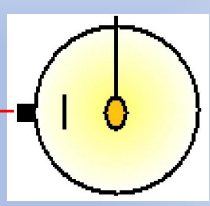
CIE-USNC 2020 Meeting - Technical Presentation

Potential Use of KrCl* Excimer Lamp for Disinfection of Air and Surfaces in Occupied Rooms

Ultraviolet radiation in the 200-300 nm region is known to inactivate pathogens. Systems using low-pressure mercury lamps were developed in the 1920 – 1940's1, which emits primarily at 253.7 nm (GUV) to be used for upper room disinfection. Over the last few years there is a growing body of research on shorter wavelength GUV lamps, primarily Krypton-Chloride Excimer lamps, (KrCl*) that emit primarily at 222 nm. Studies show that these lamps are just as effective as the low-pressure mercury lamps in inactivating viruses, or killing bacteria, on both surfaces and air. Further, the research shows that the penetration depth of the 222-nm emission, for both skin and eyes, is much less than that at 254 nm, making uses of such systems potentially safe for direct exposure in occupied areas. Results of various studies on the use of such sources for viral deactivation and human safety will be presented.

Rolf S. Bergman, Ph.D.

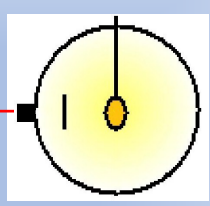
Dr. Rolf Bergman is currently an independent consultant (sole proprietor) in lighting technology and measurements. After graduating with a Ph.D. in Electrical Engineering in 1972 from the University of Minnesota, Dr. Bergman worked for over twenty-eight years at GE Lighting, all at Nela Park, Cleveland, OH, both as an individual contributor and manager in lamp technology. While at GE Lighting he was involved new product and process development, measurement capability and industry standards. Dr. Bergman was named Chief Scientist, Lamp Technology in 1992, a position he held until retirement in 2001. Currently, among other consulting work, he serves as an assessor of lighting laboratories for accreditation to NVLAP, and accrediting body organized at the National Institute of Standards and Technology (NIST). Dr. Bergman served as President of the CIE/USA National Committee from 11/2003 to 11/2008. He also was the chair of CIE TC 6-47, the group that producing a global standard for photobiological risk evaluation of lamps, IEC 62471 (also CIE E9). He serves as a member of the IESNA Technical Procedures and Photobiology Committee and he is a member of CORM, an industry group that advises NIST on measurement needs in US industry. While at GE he was the author or co-author of 19 US Patents and published about 20 Journal articles with an additional 20 to 30 internal GE reports



Potential use of KrCl excimer lamps for disinfection of air and surfaces in occupied rooms

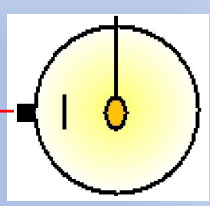
Rolf S Bergman

Rolf Bergman Consulting



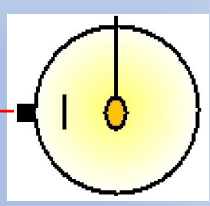
Outline

- I have not been involved in direct research on any excimer discharges so information on lamps and their output is from other sources
  - ✓I Use data provided by researchers at Dundee/St Andrews (Scotland) and testing results at Columbia University
- I have been involved with a group of researchers that meet by Zoom every Friday to discuss use of Ultraviolet Radiation in the UV-C range to combat the spread of the Sars-Cov-2 virus (Covid-19), the cause of the current pandemic now ramping up exponentially in most US states.
- Conclusions on the use of KrCl* lamps as a viable method for air and surfaces in the presence of humans will be made based on data/calculations presented



