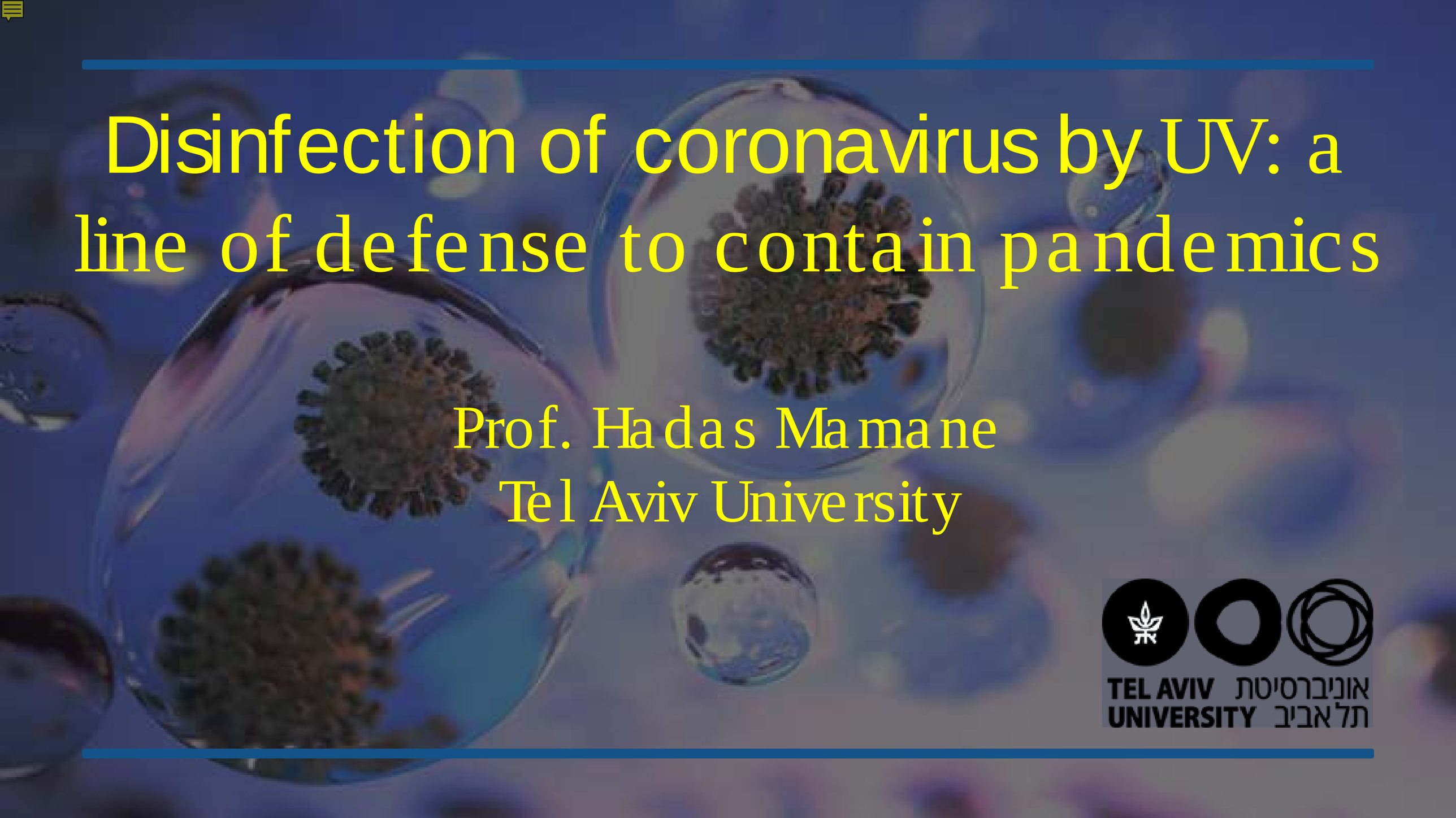
Disinfection of coronavirus by UV: a line of defense to contain pandemics

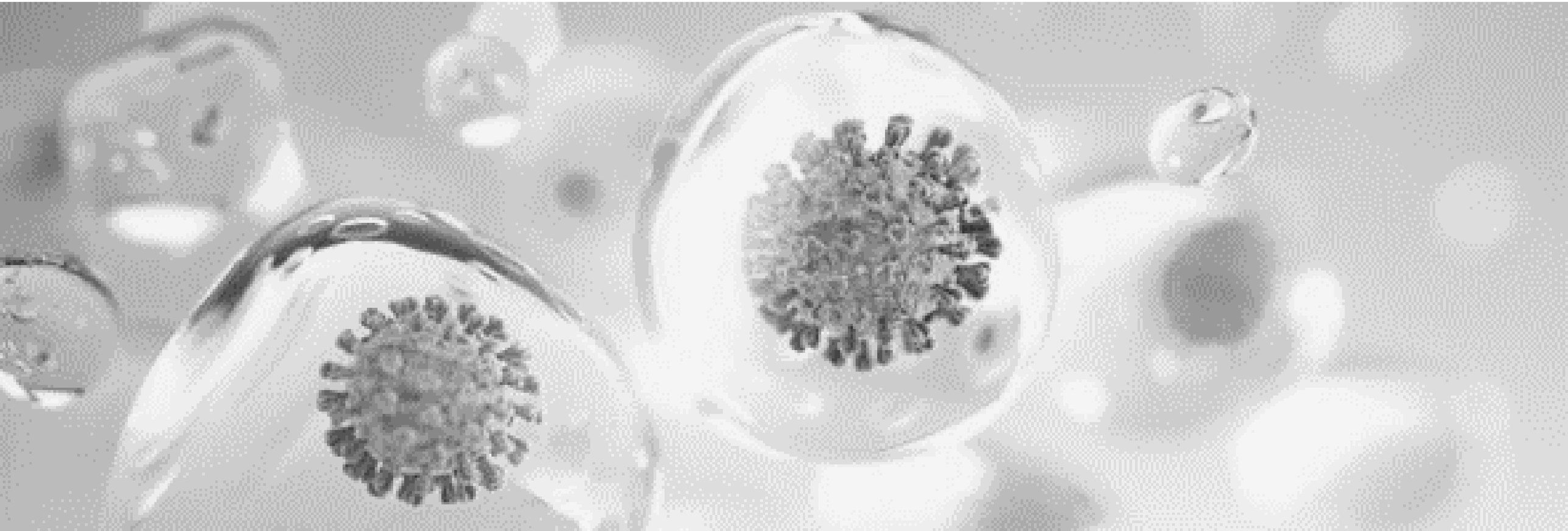
Prof. Hadas Mamane
Tel Aviv University



Airborne transmission of SARS-CoV-2 is significant and should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures.

