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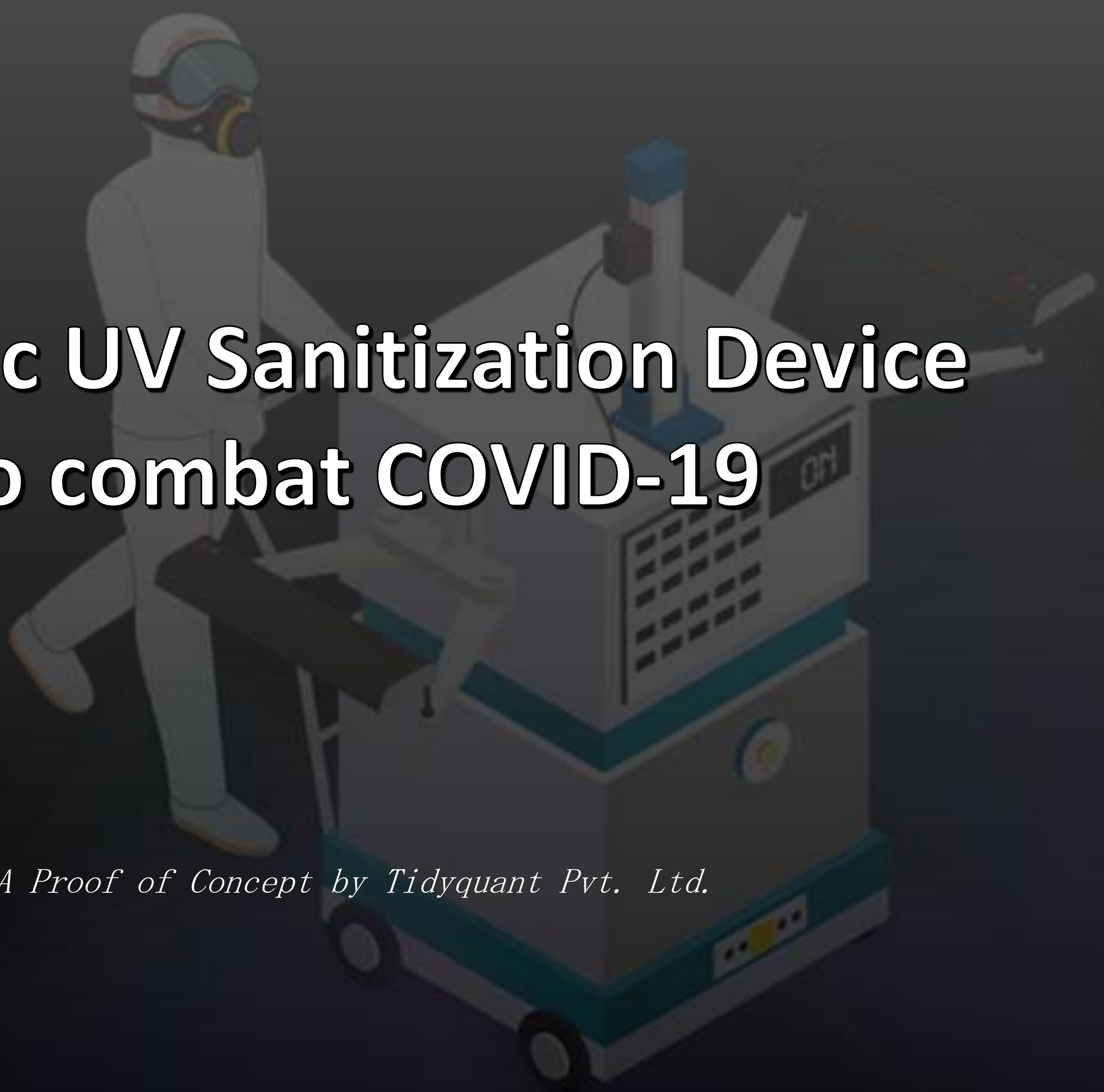
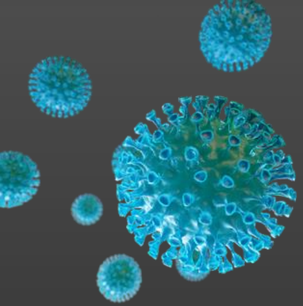


Robotic UV Sanitization Device to combat COVID-19

A Proof of Concept by Tidyquant Pvt. Ltd.



Contents

Objective

In this proof of concept (PoC) , we present an UV sanitization equipment based on Ultraviolet-C (far UVC) irradiation. This device benefits from far-UVC radiation's germicidal properties and aim to disinfect hospitals, schools, supermarkets, spacious buildings, etc. from airborne influenza and coronaviruses.