Excimer Lamps

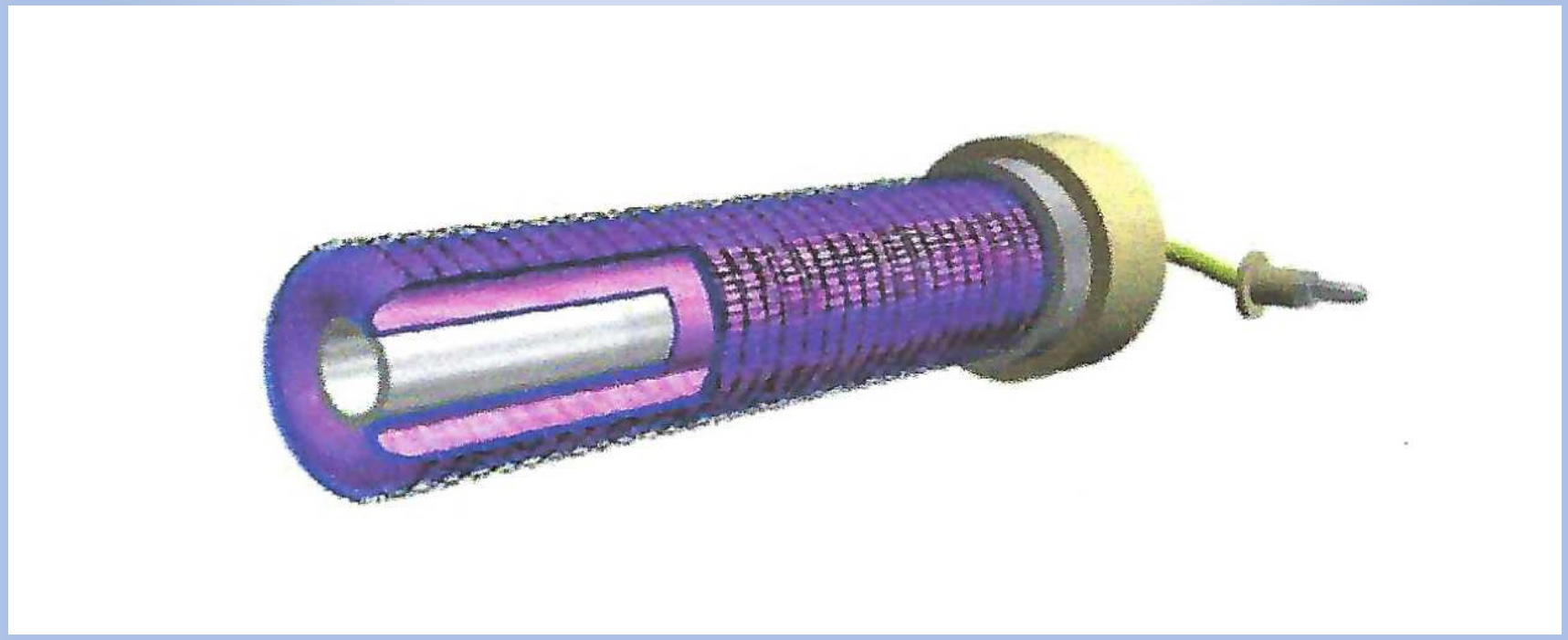
- An Excimer lamp is a quasimonochromatic photon emission source that can, over a wide range of ultraviolet wavelengths (100 to 400 nm), emit a photon by spontaneous emission of short-lived dimer molecules.
- The spontaneous emission was first shown to exist in rare gas discharges, particularly xenon. It was found that the metastable excited state of xenon could form a diatomic molecule with a ground state xenon atom that would dissociate by emitting a photon at 172 nm (vacuum UV range)
- Since then combinations of the rare gases (not He) and all the alkali elements have been shown to emit (from 108 nm for NeF* to 351 nm for XeF*)



