Far-UVC Light in Clinical Settings

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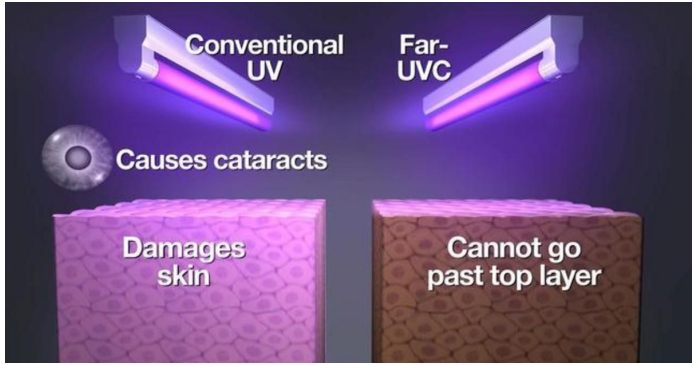
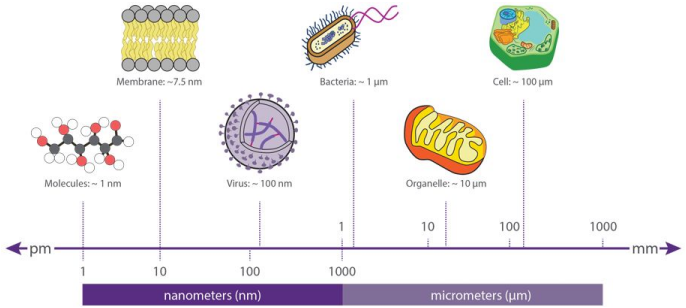
Problem Statement

- Germicidal UVC light (GUVC) (254 nm)
  - effective sterilization but is also carcinogenic to humans when exposed
- Alternative: Far-UVC light (222 nm)
  - theorized to be safe for human exposure
- We must prove far-UVC light is still effective against pathogens
  - HCoV-229E and HCov-OC43 strains → comparable to SARS-CoV-2 (Covid-19)
  - Relationship between light Intensity, distance, strain deactivation dosage and time to achieve 99.9% sterilization
- Target Environment: Hospital Bathrooms
- Design ideal, efficient device/light fixture



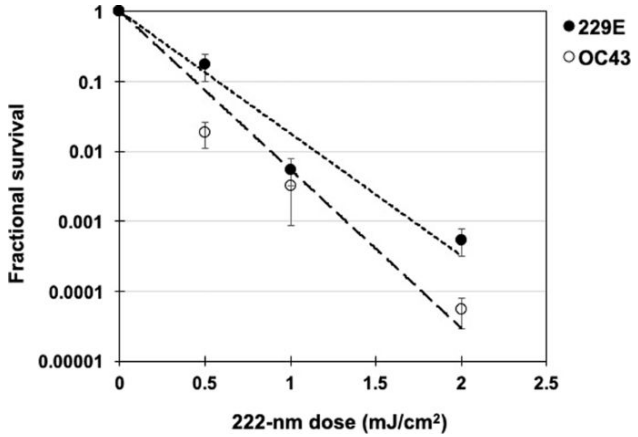
https://www.youtube.com/watch?v=8fh4LfUc-AI



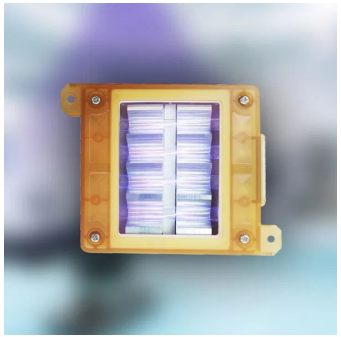
https://www.spexcertiprep.com/knowledge-base/covid-19

Relevant Background

- GUVC light 99.9% efficacy
  - HCoV-229E - exposure dosages of 1.7mJ/cm^2
  - HCov-OC43 - exposure dosages of 1.2mJ/cm^2
- Current Far-UVC devices are mainly excimer (Kr-Cl) lamps with slightly variable power outputs
  - Sailon 222nm Far-UVC light: 35 µWatts/cm2 at 100 cm
  - Ushio Care222 Filtered Far-UVC excimer lamp: 0.2W/cm2 from the source



https://www.nature.com/articles/s41598-020-67211-2



https://www.ushio.com/product/care222-filtered-far-uv-c-excimer-lamp-module/

Design Specifications

- Disinfect with 99.9% efficacy of airborne and surface adherent viral particles
  - HCoV-229E, HCoV-OC43, and SARS-CoV-2
- Product must fit in the context of a patient bathroom: ≈ 10.20 m^3 (3.72 m^2 floor)
- Adhere to current International Commission of Non-Ionizing Radiation Protection (ICNIRP) safety standards for exposure to 222 nm light by the public
  - ~ 3 mJ /cm^2 / hour with a maximum of 23 mJ / cm^2 per 8-hour exposure
  - Usable under human exposure
  - Implementable in public settings
- Shelf-life of 50,000 hours