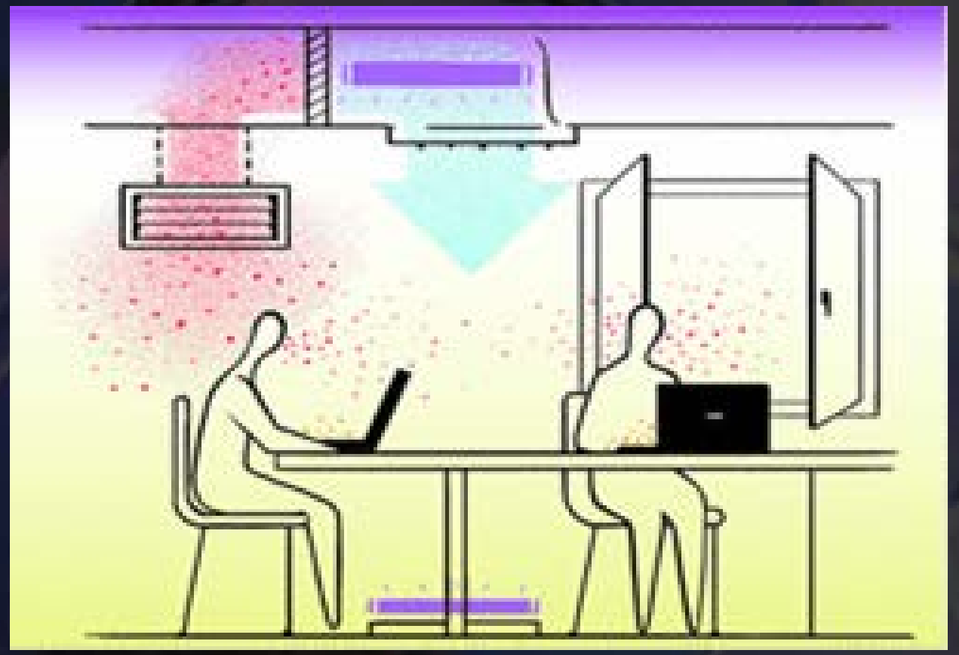
ASHRAE

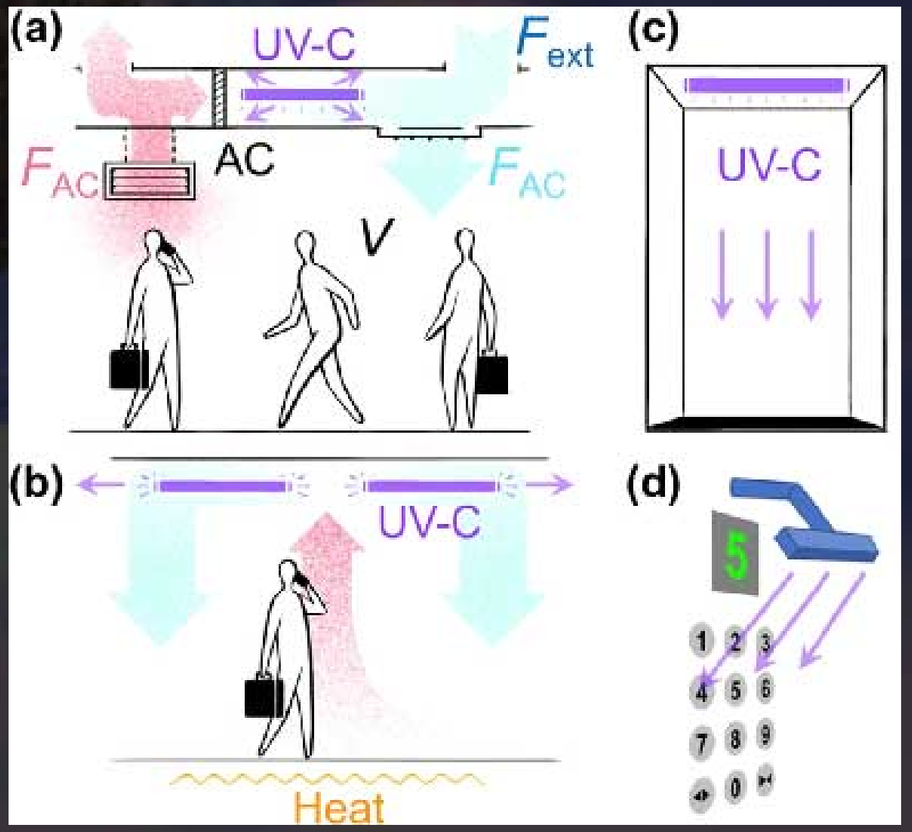
Can we use UV against airborne viruses?



Options for integrating UV systems

"we advocate for one measure that is particularly efficient, easily deployable, and economically affordable: virus inactivation by ultraviolet light."

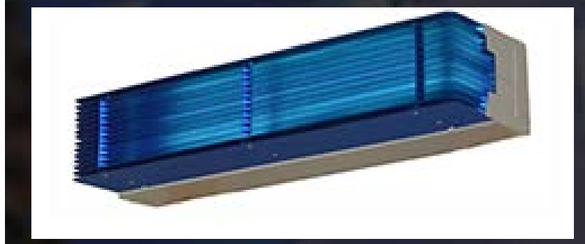


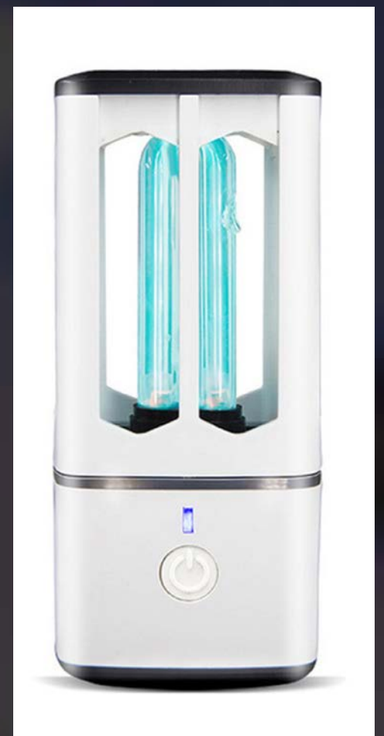


Back to Normal: An Old Physics Route to Reduce SARS-CoV-2 Transmission in Indoor Spaces
F. Javier García de Abajo, Rufino Javier Hernández, Ido Kaminer, Andreas Meyerhans, Joan Rosell-Llompart, and Tilman Sanchez-Elsner. *ACS Nano* **2020** *14* (7), 7704-7713

Types of disinfection systems using UV-C

- In-duct air disinfection
- Upper-air disinfection
- In-duct surface disinfection – coil disinfection not air
- Portable room decontamination





