

Apprentice GUV Technician Certification Course



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Goals

1. Introduction to NALMCO
2. Understand basic principles of germicidal ultraviolet (GUV)
3. GUV Standards and Guidelines
4. Application examples of GUV Fixtures
5. GUV Fixture Components
6. GUV Equipment Maintenance
7. Understand Safety of GUV Fixtures



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Learning Objectives

The Apprentice Level certification focuses on germicidal ultraviolet (GUV) fixtures applied to upper-rooms, whole-rooms, or a combination of these applications. After this training, the participant will be able to explain to interested parties:

- A. Introduction to NALMCO Certifications
- B. Discovery and Principals of GUV
- C. GUV Standards and Guidelines
- D. Applications of GUV Light
- E. Use of Ultraviolet Light in Disease Prevention
- F. GUV Lamps and Fixture Components
- G. GUV Fixture Maintenance and Safety



Qualified Installers Promote:

- ❖ Adequate Design
- ❖ Well-designed & performing fixtures
- ❖ Correct installation
- ❖ GUV Safety
- ❖ Proper Maintenance

NALMCO stands for
*The International Association Of
Lighting Management Companies.*

NALMCO offers Certifications for
people who want to become
qualified Installers of germicidal
ultraviolet (GUV) fixtures.



Apprentice GUV Technician Certification

Certification focuses on Upper-Room and Whole-Room GUV Fixtures:

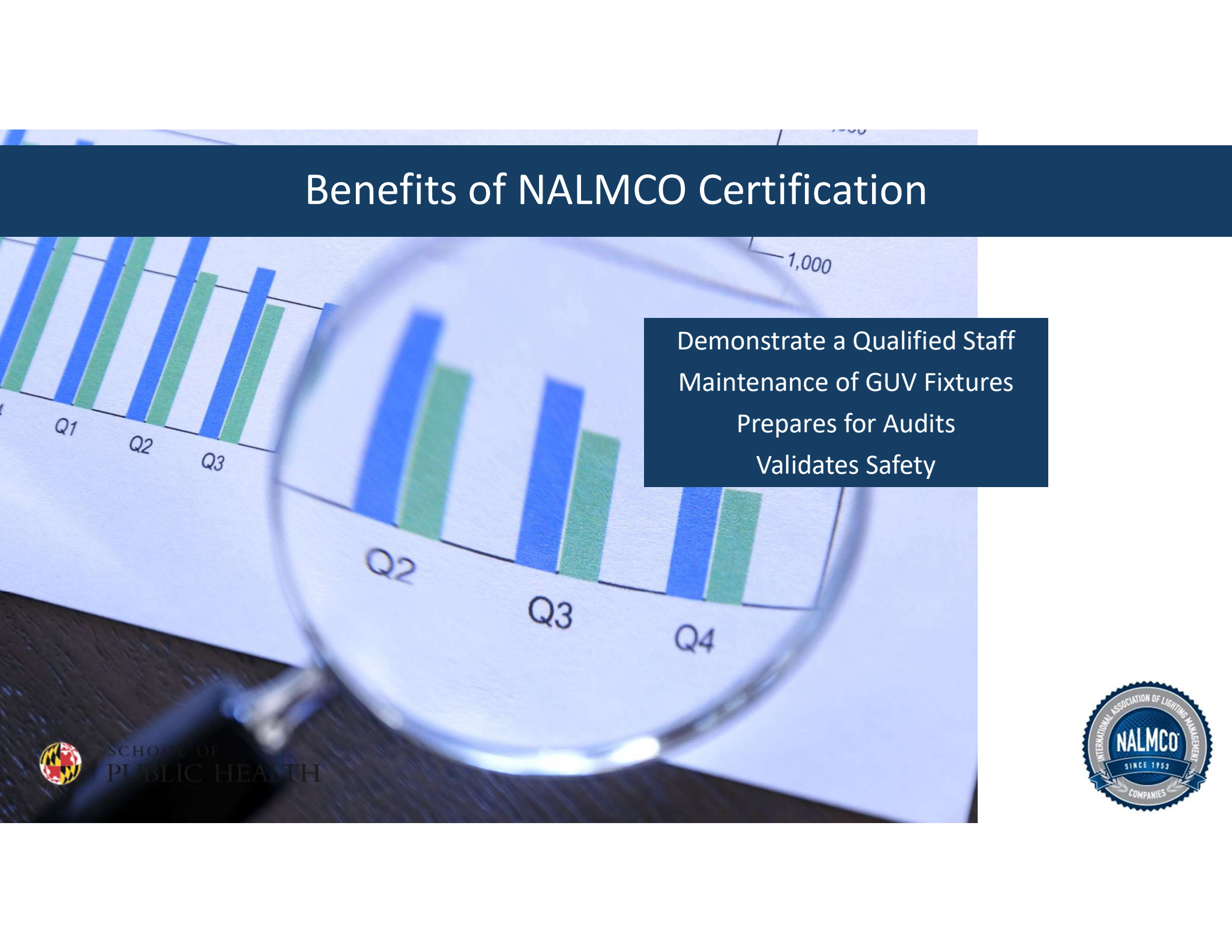
- ✓ Principals of GUV
- ✓ Applications
- ✓ GUV Standards and Guidelines
- ✓ GUV Fixtures and Lamp Technologies
- ✓ Maintenance
- ✓ Safety



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Benefits of NALMCO Certification



Demonstrate a Qualified Staff
Maintenance of GUV Fixtures
Prepares for Audits
Validates Safety



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NALMCO GUV Certifications

Partners:



Germicidal Ultraviolet (GUV) technology has gained significant recognition as an effective method for disinfection of air and surfaces across various industries. With its proven ability to eliminate harmful pathogens, it has become an integral component in maintaining a safe and healthy environment for employees, customers, and the public. With that said, it is important to train professionals responsible for the design, installation, and maintenance of GUV luminaires. This training and certification program will serve as the first step toward educating the public on the proper and safe use of GUV.



NALMCO GUV Certifications

This program is carefully designed to provide a comprehensive understanding of germicidal ultraviolet technology and its effective implementation in their respective fields. By the end of the training, attendees will possess the knowledge and skills necessary to install, maintain, and utilize GUV equipment safely and effectively.

Our esteemed panel of industry experts, who possess extensive experience in GUV technology, will facilitate the training sessions. They will share their expertise, insights, and practical guidance to ensure participants gain a thorough understanding of the subject matter.



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3 Levels Of NALMCO GUV Certification

Apprentice GUV Technician



Senior GUV Technician



GUV Management Professional



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NALMCO GUV Certification

NALMCO firmly believes that this GUV Certification Program will equip your organization with the necessary skills and knowledge to enhance its disinfection practices and promote a healthier environment. We look forward to your participation.

Resources for additional information about GUV and NALMCO's partnership with Illuminating Engineering Society (IES):

IES Committee Report CR-2-20 FAQs

The IES site provides a simplified way to quickly see the FAQs contained in the IES Photobiology Committee's Committee Report CR-2-20-V1. The full Report contains supporting information on this topic as well as an introductory video. These FAQs have been vetted through the IES ANSI-approved standards development process through a consensus of volunteers representing varied viewpoints and interests.

IES CR-2-20-V1, Germicidal Ultraviolet (GUV) - Frequently Asked Questions



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Apprentice GUV Technician Certification *Made Easy*

Online Training and Exam
Certifications accessible 24/7

Affordable, uncomplicated, annual
online recertification.

Germicidal Ultraviolet (GUV)

Module 1

Introduction



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Course Goals

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2. GUV Standards and Guidelines
3. Application examples of GUV Fixtures
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Let's Learn About Germicidal Ultraviolet: Upper-Room, Whole-Room, And Their Combinations

Let's dive in



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New Word Alert



New Words will be introduced throughout this training.



When the Bullhorn appears, a new term will be introduced.



New terms are highlighted in **dark red**.



Definitions follow new terms.



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Improving The Indoor Air Quality

Keeps us from getting sick with respiratory issues like asthma or illnesses like the flu.

Steps to breathe better air indoors include:

- Keeping the Heat, Ventilation, and Air-Conditioning (HVAC) system up to date.
- Germicidal ultraviolet lights can kill germs in the air.



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UV-C Germ-killing Lights Improve Indoor Air

UV-C germ killing lights are referred to as **germicidal ultraviolet (GUV)** in the US.

GUV is a type of germ-killing light.

GUV may kill viruses, bacteria, tiny mold particles in the air that can make people sick.

GUV installed and maintained properly in indoor spaces prevents the spread of airborne illnesses, like tuberculosis, flu, measles, and COVID-19.

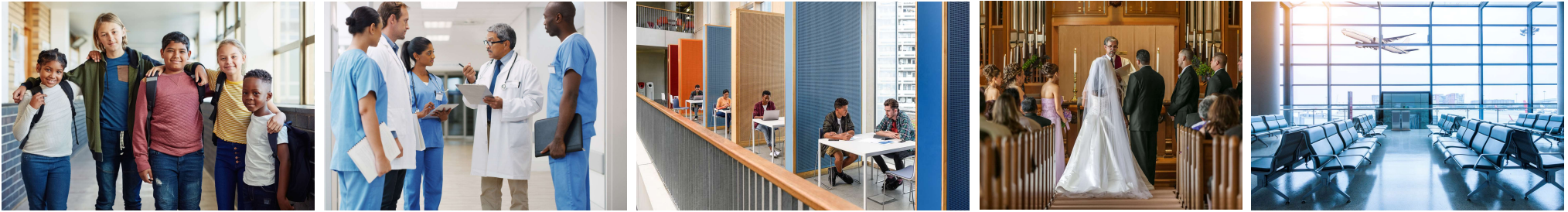


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Benefits Of GUV

Indoor spaces use **GUV** to make sure air is free from harmful germs.



GUV is used in schools, healthcare, universities, churches, airports, and many other areas where people congregate.

GUV has been safely used since the 1930s.

Review Of Key Points

- ✓ UV-C germ killing lights are referred to as germicidal ultraviolet (GUV) in the US.
- ✓ Germicidal ultraviolet (GUV) lights improve the indoor air quality.
- ✓ Many different indoor environments use GUV lights to make air safer.
- ✓ GUV has been safely used by people since the 1930s.



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Germicidal Ultraviolet (GUV)

Module 1

Introduction to UV-C



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Introduction To GUV Light

In this section we explore:

- ❖ Discovery of GUV light
- ❖ How it works
- ❖ What it does
- ❖ What are Photons



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Discovery Of Ultraviolet Light



In 1801, Johann W. Ritter experimented with sun light using a glass prism.

All the colors of the rainbow appeared.

He noticed an area of energy beyond the visible violet light, but he could not see it.

He became curious and designed an experiment to investigate this invisible area.

Invisible area



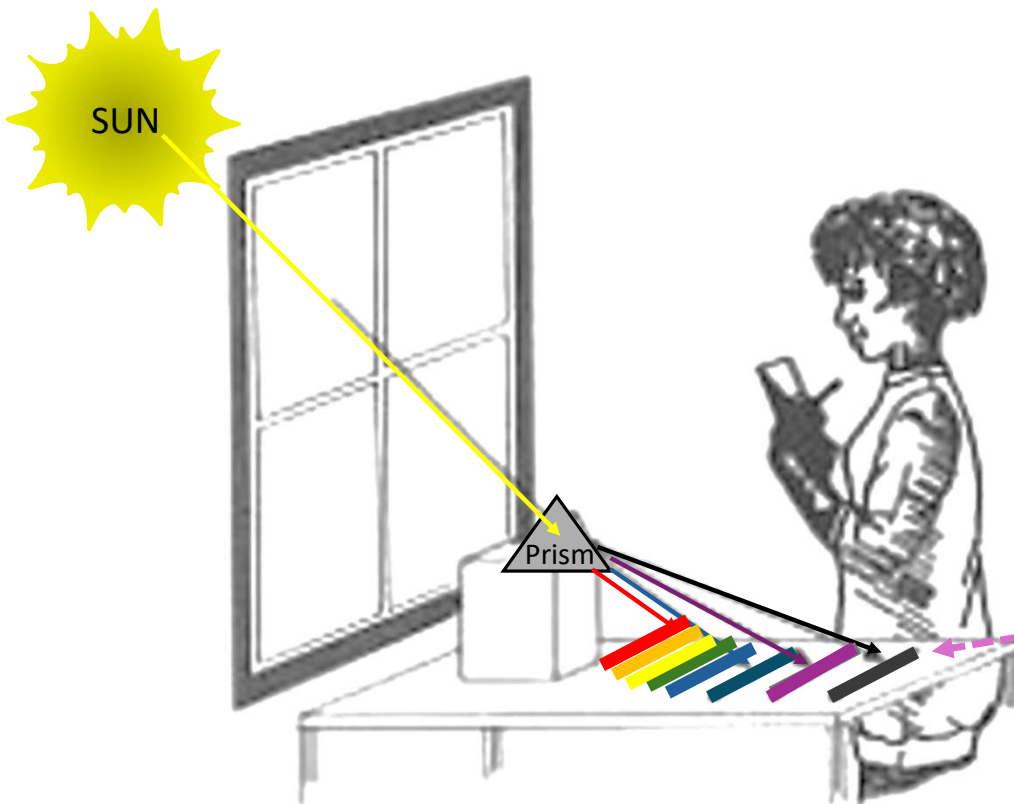
Image: ehow.com



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Johann W. Ritter's Experiment



A Line of silver chloride was placed beyond the visible violet light region.



A prism split the sunlight into rainbow colors. The silver chloride line just beyond the visible violet region darkened.



He made the invisible area visible.



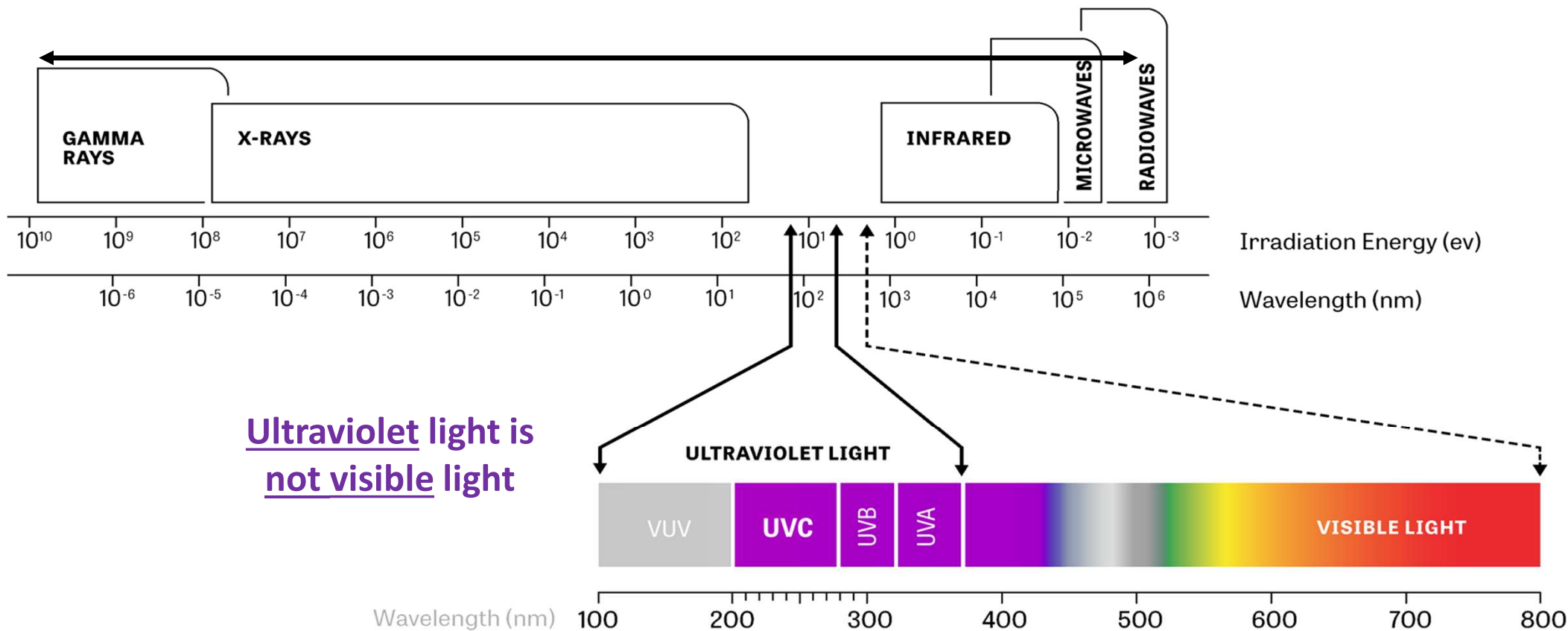
It was named *ultraviolet*.



