Far-UVC light to limit airborne transmission of SARS-CoV-2 ... and all other viruses

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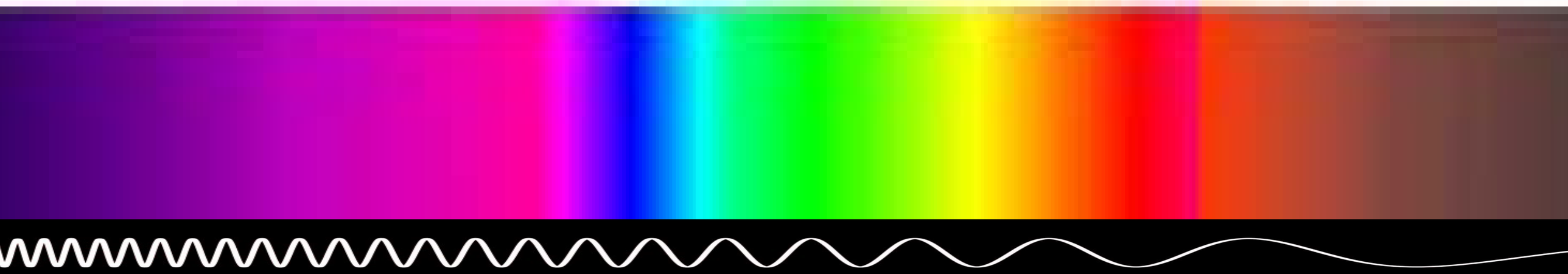
How can we kill airborne and surface viruses in occupied spaces?

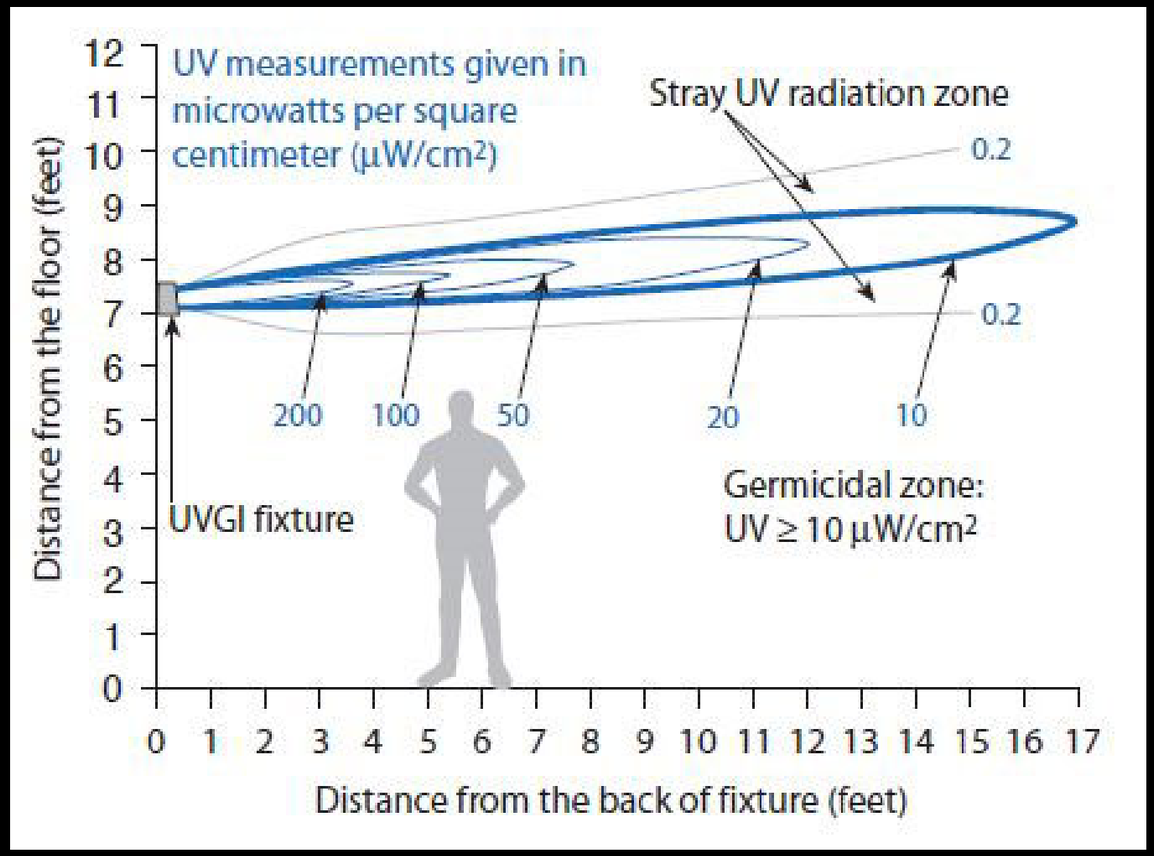
We already know how to kill every kind of microbe...