Most applications coil disinfection

This is surface disinfection not air

Our goal: UV in air ducts

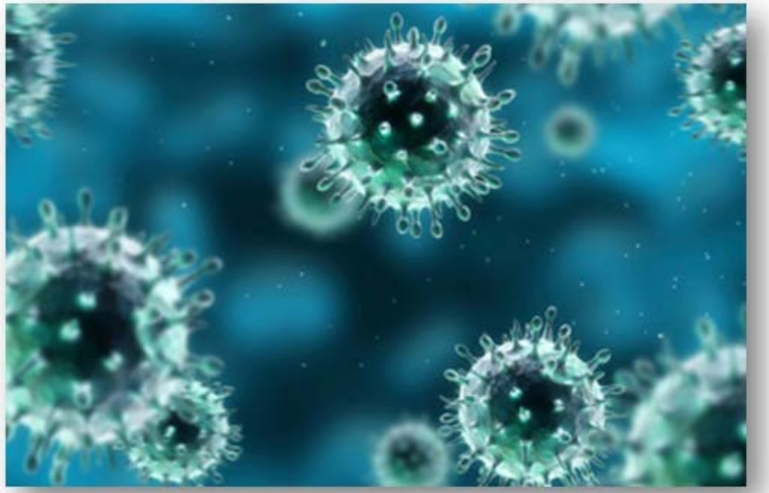
1

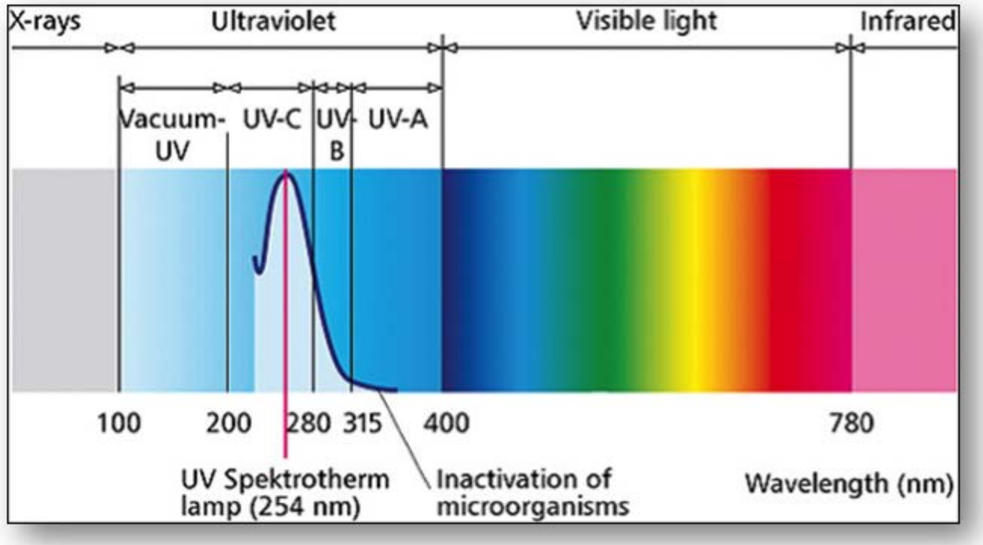
2

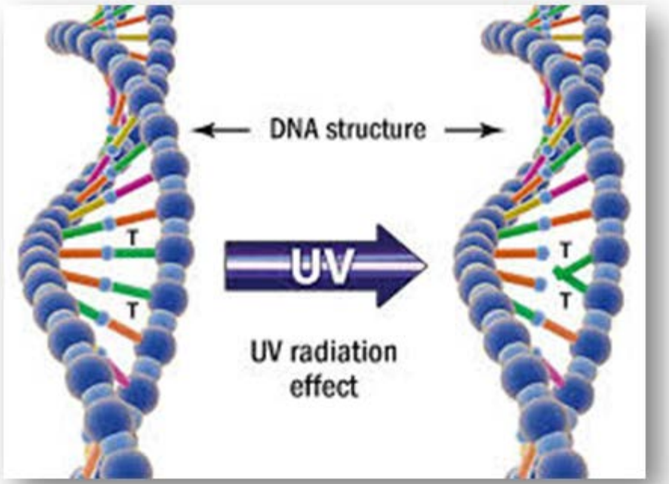
3

Designed to disinfect air as it circulates through a building

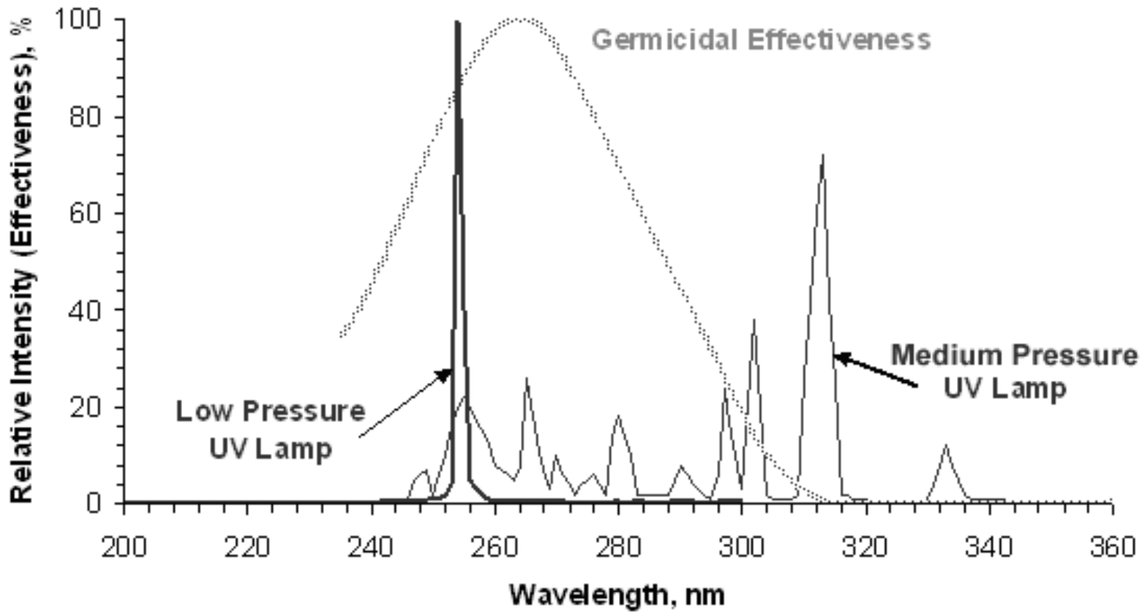
UV disinfection

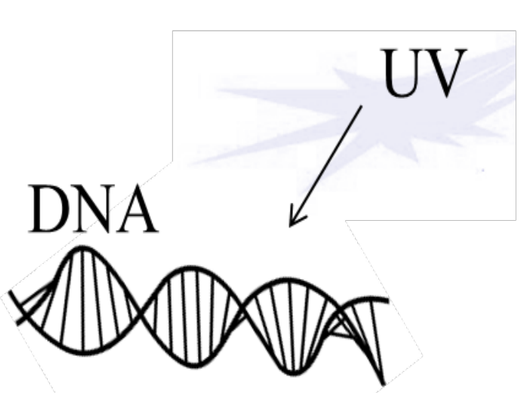


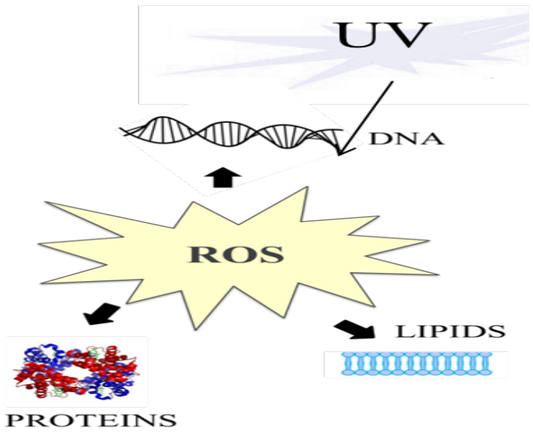


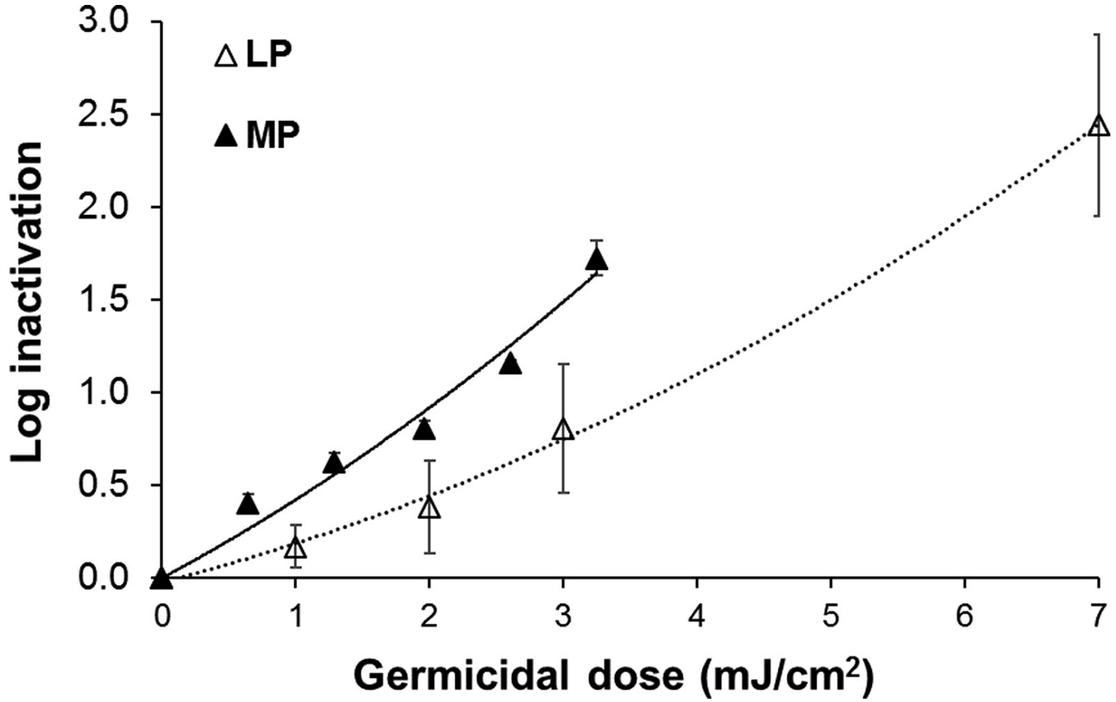


The common UV technology – Mercury vapor UV lamps



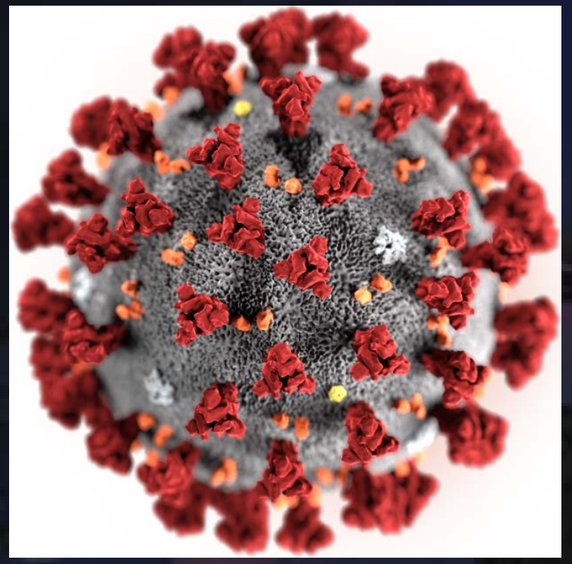


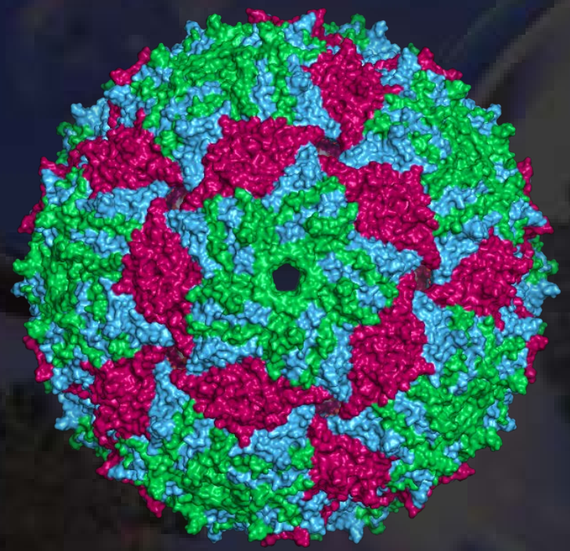


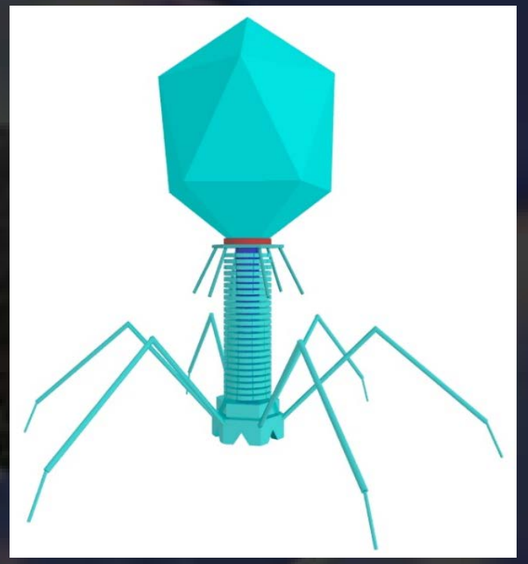


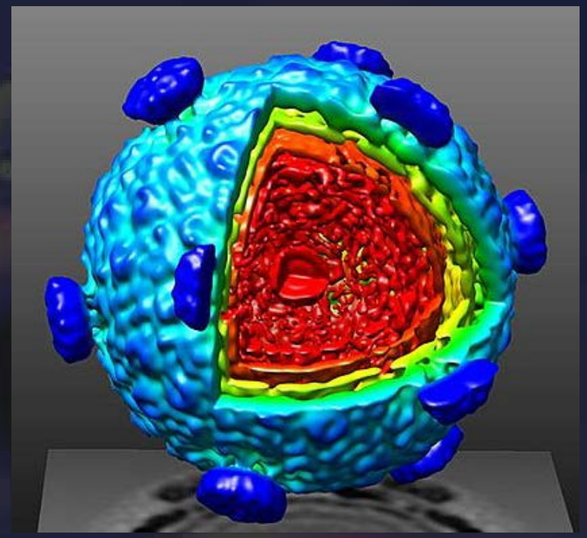
Gerchman … Mamane, 2019, Water Research

The SARS-CoV-2 and the model viruses







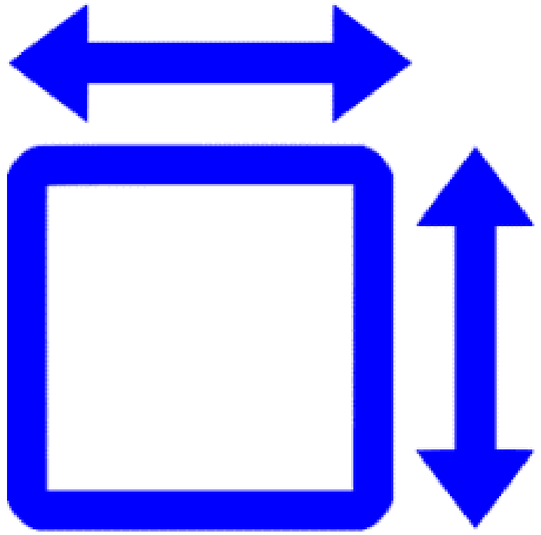


SARS-CoV-2	MS2	T4	phi6
ssRNA	ssRNA	DNA	dsRNA
29,900 b	3,569 b	169,000 bp	13,500 bp
Membrane coated	No membrane	No membrane	Membrane coated

UV LEDs

water

air



surface

Guidelines

ASHRAE®

INTERNATIONAL STANDARD

ISO 15714

First edition
2019-07

EPA United States Environmental Protection Agency

TECHNOLOGY EVALUATION REPORT

Biological Inactivation Efficiency by HVAC In-Duct Ultraviolet Light Systems

American Ultraviolet Corporation ACP-24/HO-4

Office of Research and Development
National Homeland Security
Research Center

Method of evaluating the UV dose to airborne microorganisms transiting in-duct ultraviolet germicidal irradiation devices