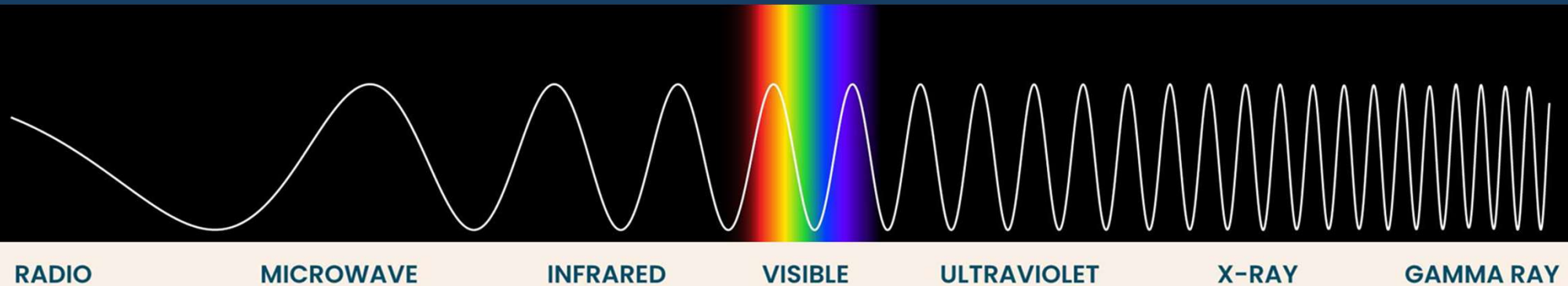
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Discovery Of Ultraviolet: Electromagnetic Spectrum



Electromagnetic Spectrum Describes All Of The Kinds Of Light



Most of the light in the universe is invisible to our eyes.

The light humans can see (rainbow colors), represents only a very small portion.

Other types of light that **cannot be seen** include radio waves, microwaves, infrared radiation, **ultraviolet** rays, X-rays and gamma rays.



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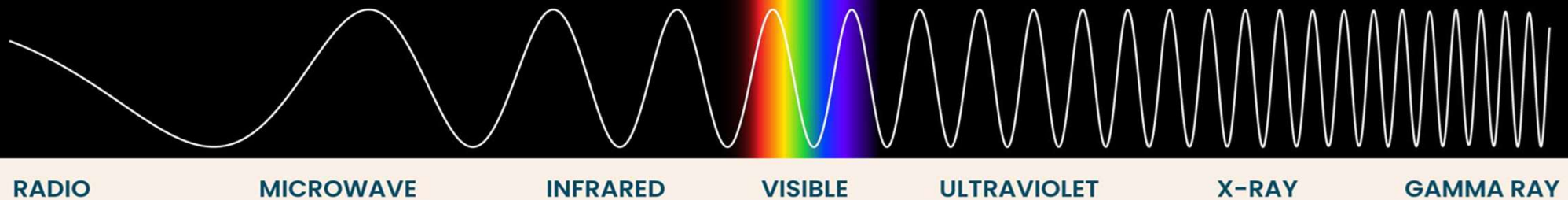


<https://hubblesite.org/contents/articles/the-electromagnetic-spectrum>

Light Travels In Waves Like Ocean Waves

Lower Energy region – Lower Frequency

Higher Energy region – Higher Frequency



As a wave, light has 3 basic properties that describe it:

1. **Frequency:** counts the number of waves that pass by a given point in one second.
2. **Wavelength:** distance from the peak of one wave to the peak of the next.
3. **Energy:** the higher the frequency of the light wave, the more energy it carries.



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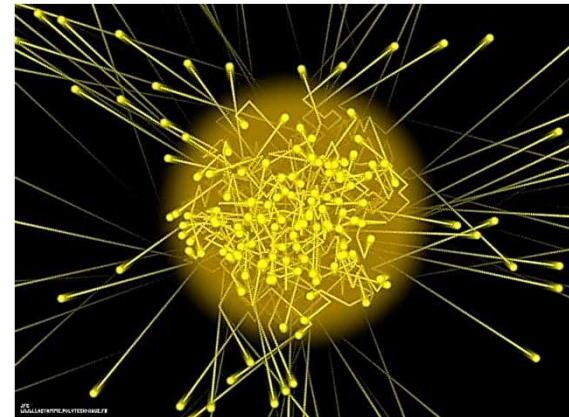
<https://hubblesite.org/contents/articles/the-electromagnetic-spectrum>

Light Is Made Up Of Lots Of Photons: What Is A Photon?

Imagine a shaft of yellow sunlight beaming through a window.



This beam is made of zillions of tiny packets of light, called photons, streaming through the air.



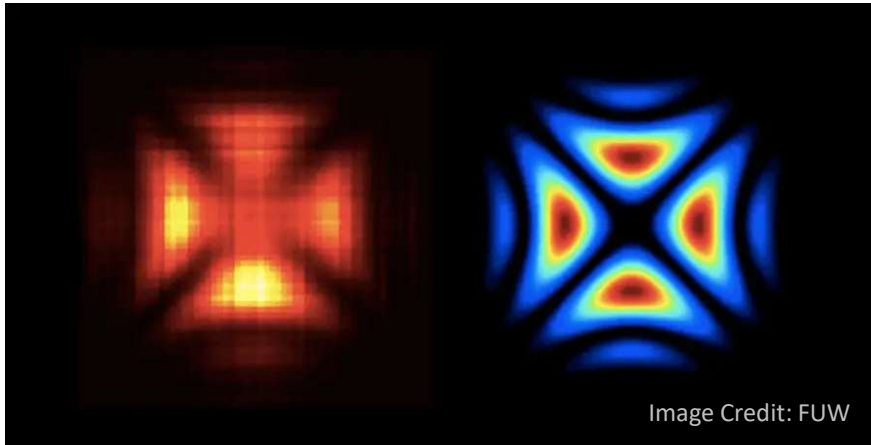
A photon is the smallest discrete amount of electromagnetic radiation. It is the basic unit of all light.



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Fun Facts About Photons



On the left: Hologram of a single photon reconstructed from raw measurements.

On the right: the theoretically predicted photon shape.

<https://www.zmescience.com/feature-post/natural-sciences/physics-articles/matter-and-energy/what-is-photon-definition-04322/>

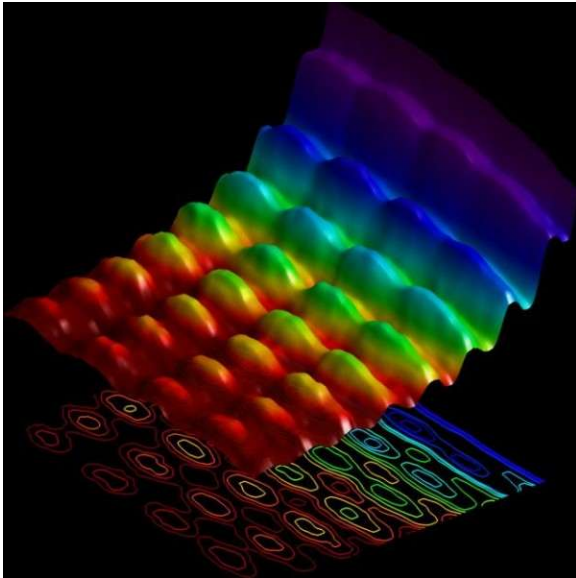
- ❖ Not only is light made up of photons, but all electromagnetic energy (i.e. microwaves, radio waves, X-rays) is made up of photons.
- ❖ Photons are always electrically neutral.
- ❖ Photons do not decay on their own.
- ❖ Photons are always in motion.
- ❖ In a vacuum, photons travel at what is known as the speed of light.



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Photons Have Dual Properties: A Wave And A Particle



The image comes from a team of scientists based in Europe at the Ecole Polytechnique Fédérale de Lausanne (EPFL). The journal Nature Communications published it on March 2, 2015

<https://earthsky.org/human-world/first-photo-of-light-as-both-particle-and-wave/>

Einstein proved that light is a flow of photons.

- ❖ The energy of these photons is the height of their oscillation frequency.
- ❖ The intensity of the light corresponds to the number of photons.
- ❖ He explained how a stream of photons can act both as a wave and particle.

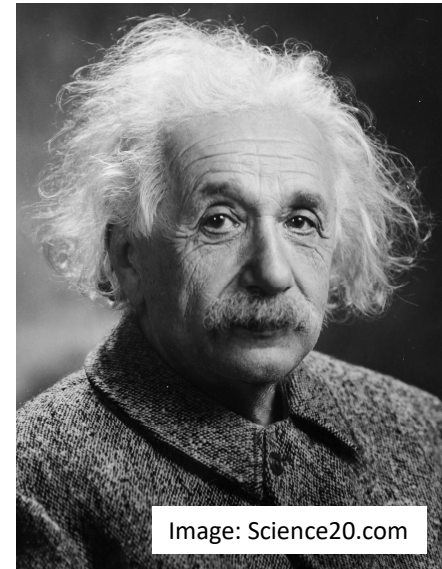


Image: Science20.com

Albert Einstein

The image on the left shows the dual nature of light
➤ both as a *wave* and a *particle*.



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Review Of Key Points

- ✓ Johann Ritter discovered the *invisible* ultraviolet region.
- ✓ Ultraviolet light is *not visible* light.
- ✓ The electromagnetic spectrum is made up of different energy regions mostly invisible to the human eye. Ultraviolet light is part of it.
- ✓ Light is described with 3 basic properties: frequency, wavelength, energy.
- ✓ Light is made up of lots of photons streaming through the air.



Module 3

GUV References / Standards And Guidelines



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GUV References / Standards And Guidelines

In this section we explore:

- ❖ Terminology.
- ❖ Use of GUV in disease prevention.
- ❖ Centers for Disease Control and Prevention (CDC) Guidelines.
- ❖ Illuminating Engineering Society (IES) Standards.
- ❖ The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Handbooks, ANSI/ASHRAE standards, and guidelines on GUV.



Ultraviolet Light Can Be Described With Different Terms

The Ultraviolet Industry has no standard language or definitions

Depending on the organization or industry group terminology for ultraviolet can differ.

This creates a lot of confusion.

Examples of terminology used in industry:

Germicidal Ultraviolet: GUV

Ultraviolet C band: UV-C or UVC

Ultraviolet Germicidal Irradiation: UVGI

Ultraviolet C band specific to wavelength: UV-C222, UV-C254, UV-C265

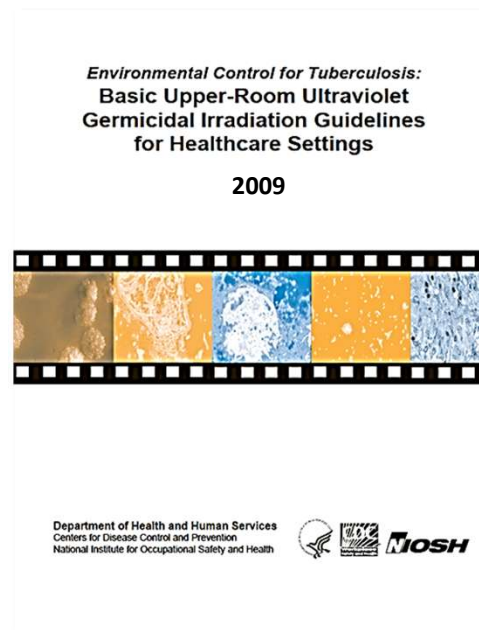
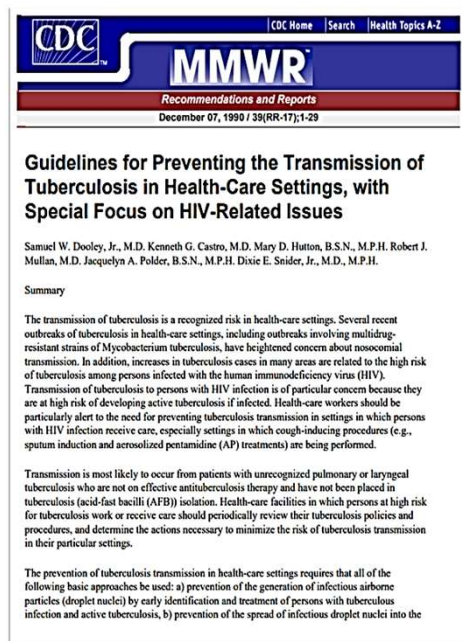
In this course we will use
germicidal ultraviolet (GUV)

The Use Of Germicidal Ultraviolet In Disease Prevention

- Years of experiments and observations lead to the discovery that ultraviolet light can help reduce the transmission of diseases.
- Specifically, the ultraviolet UV-C region of the electromagnetic spectrum shows the greatest effect on germs in the air.
- The Centers for Disease Control and Prevention (CDC) began to publish guidelines on the use of UV-C.
- These guidelines also refer to upper-room germicidal ultraviolet (UR-GUV).
- UR-GUV is strictly from the UV-C region of the electromagnetic region.

CDC/NIOSH :How Has UR-GUV Been Used In The Past?

Since 1950's bulk of research on GUV focused on controlling spread of tuberculosis (TB).



Current guidance (2009) on the design, installation, testing, and safe operation of UR-GUV systems.

Ref: CDC.com



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CDC/NIOSH : Covid-19 Pandemic Prompted Changes

Updates to guideline documents prompted by Covid-19 pandemic.

UPDATE About Germicidal Ultraviolet (GUV):

<https://www.cdc.gov/niosh/ventilation/germicidal-ultraviolet/>

“Germicidal ultraviolet (GUV), otherwise known as ultraviolet germicidal irradiation (UVGI), is the use of ultraviolet (UV) energy to kill viral, bacterial, and fungal organisms in the workplace.”

“GUV is best used as part of a layered approach to reducing exposures to airborne pathogens, along with other strategies such as ventilation systems.”

“GUV is best used in group settings such as open concept office buildings or schools.”

NEW About Ventilation and Respiratory Viruses

<https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/improving-ventilation-in-buildings.html>

“Good ventilation is essential to maintaining a healthy indoor environment and protecting building occupants from respiratory infections in the workplace.”

“Improving ventilation can reduce the number of particles in the air and lower occupants' risk of exposure to airborne hazards.”



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Recommended Practices By IES – Standards On GUV



RP-27.1-22 focused on:

- Background of UV Radiation
- Emission Limits and Measurements for Risk Group Determination
- Systems Safety Control Measures for Manufacturers
- Labeling
- Safety Control Measures for Occupied Spaces

RP-44-21 focused on:

- Types of UV Radiation
- Types of GUV Equipment and Systems
- Effects of Ultraviolet Radiation
- Design and Use of UVGI Systems for Disinfection Effectiveness
- Maintaining Systems and Verifying Performance
- Safety Measures and Restrictions
- Overview: Systems Comparison

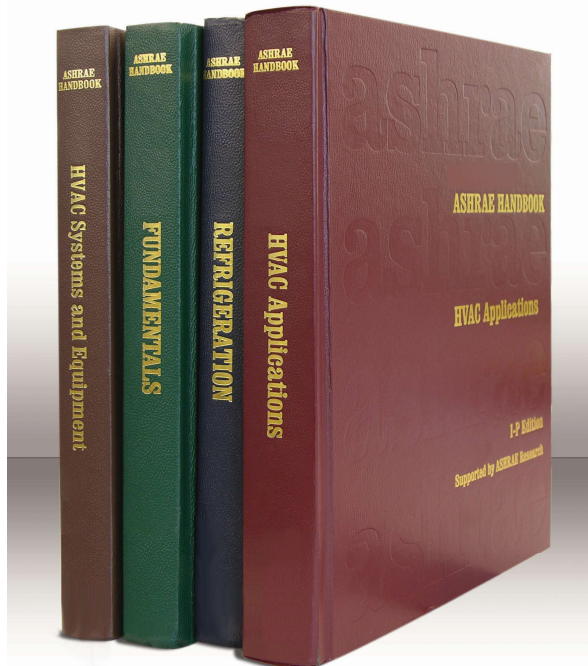


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ASHRAE: Handbooks With Chapters On GUV

ASHRAE stands for the American Society of Heating, Refrigerating and Air-Conditioning Engineers



2024 HVAC Systems and Equipment – Chapter 17 contains:

- Terminology
- GUV Fundamentals
- Germicidal Ultraviolet Sources and Equipment
- UV-C Photodegradation of Materials
- Maintenance
- Safety
- Installation and Commissioning

2023 HVAC Applications – Chapter 62 contains:

- Terminology
- UVGI Air Treatment Systems
- HVAC System Surface Treatment
- Energy and Economic Considerations
- Room Surface Treatment
- Safety
- Installation, Start-Up, and Commissioning
- Maintenance



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Review Of Key Points

- ✓ The Ultraviolet Industry has no standard language or definitions.
- ✓ Germicidal ultraviolet (GUV) is used to help prevent disease.
- ✓ CDC/NIOSH has guidelines on the use of GUV.
- ✓ IES published recommended practices on GUV applications and safety.
- ✓ ASHRAE published handbooks include chapters on GUV applications and GUV systems and equipment.