Ultraviolet light **Visible Light** **Infrared**

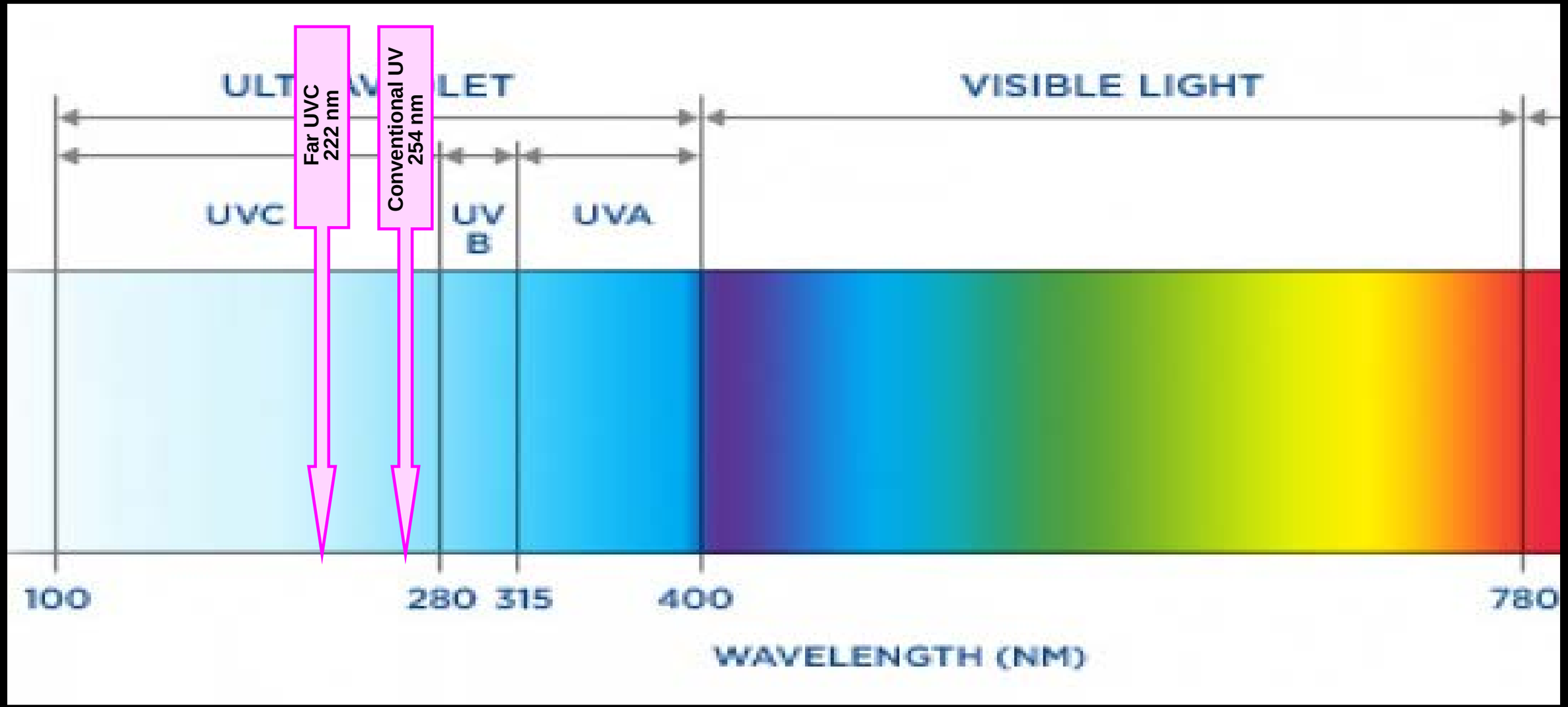


Conventional germicidal UV
can’t be shined directly onto occupied locations

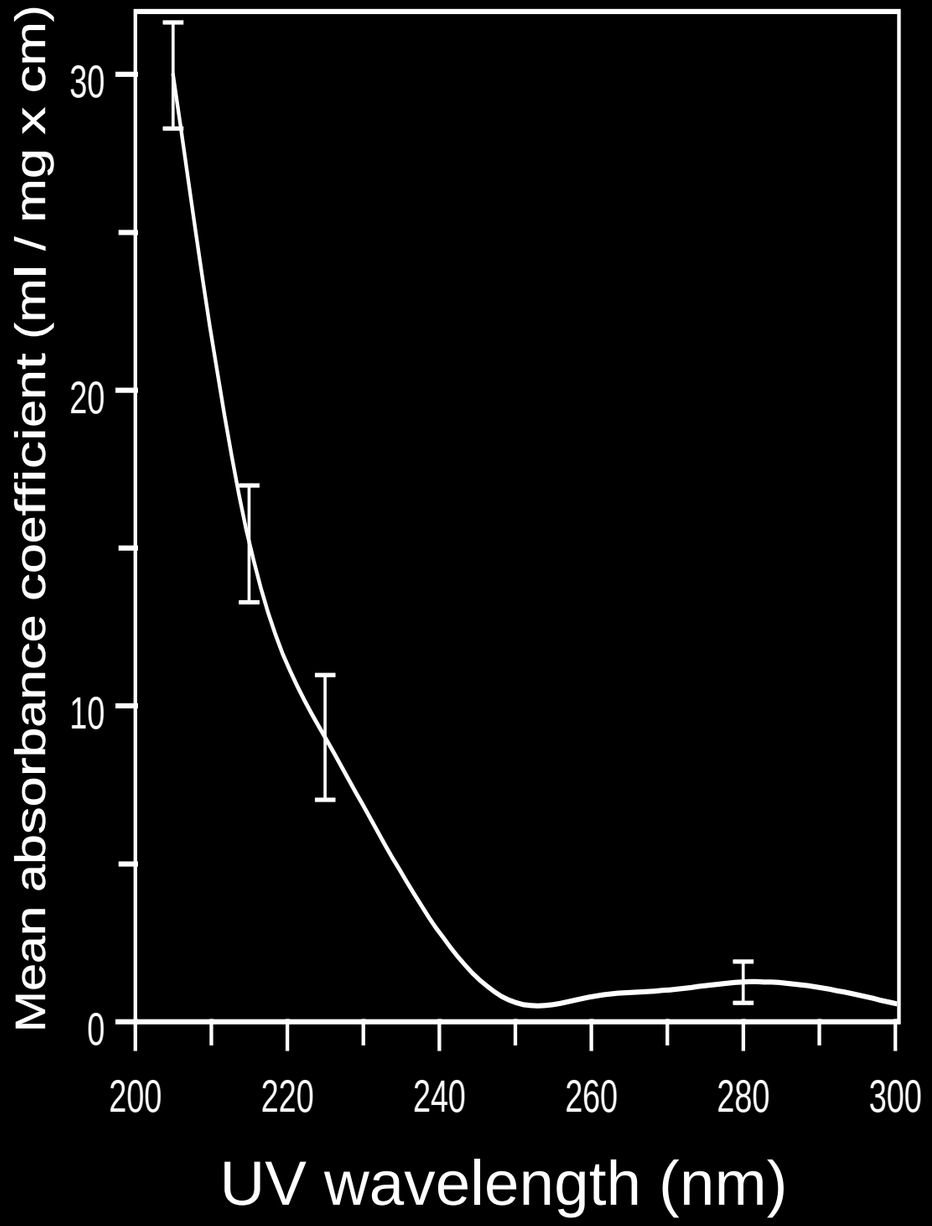
Conventional germicidal UV can't be shined directly onto occupied locations

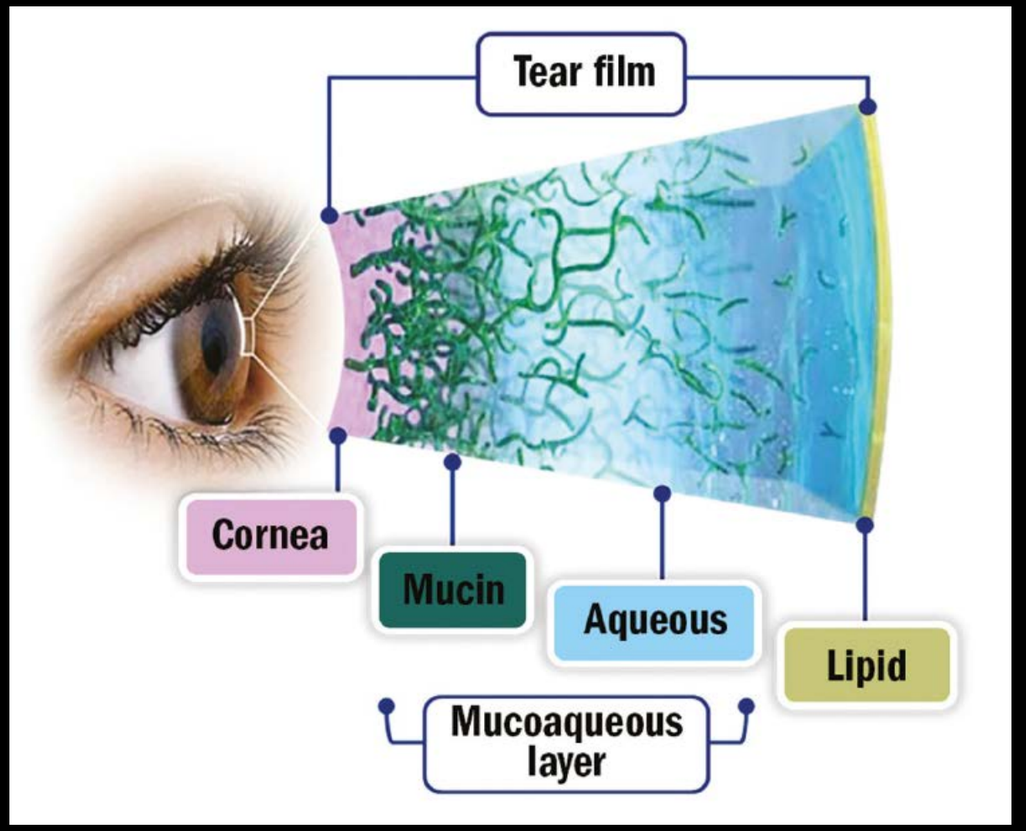


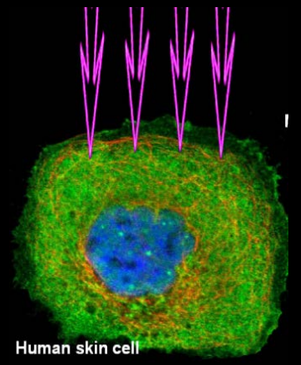
What we'd really like is a UV wavelength that will kill bacteria and viruses, but can be shined directly onto occupied locations