Méthode d'évaluation de la dose d'UV pour les microorganismes en suspension dans l'air transitant par des dispositifs d'irradiation germicide aux ultraviolets raccordés

Air disinfection

High UV doses to inactivate microorganisms:

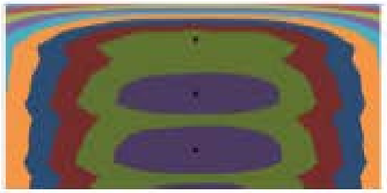
- Minimum target UV dose of 1,500 $\mu J/cm^2$
- 500 fpm moving airstream (680 m^3hr)
- Minimum irradiance zone of two feet
- Minimum UV exposure time of 0.25 second

Should always be coupled with mechanical filtration.

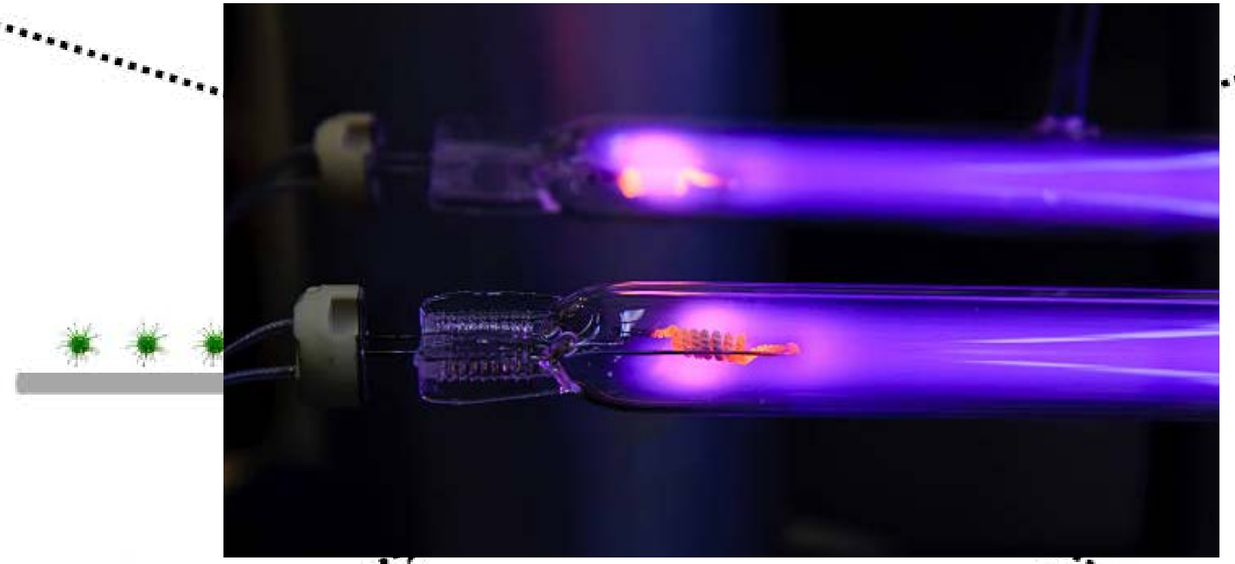
- MERV 8 filter for dust control
- Highest practical MERV filter recommended

Design of UV systems

Optical Design



No photon left behind !



Biological Testing

Thermal Design

Natural or forced

Mechanical

Parameters needed to design UV inactivation experiments

$$UV\ dose = P \times t/A = \frac{P}{Q} L$$

P = UV output in Watt

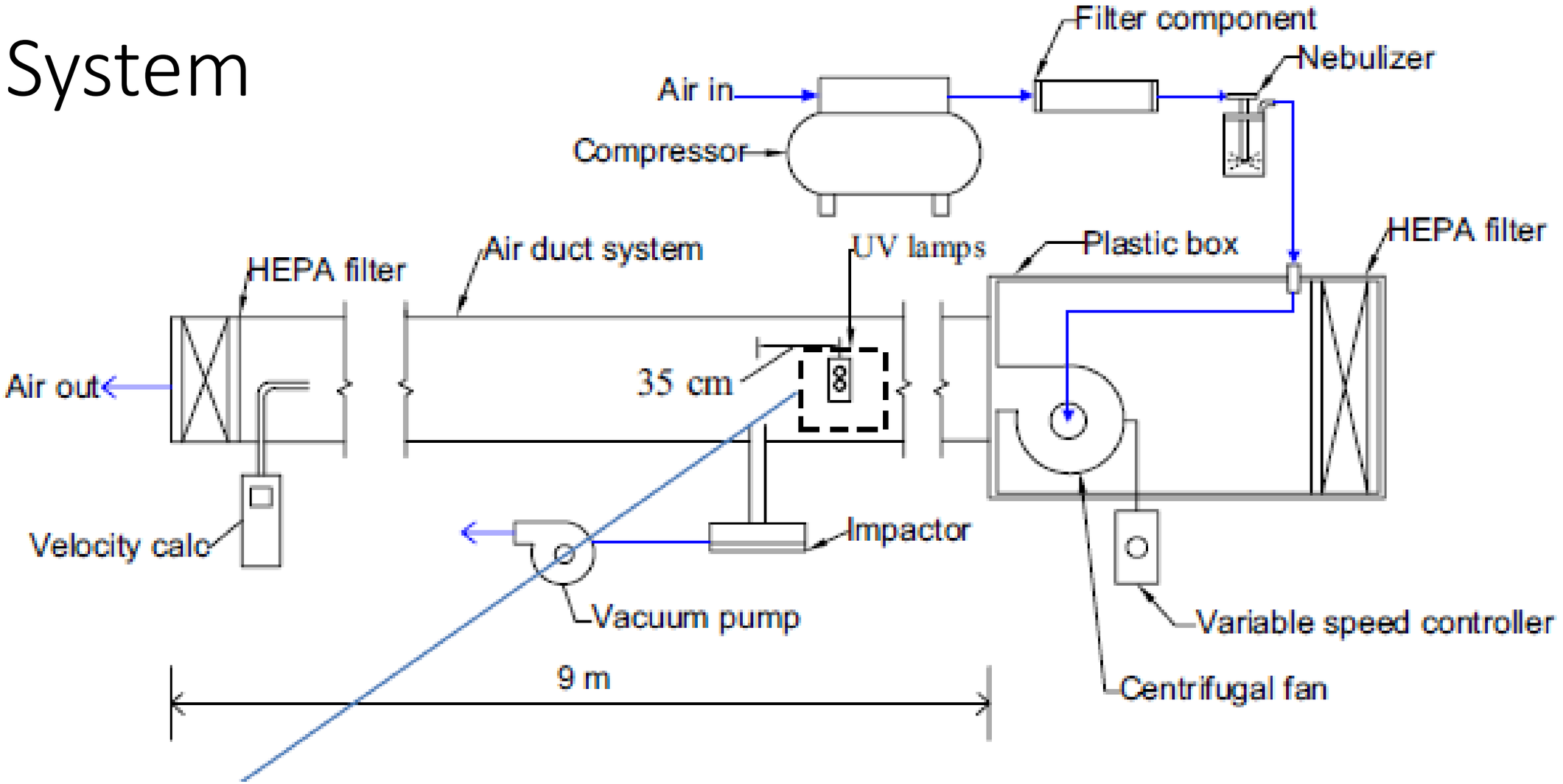
Q = Air flow in m^3/sec

L = UV exposure length

duct cross section A in m^2

- ✓ Air flow rate
- ✓ Height, Width, and Length of duct
- ✓ % reflectivity of inner surfaces
- ✓ Irradiance (single lamp): for example - $\mu W/cm^2$ @ 1 meter
- ✓ Lamp UV output power (W), UV output, lamp length and diameter, lifetime, ozone-free, voltage, Amps
- ✓ Lamp fixtures mounting, easy installation, replacement, check lamp output
- ✓ In-line operation and lamp status indicator for operators
- ✓ Position coordinates of each lamp (xi, yi, zi)
- ✓ Target microorganism rate constant k in m^2/J