Online Module 4

Applications Of GUV



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Applications Of GUV

In this section we explore:

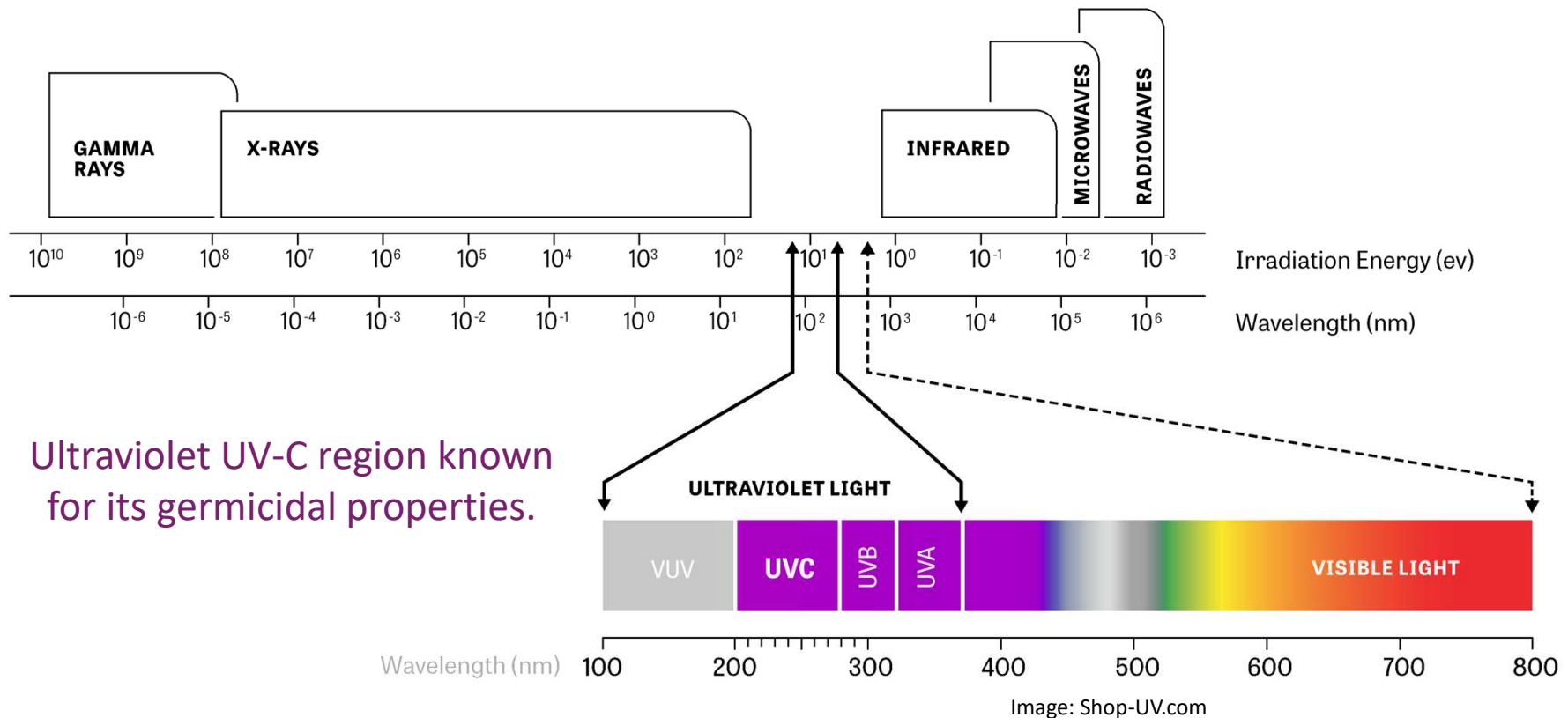
- ❖ A closer look at Ultraviolet
- ❖ UV-A / UV-B / UV-C
- ❖ Common GUV Applications
- ❖ Upper-Room Germicidal Ultraviolet (UR-GUV)
- ❖ Whole-Room Germicidal Ultraviolet (WR-GUV)



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UV-A, UV-B, UV-C And The Electromagnetic Spectrum

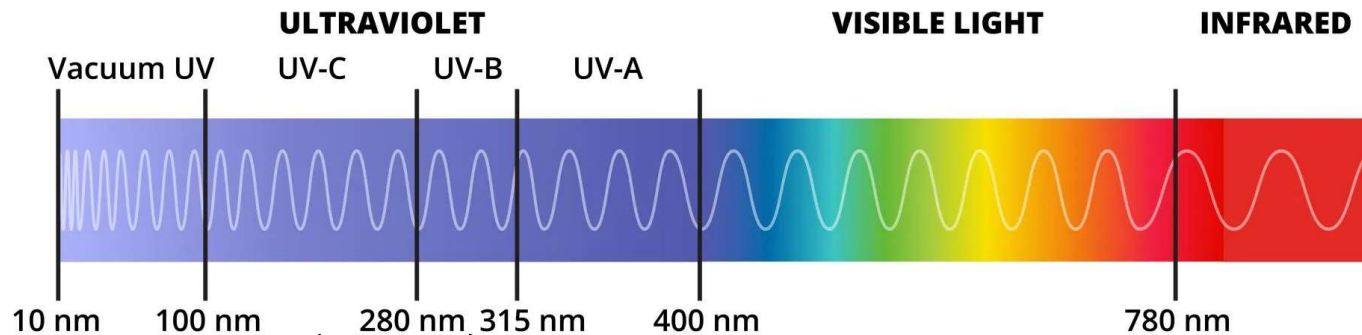


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Ultraviolet UV-A, UV-B, UV-C

ULTRAVIOLET LIGHT



UV-C (100-280 nm):

Causes reddening of skin and eye irritation.

Inactivates bacteria and viruses

Inactivating bacteria and viruses means they can no longer replicate in their disease-causing state and become harmless.

UV-B (280-315 nm):

Causes burning, skin aging, responsible for skin cancer.

UV-A (315-400 nm):

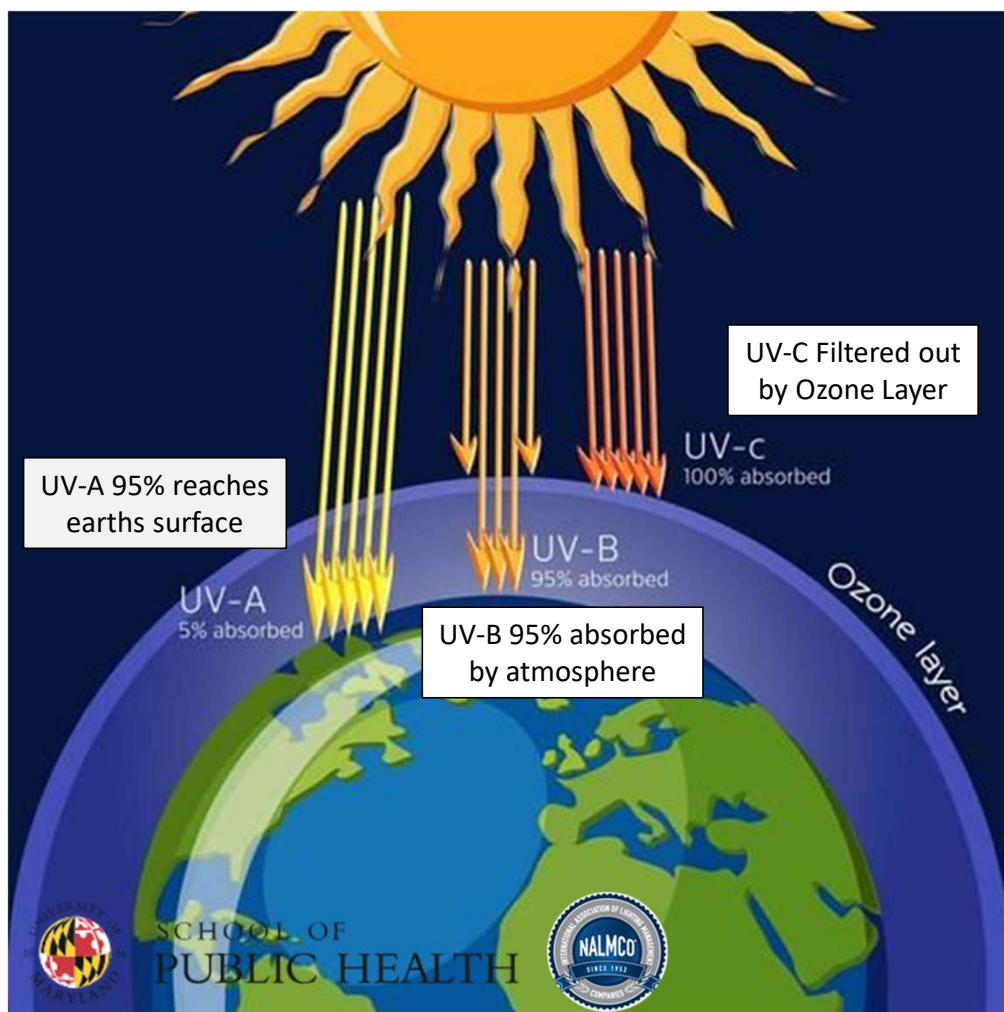
Responsible for tanning.



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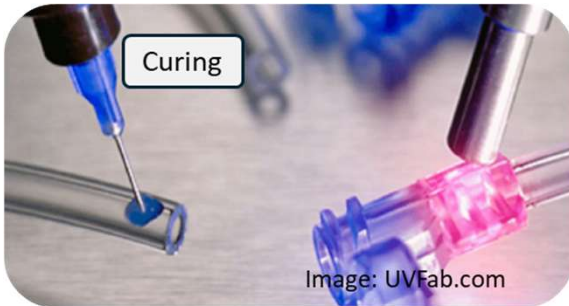


The Sun Generates Ultraviolet UV-A, UV-B, And UV-C rays

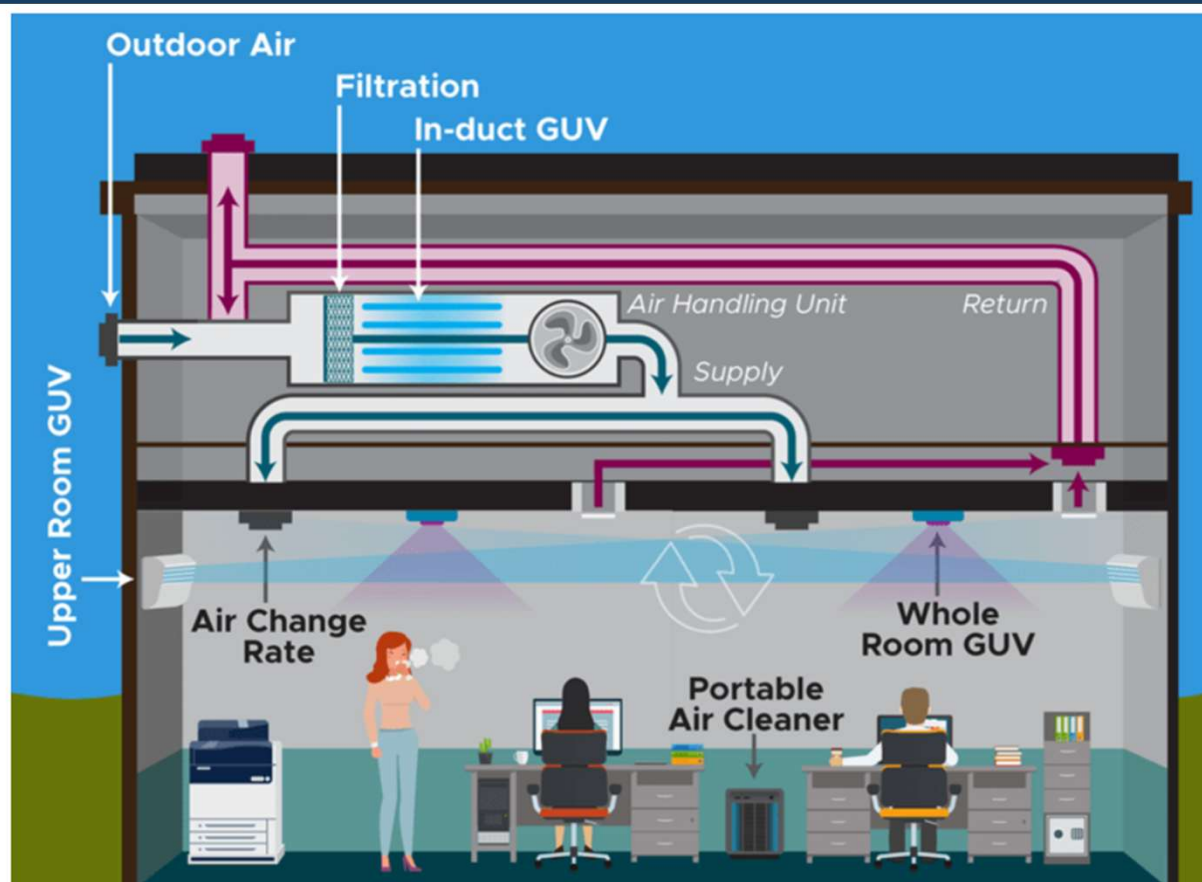


- ❖ 95% of UV-A reaches the earth.
- ❖ 5% of UV-B reaches the earth.
- ❖ UV-C is completely filtered out by the Ozone layer.
- ❖ Imagine if UV-C would not be filtered out. Life on Earth would not be possible the way we know it!
- ❖ Artificial UV-C lamps can be made to inactivate unwanted viruses or bacteria.