Kr/Cl Excimer lamps

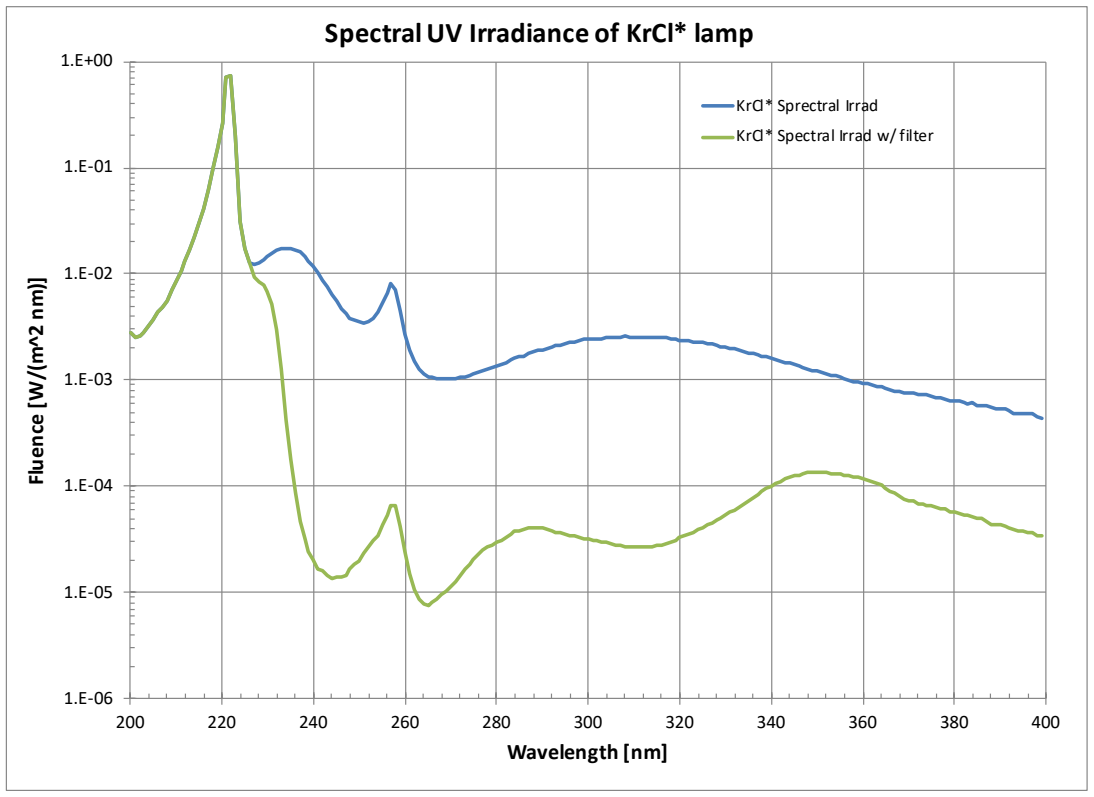
- KrCl* emit in a narrow wavelength band centered on 222 nm
  - Up to about 25 % of the input power is emitted at this wavelength
- The photon efficiency of killing bacteria or inactivating viruses appears to be about the same as that of sources at 260-270 nm
  - ✓ D-90 is about 3 J/m^2
- The penetration depth of skin at 222 nm is much smaller than that at 300 nm, even that at 254 nm from Hg.
- Ozone generation from 222-nm emission is small and can normally be handled by ventilation systems in place.

Example of an Excimer Lamp



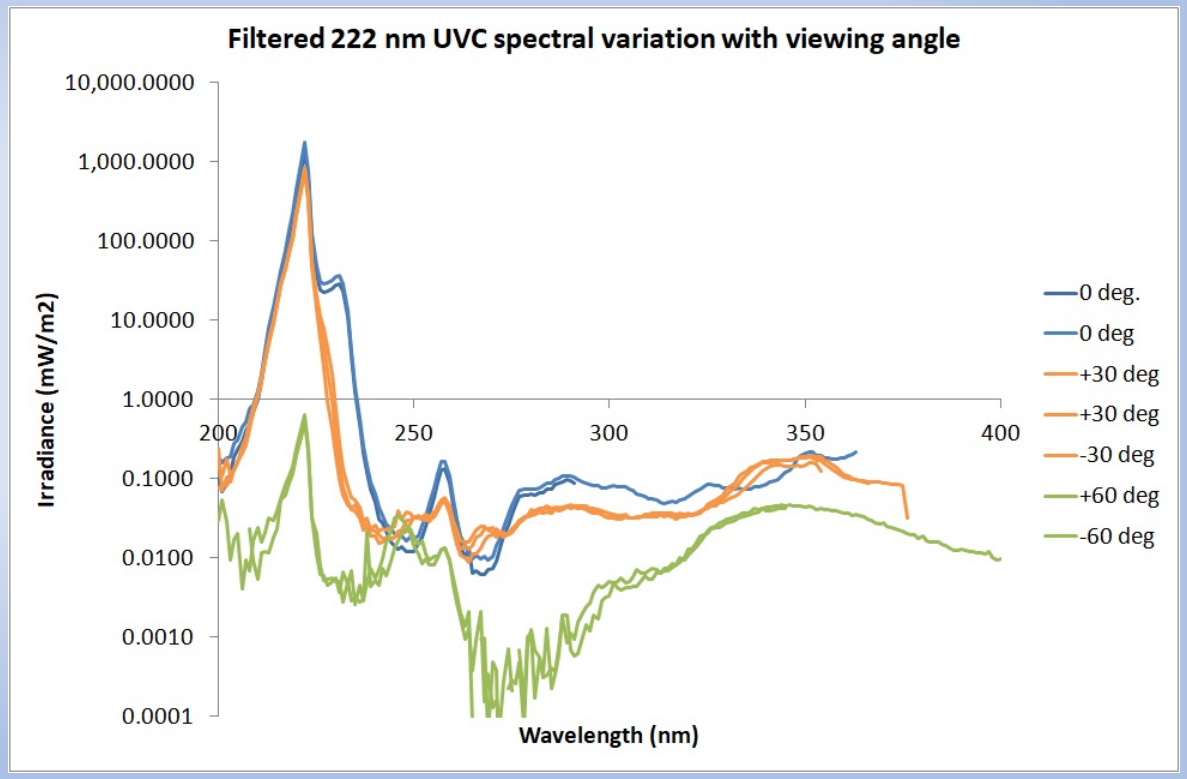
UV Spectra of a KrCl* Lamp: a) unfiltered b) through multilayer filter

