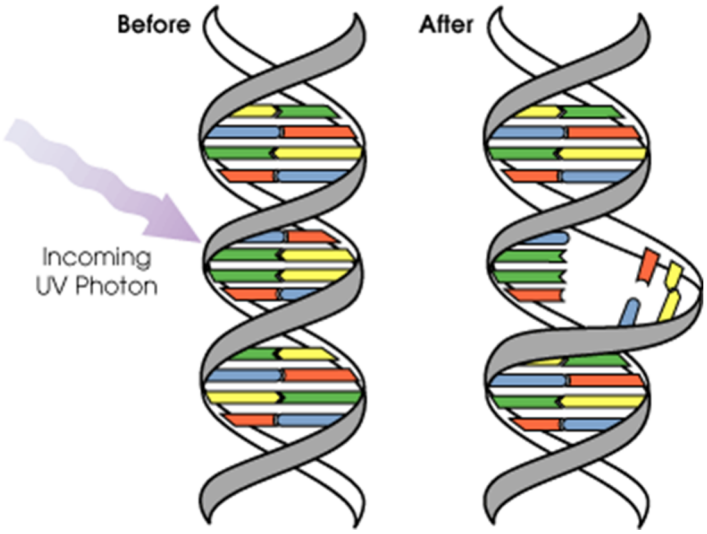
a LIGHTING STUDIO

Active Light Disinfection Technology

By: Jimmy Bates, P.E., LC, LEED™AP
September 21, 2020.

Using disinfection Ultraviolet (UV) lighting as a Germicidal can stop viruses, bacteria, mold, and fungus DNA and RNA from replicating. There are various options, each with benefits and repercussions, available to the Architecture, Engineering, and Lighting Design community as we increasingly are tasked to guide Owners and Contractors.



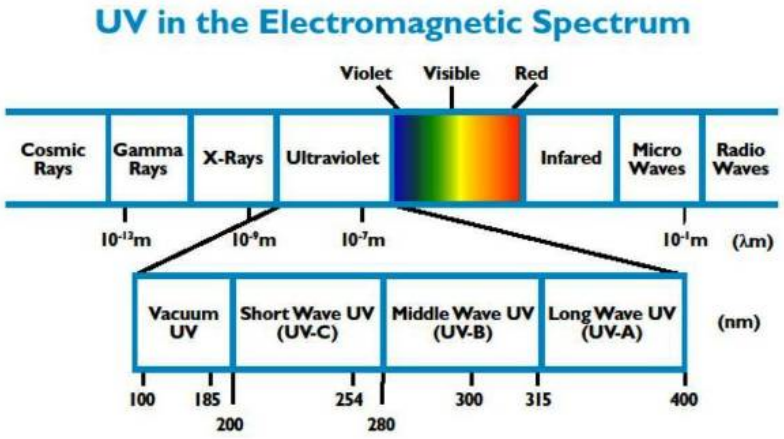
UV photons harm the DNA molecules of living organisms in different ways. In one common damage event, adjacent bases bond with each other, instead of across the "ladder," making a bulge, and the distorted DNA molecule does not function properly. (Illustration by David Herring courtesy of https://earthobservatory.nasa.gov/features/UVB)

As a disclaimer, there is "No Silver Bullet" (Fred Brooks 1986) for active light disinfection technology application, as each variant is more efficacious or beneficial for specific applications and ineffective or hazardous if misapplied for others. Careful consideration of the costs, benefits, risks, and maintenance and operations realities are essential for the appropriate application.

Pathogen	Classification	Critical dose at 4-log disinfection (mJ/cm²)
Adenovirus type 15	Virus	165
Bacillus anthracis spores - Anthrax spores	Bacteria	93
Candida	Fungi	92
Clostridium tetani	Bacteria	44
Salmonella typhimurium	Bacteria	32
Calicivirus feline	Virus	30
Giardia lamblia	Protozoa	27
Porcine Epidemic Diarrhea	Virus	25
Porcine Respiratory and Reproductive Syndrome	Virus	23
Influenza	Virus	14
Staphylococcus aureus	Bacteria	11
Salmonella enteritidis	Bacteria	11
Cryptosporidium parvum	Bacteria	10
Legionella pneumophila	Protozoa	10
Rabies virus	Bacteria	10
Escherichia coli - O157:H7	Bacteria	7
Campylobacter jejuni	Virus	5
Canine Parvovirus	Virus	3
Bovine Coronavirus (BCV)	Virus	3
SARS CoV-2 (Covid 19)	Virus	15

Example 4-log (99.99%) Kill Rate Dose Variations per Pathogen (Courtesy of Bill O'Connell, LC, LEED AP Cooper Lighting Solutions, Empowering Health and Safety through Germicidal UV)

Active Light Disinfection uses specific wavelengths (as opposed to chemicals) to inactivate microorganisms. As observed for many years in high-efficacy disinfection of water/enclosed air streams and instrument sterilization, UV light is strongly germicidal as it attacks the DNA structure of many cells, rendering them inactive. However, prolonged UV exposure can be dangerous to humans/animals and can accelerate material degradation. (From Light as a Broad-Spectrum Antimicrobial article by Peter J. Gwynne and Maurice P. Gallagher) Scientists categorize UV light into several different subtypes.