Applications Of Artificial UV-A / UV-B



Applications Of UV-C (GUV) In Disease Prevention

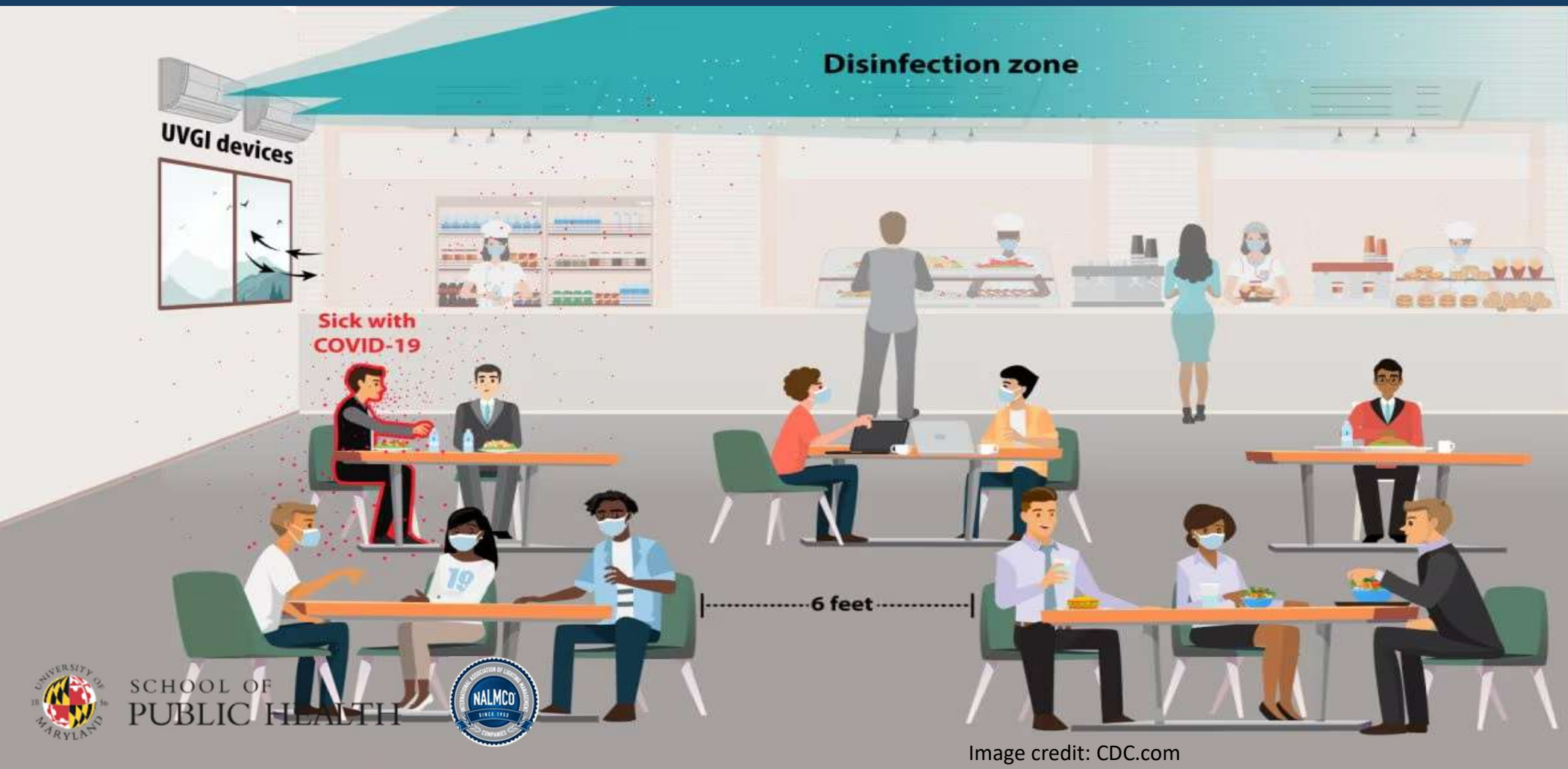


Measures to reduce spread of airborne diseases (Image: PNNL)

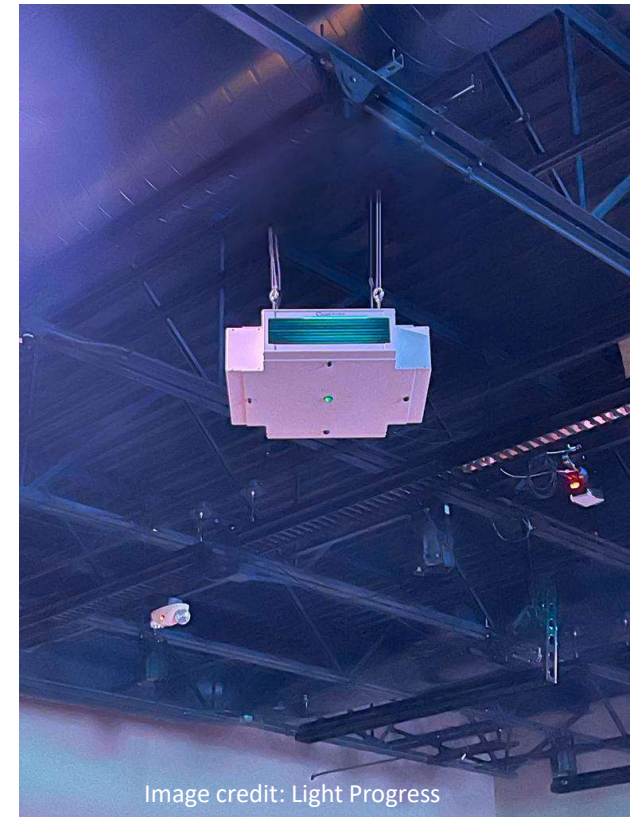
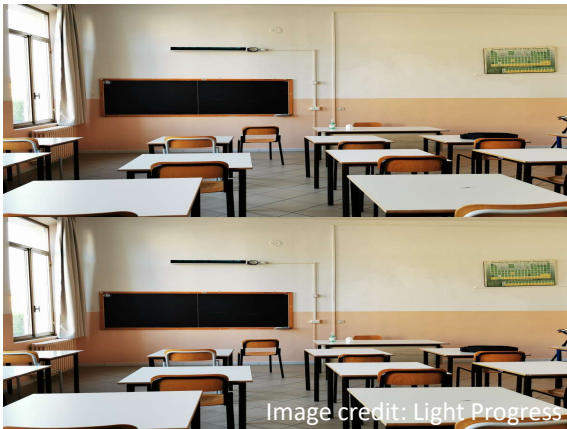


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Disease Prevention Using Upper-room GUV



Disease Prevention: Upper-room GUV



Disease Prevention: Whole-room GUV



Disease Prevention: Upper-room & Whole-room GUV Combo

Whole-room GUV

Upper-room GUV



Image Credit: Paul Jensen



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Applications Of GUV In Disease Prevention

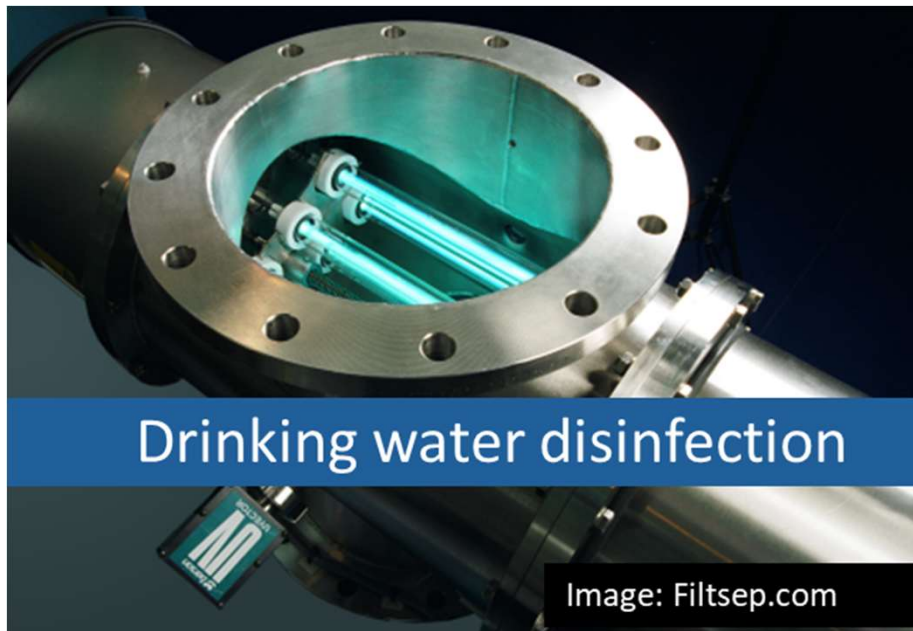
HVAC Air disinfection



Surface disinfection



Applications Of GUC In Disease Prevention



Review Of Key Points

- ✓ The sun generates UV-A, UV-B, and UV-C.
- ✓ Some UV-A and UV-B reach the earth's surface.
- ✓ UV-C is filtered out by the ozone layer and does not reach the earth.
- ✓ UV-C has germicidal properties and inactivates (kills) bacteria and viruses.
- ✓ Man made germicidal ultraviolet (GUV) lamps are used for disease prevention.
- ✓ GUV lamps are used in many different applications to eliminate unwanted bacteria and viruses from the air, on surfaces and in water.



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Online Module 5

UR And WR GUV Luminaires: Components



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UR And WR GUV Luminaires: Components

In this section we explore:

❖ Components of UR GUV luminaires

1. Lamp(s)
2. Ballast(s) or Driver
3. Optical elements
4. Luminaire Housing (some housings have reflectors, baffles, diffusers)



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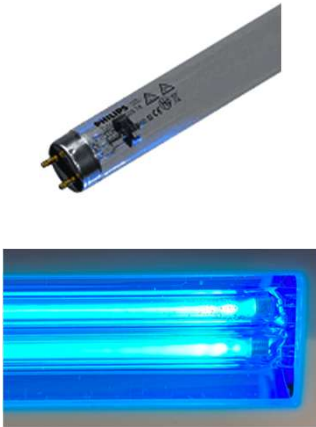


Component 1: Lamp(s)

Similar to regular light fixture:

1. Lamp(s)

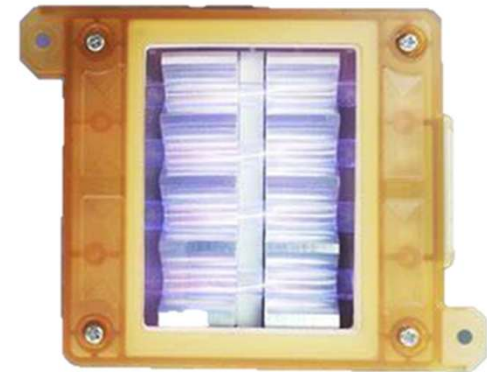
Low Pressure Mercury lamp



Light Emitting Diodes (LEDs)



Excimer lamp (KrCl*)



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Component 2: Ballast(s) Or Drivers

The same idea as a regular light fixtures:

2. Ballast(s) or Driver to operate the lamp at specified electrical conditions



Ballast for Low Pressure Mercury Lamp



KrCl* Excimer Lamp electronics



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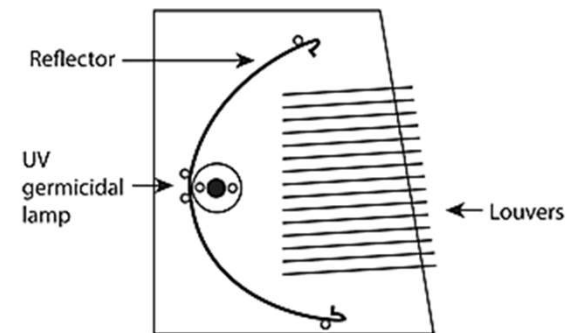
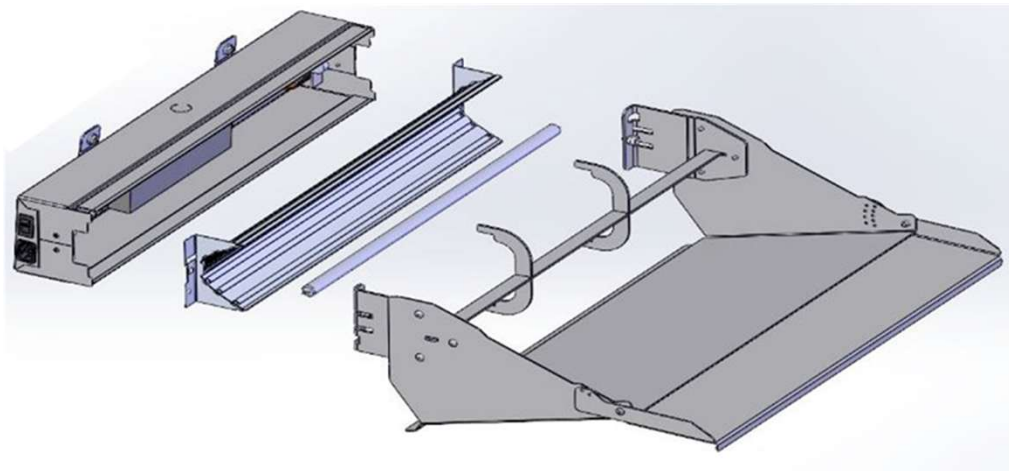


Components 3: Optical Elements

The same idea as a regular light fixture:

3. Optical elements to safely manipulate the lamp UV-C output radiation

Low Pressure Mercury Lamp Fixture:



Optical element could be a:

- parabolic reflector
- refractor
- diffuser,
- safety louver/baffle
- lens
- or combination



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Components 3: Optical Elements

KrCl* Excimer Lamps:

Diffused optics



Image Credit: Katja Auer



Images by lit Thinking



Clear optics



Image Credit: Katja Auer



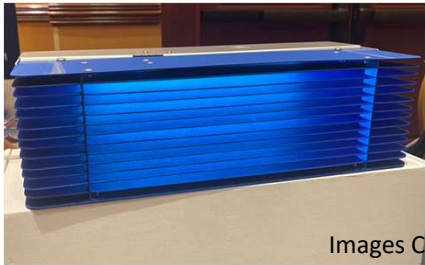
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Components 4: Housing

The same idea as a regular light luminaire:

4. A housing to mount the above 3 components in a fixed configuration for a given application



Images Credit: Bill Palmer



Low Pressure Mercury lamp
housing examples



Image credit:



Katja Auer



Image credit: lit Thinking

KrCl* housing examples



Image credit: Katja Auer

LED housing example



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Review Of Key Points

- ✓ Most UR and WH fixtures have 4 components:
 1. Lamp(s)
 2. Ballast or driver
 3. Optical elements
 4. Housing
- ✓ Different optical elements are used depending on lamp and application.
- ✓ The lamp(s) and application determine the type of housing needed.



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Online Module 6

What Does GUV Light Do? How Does It Work?



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What Does GUV Light Do? How Does It Work?

In this section we explore:

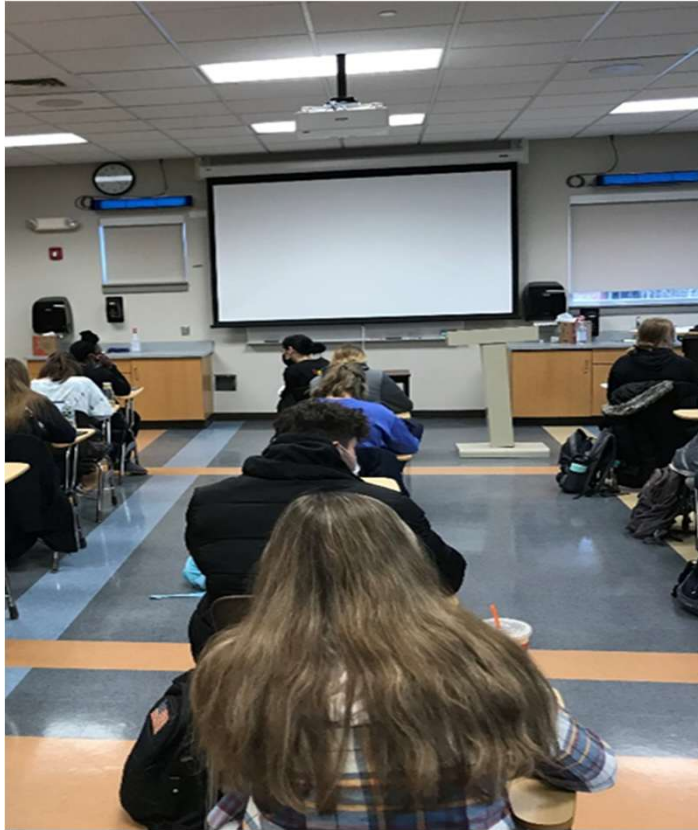
- ❖ Definition of *pathogen*
- ❖ Definition of *germicide*
- ❖ CDC Upper-Room GUV Definition
- ❖ How GUV works



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GUV Inactivates Pathogens In The Air



GUV fixtures inactivate potential *pathogens* indoors.

What is a **pathogen**?
(*adjective* pathogenic) An organism or other agent that causes disease.

<https://www.ncbi.nlm.nih.gov/books/NBK26917/>



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What Is A Germicide?



Definition *germicide*:

- something (such as an antiseptic or disinfectant) that destroys or inactivates (kills) pathogens such as bacteria and viruses.
- an agent or preparation that is effective against germs



The result is loss of ability to replicate preventing the bacteria or virus from causing infection.



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CDC UR GUV Definition



Image Credit: Paul Jensen

Upper-room UVGI (aka GUV) refers to a disinfection zone of UV-C energy located above people in the rooms they occupy.



UR GUV kills (inactivates) airborne pathogens in the room where they are released.



GUV fixtures are installed to prevent direct exposure of people in the room.

Adapted from CDC.gov



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UR GUV Inactivates Pathogens

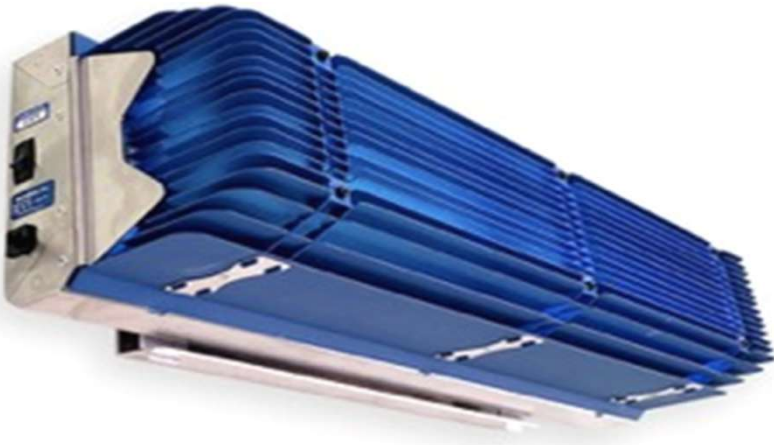


Image Credit: Bill Palmer

For airborne viral particles, UR GUV systems provide air changes per hour similar to the introduction of clean air into the space.