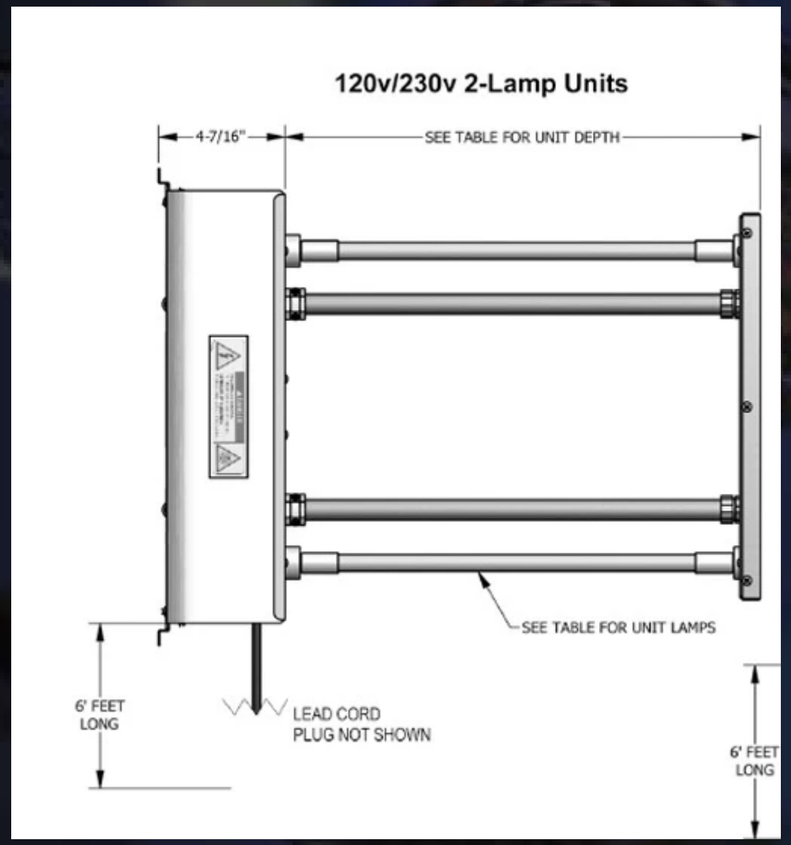
System

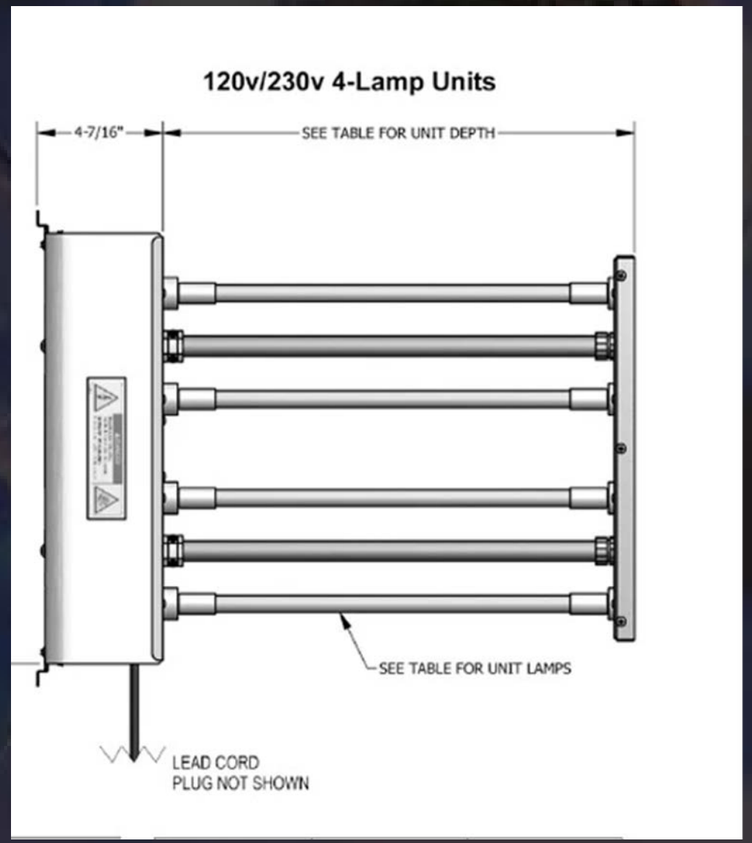


Disinfection efficacy of ultraviolet germicidal irradiation on airborne bacteria in ventilation ducts

Yi Yang[1,2] | Huihui Zhang[3] | Sunday Segbenu Nunayon[3] | Vincent Chan[4] | Alvin CK Lai[3]