Final Prototype

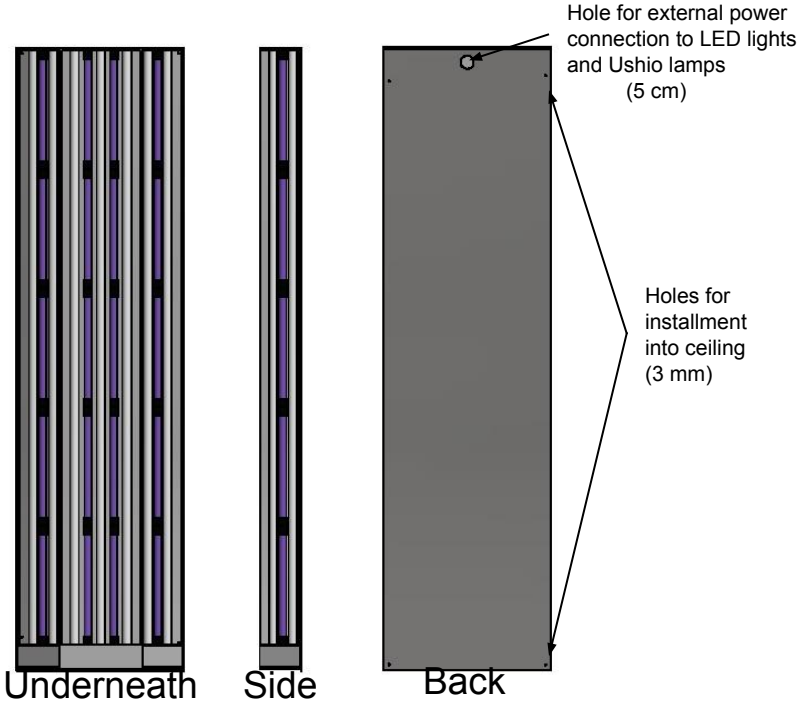


Figure 1: Underneath, side, and back views of FULED light fixture

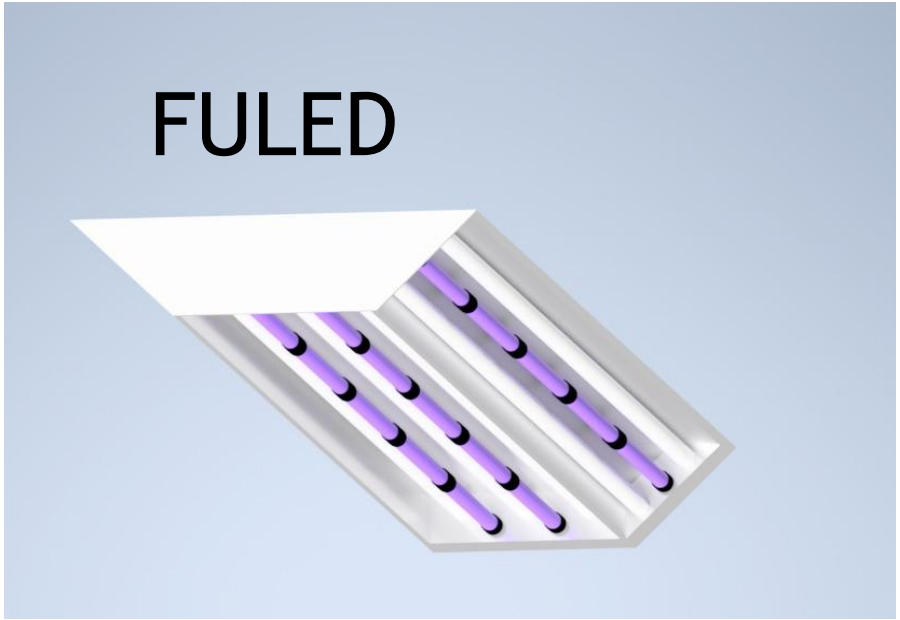


Figure 2: Angled view of entire 3D FULED fixture

Prototype Dimensions

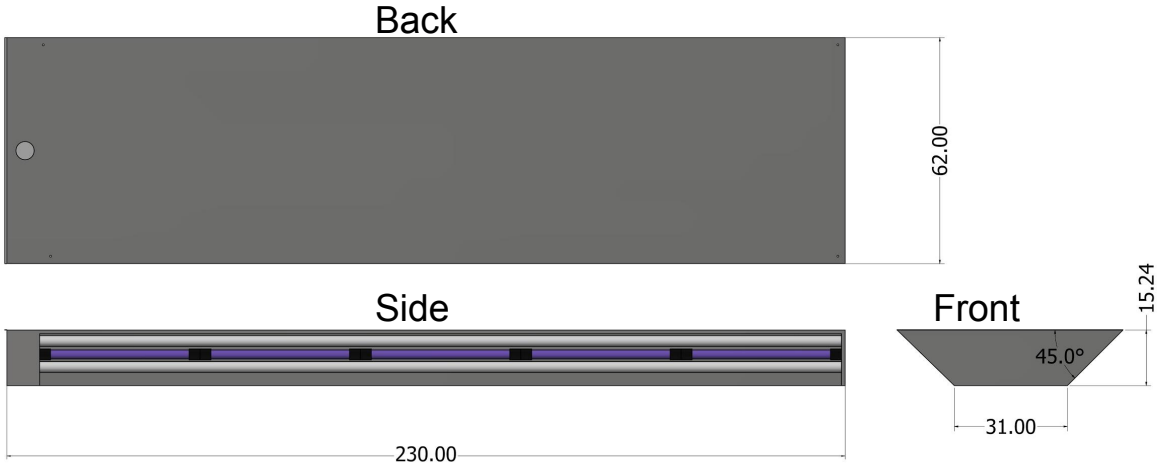


Figure 3: Back, side, and front views with dimensions in cm and angles in degrees

Ushio Far-UVC Lamp

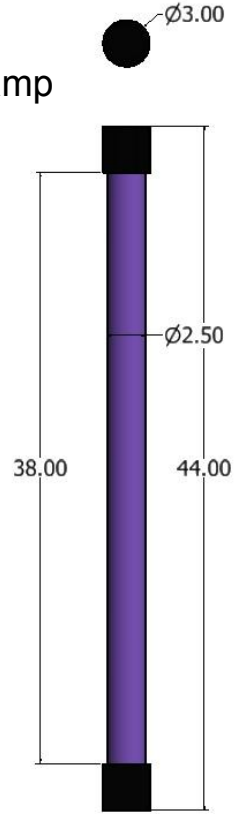


Figure 4: Ushio Far-UVC excimer lamp with dimensions in cm

Testing

- Minimum Dosage for 99.9% Effectiveness
  - HCoV-229E - 1.68 mJ/cm^2
  - HCov-OC43 - 1.17 mJ/cm^2
  - SARS-CoV-2 - 1.17 - 1.68 mJ/cm2
- Beer-Lambert's Law
  - Penetration depth through N, N_2, O, and O_2 = 110 km [1]
  - Absorbance can be considered negligible
- ICNIRP Safety Standards
  - .05 mJ/cm^2 per minute - 1 hour limit
  - .047 mJ/cm^2 per minute - 8 hour max

Element	Absorption Coefficient 1/M*m	Concentration (M)	Optical Path Length (m)	Absorbance
H_2O (g)	10^{-3}	.01904	3.04	3.32576e-5
CO_2 (g)	10^{-3}	.02272	3.04	6.90688e-5

Table 1: The absorption coefficients and concentrations for H2O and CO2 and their corresponding absorbance of Far-UVC light (222 nm).

Testing

- Most effective Far-UVC Light
  - 0.2 W/cm^2 Ushio Lamp
  - 135.4 - 194.8 minutes at 0.047 mJ/cm^2/min
  - 136.7 - 196.2 minutes at 0.05 mJ/cm^2/min

Excimer Lamp	Duration Required for 99.9% Efficacy on HCoV-OC43 (min)	Duration Required for 99.9% Efficacy on HCoV-229E (min)
Ushio Lamp (5μW/cm² at 2m)	4,439,409	6,386,199
Sailon Lamp (35μW/cm² at 100 cm)	634,305	912,319
Larson Lamp (80 μW/cm² at 3.9878 cm)	277,477	399,157
Ushio Lamp (.2W/cm² from the source)	135.4	194.8

Table 2: The durations for each lamp to reach 99.9% efficacy adhering to the 0.047 mJ/cm^2/min limit