WR GUV Inactivates Pathogens



Image credit: Lit Thinking

Whole-room GUV
creates a disinfection
zone of UV-C energy
throughout the entire
room.



Image credit: Katja Auer



Image credit: Katja Auer



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How UR GUV works



1.

Air passes through the disinfection zone from:

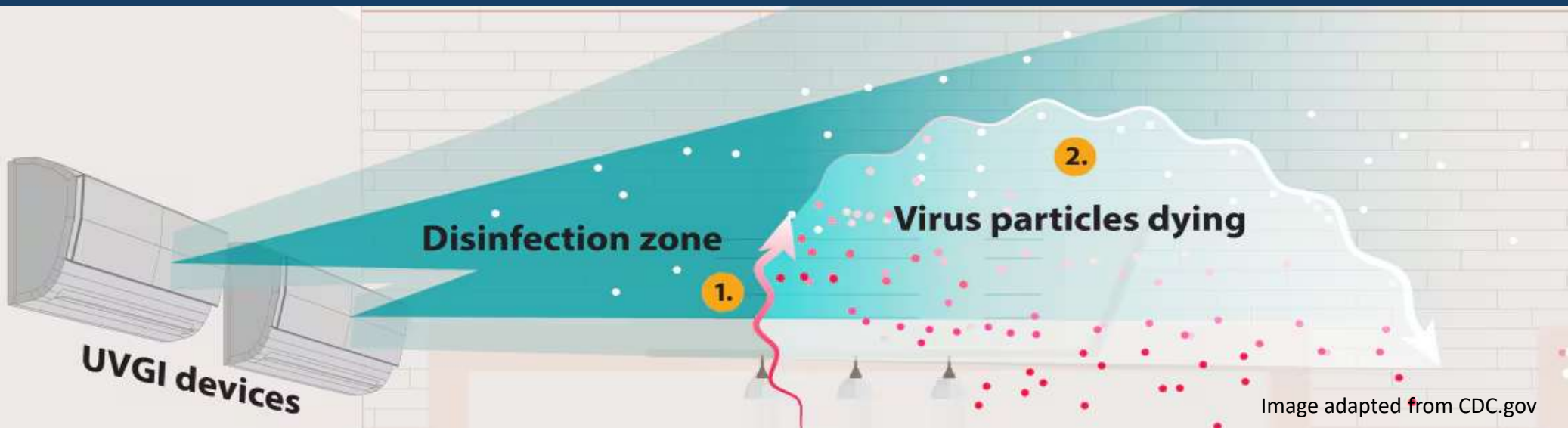
- a. air flow through HVAC system diffusers
- b. fans
- c. convection (heat sources such as occupants and computers)
- d. and/or open windows.



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How UR GUV works



2. The airborne pathogens (viruses) are inactivated (killed) once they receive an appropriate amount of UV-C energy.

Viral particles remain in the air but are no longer infectious and are dying.



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Review of Key Points

- ✓ GUV fixtures inactivate (kills) potential *pathogens* (organism that causes disease) indoors.
- ✓ A *germicide* destroys or inactivates (kills) pathogens such as bacteria and viruses.
- ✓ Upper-room GUV (UR GUV) refers to a disinfection zone of UV energy that is located above people in the rooms they occupy.
- ✓ Whole-room GUV (WR GUV) creates a disinfection zone of UV-C energy throughout the entire room.
- ✓ UR & WR GUV works by: Air passing through GUV disinfection zones, where airborne pathogens (viruses) are inactivated (killed) once they receive an appropriate amount of GUV energy.



Online Module 7

GUV Lamp Technologies



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GUV Lamp Technologies

In this section we explore:

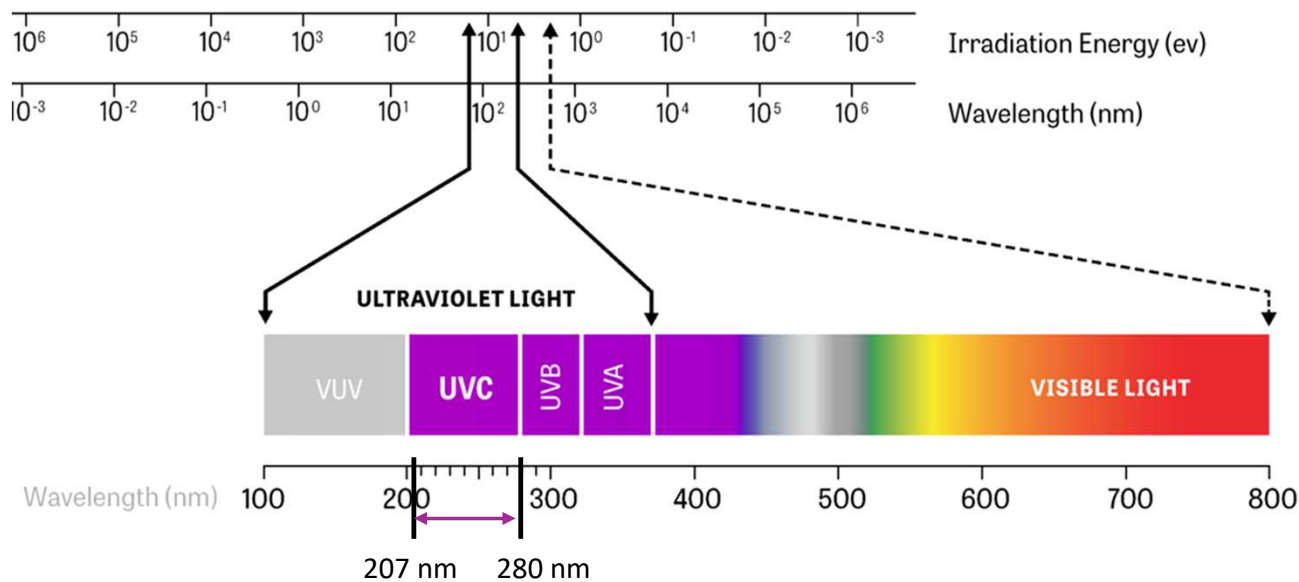
- ❖ Artificial germicidal lights
- ❖ Definition *Photobiology*
- ❖ Optimal germicidal wavelength
- ❖ UV Lamp Technologies



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Artificial GUV Creates Certain Wavelengths



GUV ranges from 207 nm to 280 nm wavelengths

Ultraviolet GUV region is known for its germicidal properties.



This region inactivates bacteria and viruses.



GUV lamp technologies can create different germicidal wavelengths



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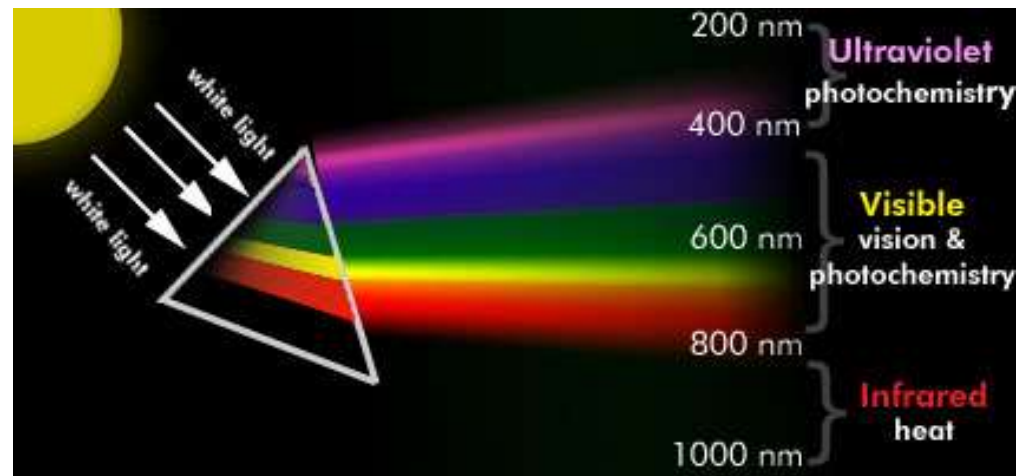
Photobiology And Its Effect On Living Organisms



What is *photobiology*? The study of the effects of light on living organisms (Merriam-Webster) .

- "**Photobiology** is broadly defined to include all biological phenomena involving non-ionizing radiation.
- It is recognized that photobiological responses are the result of chemical and/or physical changes induced in biological systems by non-ionizing radiation."

(Constitution of the American Society for Photobiology)



GUV has a photobiological effect on bacteria and viruses.



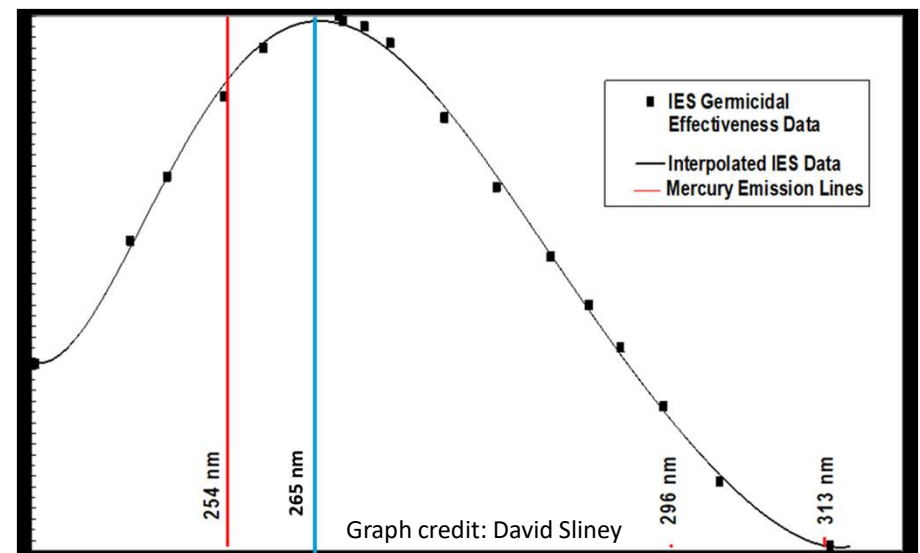
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Optimal Germicidal Wavelength

- The *Germicidal Action Spectrum* defines relative effectiveness of differing wavelengths in producing a photobiological responses.
- The most effective photobiological response is at about 265 nm.
- Bacteria and viruses differ in how they respond to GUV, but most will be inactivated (killed) when exposed to enough GUV energy.
- Artificial UV-C lamps generate different wavelengths (e.g., 222 nm, 254 nm) where all are effective in inactivating bacteria and viruses.

IES Germicidal Action Spectrum



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Artificial GUV Lamps Act As A Germicide

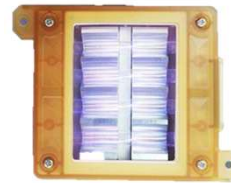
Artificial GUV lamps create photobiological responses.

What types of GUV lamp technologies are used for UR & WR GUV fixtures?

1. Low Pressure Hg Lamps – generate 253.7 nm
(commonly referred to as 254 nm)



2. Excimer lamps – generate 222 nm
(commonly referred to as KrCl*)



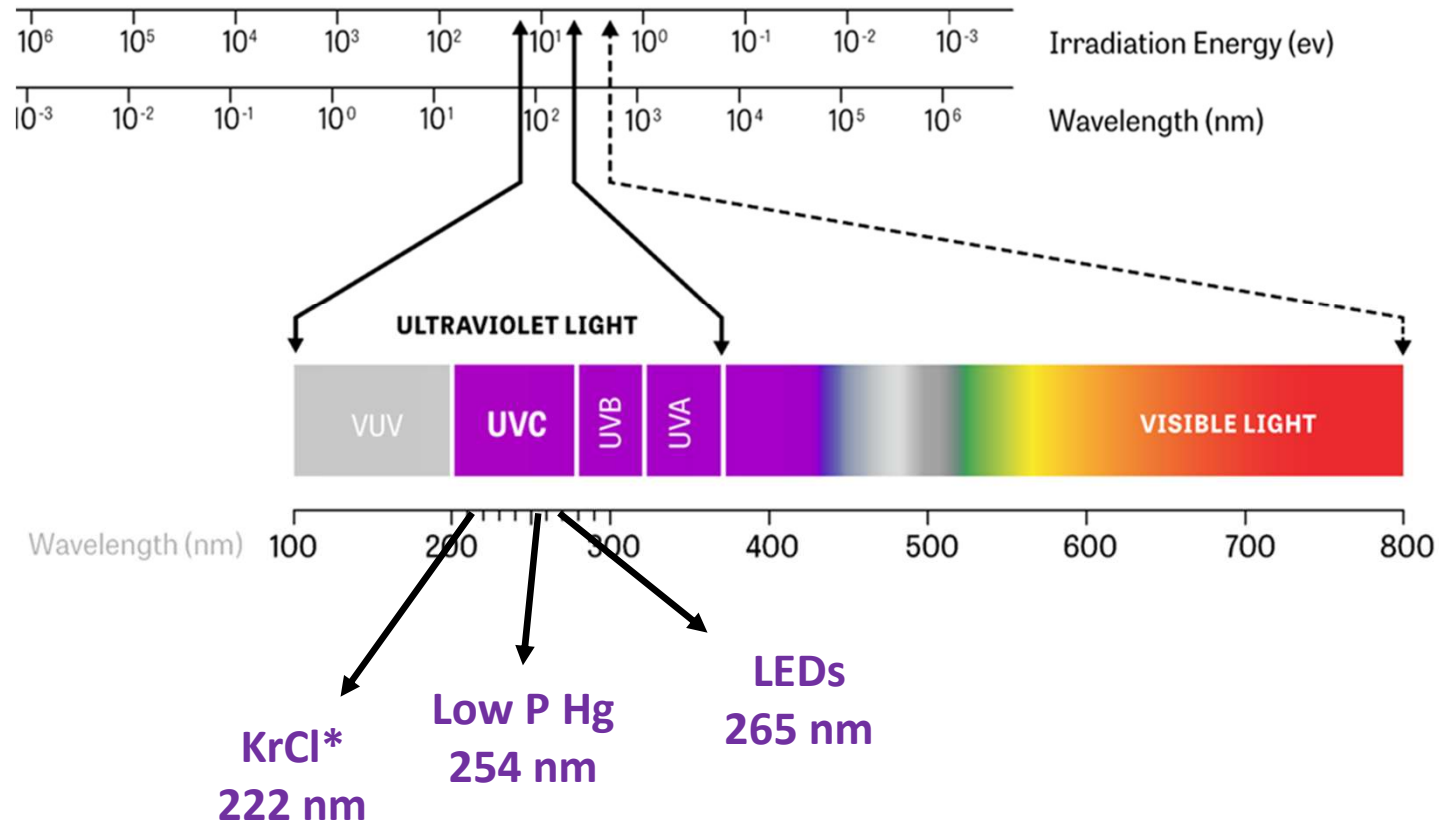
3. Light Emitting Diodes (LEDs) – can generate various wavelengths
(mostly 265 nm for germicidal applications)



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UR GUV Lamp Technologies



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UR GUV Lamp Technologies: Low Pressure Hg Lamps

- Low pressure mercury (Hg) discharge lamps generate UV-C at 253.7 nm (rounded 254 nm).
- Available in many different lengths and shapes.
- Most efficient method to generate GUV.



Image: Ushio GTL3 3W
Low Pressure Lamp



Image: Philips TUV 4W
Low Pressure lamp

- Electrically the same as fluorescent lamps (hot cathode starting).
- Available in various sizes and wattages and equipped with ballasts.
- Constructed with special kind of glass transmitting about 80% of 253.7 nm energy generated by Hg discharge.

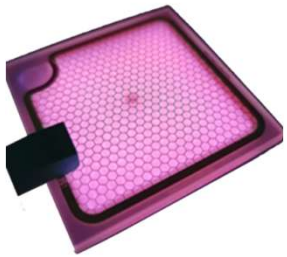


Image: ultraviolet.com

Ref: ANSI/IES RP-44-21

UR GUV Lamp Technologies: Excimer Lamps

- Excimer lamps are very small compared to mercury lamps
- Use rare-gas-halogen excimer (e.g., krypton-chloride, KrCl*) lamps producing most emissions between 200 nm to 230 nm.
- Most emission is at 222 nm.