Curtesy of Ewan Eadie et.al



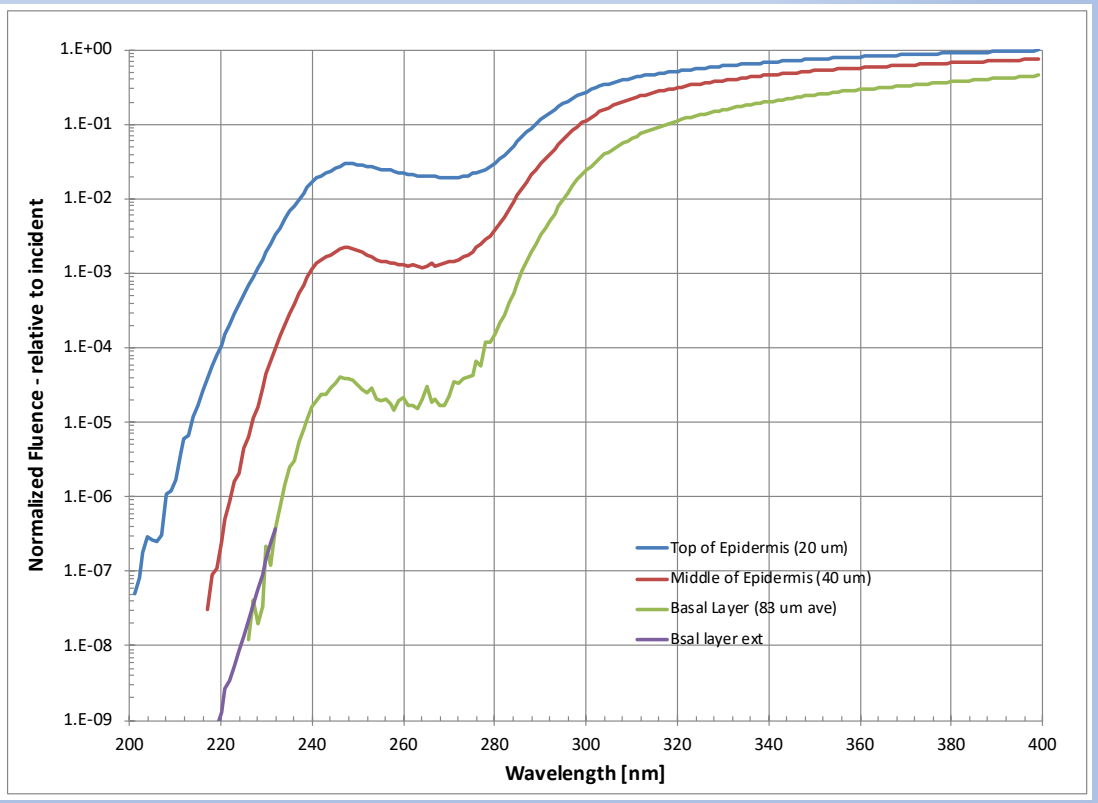
Variation in Spectral Irradiance of filter as a function of angle