This device can be operated remotely using a Bluetooth channel, electromagnetic relays, stepper motors, and an android mobile device. Therefore, It offers a quicker dry sanitization procedure compared to conventional chemical sanitization.

Due to strong absorbance of Far-UVC radiation in biological tissues, it cannot penetrate even the outer layers of human skin and therefore it's an ideal candidate for our proposed sanitization device.

As a safety measure, this device will also be equipped with a PIR sensor that will trigger an alarm if someone comes in proximity of this device.

Sanitization method employed by this device can neutralize a wide range of pathogens such as Salmonella, Listeria and E. coli, SARS viruses, etc.

Coronavirus

- Coronavirus is a member of SARS (severe acute respiratory syndrome) virus family. It's a single stranded RNA virus that is protected by a lipid envelop as shown in figure 1.1.
- As per the findings of research paper [Ref 12], size of this coronavirus is found to be in the range of 60 - 140 nm approximately.
- This virus causes multiple respiratory diseases of varying severity, including common cold, pneumonia and bronchiolitis that can lead to death of an infected human.

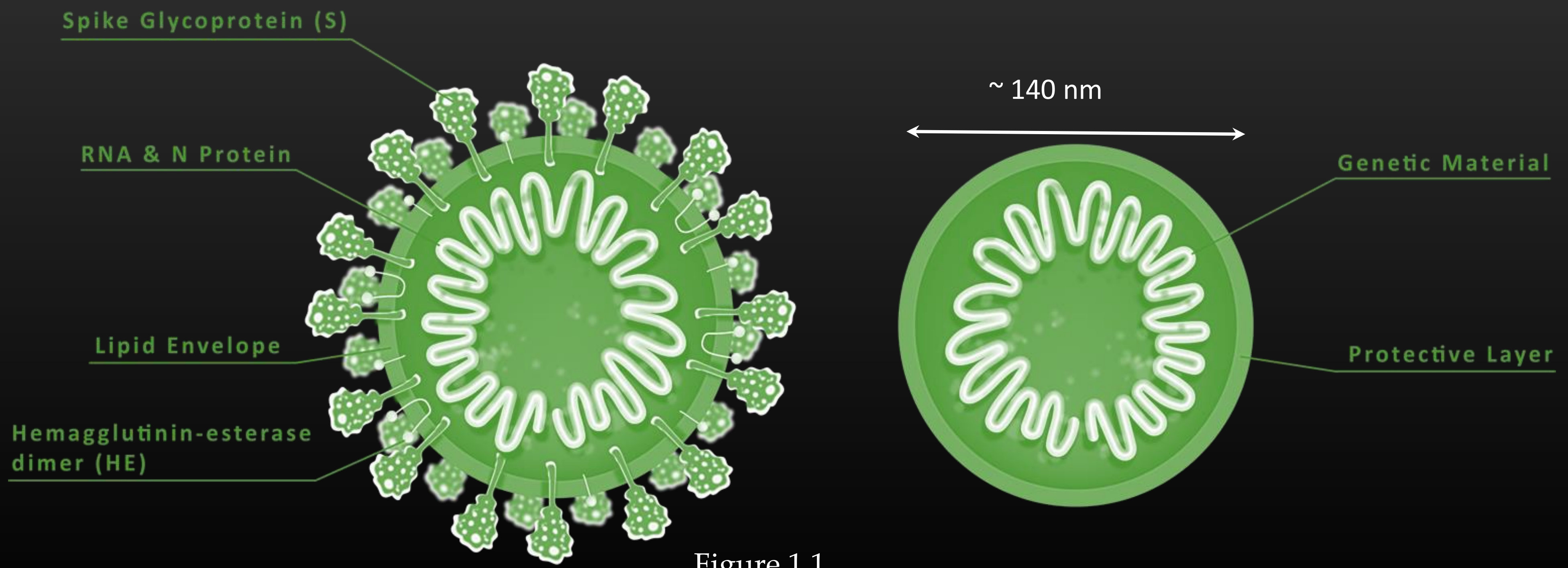


Figure 1.1

Coronavirus Invasion

- When contamination occurs and virus gets inside the host body, spike glycoprotein is used by the virus to gain entry into the human cell. In doing so, it injects genetic material (RNA) into human cell.
- Coronavirus hijacks the cellular processes to produce virally encoded protein that will replicate the virus's genetic material.

