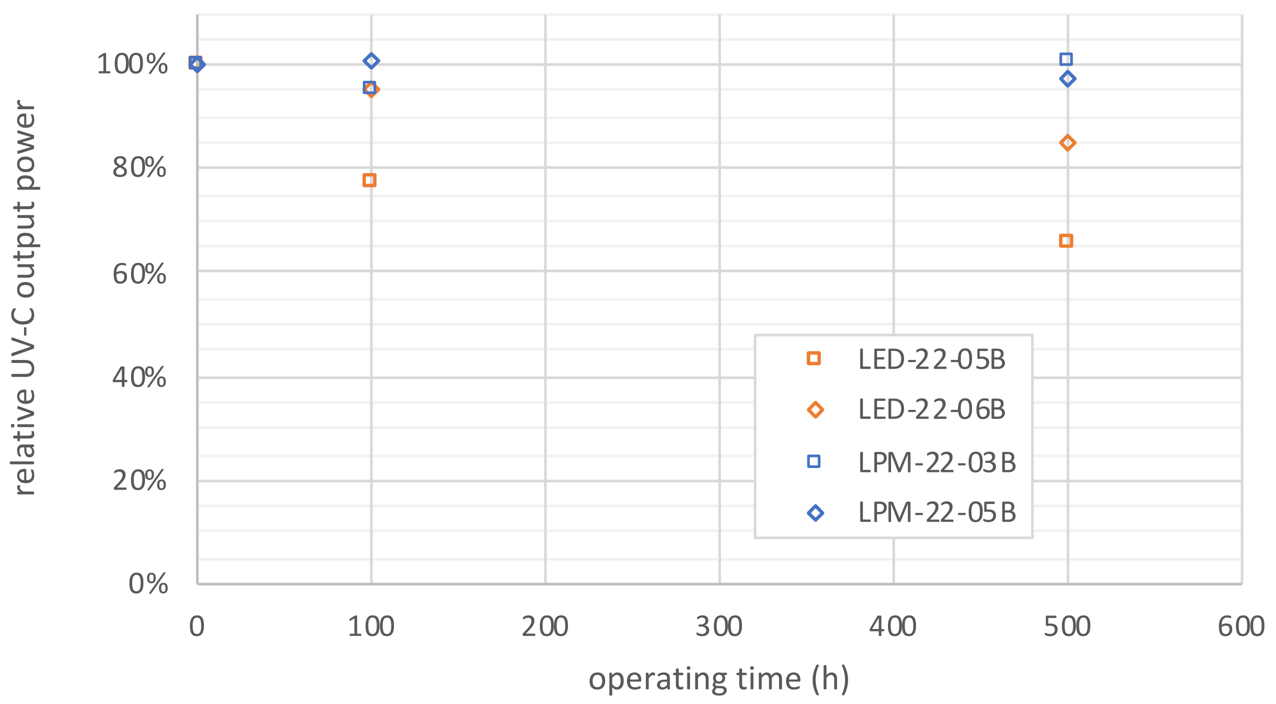
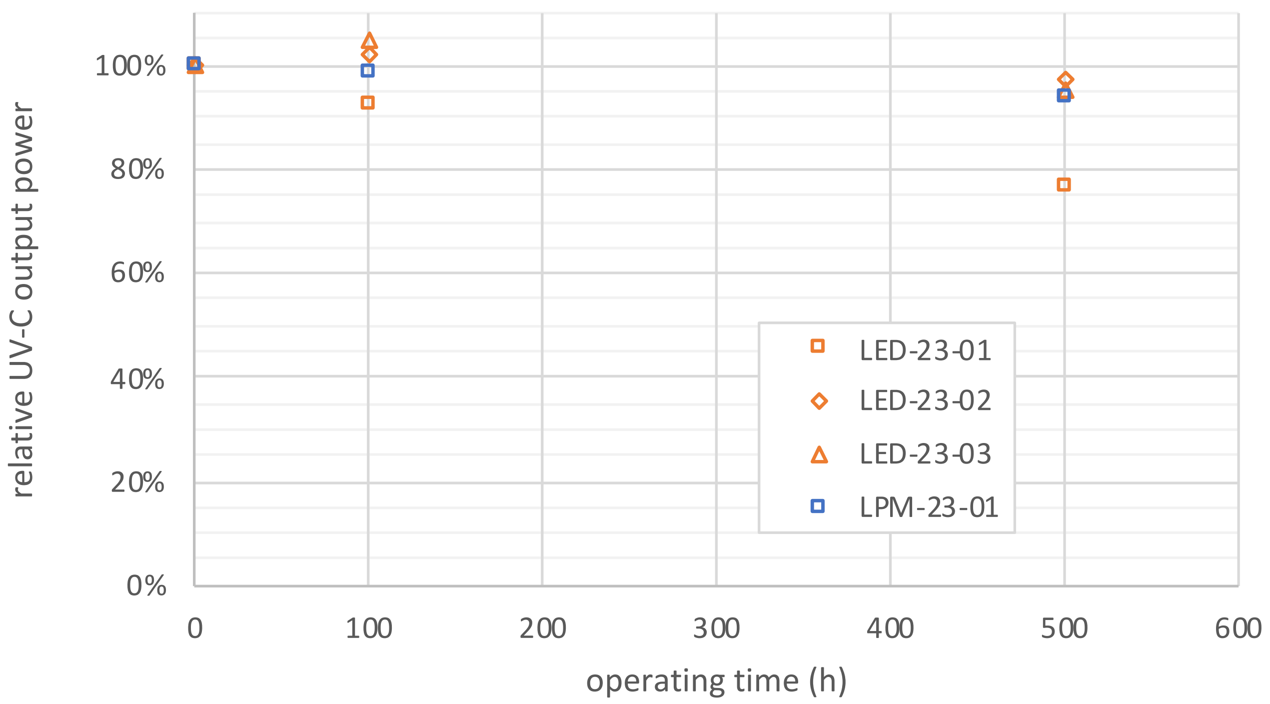
Preliminary findings: radiant flux maintenance

- Tested LED products
  - Had similar curve slope from 100–500 h in Rounds 1 and 2
    - Suggests 100 h of seasoning might be appropriate
  - Had less depreciation at 500 h in Round 2 than in Round 1, but the ranges overlapped

Round 1



Round 2



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Next steps

- Targeting publication of GUV Round 2 report before end of 2023
  - https://www.energy.gov/eere/ssl/germicidal-ultraviolet-disinfection
- Future rounds of GUV testing
  - Whole-room luminaires for occupied rooms
    - Using KrCl excimer sources with 222 nm (Far UV-C) peak wavelength
  - Round-robin comparison testing
    - Round 2 test lab gonio vs Round 1 test lab mirrorless gonio and integrating hemisphere
  - UL 8802 testing vs CALiPER predictions
  - Other TBD…