Excimer Lamp	Duration Required for 99.9% Efficacy on HCoV-OC43 (min)	Duration Required for 99.9% Efficacy on HCoV-229E (min)
Ushio Lamp (5μW/cm² at 2m)	4,529,210	6,503,482
Sailon Lamp (35μW/cm² at 100 cm)	647,033	929,074
Larson Lamp (80 μW/cm² at 3.9878 cm)	283,093	406,493
Ushio Lamp (.2W/cm² from the source)	136.7	196.2

Table 3: The durations for each lamp to reach 99.9% efficacy adhering to the 0.05 mJ/cm^2/min limit

Testing

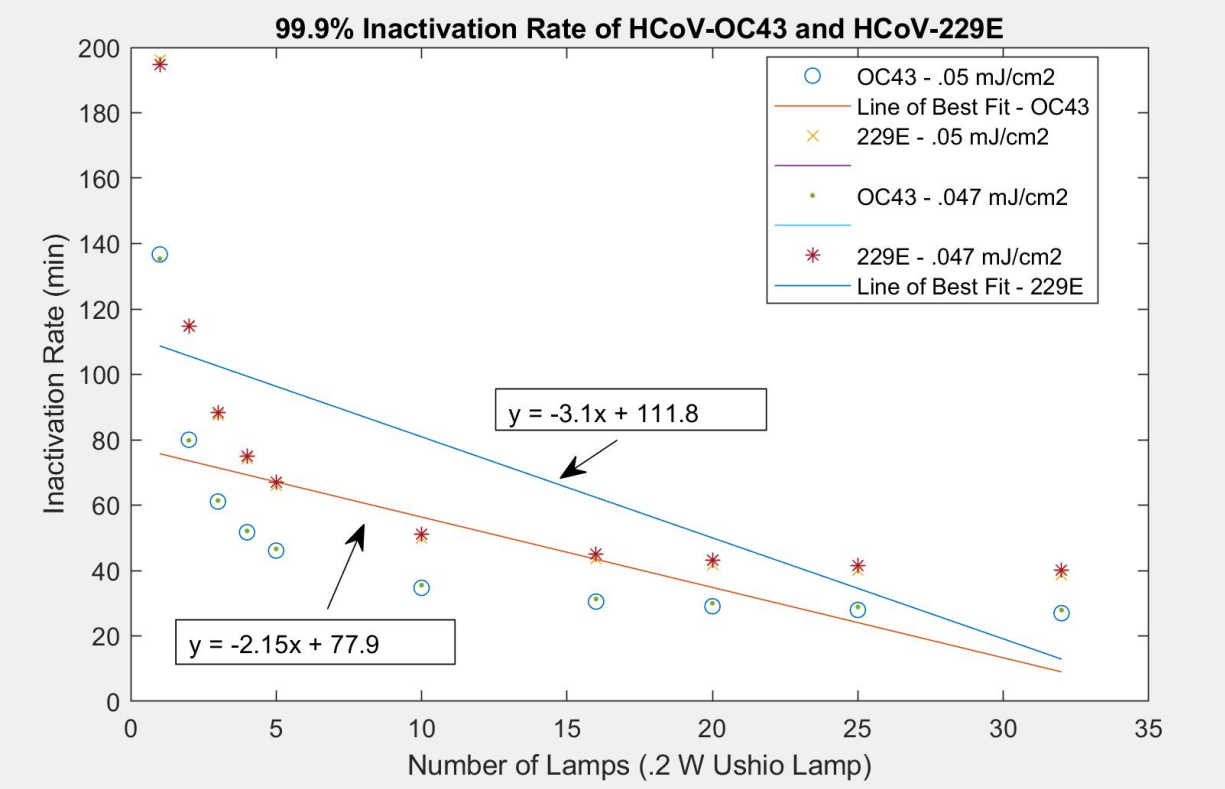
Number of Lamps - Ushio Lamp (.2W/cm² Intensity)	Duration Required for HCoV-OC43 at a rate of 0.05 mJ/cm²/min (min)	Duration Required for HCoV-229E at a rate of 0.05 mJ/cm²/min (min)	Duration Required for HCoV-OC43 at a rate of 0.047 mJ/cm²/min (min)	Duration Required for HCoV-229E at a rate of 0.0047 mJ/cm²/min (min)
1	136.7	196.2	135.4	194.8
2	80	114.9	79.8	114.8
3	61.1	87.7	61.4	88.3
10	34.7	49.9	35.5	51.1
20	29.06	41.7	29.95	43.1