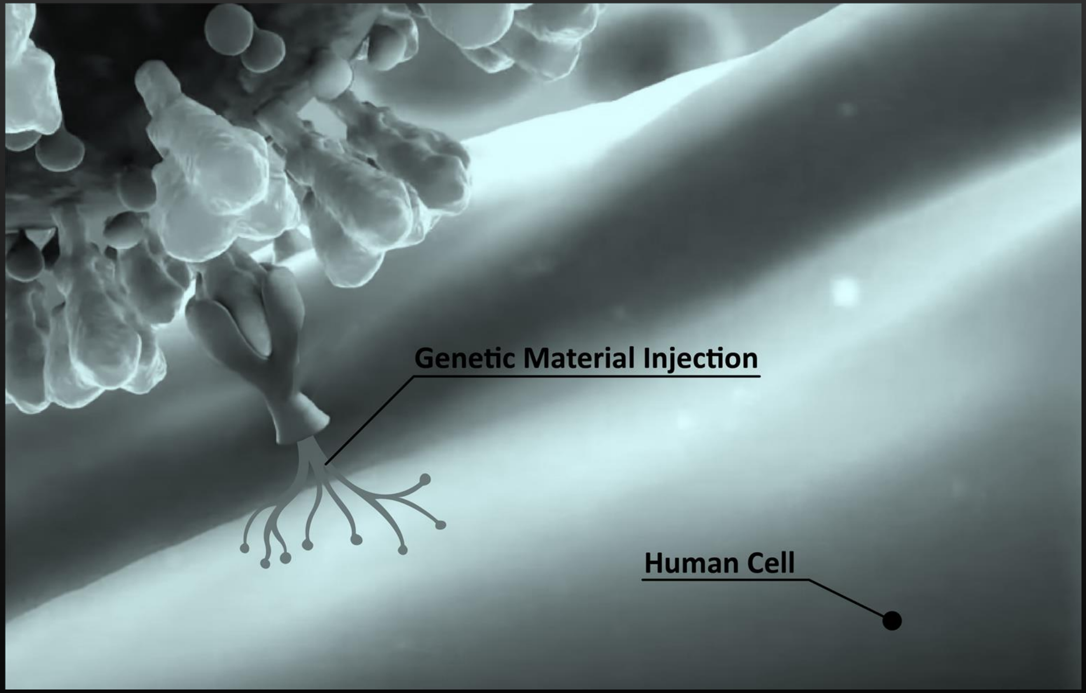


Figure 1.2a : Genetic material injection into human cell

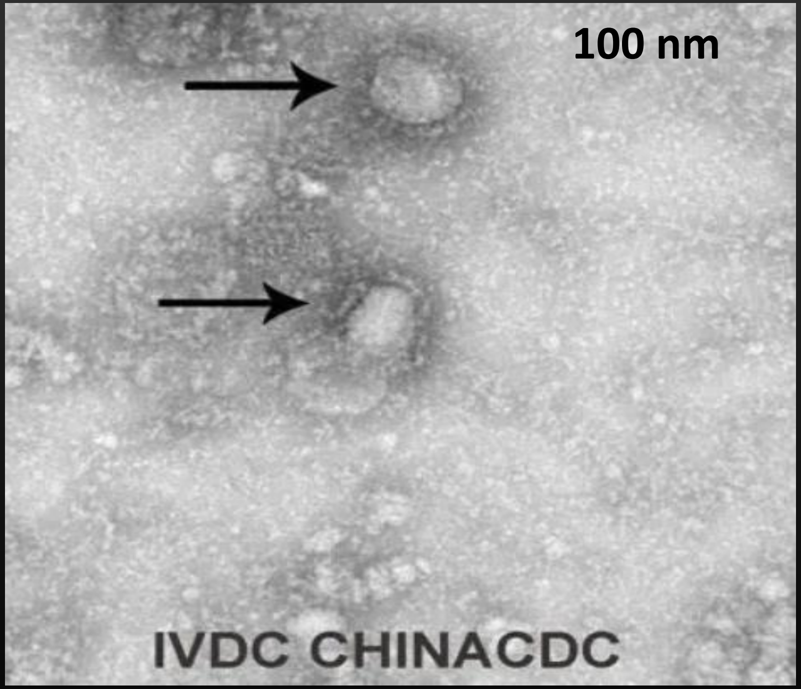


Figure 1.2b : Electron microscopy image of the first isolated case of the coronavirus