Curtesy of Ewan Eadie



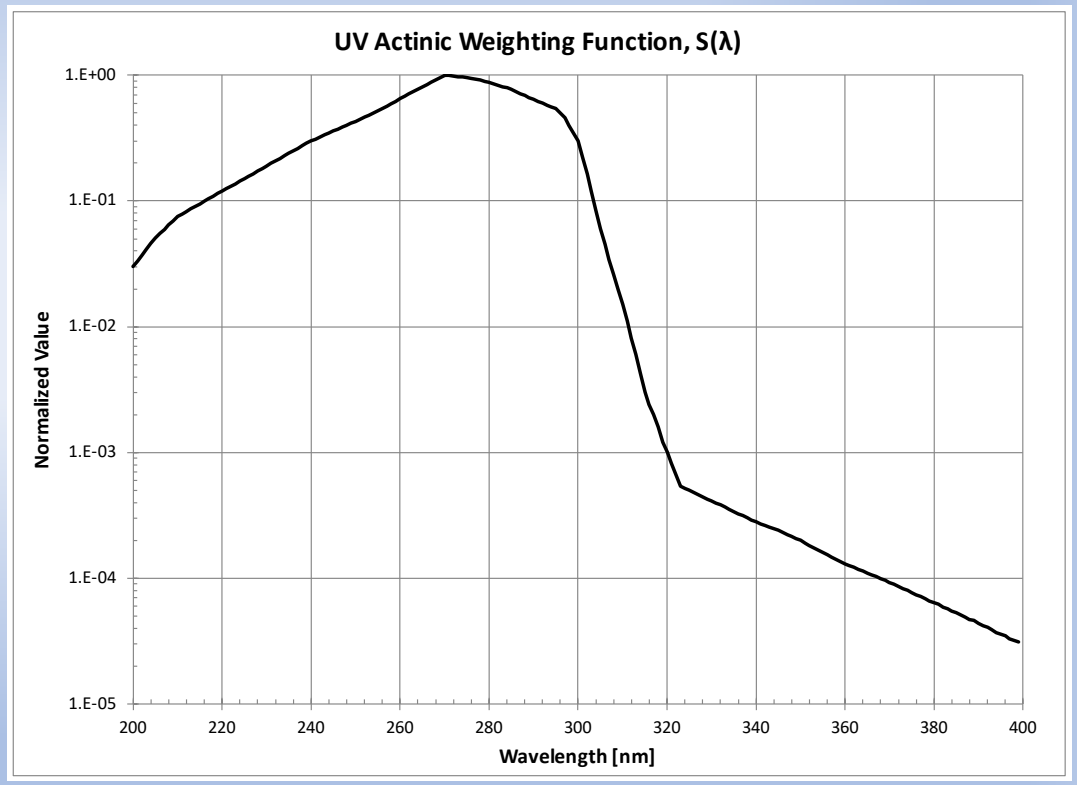
Model of Skin Penetration Depth as a function of UV Wavelength