Mean wavelength-dependent UV absorbance coefficients, averaged over published measurements for eight common proteins





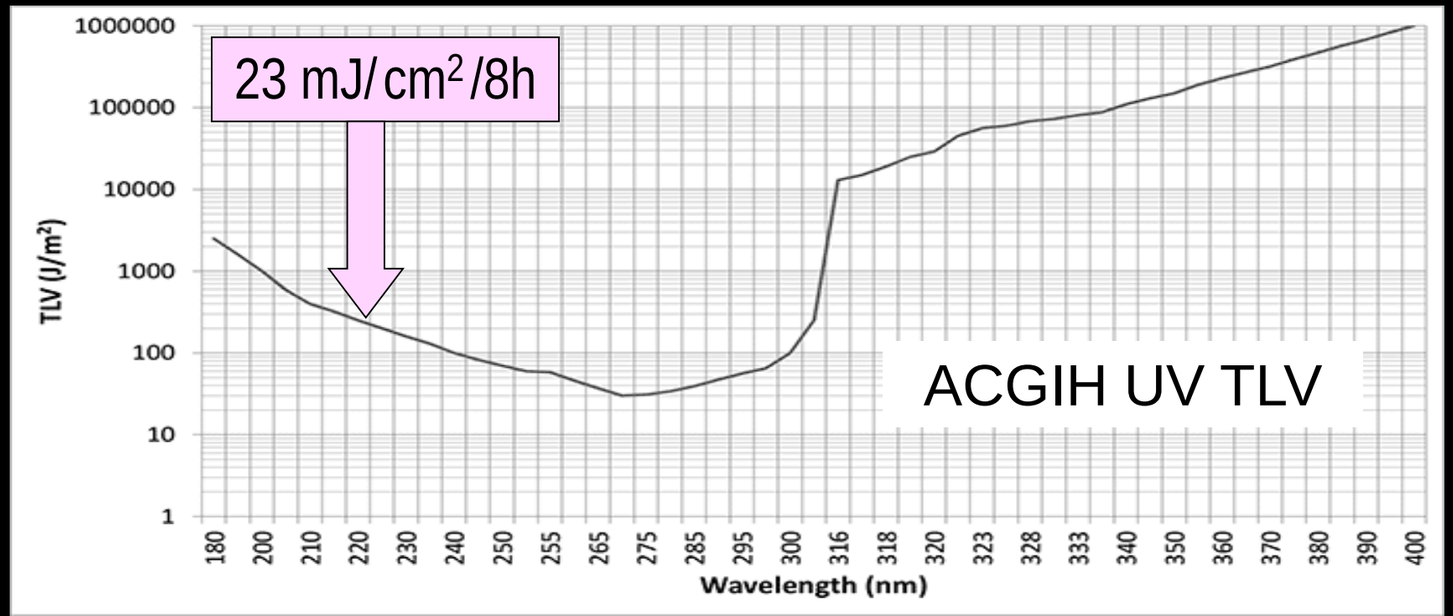


Far-UVC Light

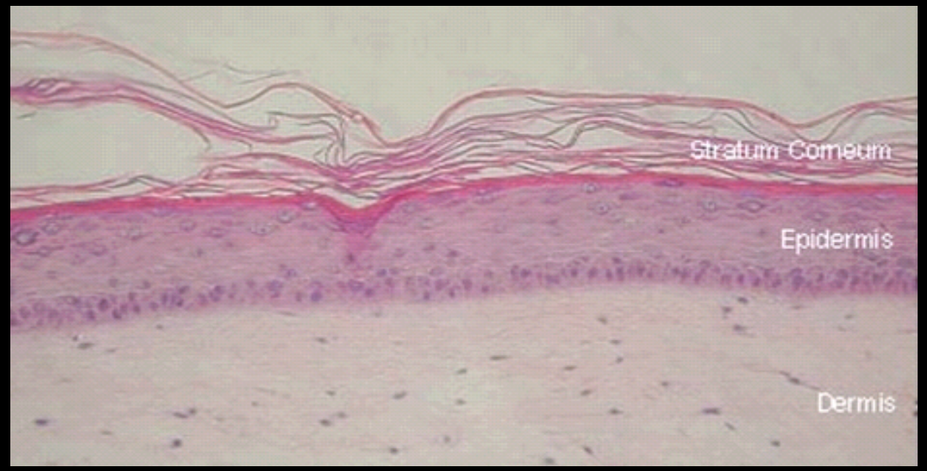
- Is it safe?
- Does it work?