Germicidal Properties of UV Light

- Ultraviolet (UV) radiation is sandwiched between X rays and visible light, i.e., between 100 and 400 nm. The UV spectrum is separated into Vacuum UV (100-200 nm), Far-UVC (200-222 nm), UVC (222-280 nm), UVB (280-315), and UVA (315-400 nm) as shown in the figure 1.3
- Since the size of microorganisms found in air, water and on surfaces typically varies from 50 nm to 2 μm, the genetic material (DNA or RNA) of these microorganism can be disrupted by irradiating UV light with short (comparable to the size of microorganism) wavelengths. DNA and RNA present in nucleic acid are responsible for microbial replication and protein synthesis.
- According to a new study at the Centre for Radiological Research at Columbia University, Irving Medical Centre (NY, USA) [9] , Far-UVC at 222 nm inactivates more than 95% of airborne aerosolized H1N1 influenza viruses at a low dose of 2 mJ/cm^2 without harming human tissues.

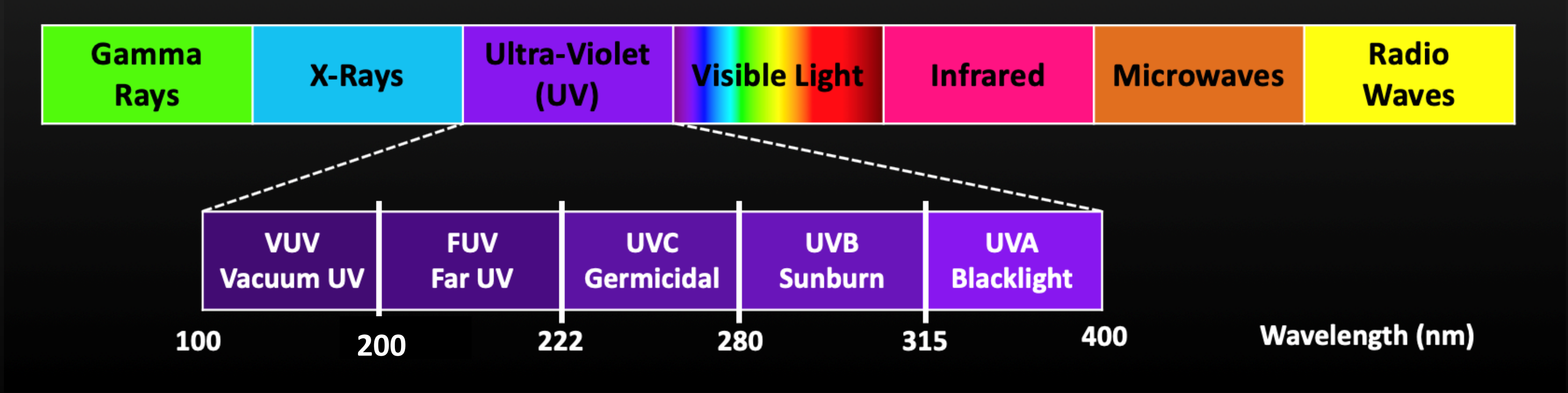


Figure 1.3: UV spectrum

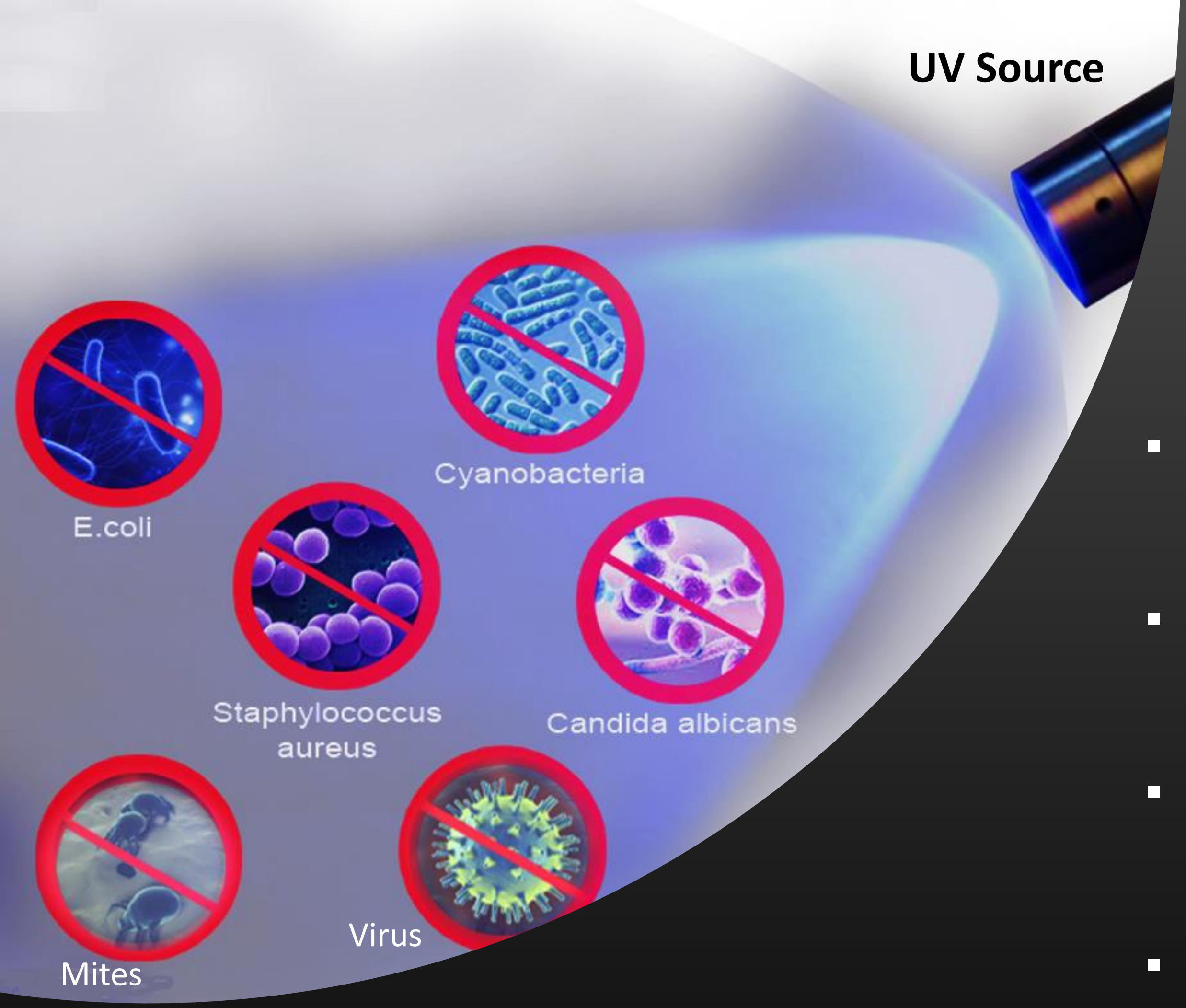
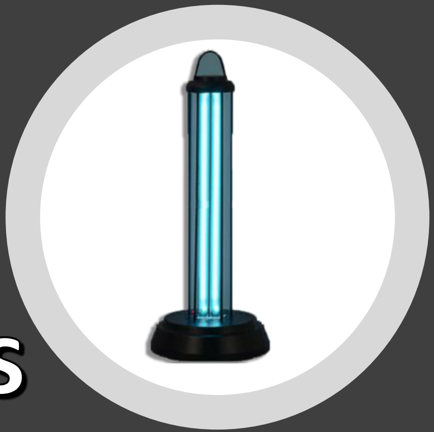


Figure 1.4: Type of pathogens UV can kill

UV Treatment of Pathogens

- Due to germicidal properties of UVC, it has been widely used for dry sanitization methods for a long time. Also, UVC disinfection is a widely used technique for water purification.
- According to a study published in Nature [17], a specific spectrum of ultraviolet light known as Far-UVC can efficiently inactivate pathogens without harm to exposed human skin.
- Short-wavelength of Far-UVC can neutralize microorganisms by destroying nucleic acids and scrambling their DNA (or RNA), leaving them unable to perform any vital cellular functions.
- Due to its strong absorbance in biological tissues, far-UVC light cannot penetrate even the outer layers of human skin or eye. However, because bacteria and viruses are of micrometer and nanometer scales respectively, far-UVC can penetrate and inactivate them [Ref 14].

Commercial UVC Lamps



- There are several types of commercial and industrial UV lamps are available with varying wavelength (250 – 280 nm) , power (8 – 100 Watt) and exposure time. However, most commonly used wavelength in UVC lamps is 254 nm.

- Although, these portable UVC lamps are very convenient to disinfect small objects and personal gadgets but should not be exposed to human skin because UVC can penetrate through the outer layer of human skin.