Table 4: Durations required to reach 99.9% efficacy adhering to the two ICNIRP limits

Results

- Final Design
  - 20 - 0.2 W/cm^2 Ushio Lamp
  - 99.9% disinfection of SARS-CoV-2
    - 29.06-41.7 minutes at 0.05mJ/cm^2/min
    - 29.95-43.1 minutes at 0.047mJ/cm^2/min

Graph 1: Inactivation Rate vs Number of Lamps for HCoV-OC43 and HCoV-229E at 0.05 mJ/cm^2/min and 0.047 mJ/cm^2/min



Conclusion & Discussion

- Used deactivation dosages for 2 strains of coronavirus to make connections with SARS-CoV-2 and determined
    - Most effective type of lamp (.2 W Ushio Lamp)
    - Optimal amount of lamps to use (20 bulbs)
    - Required exposure time to reach 99.9% inactivation (27-40 min for our design)
- Final design also has visible lighting, is in an optimal shape, can be easily fixed to the ceilings and has high efficacy
- Met the ICNIRP safety standards
- The absorbance was found to be negligible

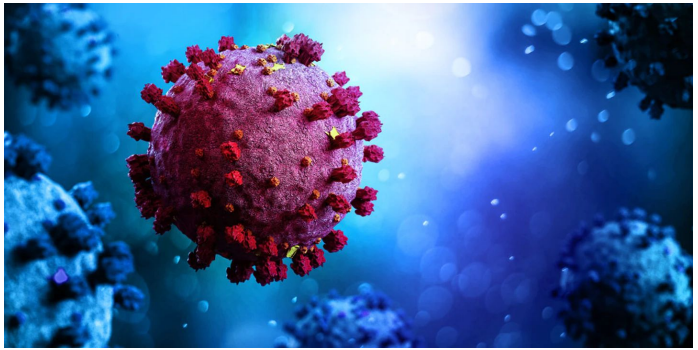


Figure 4: What coronavirus would look like under UV lighting [3]

Future Work

- Experimental testing to prove efficacy and ensure safety
- Finding optimal ratio of Intensity : Effectiveness : Cost
  - Making this marketable and available
- Incorporate reflective materials to better hit target areas
- Far-UVC LEDs to improve intensity and be more energy efficient
- Long term effects of far-UVC light on humans

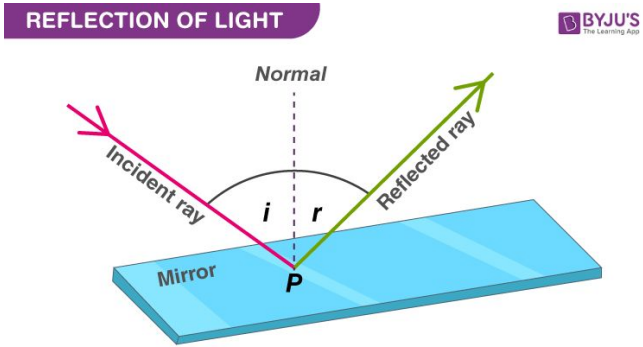
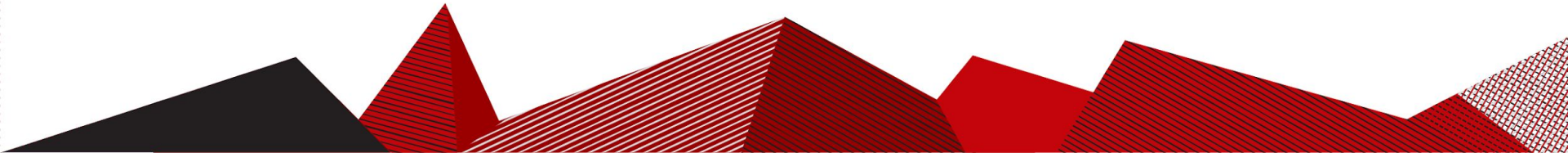


Figure 5: Image of the reflection of a light ray on a surface []

Figure 6: Image of an LED light []

Thank you for watching!

Questions???



Acknowledgements

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References

[1] - Buonanno, M., Welch, D., Shuryak, I. et al. Far-UVC light (222 nm) efficiently and safely inactivates airborne human coronaviruses. Sci Rep 10, 10285 (2020).

[2] - Sveta. “(7) Absorption.” *SlideServe*, 10 Sept. 2014, www.slideserve.com/sveta/7-absorption.

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