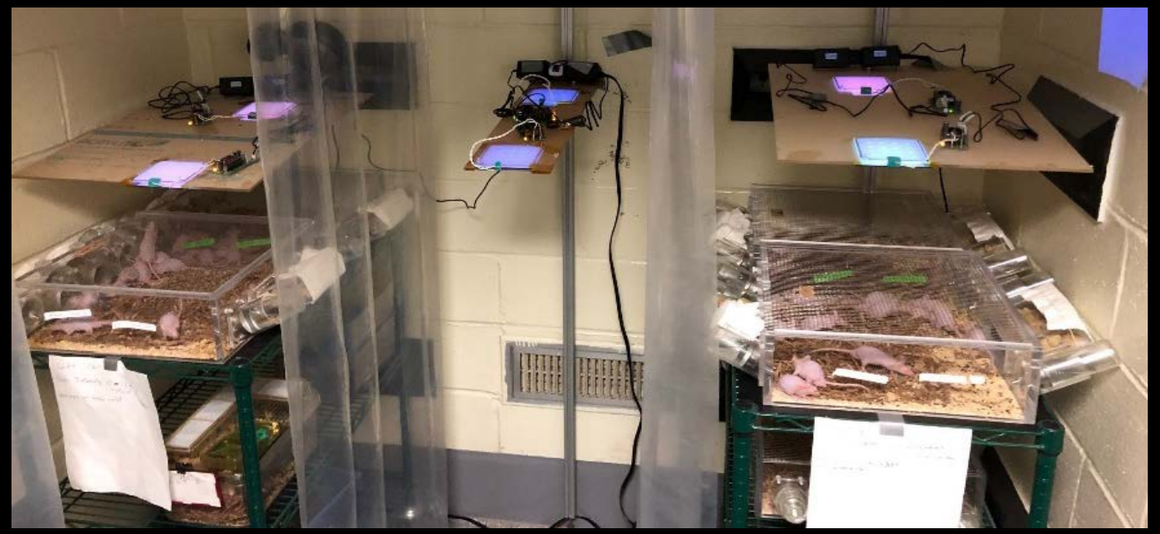
Far-UVC Safety

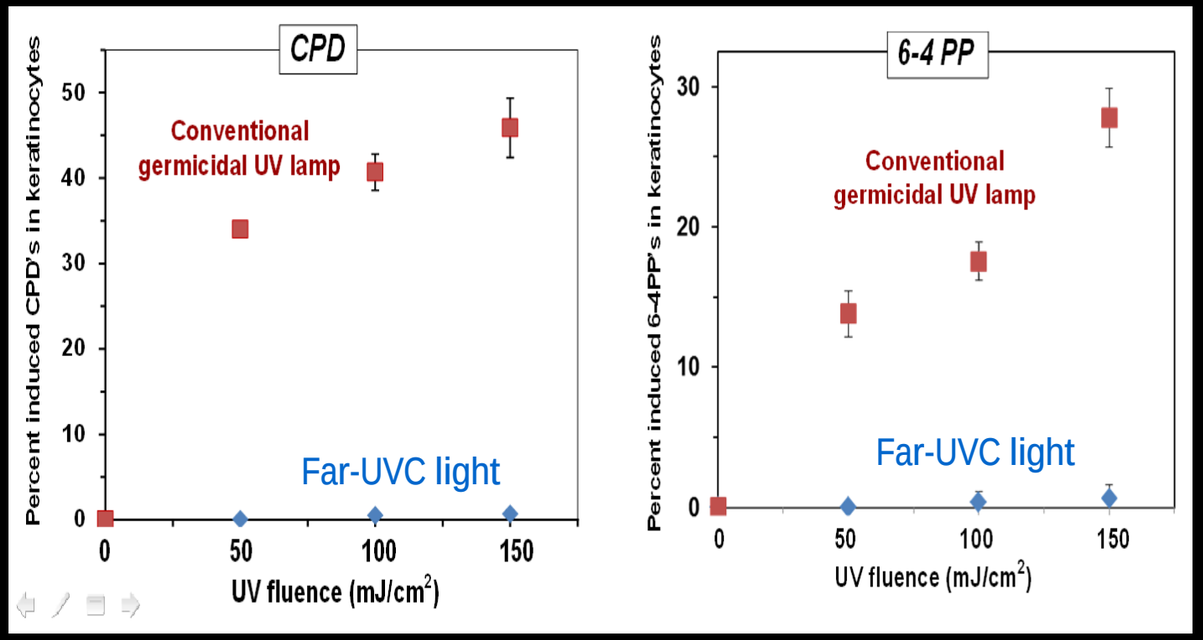
1. It’s the biophysics
2. Many studies, both at Columbia and elsewhere, human skin models, human skin, mouse skin, mouse eyes
3. There is an existing national and international safety regulatory framework



Far-UVC safety studies







60 Week Exposure Safety Study

100 SKH-1 hairless mice exposed 8 hrs / day to graded high doses of 222-nm far-UVC light

50 weeks into the study:
No skin lesions, no eye issues

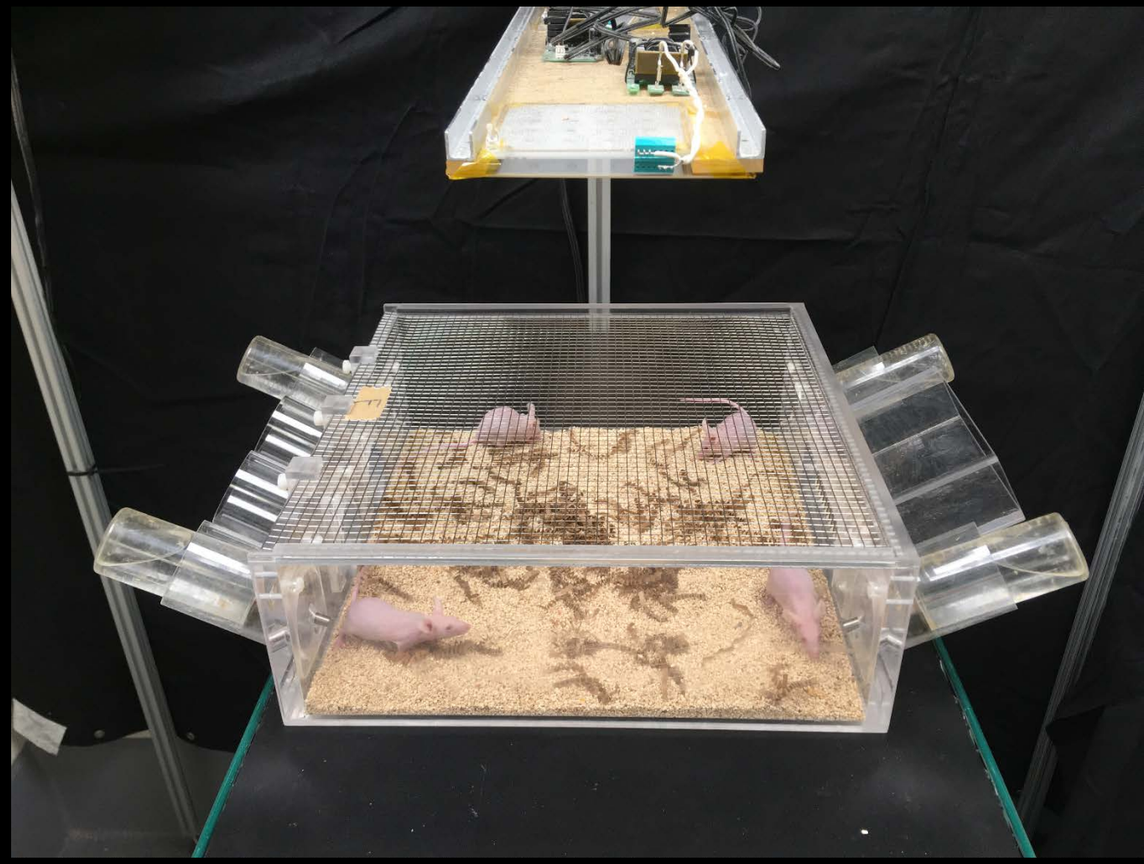
Long Term Hairless Mouse Study

- 222 nm excimer lamps with high-wavelength filter
- Daily doses of:
  - 500 mJ/cm^2
  - 250 mJ/cm^2
  - 125 mJ/cm^2
- 8 hours per day
- 5 days per week
- Automated on/off
- 60 weeks total
- Custom mouse cages

- **Hairless albino SKH-1 mice**

- **12 males, 12 females per fluence (total 96 mice)**

- **60 week study:**
  - ⇒ **Regular exams during study**
  - ⇒ **Currently in week 48**



- Skin and eyes examined for DNA lesions and abnormal pathology at end of study

Eye Exams: Details

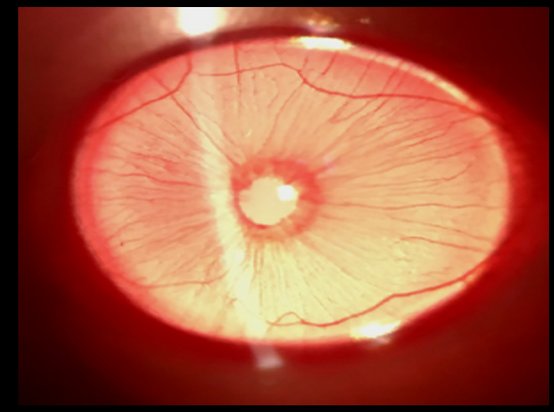
- Daily for the first week
- Weekly for the next 3 weeks
- Bimonthly for the next 2 months
- Monthly thereafter:

  Slit lamp biomicroscopic exams of the anterior segment of each eye (ocular adnexa, limbus, cornea, iris and lens).