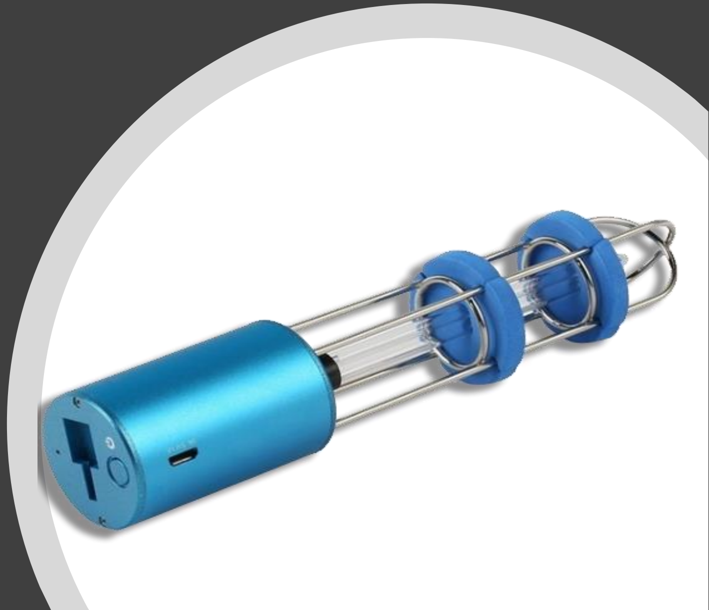


Figure 1.5: Examples of commercially available UV lamps

Why Far-UVC and Vacuum UV (VUV)

- Since germicidal wavelength (254 nm) of UVC radiation can penetrate the outer layer of human skin, this type of radiation can cause skin cancer such as deadly melanoma.

- Far-UVC at wavelengths from 200 to 222 nm are completely absorbed by the dead outer layer of skin and by the outer tear layer of the eye, and therefore these wavelengths are safe for humans [14].

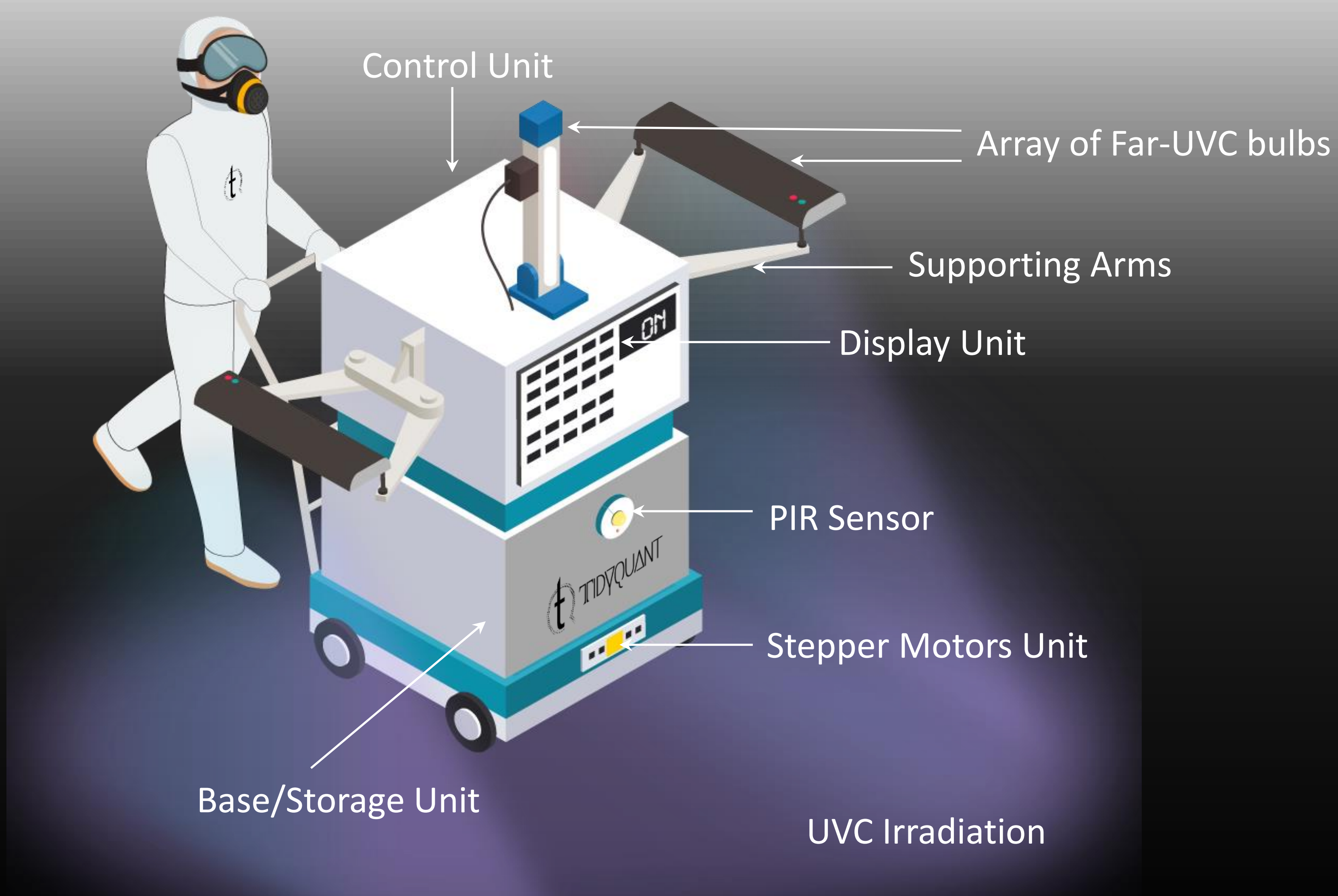
- Radiation below 200 nm is called vacuum ultraviolet (VUV) because air begins to absorb radiation at these wavelengths and a vacuum is required for experimental work. Since the average size of human cell is 100 μm, this short wavelength radiation is mainly absorbed by outer layer (dead skin) of human skin and does not harm humans [Ref 14].