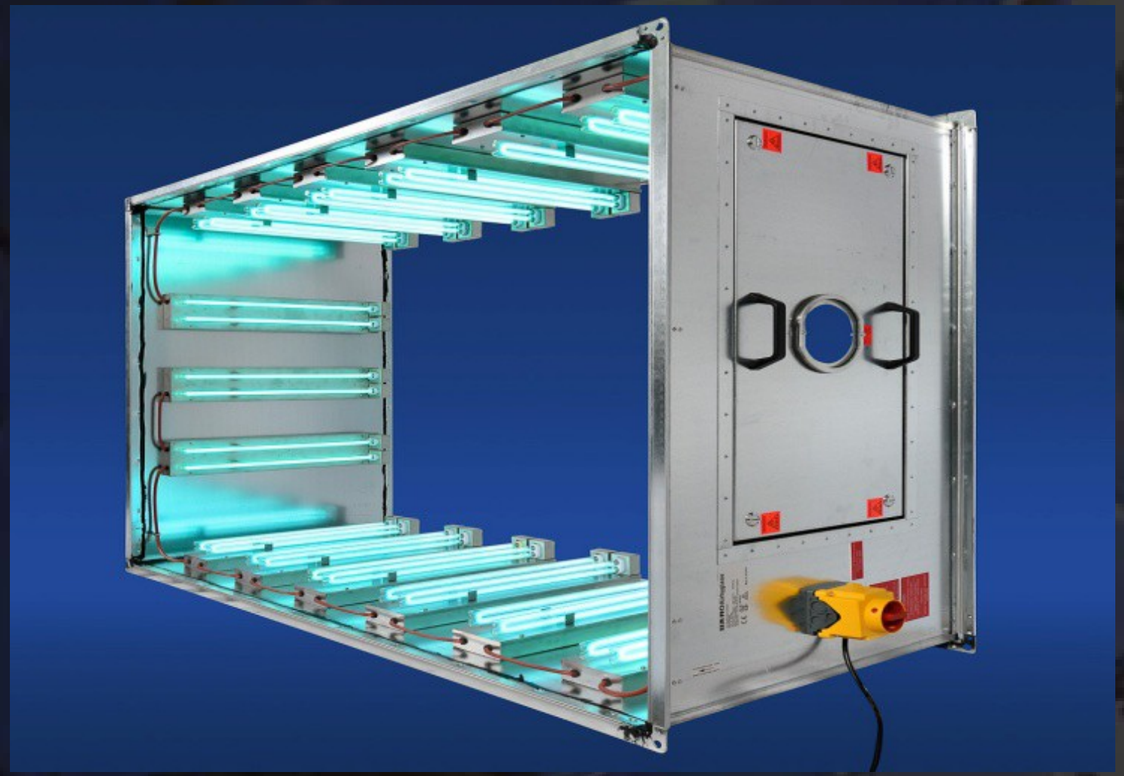
Lamp fixtures





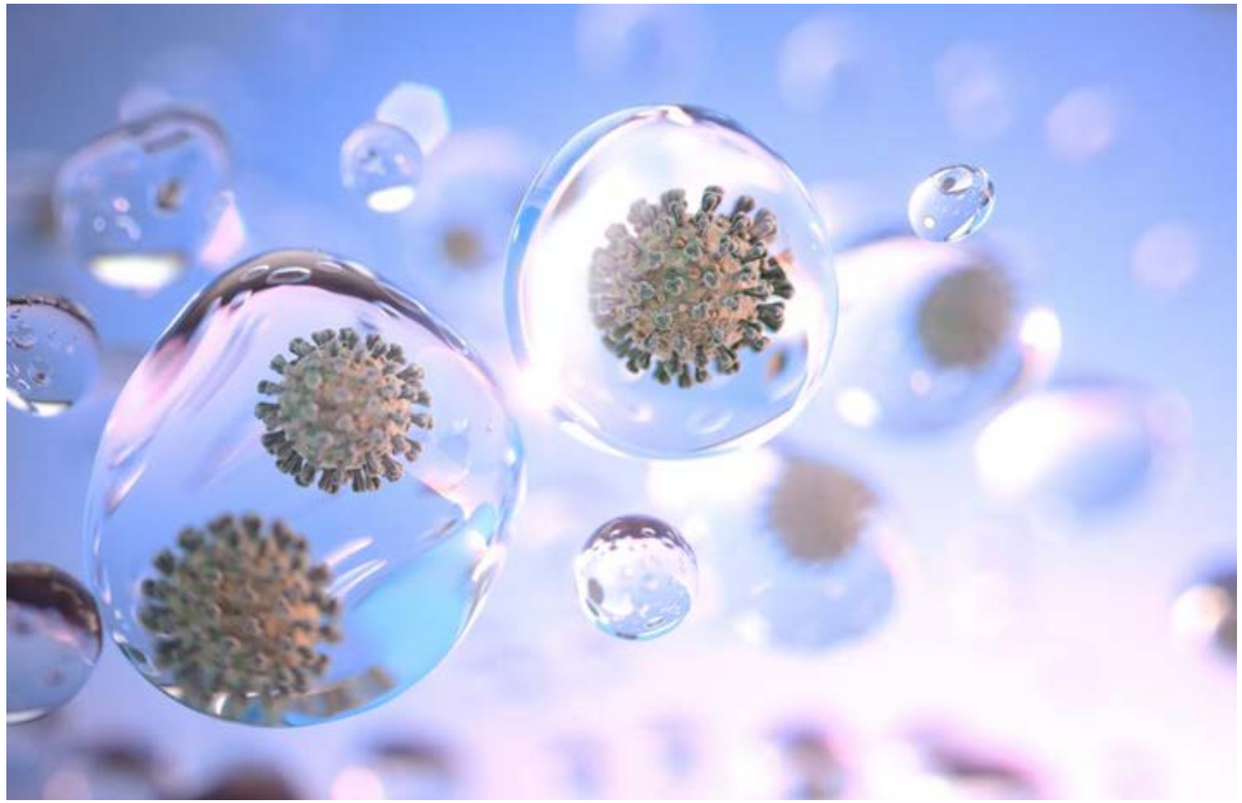
https://www.prolampsales.com/products/aerologic-uv-air-duct-commercial-disinfection-models-four-lamp-high-output-16-75-partial-internal-option-21-1875-full-internal-option

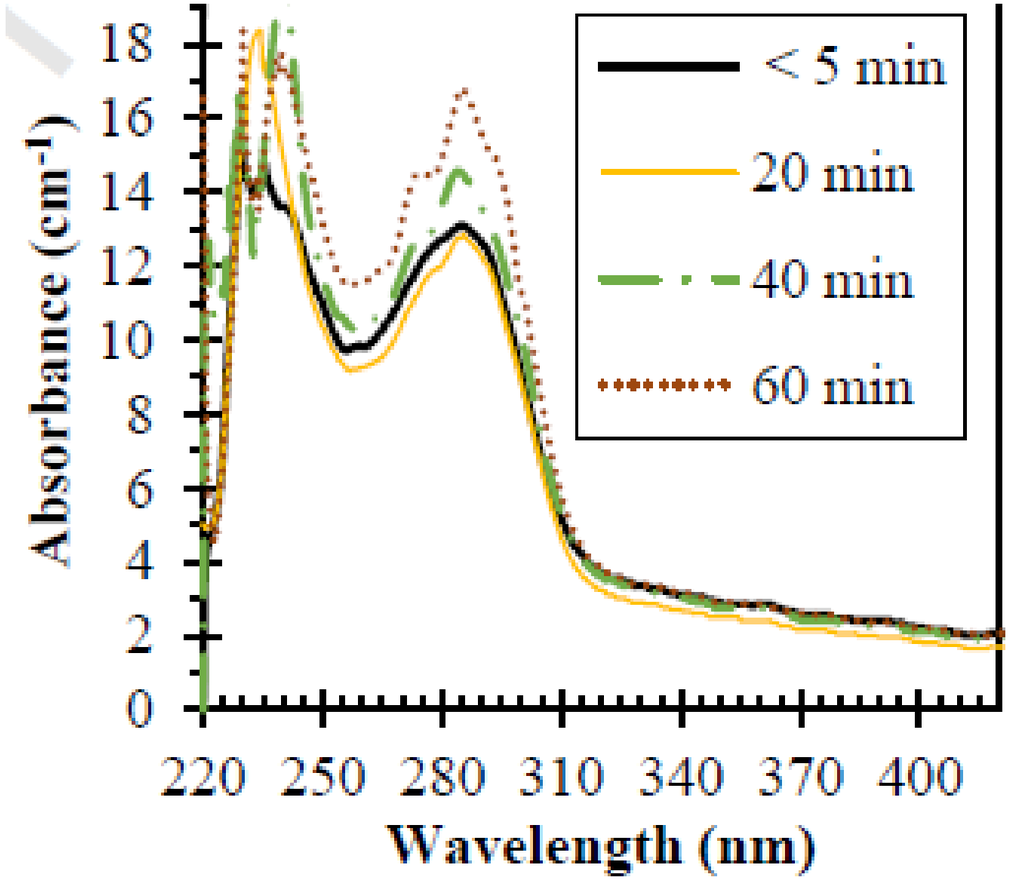
Options



Standard 52.2 Minimum Efficiency Reporting Value (MERV)	Composite Average Particle Size Efficiency, % in Size Range, µm			
	Range 1 0.30 to 1.0	Range 2 1.0 to 3.0	Range 3 3.0 to 10.0	Average Arrestance, %
1	N/A	N/A	$E_3 < 20$	$A_{avg} < 65$
2	N/A	N/A	$E_3 < 20$	$65 \le A_{avg}$
3	N/A	N/A	$E_3 < 20$	$70 \le A_{avg}$
4	N/A	N/A	$E_3 < 20$	$75 \le A_{avg}$
5	N/A	N/A	$20 \le E_3$	N/A
6	N/A	N/A	$35 \le E_3$	N/A
7	N/A	N/A	$50 \le E_3$	N/A
8	N/A	$20 \le E_2$	$70 \le E_3$	N/A
9	N/A	$35 \le E_2$	$75 \le E_3$	N/A
10	N/A	$50 \le E_2$	$80 \le E_3$	N/A
11	$20 \le E_1$	$65 \le E_2$	$85 \le E_3$	N/A
12	$35 \le E_1$	$80 \le E_2$	$90 \le E_3$	N/A
13	$50 \le E_1$	$85 \le E_2$	$90 \le E_3$	N/A
14	$75 \le E_1$	$90 \le E_2$	$95 \le E_3$	N/A
15	$85 \le E_1$	$90 \le E_2$	$95 \le E_3$	N/A
16	$95 \le E_1$	$95 \le E_2$	$95 \le E_3$	N/A

Complexities - saliva interference



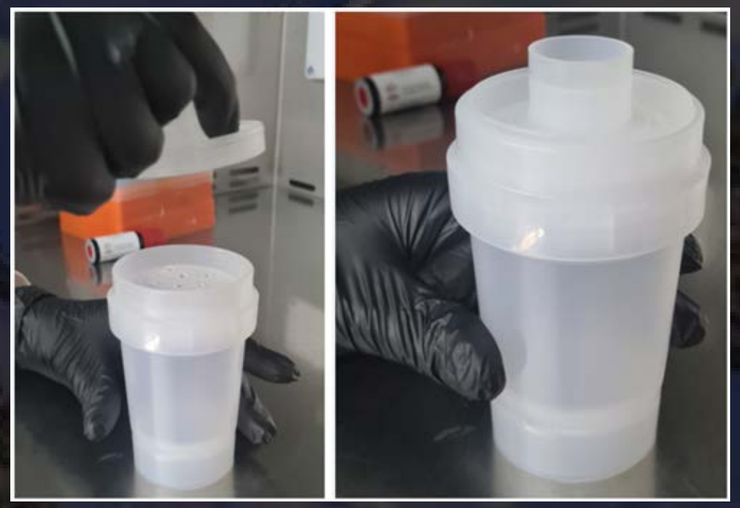


Fateme Barancheshme, Julie Philibert, Natali Noam-Amar, Yoram Gerchman, Benoit Barbeau, Assessment of saliva interference with UV-based disinfection technologies, Journal of Photochemistry and Photobiology B: Biology, Volume 217, 2021,

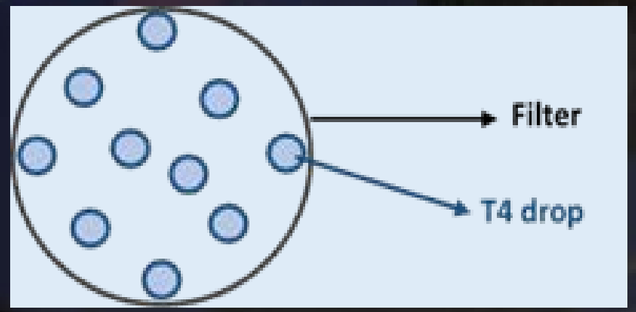
Aerosols

- Small aerosols (<10 µm), are airborne and infectious for extended periods (minutes, hours, or days) and travel longer distances
- Large droplets (100 µm diameter) may shrink by evaporation before they settle, and become an aerosol (<10 µm)
- Role of indoor air management is critical in providing a line of defense