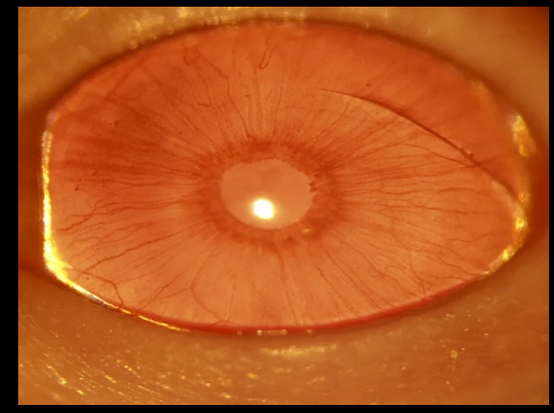
  Assess inflammation, neovascularization, intraocular pressure, abnormal cell growth, and corneal and lens transparency

- As of week 48:

  No UV related eye pathology vs controls



Before study, Aug 2019



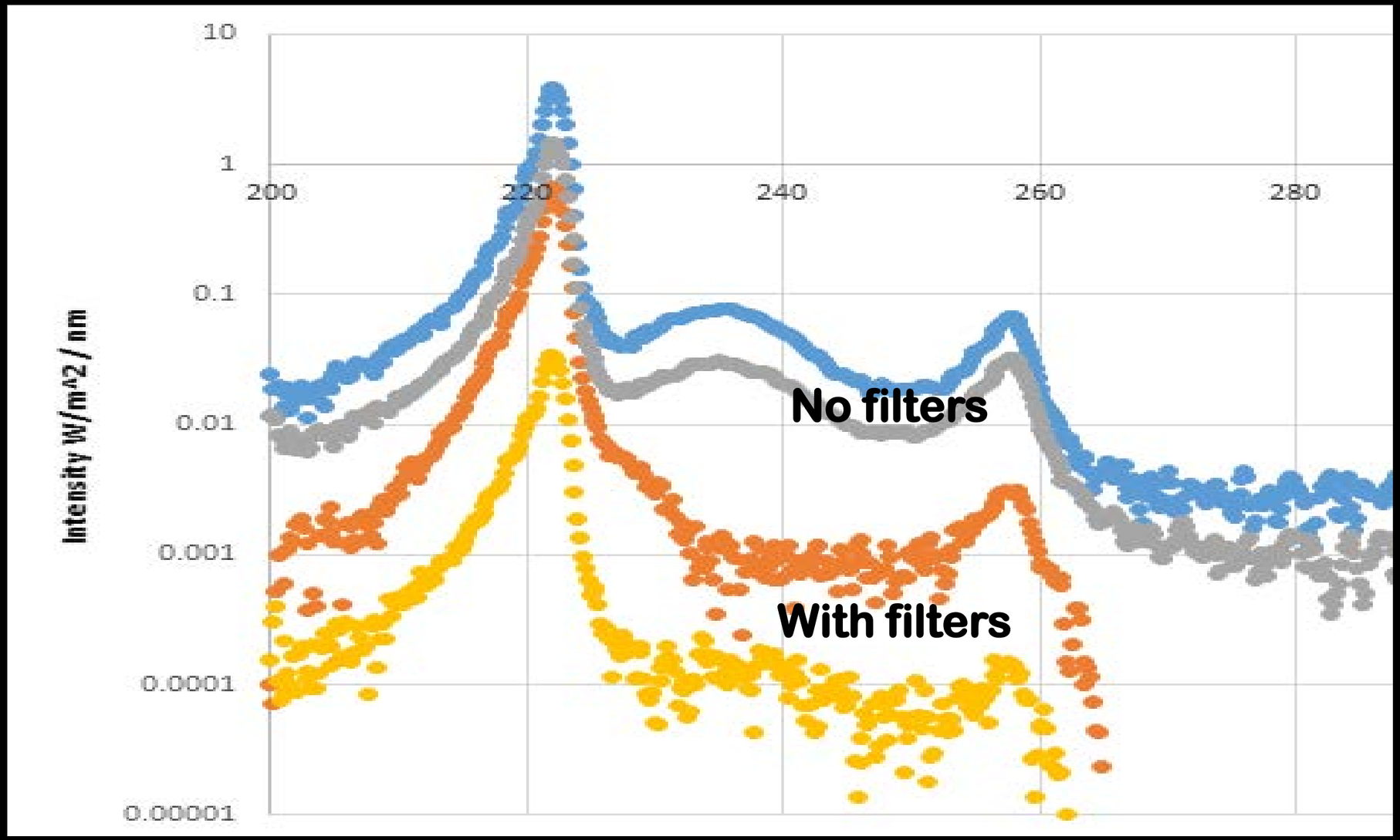
Typical screening image

Are mice a good model for far-UVC light safety in humans?

- **Central to the biophysical rationale for the safety of far-UVC light is the shielding effect of the stratum corneum for skin and of the tear layer for the eyes**
- **So the key determinant of the relevance of the mouse models to human safety is the relative thickness (mouse vs. human) of the stratum corneum and the relative thickness (mouse vs human) of the ocular tear layer**

	Mouse (μm)	Human (μm)
Stratum corneum thickness	5.8±0.3	16.8±0.7
Ocular tear layer thickness	7.4±0.8	6.0±2.4

222 nm Kr-Cl Excimer Lamps: Higher wavelength contaminants and filtration



Human Skin Safety without Filter

Photodermatology, Photoimmunology & Photomedicine

ORIGINAL ARTICLE

The effect of 222-nm UVC phototesting on healthy volunteer skin: a pilot study

Julie A Woods[1], Alan Evans[2], Paul Donald Forbes[3], Philip J Coates[4], June Gardner[1], Ronan M Valentine[1], Sally H Ibbotson[1], James Ferguson[5], Christopher Fricker[6] & Harry Moseley[1]

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Key words:
cyclobutane pyrimidine dimers; human skin; phototesting; volunteer study; UVC; 222-nm non-ionizing radiation

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Accepted for publication:
7 December 2014

Conflicts of interest:
None.

ABSTRACT

...hands is now common in healthcare and ...ly, the use of such antiseptics will present ...d allergic dermatitis. New, less irritant and ...pproaches are under investigation.

...22 nm) conventionally used to sterilize ... assessed for tolerability in human skin. Using ...ge study methodology, four skin phototype I and II healthy vo... ...ir minimal erythema dose (MED) determined. Punch biopsies o... ...tes were stained for cyclobutane pyrimidine dimers (CPD). The degre... ...was compared with that in biopsies from unexposed skin and from areas ... ...d to UVB (280–315 nm) radiation.

Results

Calibrated spectral measurements revealed emission at a peak wavelength of 222 nm with 97% emission at wavelengths less than 250 nm. At low doses below the threshold bacteriostatic effect, the source was capable of inducing both erythema and CPD formation in human skin. In two individuals, cells in the basal layer were not shielded by the overlying tissue as indicated by the presence of CPD.

Conclusion

The source showed an erythemogenic or CPD potential at lower doses than those required to reach the reported threshold bacteriostatic effect.

"At low doses…. The source was capable of inducing both erythema and CPD formation in human skin "

Human Skin Safety with filter

Exploratory clinical trial on the safety and bactericidal effect of 222-nm ultraviolet C irradiation in healthy humans

Tomoaki Fukui[1], Takahiro Niikura[1]*, Takahiro Oda[1], Yohei Kumabe[1], Hiroyuki Ohashi[2], Masahiro Sasaki[2], Tatsushi Igarashi[2], Makoto Kunisada[3], Nozomi Yamano[3], Keisuke Oe[1], Tomoyuki Matsumoto[1], Takehiko Matsushita[1], Shinya Hayashi[1], Chikako Nishigori[3], Ryosuke Kuroda[1]

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OPEN ACCESS

Citation: Fukui T, Niikura T, Oda T, Kumabe Y, Ohashi H, Sasaki M, et al. (2020) Exploratory clinical trial on the safety and bactericidal effect of 222-nm ultraviolet C irradiation in healthy humans. PLoS ONE 15(8): e0235948. https://doi.org/10.1371/journal.pone.0235948

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Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Funding: This study is mainly funded by Department of Orthopaedic surgery, Kobe University Graduate School of Medicine and partially supported by Ushio Inc. including rental of UVC irradiation equipment. The funding agency provided support in the form of salaries for the authors (H.O., M.S., and T.I.). The specific roles of them are as follows; H.O.: data curation and

...avelength of 222 nm reaches only the stratum corneum, it does ... This study aimed to investigate the safety of 222-nm UVC irradiat... ...s skin sterilization effect in healthy volunteers.