- By adopting vacuum-UV, the ozone producing low-pressure Hg vapor lamps, can be used as an effective mean of disinfecting the airborne microorganisms[7]

UV Type	Wavelength (nm)	Safe for skin and eyes	Practical Usage
VUV	100-200 nm	Yes	Medical Equipment sterilization
Far UVC	200-222 nm	Yes	Medical equipment sterilization, disinfection, sensing
UVC	222 – 280 nm	No	Medical equipment sterilization, disinfection, sensing

Table 1.1 UV wavelengths and their practical usage [Ref 13]

Proposed Far-UV Sanitizer Device (Model-1)



Design Description

Control Unit: This unit will consist of microcontroller board, Arduino board, electromagnetic relays and a Bluetooth module allowing system to communicate with other units. Bluetooth module will allow user to operate the device remotely with the help of an android mobile application.

Array of Far-UVC bulbs: The robotic UV device will be employed with an array of powerful short wavelength (Far-UVC) lights that emit enough energy to scramble DNA or RNA of any microorganisms that have been exposed. As an alternative to Far-UVC, ozone producing low-pressure Hg vapor lamps (irradiating VUV) can also be used as mentioned in previous slides.

PIR (passive infrared) Sensor: As a safety measure, UV robot will be equipped with PIR sensors. The device will automatically be turned off when PIR sensor detects a moving warm body around the area of exposure.

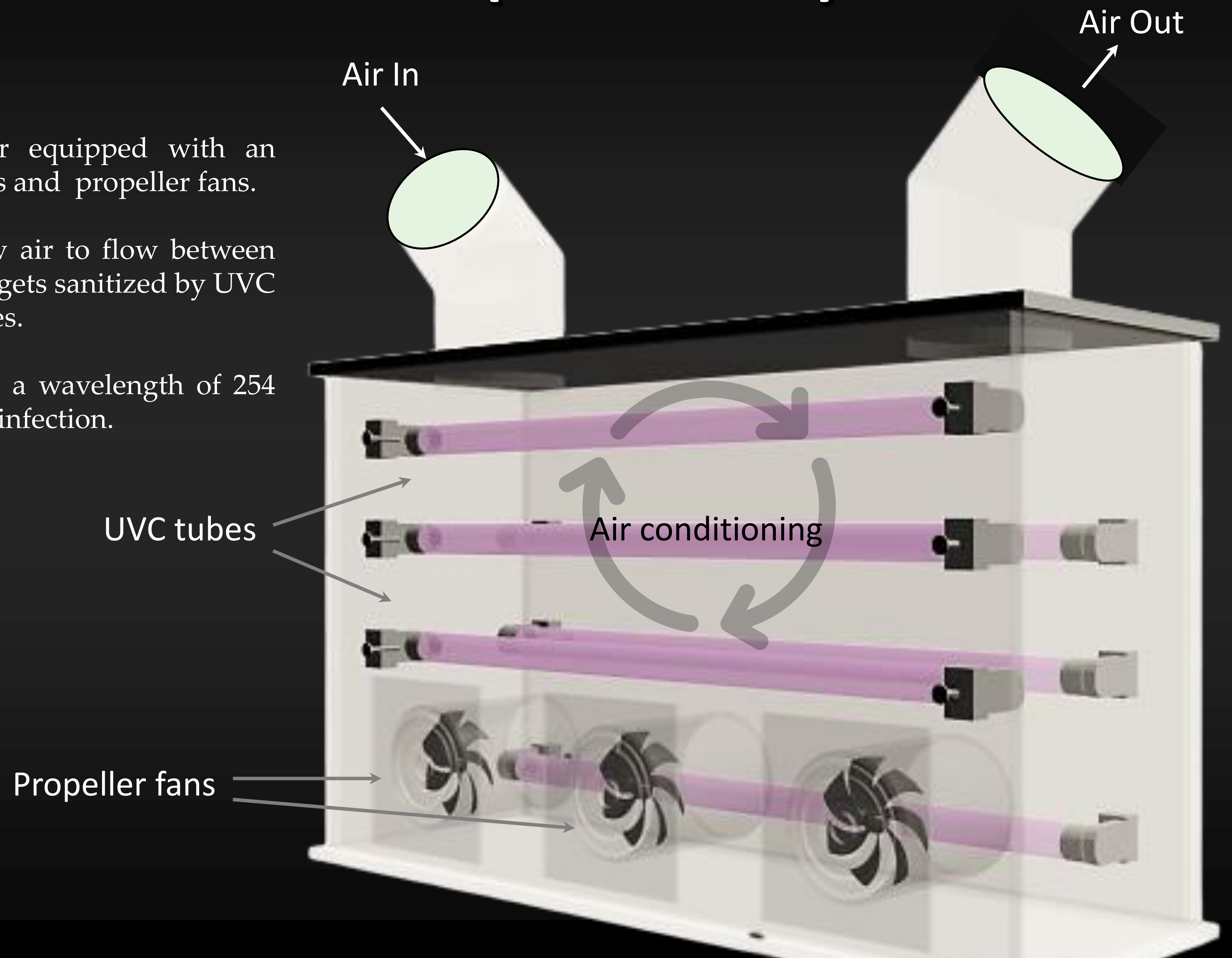
Display Unit: This unit comprises a matrix of programmable LED lights and an alpha-numeric display. These LEDs will indicate various functions such as green LED: Power supply turned on , red LED: UV radiation is activated and blue LED: Bluetooth connection is established.