Courtesy of
https://materion.com/resource-center/newsletters/materials-news-stats-and-chats/killing-germs-with-leds

UV-A light (315-400nm) is the least harmful to humans. UV-B light (280-315nm) causes sunburns with prolonged exposure along with the increased risk of skin cancer and other cellular damage, despite that about 95% of all UV-B light is absorbed by ozone in the Earth's atmosphere. In contrast, UV-C light (200-280nm) is extraordinarily harmful yet, thankfully, almost entirely absorbed by the Earth's atmosphere. (Courtesy of http://solar-center.stanford.edu/about/uvlight.html). The below chart well identifies the technology and some of the practical uses.

Germicidal irradation, benefits, and differences of
ULTRAVIOLET LIGHT

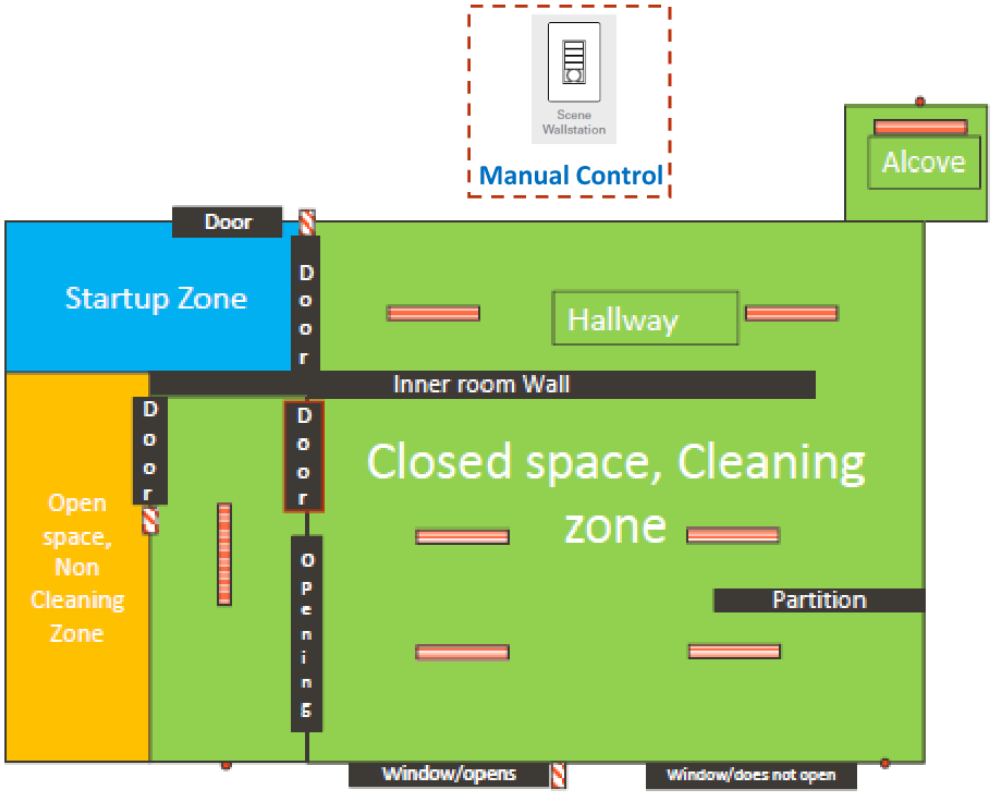
UV type	**NANOMETERS** (nm)	**SAFE** for skin and eyes	**RAPID DEGRADATION** on materials like plastic and rubber	**PRACTICAL USES**
VUV Far-UV	100-200	YES	YES	Medical equipment
Far-UVC	207-222	YES	YES	Germicidal, **most effective for disinfecting**, sensing
UV-C	200-280	NO	YES	Germicidal, **most effective for disinfecting**, sensing
UV-B	280-315	NO	YES	Curing, tanning, medical applications
UV-A	315-400	NO	NOT TYPICALLY	Curing, printing, lithography, sensing, medical applications

Chart courtesy of https://insights.regencylighting.com/can-uv-light-kill-viruses-like-covid-19