Methods

This trial was ...cted on 20 healthy volunteers. The back of the subject was irradiated with 222-nm ...C at 50–500 mJ/cm^2, and the induced erythema (redness of skin) was evaluated. Subsequently, the back was irradiated with a maximum amount of UVC not causing erythema, and the skin swabs before and after the irradiation were cultured. The number of colonies formed after 24 hours was measured. In addition, cyclobutene pyrimidine dimer (CPD) as an indicator of DNA damage was measured using skin tissues of the nonirradiated and irradiated regions.

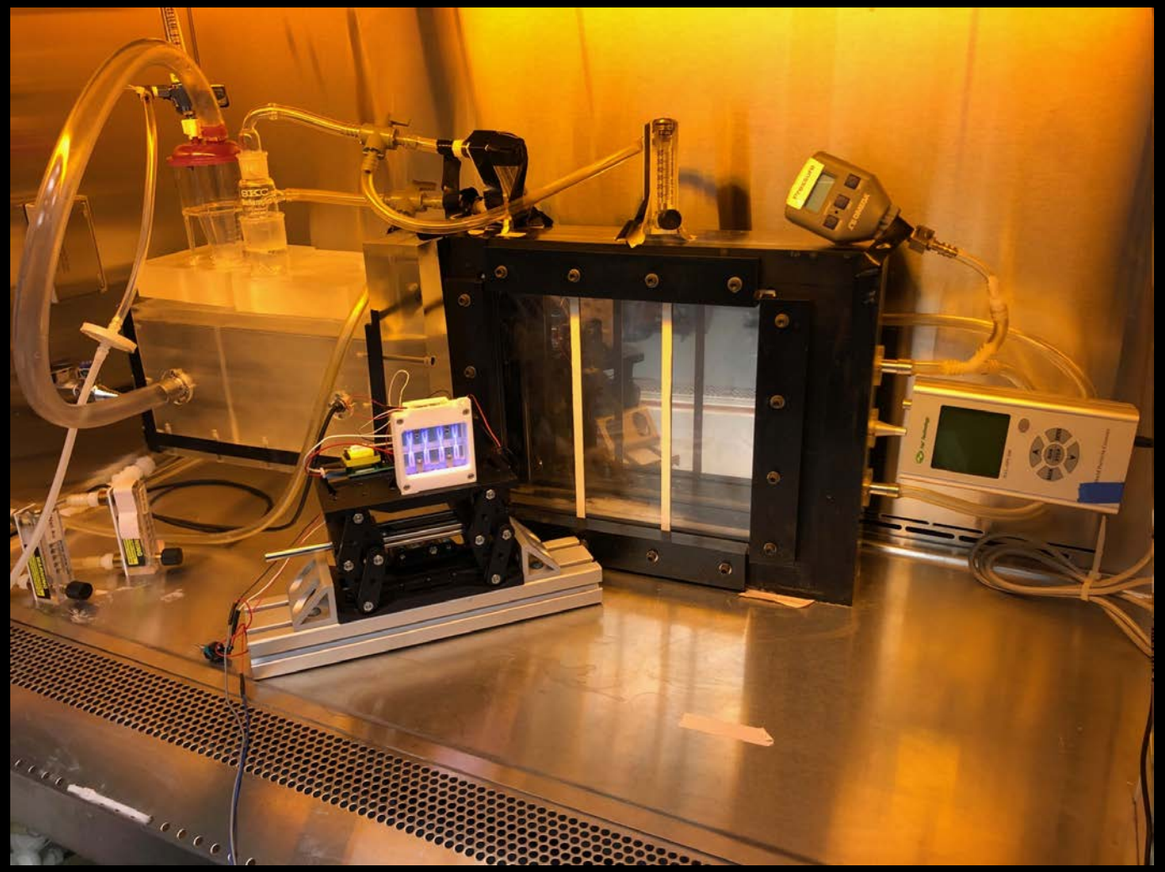
Results

All subjects experienced no erythema at all doses. The back of the subject was irradiated at 500 mJ/cm^2, and the number of bacterial colonies in the skin swab culture was significantly decreased by 222-nm UVC irradiation. The CPD amount produced in the irradiated region was slightly but significantly higher than that of the non-irradiated region.

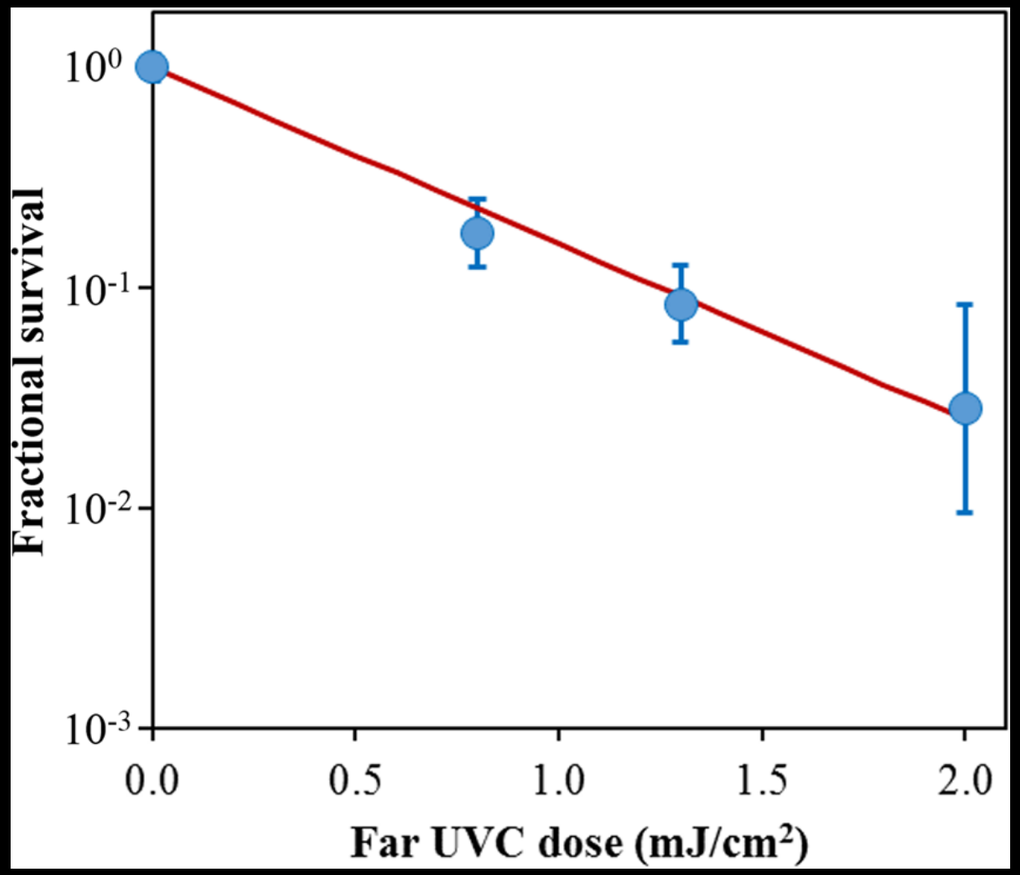
"The back of the subject was irradiated with 222 nm UVC at 5-500 mJ/cm^2 and the induced erythema was evaluated…. All subjects experienced no erythema at all doses"