MS2 recovery from air sampler (Bobcat) filter



Extract the MS2 using the extraction foam (PBS)

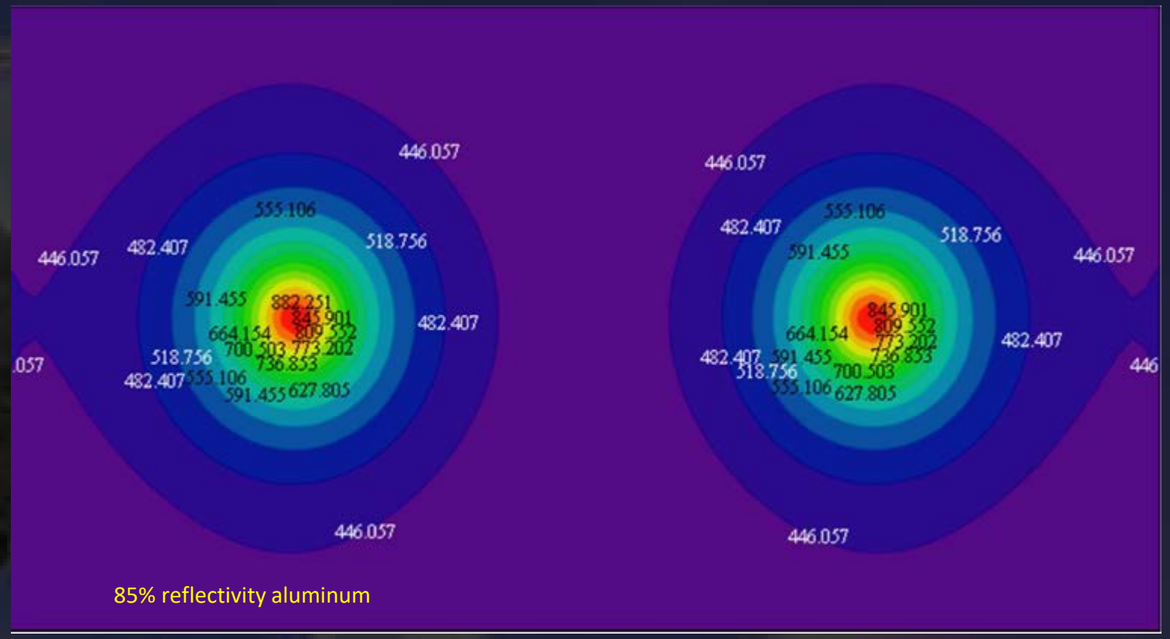


MS2 recovery from Bobcat filter

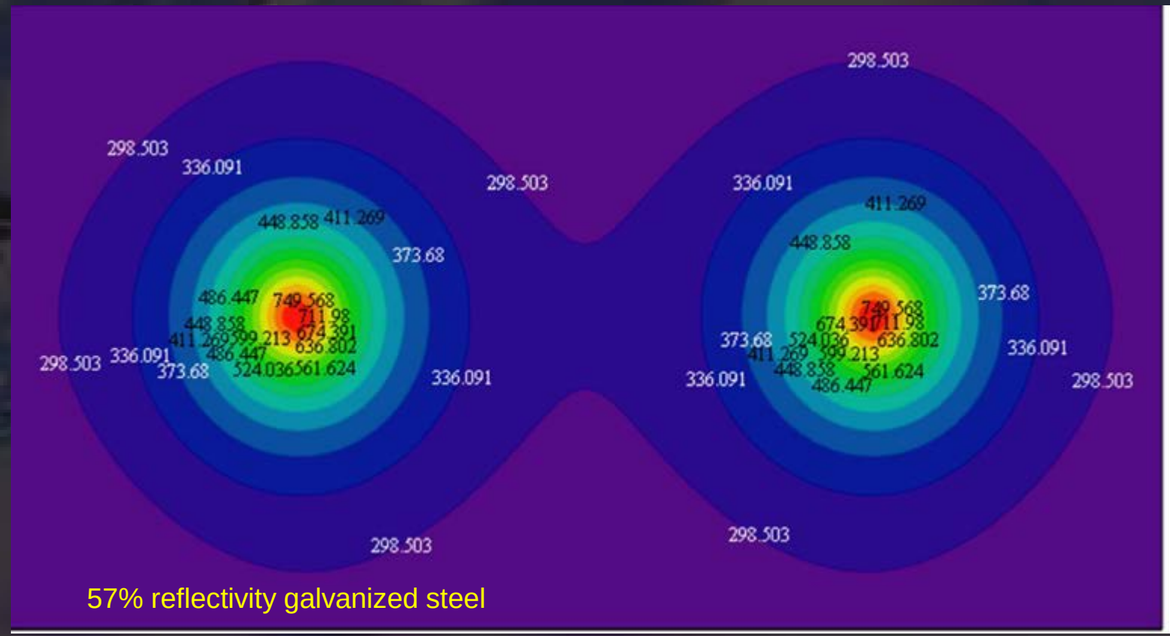
		PFU/mL								
Sample	ul	1.00E-06	1.00E-05	1.00E-04	1.00E-03	1.00E-02	1.00E-01	dil	Average	STDEV
1	1000	38	~400	Lawn	Lawn	Lawn	Lawn	3.80E+07	4.55E+07	1.06E+07
2	1000	53	~320	Lawn	Lawn	Lawn	Lawn	5.30E+07		
control	host plate	No plaques	√							

UV reflectivity

MATERIAL	REFLECTIVITY %	MATERIAL	REFLECTIVITY %
ePTFE	98.5	Molybdenum	25
Spectralon	95	White botting paper	25
Smoked magnesium oxide	93	AZO photographic paper, unexposed	24
Evaporated aluminum	87	Silver	23
Alzak sheet aluminum, brightened	87	White water paint	23
Alzak sheet aluminum	84	White wallpaper	22
Magnesium oxide	81	Stainless steel	20
Aluminum - sputtered on glass	80	Brownish figured wallpaper	18
Pressed calcium carbonate	78	Tungsten	18
Pressed magnesium oxide	77	Linen	17
Calcium carbonate	75	Fluorescent lamp phosphors	17
Magnesium carbonate	75	Duralumin	16
Aluminum - treated surface	74	Kalsomine white water paint	12
Aluminum foil	73	Medusa cement	11
Aluminum paint	65	Alabastine white water paint	10
Barytes	65	White baked enamel	9
New plaster	58	White oil paint	8
Galvanized duct - smooth	57	Black paint	7
Galvanized duct - rough	53	Brass	7
Aluminum - untreated surface	50	Brown wrapping paper	7
White wall plaster	46	Titanium oxide	6
Stellite	46	AZO photographic paper, exposed black	6
Chromium	44	Celluloid	6
AZO photographic paper, white back	39	Pongee silk	6
Chrome steel	39	Brown baked enamel	6
Rhodium	38	Casein vehicle	6
Nickel	37	Flat black Egyptian lacquer	5
S.W. white Decotint paint	33	Lithopone	5
Ivory wallpaper	31	Zinc oxide in clear lacquer	5
Pink figured wallpaper	31	Black lacquer paint	5



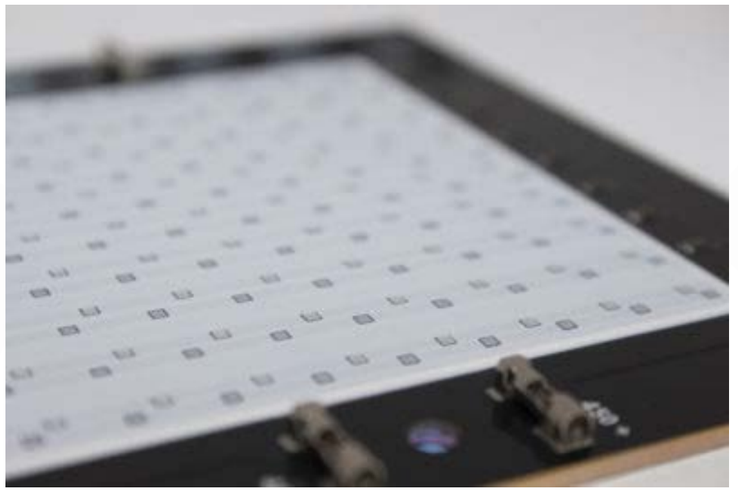
85% reflectivity aluminum



57% reflectivity galvanized steel

Another UV source - UV LEDs

- LED produces selected wavelengths with low electrical output power
- On/off cycles, does not contain mercury, compact
- Lower performance and high price are the main barrier to wider adoption of UV-C LEDs by the UV-C disinfection market today