Images credit: USHIO

Advantage: effect on human skin and eyes is much reduced as compared to 253.7 nm mercury emission.

Disadvantage: potential of ozone production.

ASHRAE Handbook 2024 Systems & Equipment Ch17

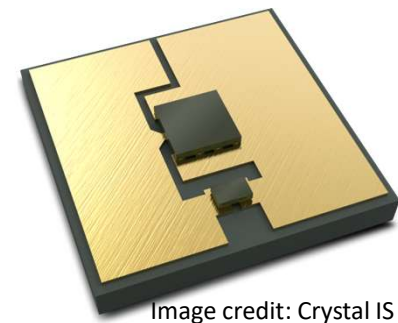
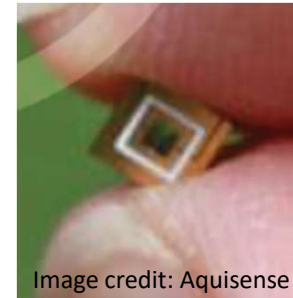


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UR GUV Lamp Technologies: Light Emitting Diodes (LEDs)

- Very small in size and often many are used in one GUV Luminaire.
- Typically have a peak wavelength emission between 260 to 280 nm when used for germicidal applications.
- Can be designed for germicidal output around the peak efficiency of the standard germicidal response function (~265 nm).
- Highly customizable, but their specific spectral distribution, peak wavelength, and performance characteristics can differ widely across manufacturers.

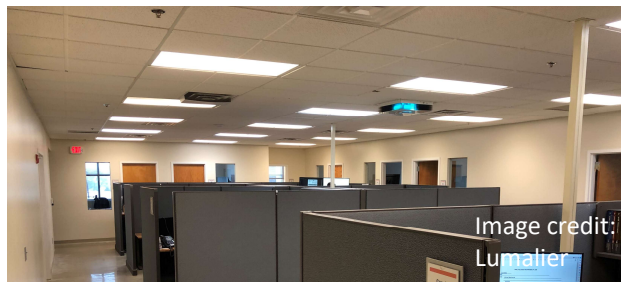
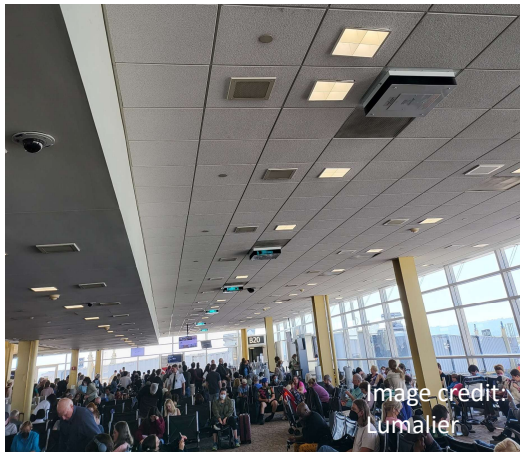


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Images Of Various UR & WR GUV Lamp Technology Fixtures

254 nm Fixture



KrCl* Fixture



LED Fixtures

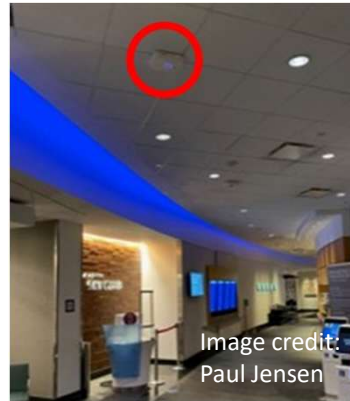


Examples: Installation Options UR & WR GUV Fixtures

Wall Mount



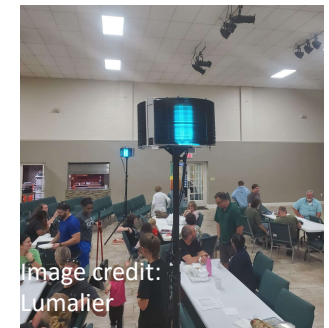
Ceiling Mount



Tri-pod mount



Pendant Mount



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Review of Key Points

- ✓ GUV lamp technologies can create different germicidal wavelengths.
- ✓ Photobiology is the study of the effects of light on living organisms, which can result in chemical and/or physical changes in viruses and bacteria.
- ✓ The Germicidal Action Spectrum defines the photobiological response of the different wavelengths on bacteria and viruses.
- ✓ There are 3 lamp types used for UR and WR GUV applications:
 1. Low pressure Mercury lamps (254 nm)
 2. KrCl* Excimer lamps (222 nm)
 3. Light Emitting Diodes (LEDs) (around 265 nm)



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Online Module 8

Mechanisms of GUV inactivation



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How does GUV inactivate?

In this section we explore:

- ❖ How GUV inactivates bacteria and viruses
- ❖ Photons damage cells
- ❖ Susceptibility of microorganisms & viruses to GUV
- ❖ Examples of Well Studied Bacteria and Viruses



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How GUV Inactivates Bacteria And Viruses

Bacterial cells: Target molecule for UV-C photons is DNA molecule in nucleus of bacterial cells.

Viruses: Do not have a cell, so RNA is photon target (e.g., influenza virus, RSV, and SARS-CoV-2 are RNA viruses).

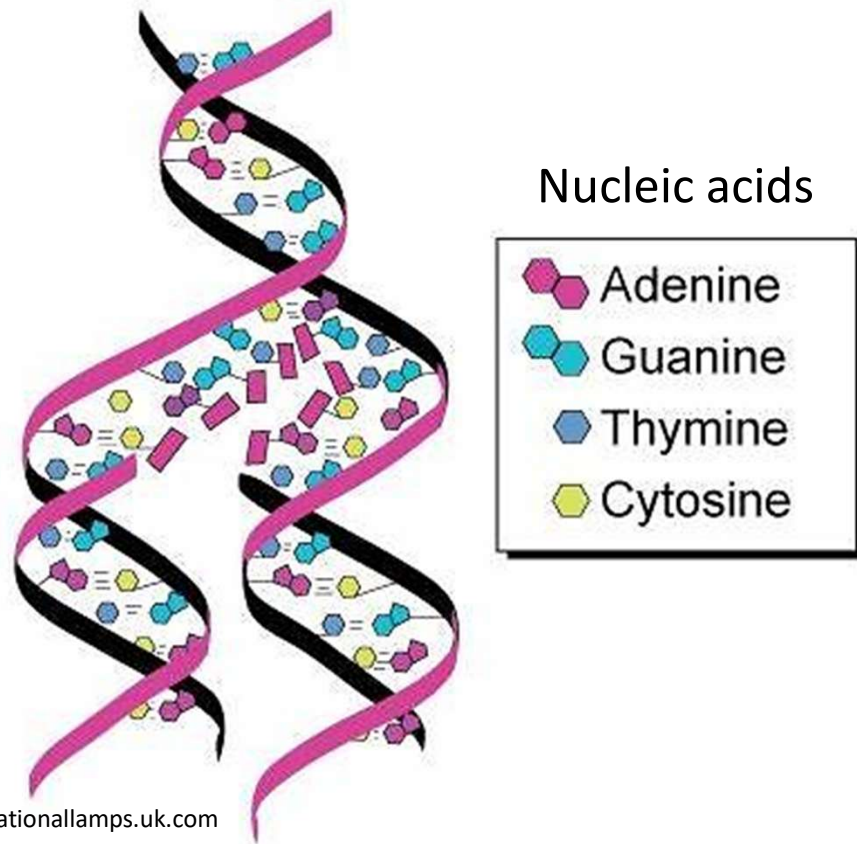


Image: Internationallamps.uk.com

GUV Inactivates Microorganisms By Damaging Their Structure

GUV inactivates bacteria and viruses by damaging the structure of nucleic acids and proteins at molecular level.



Absorbed UV-C photons damage DNA/RNA in various ways.



The more UV-C photons a lamp generates the greater the inactivation of the bacteria or virus.



The higher the lamp intensity the faster the inactivation.

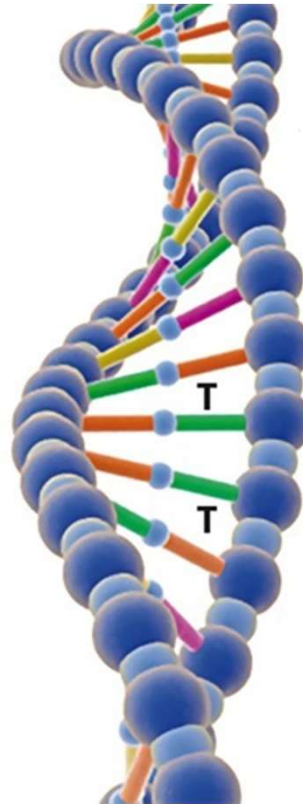


Image shows:

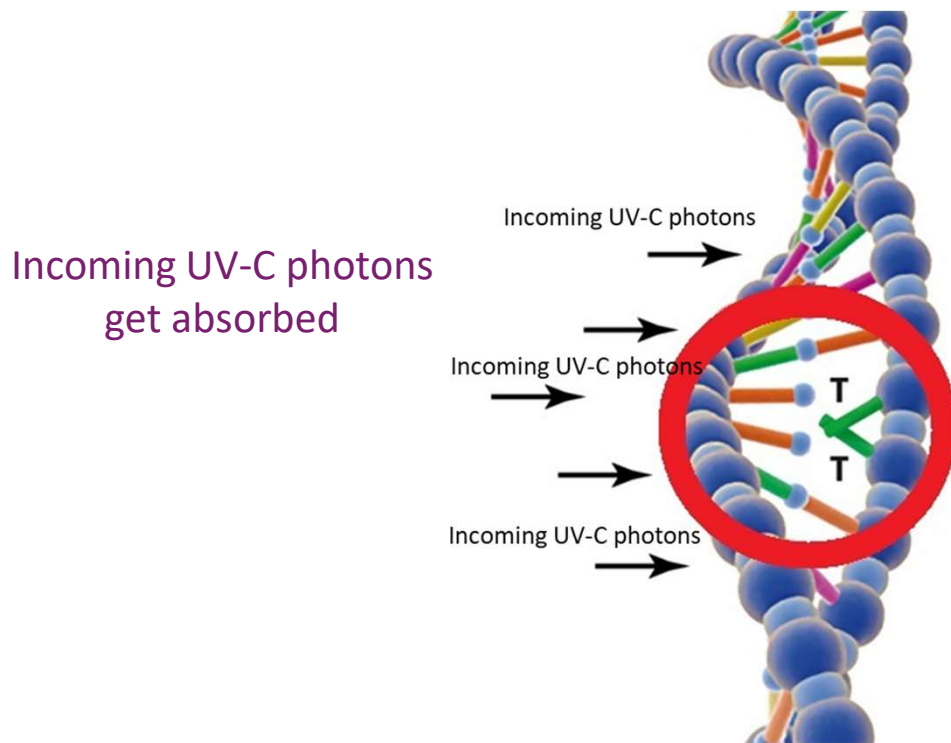
- Unharmed DNA/RNA strand
- nucleic acids intact



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How GUV Inactivates. Photons Damage Cell



Adenine-thymine bonds are destroyed



Thymine-thymine (pyrimidine dimers) bonds form.



Creates error in DNA/RNA.



Microorganisms and viruses no longer reproduce in pathogenetic state.



Cell becomes sterile

Note: Excimer lamps (222 nm) cause protein damage.

Susceptibility Of Microorganisms & Viruses To GUV

Fungal Spores	Bacterial Spores	Mycobacteria	Vegetative Bacteria	Viruses
<i>Aspergillus versicolor</i> <i>Penicillium chrysogenum</i> <i>Stachybotrys chartarum</i>	<i>Bacillus anthracis</i> <i>Bacillus cereus</i> <i>Bacillus subtilis</i>	<i>Mycobacterium tuberculosis</i> <i>Mycobacterium bovis</i> <i>Mycobacterium leprae</i>	<i>Staphylococcus aureus</i> <i>Streptococcus pyogenes</i> <i>Escherichia coli</i> <i>Pseudomonas aeruginosa</i> <i>Serratia marcescens</i>	Influenza viruses Measles Coronavirus Smallpox
LEAST SUSCEPTIBLE		253.7 nm	MOST SUSCEPTIBLE	

UVResources.com

In each group, an individual species may be significantly more resistant or susceptible than others.



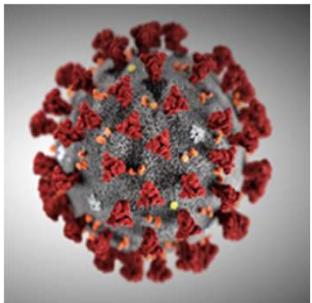
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Examples Of Well Studied Bacteria And Viruses

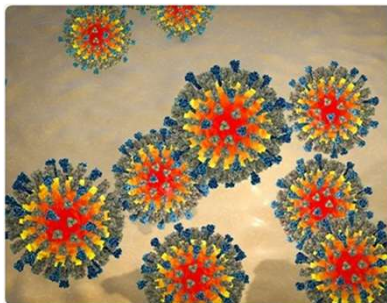
There is much research on disease causing bacteria and viruses.

It is well understood how GUV inactivates them.



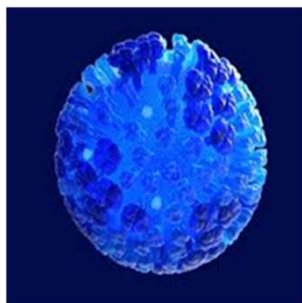
SARS-COV-2

www.stemcell.com/wallcharts/covid19



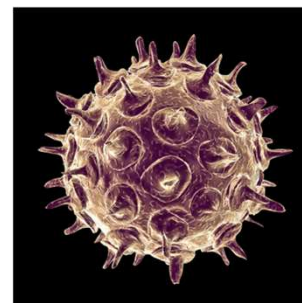
Measles virus

<https://www.news-medical.net/news/20180226/Australian-brings-measles-to-New-York-sparking-fears-for-unvaccinated.aspx>



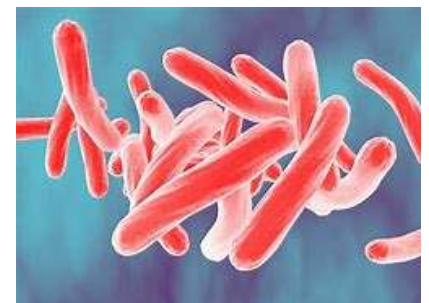
Influenza Virus

CDC.gov



**Varizella zoster
(Chicken pox
virus)**

<https://procon.org>



**Mycobacterium
tuberculosis**

<https://microbiologyresearch.org>



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Review of Key Points

- ✓ Bacterial cells: Target molecule for UV-C photons is DNA molecule in nucleus of bacterial cells.
- ✓ Viruses: Do not have a cell, so RNA is the UV-C photon target.
- ✓ GUV inactivates bacteria and viruses by damaging the structure of nucleic acids and proteins at molecular level.
- ✓ The more UV-C photons a GUV lamp generates the greater the inactivation of the bacteria or virus and the cell will die off.
- ✓ Viruses generally need fewer UV-C photons than bacteria to be inactivated (killed).