Far-UVC efficacy studies

222 nm inactivation of aerosolized H1N1 influenza virus



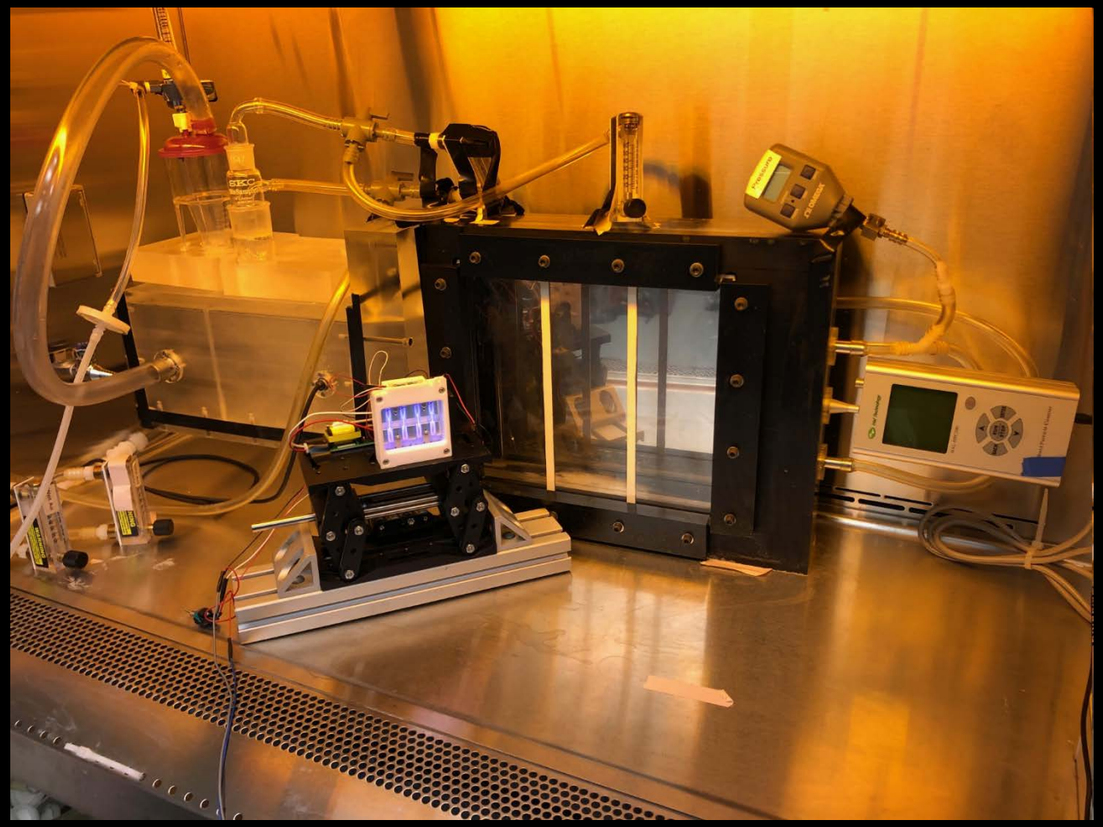
$TCID_{50}$ technique



Welch et al 2018

Far-UVC efficacy studies

Far-UVC inactivation of aerosolized coronaviruses



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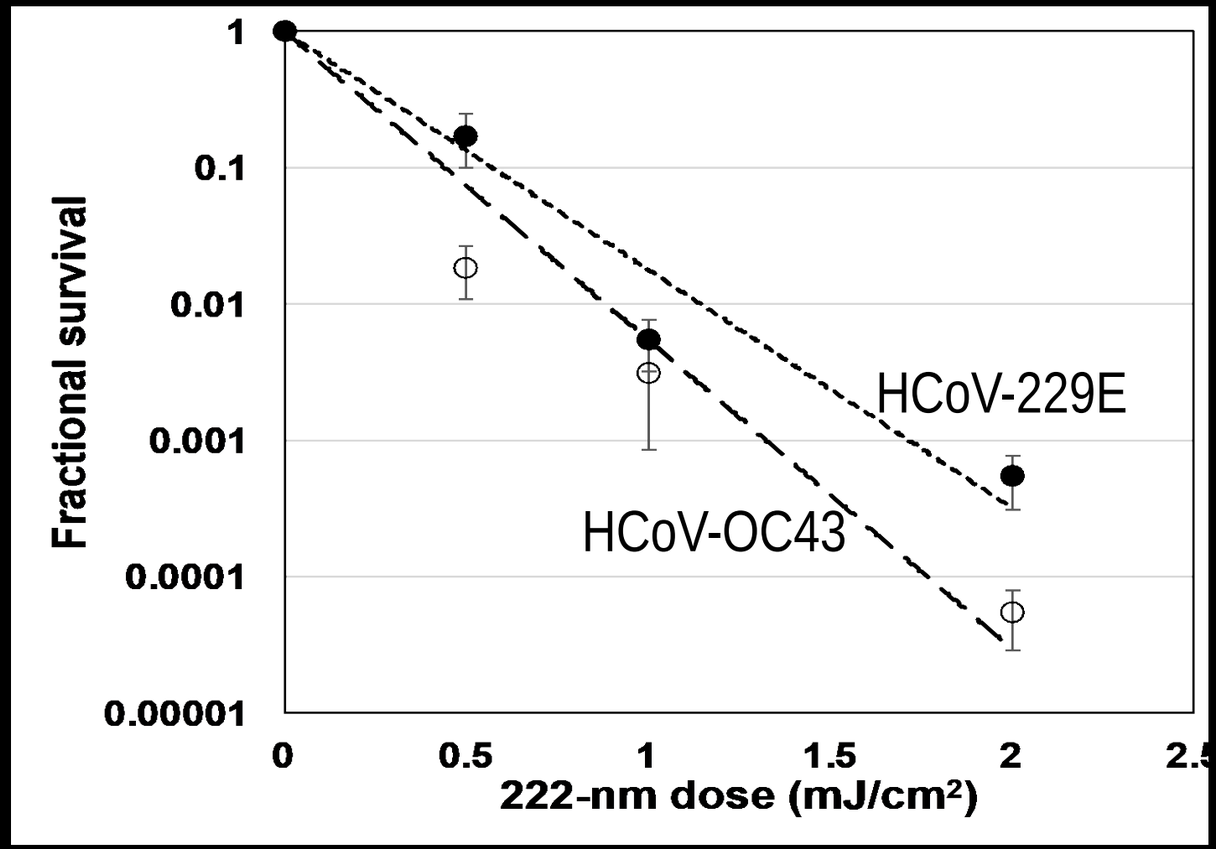

Buonanno et al 2020

SCIENTIFIC REPORTS | (2020) 10:10285 | https://doi.org/10.1038/s41598-020-67211-2