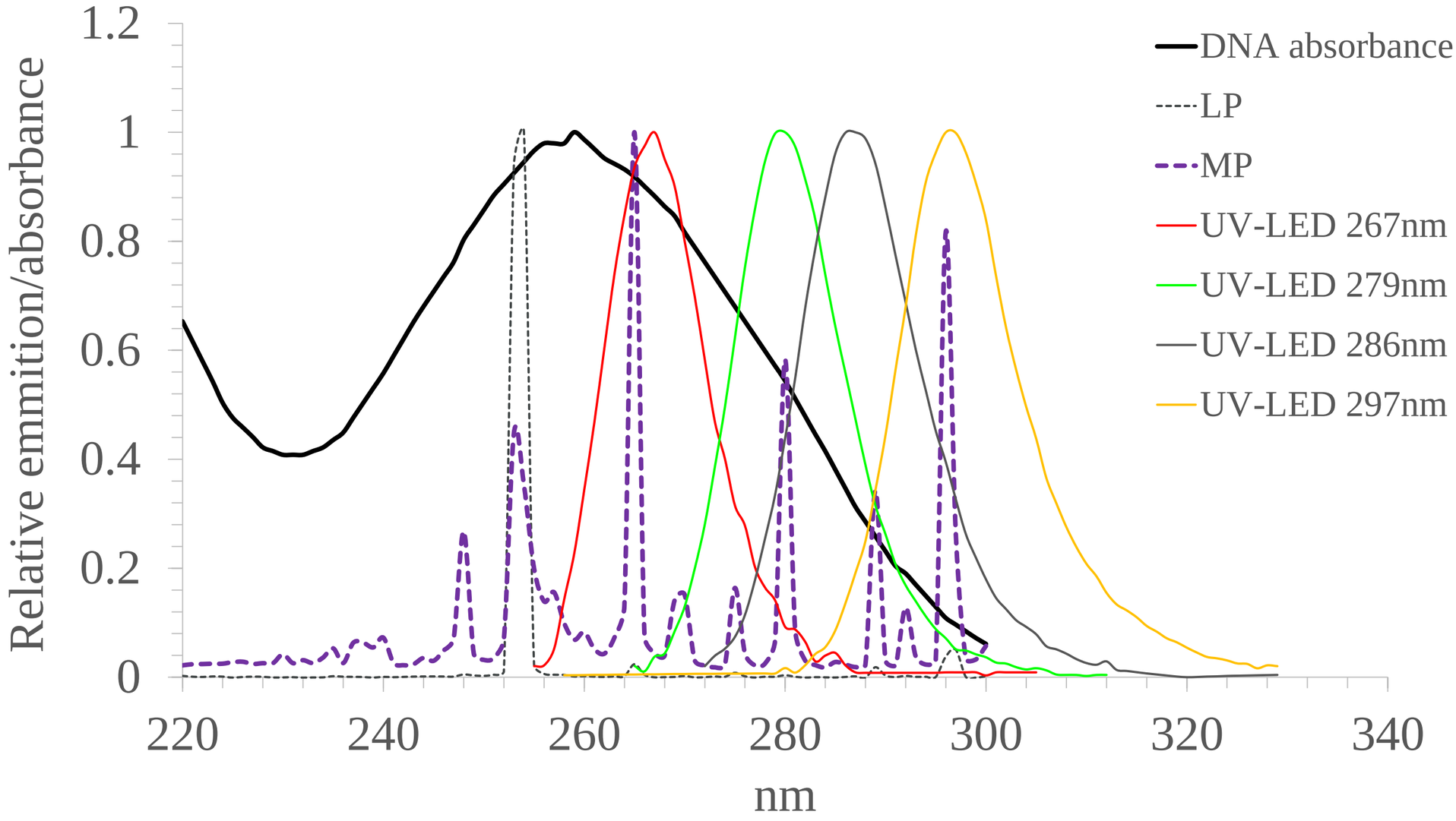


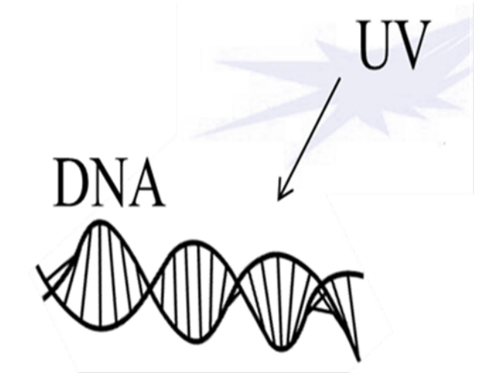
single, chip-on-board, strip, to complete light source module

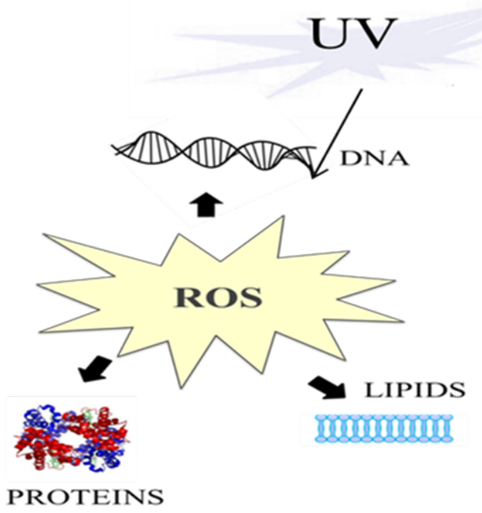
Market products

A unique triple attack on Viruses and Bacteria

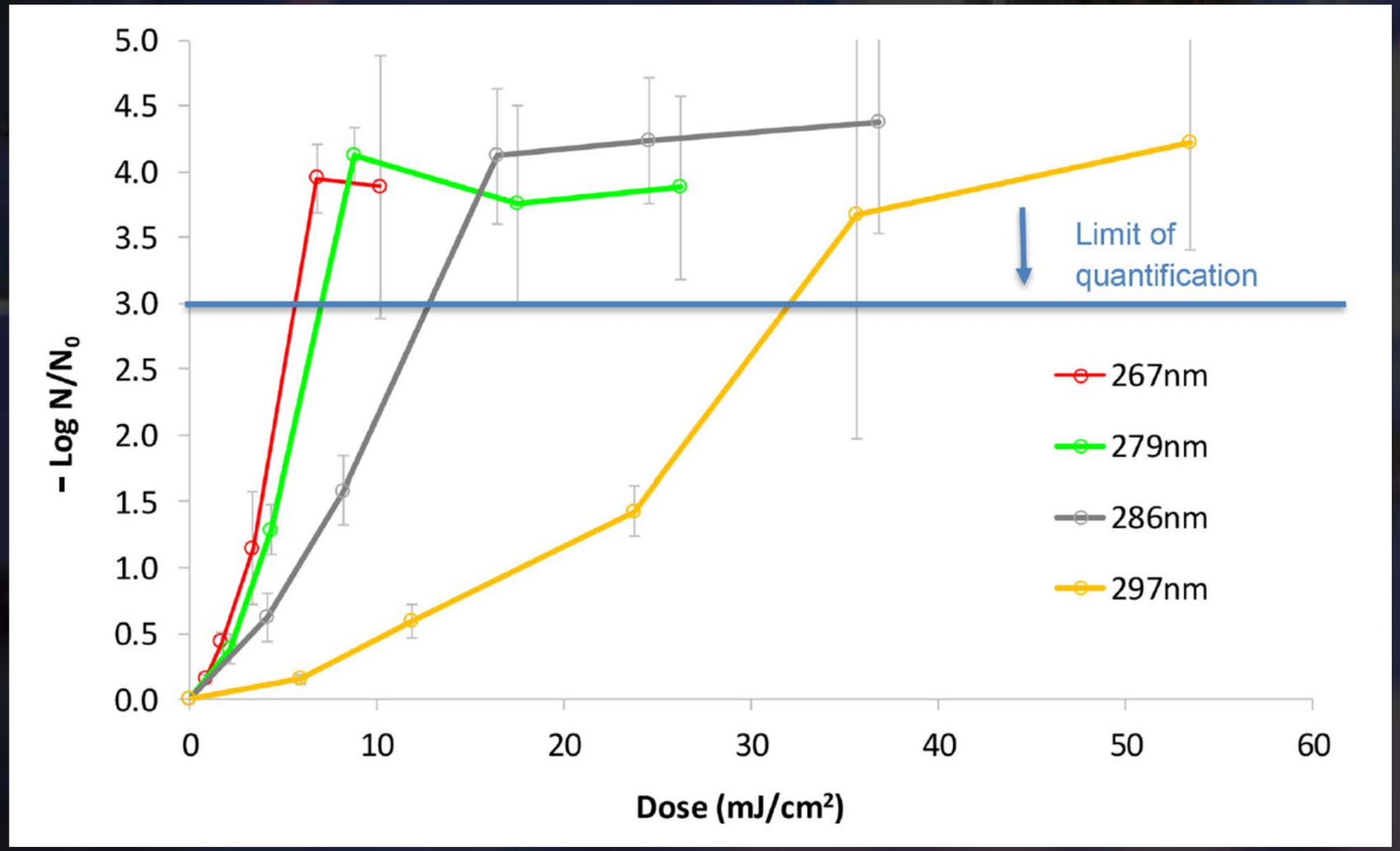
Integrated with DNA absorbance and MP/LP







Results UV Dose response of hCoV-43 viruses at different wavelength



Dose needed for 3-log reduction (mJ/cm²)	
267nm	5.7
279nm	7.2
286nm	12.8
297nm	32

Thanks