Online Module 9

UR & WR GUV Fixture Maintenance



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UR & WR GUV Fixture Maintenance

In this section we explore:

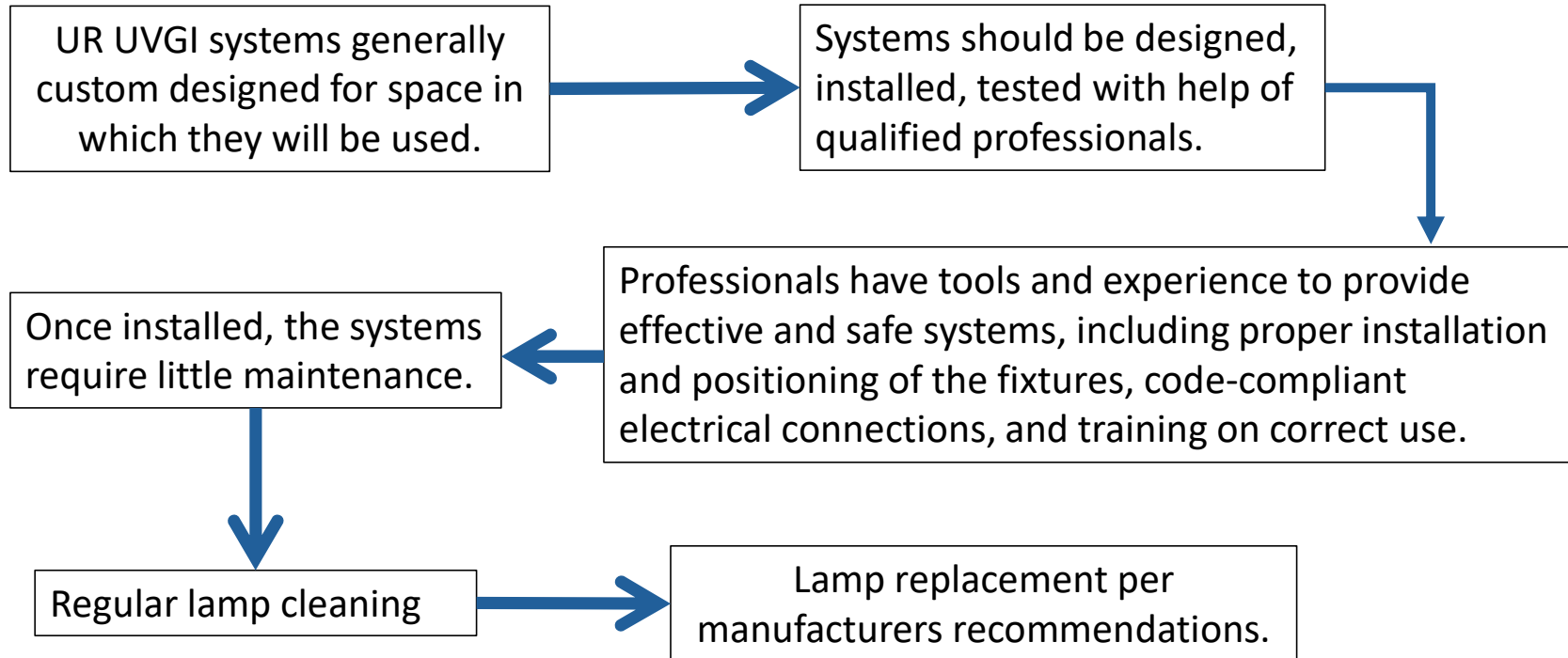
- ❖ UR GUV Maintenance described by CDC
- ❖ UR & WR GUV Luminaire: 6 Maintenance Steps
- ❖ UR GUV – Maintenance: Example
- ❖ When to change GUV lamps



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UR GUV Maintenance As Described By CDC



Let's explore what is needed for maintenance



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UR & WH GUV Fixtures: 6 Maintenance Steps

Step 1: Use proper Personal Protective Equipment (PPE)

Step 2: Have all required tools and meters

Step 3: Take Witness Point measurement

Step 4: Turn off power to UR/WR GUV Fixture

Step 5: Clean UV-C lamp(s) or

Step 6: Replace lamp(s) per manufacturers recommendations



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UR & WR GUV – Maintenance: Step 1



Image: greciacontabilidad

Before any maintenance begins: Proper Personal Protective Equipment PPE shall be worn

- PPE includes:
- UV Safety glasses
 - Appropriate footwear
 - Gloves
 - Clothing covering skin



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UR & WR GUV – Maintenance: Step 2

Have all required tools

- Ladder
- Appropriate screwdriver(s) – consult fixture manual
- Gloves (lint free, nitrile, latex – any gloves allowing safe handling of GUV lamps)
- Commercial glass cleaner or isopropyl alcohol
- Wavelength appropriate calibrated Radiometer
- Maintenance Log
- Manufacturers instructions



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UR & WR GUV – Maintenance: Step 3

Witness Point measurement



A *witness point* is a consistent point of measurement within the space. This is taken with a calibrated radiometer.



Calibrated
radiometers



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UR & WR GUV – Maintenance: Step 3

Witness Point measurement (PPE needed!)

Make note of the witness point in notebook.

Measure output pre- and post maintenance to verify output at witness point.

Compare values to previous measurement in maintenance log.

Measurement should be around 70% of the initial value at installation.

Is value less than 70%, investigate if: Does lamp need to be cleaned?

It is time for replacement? Is there another issue?



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UR & WR GUV – Maintenance: Step 4

Turn power off to GUV Luminaire

NEVER perform maintenance on
a GUV Luminaire with lamps on.

This step is so important that it has its own slide.



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Maintenance: Step 5

Clean GUV Luminaires & lamp(s) per manufacturers instructions

- Wear nitrile, or latex gloves, or lint free gloves to avoid depositing oils from one's hands on the bulb envelope.
- A dirty lamp should be cleaned with a lint-free cloth and commercial glass cleaner or isopropyl alcohol. DO NOT use soap.
- Clean reflectors and UV-C lamps with $\geq 70\%$ alcohol and lint-free cloths
- Before activation, lamps should be wiped down with isopropanol after installation to remove any contaminants (e.g., fingerprints).
- Measure output pre- and post maintenance.



UR & WR GUV – Maintenance: Step 6

Replace lamp(s) per manufacturers recommendations

When servicing upper room GUV Luminaires:

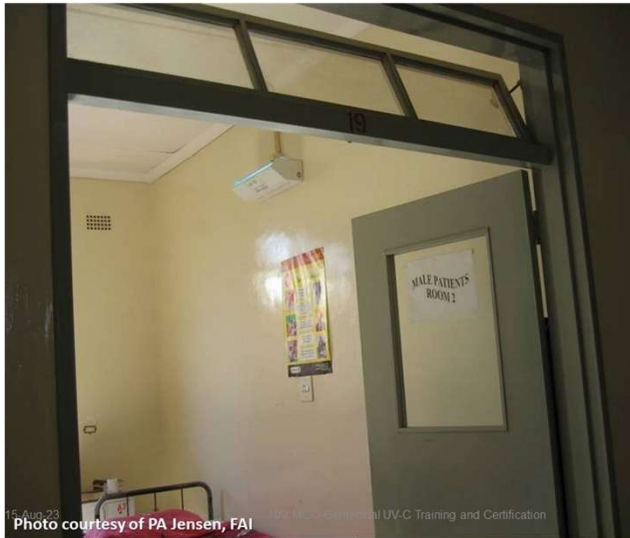
- Wear UV-protective gloves / clothing / face shield
- Turn off the GUV Luminaire
- Confirm the proper lamp for replacement
- Take care not to break lamp
- Wipe off any fingerprints (oil from fingers harmful to lamp life)
- Verify GUV lamp output after installation



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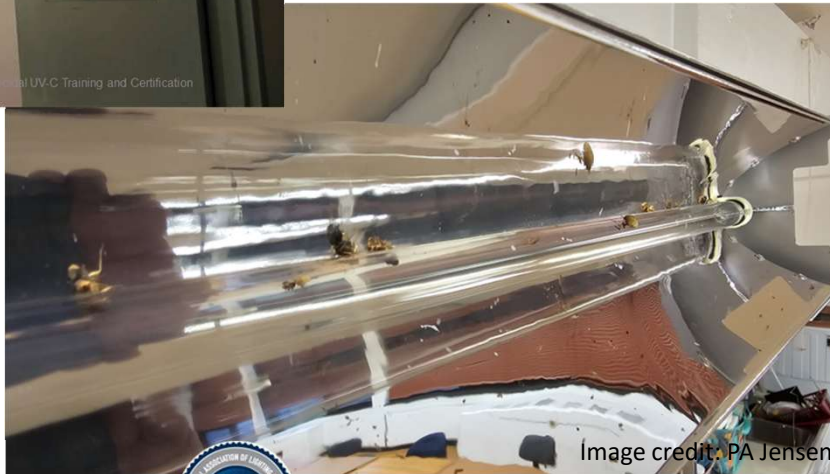
UR GUV – Maintenance: Example



Shown 254 nm UR GUV semi open luminaire installed 1 year ago.

Witness point measurement at installation = $20 \mu\text{W}/\text{cm}^2$

- Average 254 lamp depreciation is 15% at 9,000 h (1 year)
- Today's measurement = $10 \mu\text{W}/\text{cm}^2$
- 50% drop!



A closer look reveals the problem.

Cleaning is necessary to maintain best lamp performance.

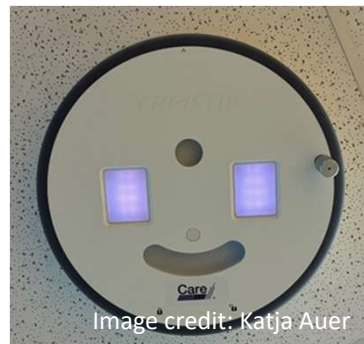


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When To Change GUV lamps

- Follow manufacturer recommendations
- If unsure, contact the manufacturer
- Chronological hours
- Operational hours
- Reduction in output



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Review of Key Points

✓ The 6 Maintenance Steps are:

Step 1: Use proper Personal Protective Equipment (PPE)

Step 2: Have all required tools and meters

Step 3: Take Witness Point measurement

Step 4: Turn off power to UR/WR GUV Luminaire

Step 5: Clean UV-C lamp(s) or

Step 6: Replace lamp(s) per manufacturers recommendations



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Online Module 10

UR & WR GUV Safety



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UR & WR GUV Safety

In this section we explore:

- ❖ UR & WR GUV – Safety Rules
- ❖ How to know what level of GUV exposure is safe
- ❖ National & International Organizations promoting GUV Safety
- ❖ UR & WR GUV – Safety: Exposure Limits



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UR GUV Fixtures – Safety Rules

- Fixtures need to be installed correctly to prevent unwanted exposures.
- Only authorized personnel should install fixtures to keep building occupants safe from exposure.
- Occupant safety is verified by installers and maintenance personnel who validate that exposure to GUV does not exceed safety guidelines.
- Several organizations developed safety guidelines to help prevent overexposure to GUV.



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National & Int'l Organizations Promoting GUV Safety



ICNIRP International Commission on Non-Ionizing Radiation Protection



ISO International Organization of Standards



IEC International Electrotechnical Commission



NIOSH National Institute for Occupational Safety and Health

Mostly, they relate to harmful sunlight exposures (to the dangerous UV-B wavelengths). GUV (UV-C) is filtered out by the ozone layer and considered much safer in terms of delayed effects.



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How To Know What GUV Level Is Safe

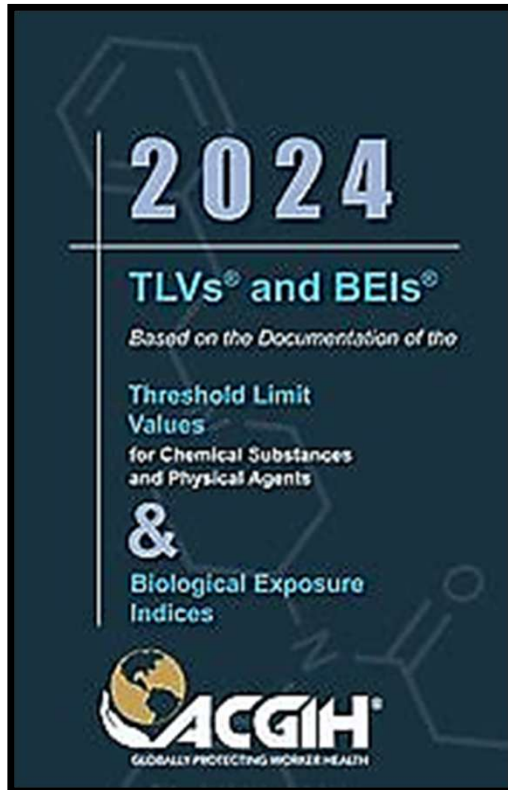
- In 1972, the Centers for Disease Control and Prevention (CDC) and National Institute for Occupational Safety and Health (NIOSH) published a recommended exposure limit (REL) for occupational exposure to UV radiation.
- REL is intended to protect workers from the acute effects of UV exposure.
- The American Conference of Governmental Industrial Hygienists (ACGIH) issued similar Threshold Limit Values (TLVs®) for occupational exposure to ultraviolet radiation.
- The RELs and TLVs® for occupational exposure to UV incident on skin or eye are based on the irradiance and time of exposure.
- ACGIH(TLVs®) and NIOSH (RELs) have guidance on occupational limits, which are limited to direct exposure of the eyes, but considered goals regarding skin exposure. TLV® and REL values are the same for 254 nm.



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ACGIH: Threshold Limit Value TLVs®



- In the US, our widely used professional exposure guidelines are known as: Threshold Limit Values (TLVs®)
- TLVs® are based on occupancy use of spaces treated by UR & WR GUV systems.
- GUV inspection, maintenance, and repair workers typically do not remain in one location during their 8-hour workday.
- Hence, they do not exceed TLVs® and will not be overexposed to GUV.



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CDC/NIOSH: Recommended Exposure Limit (REL)

- Exposures exceeding CDC/NIOSH **REL** levels require use of personal protective equipment (PPE).
- The calculated **REL** is time-weighted at a steady-state, continuous exposure for that duration and an average value is taken.



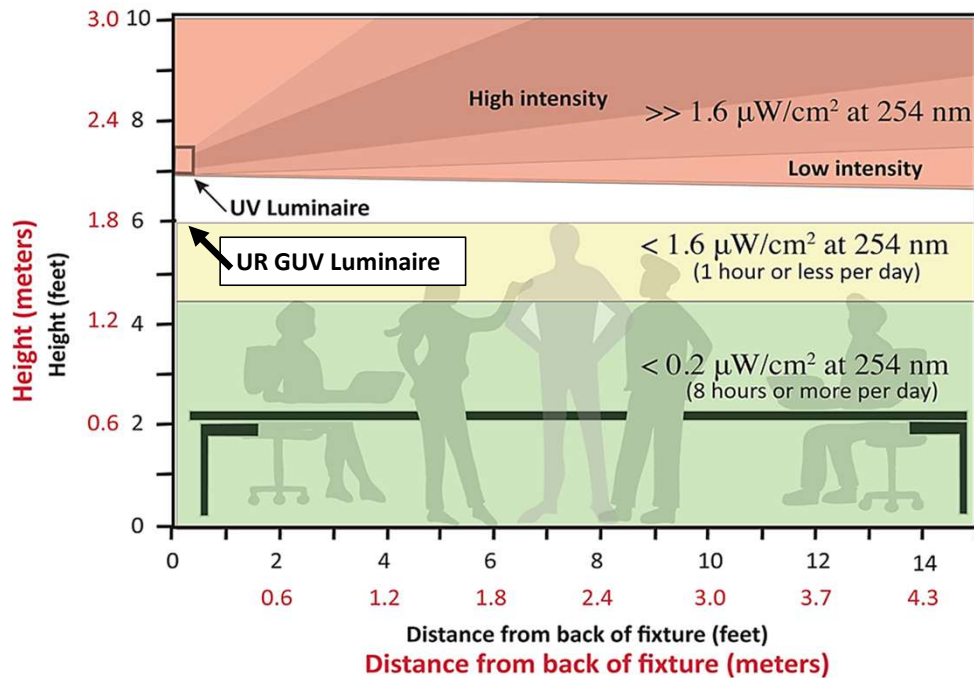
Time-weighted average takes the average GUV exposure a person may receive while standing, sitting, or walking through an area with UR GUV luminaires in a period of 8 h.



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Example of Time Weighted Average To Assess GUV Risk



- During a day most individuals do not remain in a fixed position. They move around.
- Properly installed and commissioned UR GUV luminaires will not exceed exposure guidelines.
- A time-weighted average is calculated at a steady-state, continuous GUV exposure for the duration of exposure to UR & WR (or their combinations) GUV luminaires.
- Determining TWA is important for occupant safety.



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Review of Key Points

- ✓ Occupant safety is verified by installers and maintenance personnel who validate that exposure to GUV does not exceed safety guidelines.
- ✓ CDC and NIOSH published a recommended exposure limit (REL) for occupational exposure to UV radiation to keep workers safe.
- ✓ The American Conference of Governmental Industrial Hygienists (ACGIH) issued similar Threshold Limit Values (TLVs®) for occupational exposure to ultraviolet radiation.
- ✓ Time-weighted average takes the average GUV exposure a person may receive while standing, sitting, or walking through an area with UR & WR (or their combinations) GUV luminaires in a period of 8 h.