SCIENTIFIC REPORTS

nature research

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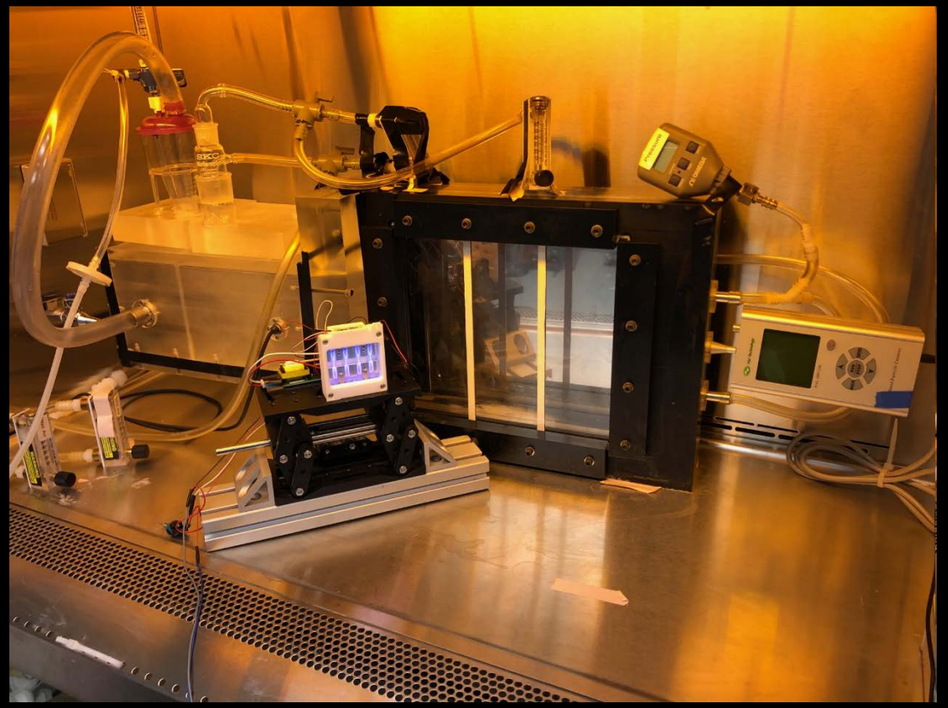
Far-UVC light (222 nm) efficiently and safely inactivates airborne human coronaviruses

Manuela Buonanno, David Welch, Igor Shuryak & David J. Brenner ✉

A direct approach to limit airborne viral transmissions is to inactivate them within a short time of their production. Germicidal ultraviolet light, typically at 254 nm, is effective in this context but, used directly, can be a health hazard to skin and eyes. By contrast, far-UVC light (207–222 nm) efficiently kills pathogens potentially without harm to exposed human tissues. We previously demonstrated that 222-nm far-UVC light efficiently kills airborne influenza virus and we extend those studies to explore far-UVC efficacy against airborne human coronaviruses alpha HCoV-229E and beta HCoV-OC43. Low doses of 1.7 and 1.2 mJ/cm^2 inactivated 99.9% of aerosolized coronavirus 229E and OC43, re... As all human coronaviruses have similar genomic sizes, far-UVC light would be expected to show similar inactivation efficiency against other human coronaviruses including SARS-CoV-2. Based on the beta-HCoV-OC43 results, continuous far-UVC exposure in occupied public locations at the current regulatory exposure limit (~3 mJ/cm^2/hour) would result in ~90% viral inactivation in ~8 minutes, 95% in ~11 minutes, 99% in ~16 minutes and 99.9% inactivation in ~25 minutes. Thus while staying within current regulatory dose limits, low-dose-rate far-UVC exposure can potentially safely provide a major reduction in the ambient level of airborne coronaviruses in occupied public locations.



"Based on the HCoV-OC43 results, continuous far-UVC exposure in occupied public locations at the current regulatory exposure limit (3 mJ/cm2/hour) would result in ~90% viral inactivation in ~8 minutes, 95% in ~11 minutes, 99% in ~16 minutes and 99.9% inactivation in ~25 minutes"

Buonanno et al 2020

American Journal of Infection Control 000 (2020) 1–3

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American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Effectiveness of 222-nm ultraviolet light on disinfecting SARS-CoV-2 surface contamination

Hiroki Kitagawa MD [a,b,c,*], Toshihito Nomura MD, PhD [b,d], Tanuza Nazmul MBBS [d], Keitaro Omori MD, PhD [b], Norifumi Shigemoto MD, PhD [a,b,c,e], Takemasa Sakaguchi MD, PhD [d], Hiroki Ohge MD, PhD [a,b]

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Key Words:
COVID-19
Environmental contamination
Disinfection
Far-UVC

Background: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes coronavirus disease 2019 (COVID-19), has emerged as a serious threat to human health worldwide. Efficient disinfection of surfaces contaminated with SARS-CoV-2 may help prevent its spread. This study aimed to investigate the in vitro efficacy of 222-nm far-ultraviolet light (UVC) on the disinfection of SARS-CoV-2 surface contamination.
Methods: We investigated the titer of SARS-CoV-2 after UV irradiation (0.1 mW/cm^2) at 222 nm for 10-300 seconds using the 50% tissue culture infectious dose ($TCID_{50}$). In addition, we used quantitative reverse transcription polymerase chain reaction to quantify SARS-CoV-2 RNA under the same conditions.
Results: One and 3 mJ/cm^2 of 222-nm UVC irradiation (0.1 mW/cm^2 for 10 and 30 seconds) resulted in 88.5 and 99.7% reduction of viable SARS-CoV-2 based on the $TCID_{50}$ assay, respectively. In contrast, the copy number of SARS-CoV-2 RNA did not change after UVC irradiation even after a 5-minute irradiation.
Conclusions: This study shows the efficacy of 222-nm UVC irradiation against SARS-CoV-2 contamination in an in vitro experiment. Further evaluation of the safety and efficacy of 222-nm UVC irradiation in reducing the contamination of real-world surfaces and the potential transmission of SARS-CoV-2 is needed.

Ongoing developments

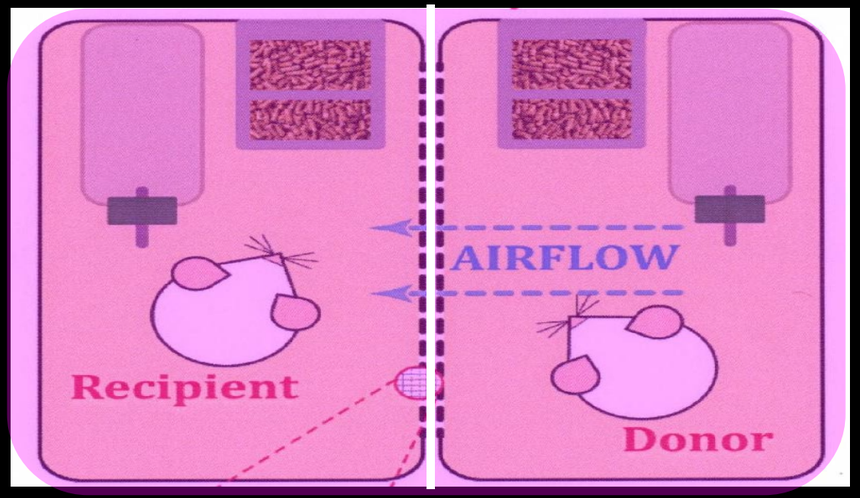
- **Airborne transmission animal models to better understand the influence of environmental factors**

Ferrets

Syrian Hamsters

Humanized (ACE2) mice

Guinea pigs for influenza



Ongoing developments

- **Understanding wavelength specific risks**

Ongoing developments

- **Understanding wavelength specific risks**

Newport 1000 Xe light source, UV enhanced

Cornerstone 260 1/4 m UV-Vis Monochromator

Some future developments for far-UVC light

- **Installing and testing far-UVC lights:**
  - ***Demonstration projects***
  - ***Real world projects***

- **A demonstration project at the New York Presbyterian Hospital Gamma Knife Facility**




Where and how could far-UVC light be used?

- In any indoor situation where people are coming close together…. Restaurants, food preparation facilities, hospitals, nursing homes, dental clinics, buses, trains, planes, train stations, offices, schools, shops,, theaters, gyms….