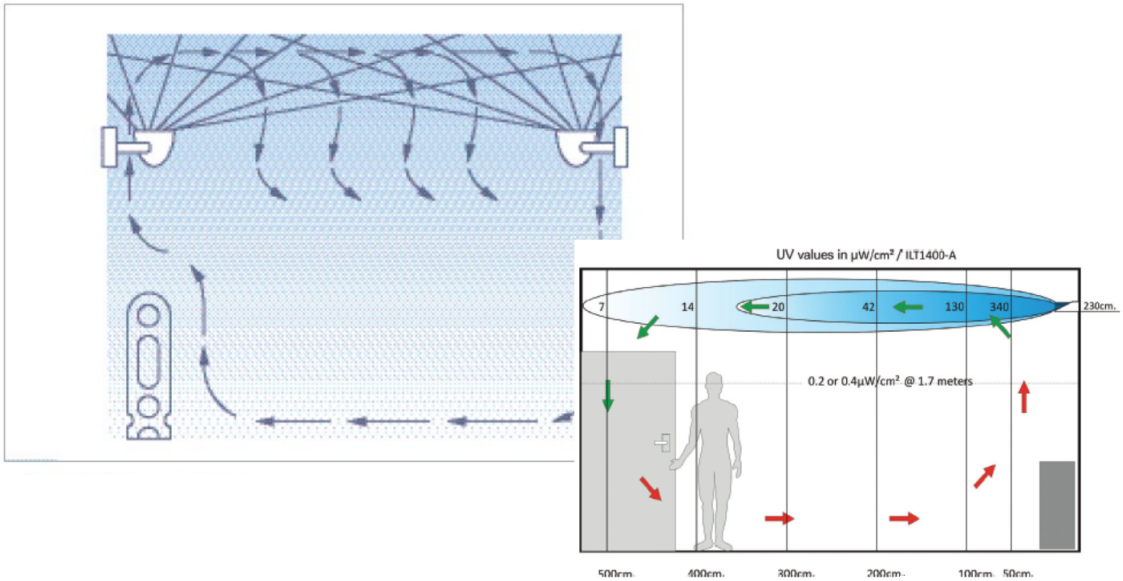
Far-UV-C, the Ultraviolet radiation band between 200–230 nanometers (nm), has been proven to penetrate and inactivate surface pathogens, such as bacteria, parasites, fungi, and viruses. Early studies indicate no harm to humans from continuous low dosages of 222 nanometers. Simultaneously, far-UV-C light effectively inactivates over 90% of contaminants, based on the intensity and brief exposure time.

Commonly used as a disinfectant in food, air, and water, UV-C effectively kills microorganisms by destroying their cells' nucleic acids or for industrial within-duct or upper air cleaning. For applications with direct exposure risk, below is a sample safeguard application with access controls assuring unoccupied during UV-C application. (Courtesy of UV-C Technology Overview & Applications, Rajamanickam Vennila, Jaak Geboers, Nitin Tyagi, Dana Wallace, Don Jacklin, May 2020).

UV-B, particularly the shorter wavelengths near 300 nm and below, can be relatively effective as a germicidal source. But again, accidental exposure results in a significantly higher risk of severe sunburn and even delayed effects for both skin and eyes. For UV-B and UV-C, essential safeguards to mitigate exposure risks.

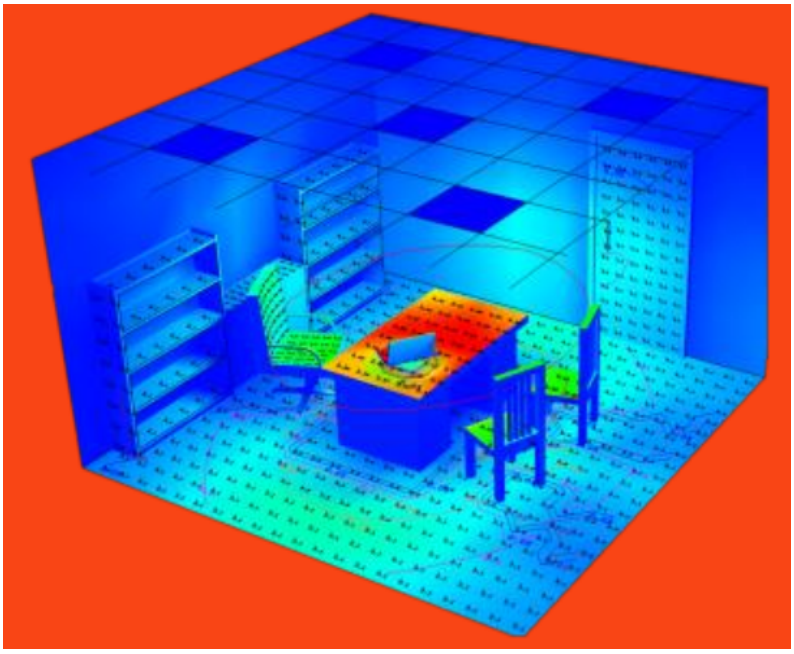


Essential Safeguards - Generic Example (Courtesy of Bill O'Connell, LC, LEED AP Cooper Lighting Solutions, Empowering Health and Safety through Germicidal UV)
Air passing through, cleansed by the UV-C lighting in upper air purification and air purification integral with HVAC unit coils and ducts, has long achieved 70-80% viral reduction.