Stepper Motor Unit: The KM Series of high-torque stepper motors are recommended. These motors will provide stepper movements with a high degree of precision while the device is in operation. Also, these motors provide a cost-effective, high-performance alternative to bulky servo motor systems.

Exposure Time: The exposure time for sanitization can be calculated using the following equation $t = (2\pi.L.r.D)/P$, where t is the time of exposure, L is the length of Far-UVC bulb, r is distance between source and target surface, D is UV dosage received by surface unit (expressed in J/cm^2) and P is the power or intensity of the UVC bulb.

Portable Air Sanitizer (Model-2)

- We propose a portable air sanitizer equipped with an assembly of long germicidal UVC tubes and propeller fans.
- Propeller fan mechanism would allow air to flow between inlet and outlet valves. In doing so, air gets sanitized by UVC radiation emitted from fluorescent tubes.
- Fluorescent tubes emit radiation with a wavelength of 254 nm that is widely used for bacterial disinfection.



UVC Drone Sanitizer (Model -3)

- We propose an UAV (unmanned aerial vehicle) sanitizer equipped with UVC LED bulbs and drone technology.
- This drone sanitizer can be hovered over the surfaces where conventional sanitizer is not reachable.
- Sanitization process can monitored and controlled using a ground based controller that is equipped with display unit.
- Radiation with a wavelength of 254 nm emitting from powerful UVC LED lights can disinfect air and surfaces.

Safety Measures

- UV radiation is easily absorbed by clothing, plastic or glass. Once absorbed, UV radiation is no longer active. When working with open UV radiation during sanitization, personal protective equipment (PPEs) covering all exposed skin areas are recommended.

- Use of UV goggles and full-face shields are recommended. UV filter (ANSI Z87 rated) eyeglasses with wrap around lens to protect the side exposure is also recommended.

- UVC exposure can be reduced through product safety design considerations and controls. Proper training and monitoring of UV sanitization device can help to avoid overexposure.

- A room should be ventilated after UV disinfection, and people are suggested to enter the room half an hour later.

Conclusion

- Genetic material (DNA or RNA) of a virus can be disrupted by exposing them to a radiation consist of wavelengths that are comparable to the size of virus.

- Viruses such as influenza virus were originally thought to be only transmitted from person to person via aerosols of body fluids. However, in a study conducted by WHO [16], the production of infectious droplets of diameter $< 5\ \mu m$ could remain suspended in air and may infect a susceptible host [15].

- To establish a correlation between UV exposure time and inactivation of coronavirus, in vitro tests need to be carried out.

- In order to obtain an optimal exposure time, SEM images of samples (taken from infected person during inoculation process) with varied exposure time will have to be analysed.

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