Curtesy of Kenneth Wood

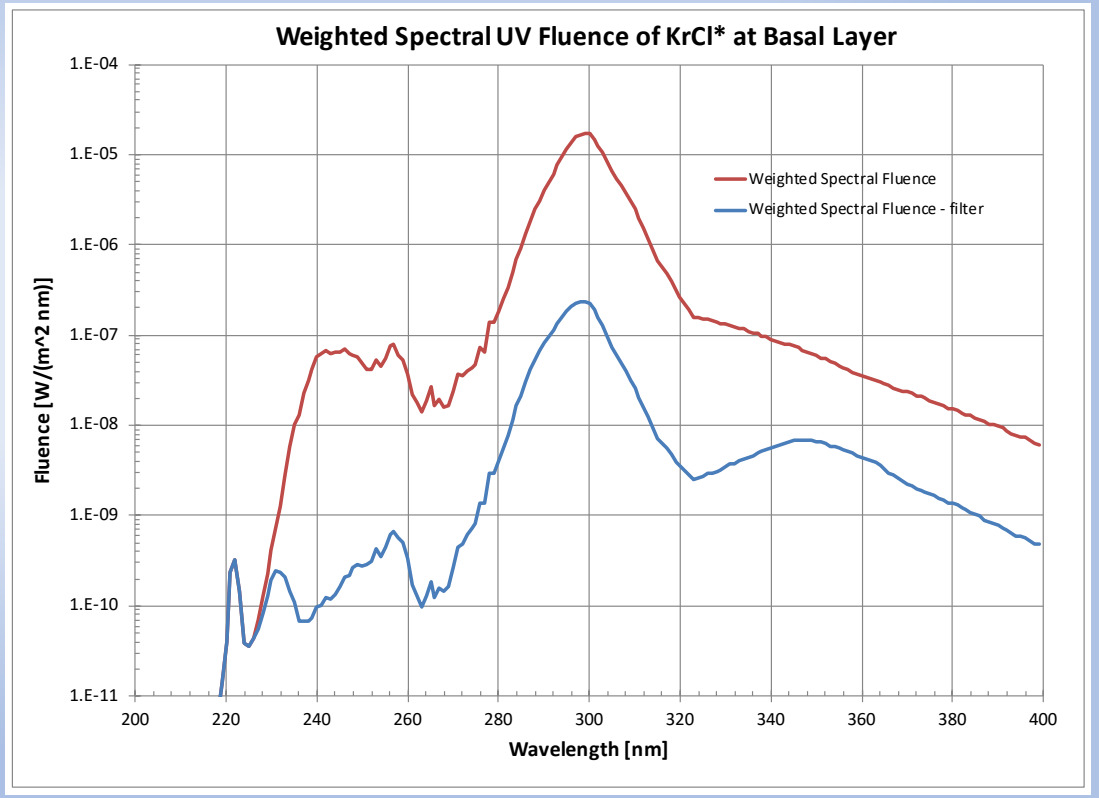


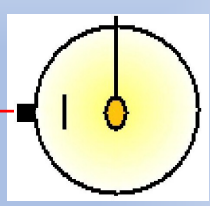
UV Actinic Weighting Function vs. Wavelength

ACGIH



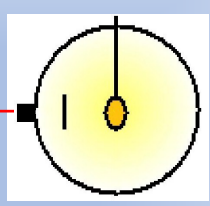
Weighted Spectral UV Fluence of KrCl* at Basal Layer vs. Wavelength





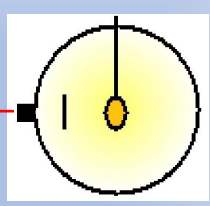
Results

- KrCl* emission without considering skin penetration reduction, based on a TLV of 300 J/m^2 (8-hour time-weighted exposure),
- The photon efficiency of killing bacteria or inactivating viruses appears to be about the same as that of sources at 260-270 nm
  - ✓ D-90 is about 3 J/m^2
- Modeling of the penetration depth of skin at 222 nm shows that the number of photons reaching the basal layer is about 6 orders of magnitude smaller than that at 300 nm, even 3 orders of magnitude smaller that at 254 nm from LPM lamps.



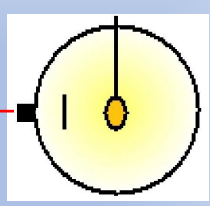
Results (cont.)

- Early studies at Columbia and Dundee have shown that skin erythema and pre-cancer growth tests using KrCl* lamps were not prevented.
- Later tests with the same lamps with filter to minimize emission in the UV above 230 nm show that no erythema or pre-cancer growth was found.
- Ewan Eadie has tested his own upper arm with filtered KrCl* lamp emission dose up to 100 times that of the TLV with no signs of erythema.



Conclusions

- For human skin it seems likely that direct exposure for up to 8 hours with a dose level that will inactivate the virus in about 1 minute will not cause any harm.
  - ✓Long term testing is under way to confirm above conclusion
- For the human eye the above statement has not been confirmed. However direct exposure to the eye from systems mounted on the ceiling will significantly lower the time-weighted average exposure.
- This lamp source has other continuing uses for air and surface disinfection after the Covid-19 pandemic ends.



Acknowledgements

Ewen Eadie

Head of Scientific Services for Photobiology and Optical Radiation Photobiology Unit, Level 8, Ninewells Hospital, Dundee, Scotland

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Kenneth Wood

SUPA, School of Physics & Astronomy, University of St Andrews, St Andrews, Scotland

For providing spectral data in electronic form of the fluence as a function of depth for human skin based on Monte Carlo modeling