Images courtesy of UV-C Technology Overview & Applications, Rajamanickam Vennila, Jaak Geboers, Nitin Tyagi, Dana Wallace, Don Jacklin, May 2020)

For UV-A and near UV lighting, some exciting applications combine architectural white light with UV-A lighting either individually or simultaneously, blending the output from for in-use disinfection. (courtesy of https://hubbellcdn.com/brochure/SpectraClean_B_EV.pdf,) including the adaptation of lighting simu.ation software to assess Irradiance levels.

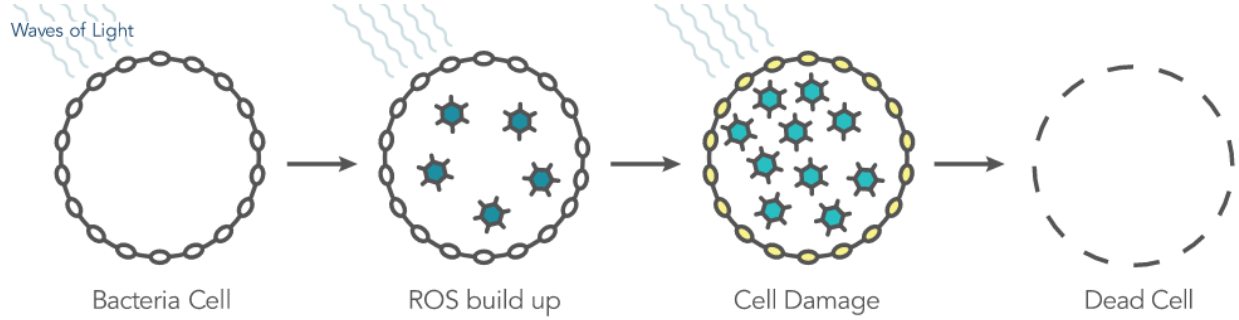


Pseudocolor Irradiance Image (Courtesy of Bill O'Connell, LC, LEED AP Cooper Lighting Solutions, Empowering Health and Safety through Germicidal UV)

The Illumination Engineering Society (IES) staters that "UV-A and longer (visible) wavelength" light has ineffective germicidal attributes. Comparatively, on the order of 1,000 times less effective than other UV germicidal technologies. Even the somewhat more promising UV-A and violet (e.g., 405 nm) light "requires very high doses not practical. . . for viral sterilization." (Courtesy of IES CR-2-20-V1 IES Committee Report: Germicidal Ultraviolet (GUV) – Frequently Asked Questions)

Images of white antimicrobial and architecture lighting (left) versus violet enhanced antimicrobial only (right), courtesy of Results with VioSafe™ in Active Trauma Room at Samaritan Hospital, Troy, NY

a LIGHTING STUDIO



Bacteria Cell Contact that begins to create Reactive Oxygen Species (ROS), possibly inactivating harmful cell (Courtesy of Orion Energy Systems, Inc.)

Oh, what a time to be a lighting designer. There are mobile GUV solutions. The ability to calculate irradiance studies to predict effectiveness increasingly more with LED sources. A resurgence in prior proven methodologies for sterilizing HVAC coils actively or cleaning upper air delivery safely above occupants' exposure angles. Even lighting fixtures with both Germicidal UV safe for occupants and architectural lighting. Available to, and ever evolving for, us as we mitigate the risks at hand.

About the Authour: Jimmy Bates has provided lighting design services since 2000, working at both small consulting and large integrated A/E firms before joining AEI as A Lighting Studio Director. Jimmy has extensive experience in lighting, daylighting, and sustainable system design including involvement in technically complex projects aligned with AEI's expertise in Higher Education, K-12, Mixed Use, High Rise, Hospitality, Retail, Senior Living, Corporate and Healthcare, as well as Civic, Museum, University, and Science and Technology. Jimmy is Lighting Certified and a registered Porfessional Engineer in Maryland, Virginia, and Pennsylvania. A Lighithng Studio at AEI is also an official AIA Continuing Education Service Provider. For more information, or to arrange for a virtual presentration, please contact Jimmy Bates at 215.910.1979 or jbates@aldersonengineering.com.

A Lighting Studio at AEI since the beinning of 2019
Bachelor of Science in Architectural Engineering,
University of Colorado
Master of Business Administration,
The George Washington University

Jimmy Bates, P.E., LC, LEED™AP
A Lighting Studio at Alderson Engineering, Inc.