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Online Module 11

Over-Exposure to GUV



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Over-Exposure to GUV

In this section we explore:

- ❖ Accidental overexposures from faulty installations
- ❖ What happens when overexposed to GUV
- ❖ Strategies to avoid overexposure
- ❖ UR and WH GUV fixture safety



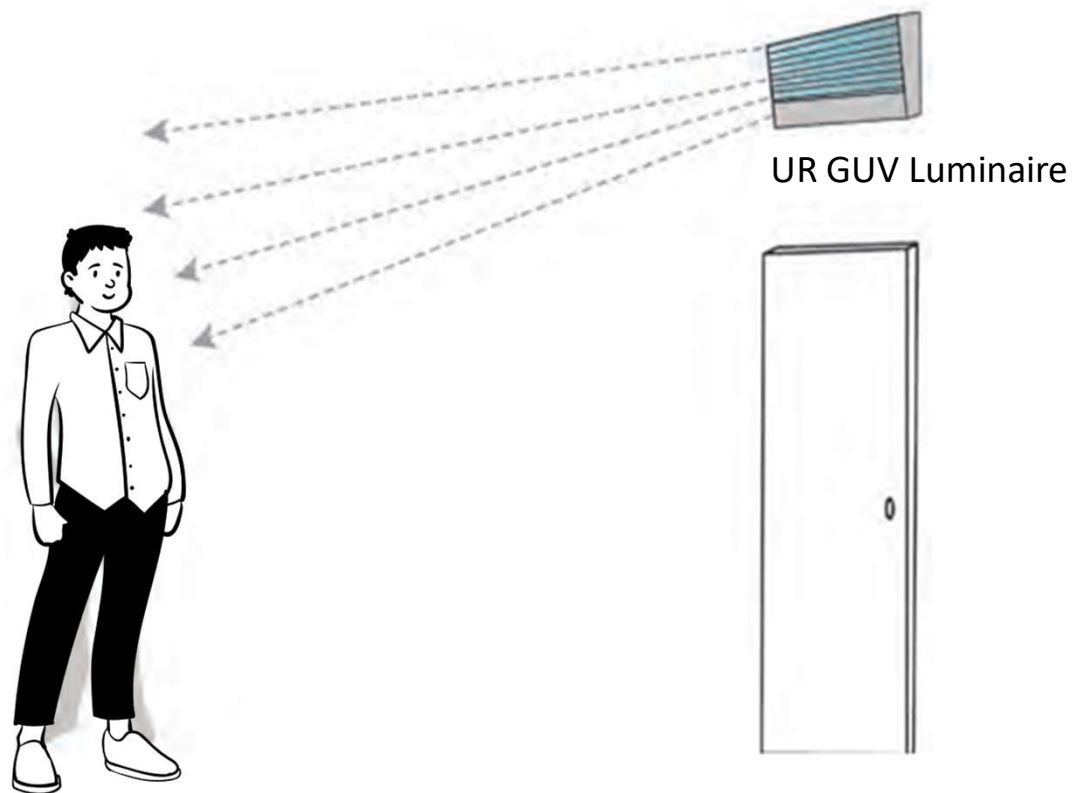
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Accidental overexposure from faulty installation

Baffles in 254 nm UR GUV
Luminaires aimed downward!

Don't install fixture upside down!



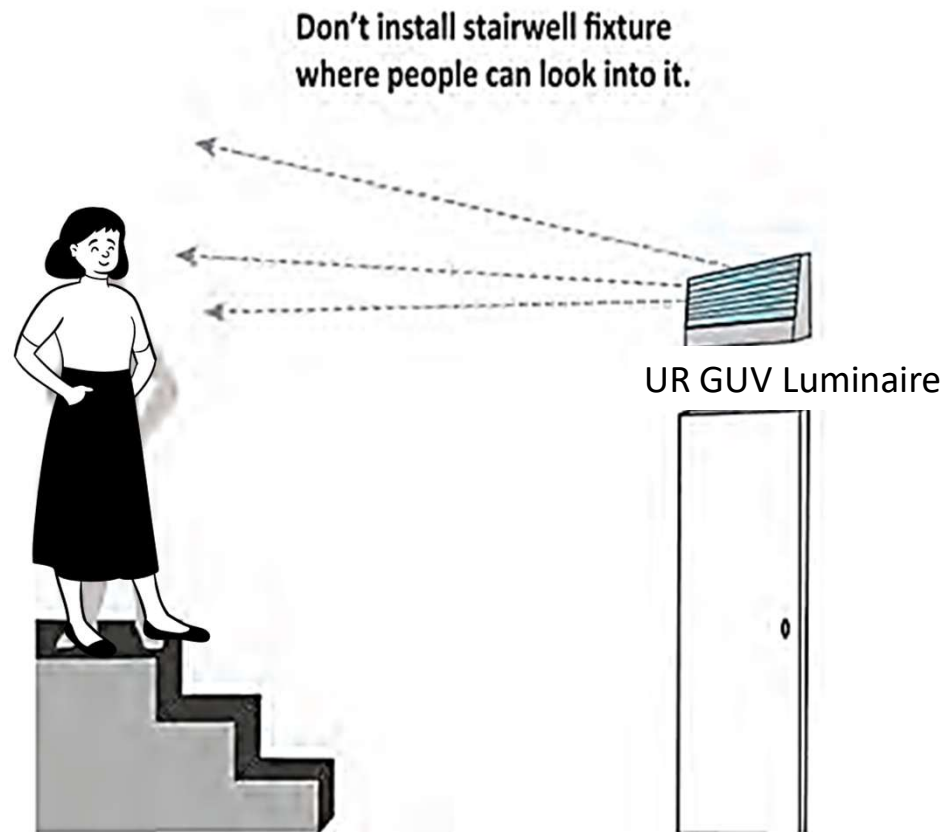
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Images adapted from Illuminating Engineering Society

Accidental overexposures from faulty installation

Baffles in 254 nm UR GUV
Luminaires aimed at face!



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Images adapted from Illuminating Engineering Society

Example of a correct installation

Competent installation is important.

UR GUV fixtures are validated to not overexpose people – even when sitting for several hours.

The image shows an installation adhering to safety standards.



Image Credit: Paul Jensen



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What happens when overexposed to GUV

- Overexposure affects plants.
- Overexposure may have non-permanent affects on our skin and eyes.

Let's explore more closely.



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Overexposure causes skin reddening : Erythema



Erythema: abnormal redness of the skin or mucous membranes due to capillary congestion (as in inflammation)

- ❖ Erythema is a mild sunburn-like effect without tanning.
- ❖ Results in itching of skin.
- ❖ Occurs when exposed to at least 2-3x of GUV above the safety limit.

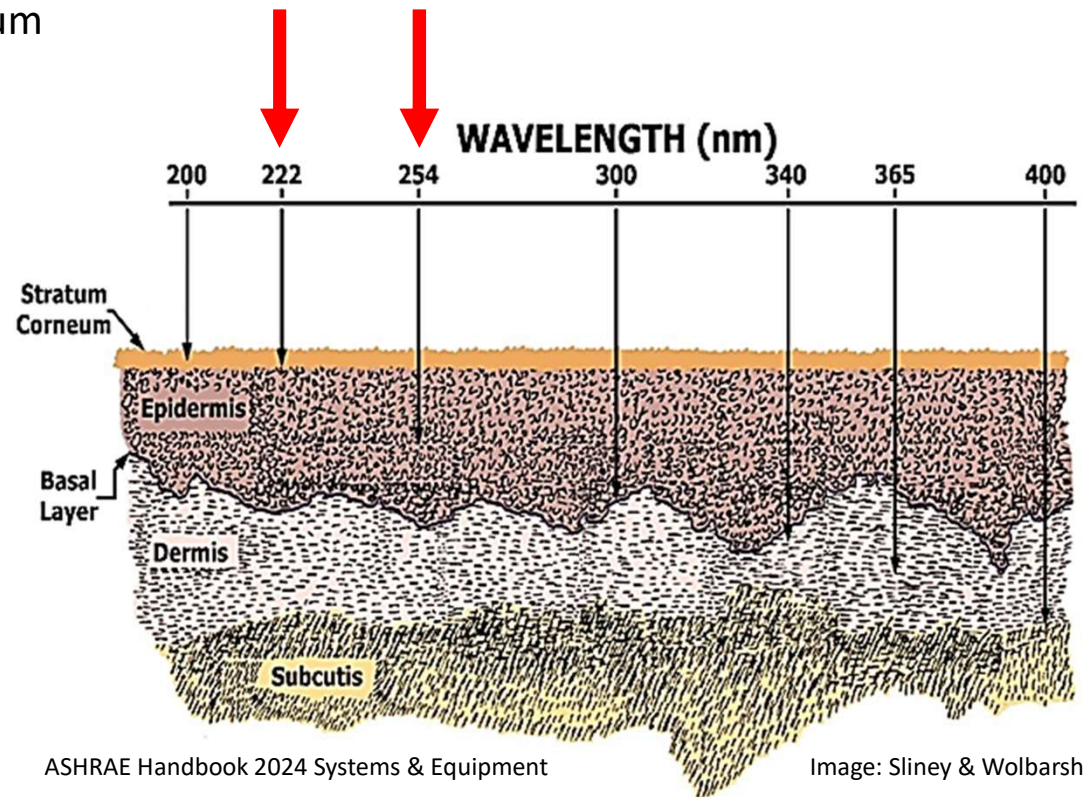


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GUV and the skin

- UV is scattered and absorbed in the stratum corneum (outer dead layer of human skin).
- UV is not transmitted through the epidermis.
- 222 nm is even less penetrating into the skin as compared to the 254 nm.
- 222 nm stops before entering the epidermis and has less potential to cause damage to skin tissue.



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Wavelengths above 300 nm

! Wavelengths above 300 nm enter the dermis!

GUV wavelengths at 222 nm, 254 nm, and 265 nm do not enter the dermis.

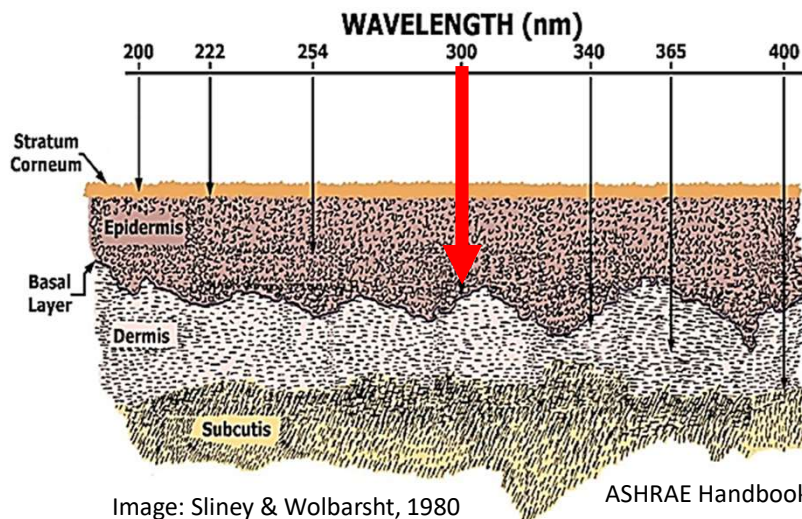


Image: Sliney & Wolbarsht, 1980

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- GUV wavelengths have a shallow penetration depth into skin.
- Repeated over-exposure to GUV is very rare.
- Long term effects: Skin cancer has not been linked with GUV.



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Overexposure causes eye irritation: Photokeratitis



Keratitis: inflammation of the cornea of the eye

- Eyes are well adapted to the UV in outdoor sunlight.
- When ground surface is highly reflective with eyes exposed, reflection produces an irritation on the eye's surface – the cornea.
- This irritation is termed photokeratitis, or snow blindness or welder's flash.



Image: 10FAQ.com



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Overexposure causes eye irritation: Conjunctivitis



Image: 10FAQ.com



Conjunctivitis: inflammation of the conjunctiva [ocular lining]).

- Symptoms may not be evident until 6 - 12 hours after GUV exposure.
- Symptoms include an abrupt sensation of sand in the eyes, tearing, and eye pain, possibly severe.
- Symptoms resolve within 24 to 48 h.

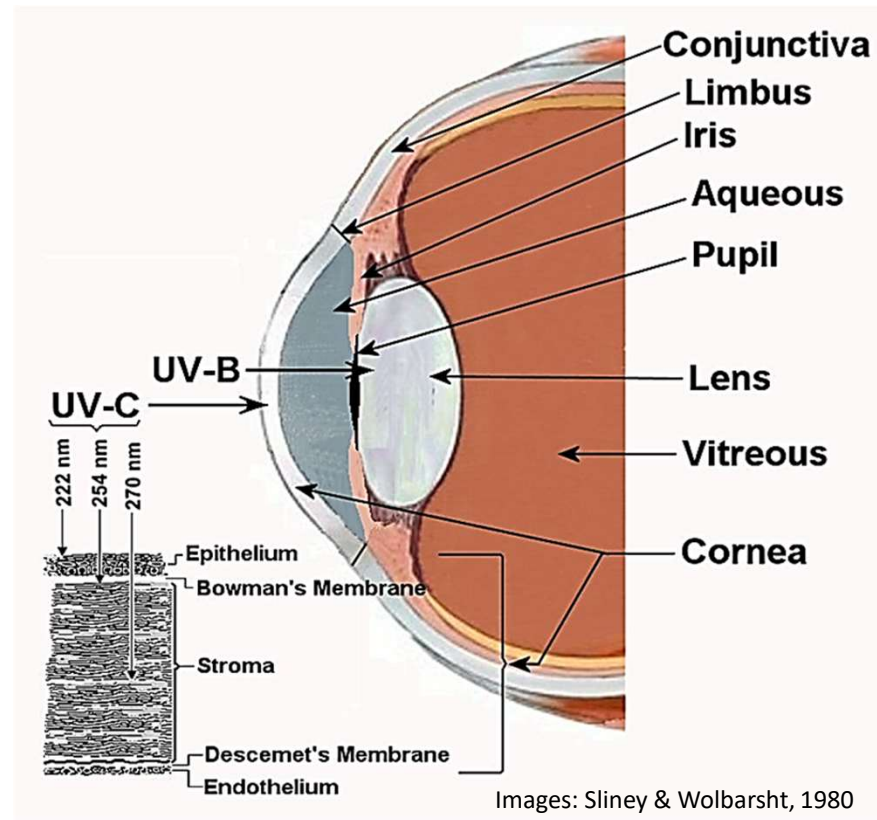


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GUV Hazards to the Human Eye

- GUV is completely absorbed in the cornea.
- GUV does not penetrate past the cornea.
- Inside tissues are protected.



Can GUV penetrate walls?

- GUV energy does not normally penetrate through solid substances or walls.
- GUV is attenuated by most materials.
- GUV does not penetrate through regular glass.

What GUV can penetrate:

- ✓ Quartz glass and soda barium glass used for GUV lamps.
- ✓ Polytetrafluoroethylene (PTFE) plastic has high transmissions for GUV.



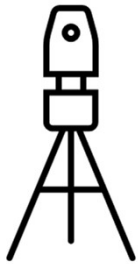
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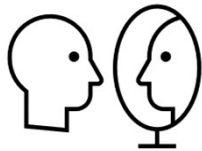
Strategies to avoid overexposure from GUV



1. Well-designed and commissioned GUV installations, education of maintenance personnel, signage, and safety switches can avoid overexposure.



2. During commissioning and before operation of the GUV installation, use hand-held radiometers reading the specific wavelengths (222 nm, 254 nm, 265 nm) of the GUV fixture(s) installed.



3. Validate that there is no stray GUV reflecting from walls, ceilings, and other objects in a room.



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When to take UR & WR GUV Measurements

- Always at the initial installation.
- Whenever new lamps are installed (newer lamps may have increased GUV levels).
- Whenever modifications are made to the GUV fixture system or room (e.g., adjusting fixture height or location or position of louvers, adding UV-absorbing or -reflecting materials, changing room dimensions or modular partition height)



Image credit: Light Progress



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GUV Fixture Safety



- UR and WR GU fixture should have on/off switches and an electrical disconnect.
- If UR and WR GU measurements taken at initial installation exceed recommended exposure limit, all highly UV-reflecting materials should be removed, replaced, or covered.
- Ultraviolet absorbing paints can be used on ceilings and walls to minimize reflectance into occupied space.
- Most ceiling tiles have a relatively low reflectance.



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Review of Key Points

- ✓ Accidental overexposures can occur.
- ✓ GUV overexposure can cause photokeratitis or conjunctivitis which will heal and leave no lasting effects.
- ✓ GUV overexposure can cause erythema, a mild sunburn-like effect, subsiding within 24 – 48 hours.
- ✓ GUV wavelengths 222 nm, 254 nm, and 265 nm do not enter the skin's dermis or penetrate past the eye's cornea.
- ✓ Strategies can be set in place to prevent accidental overexposure.



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