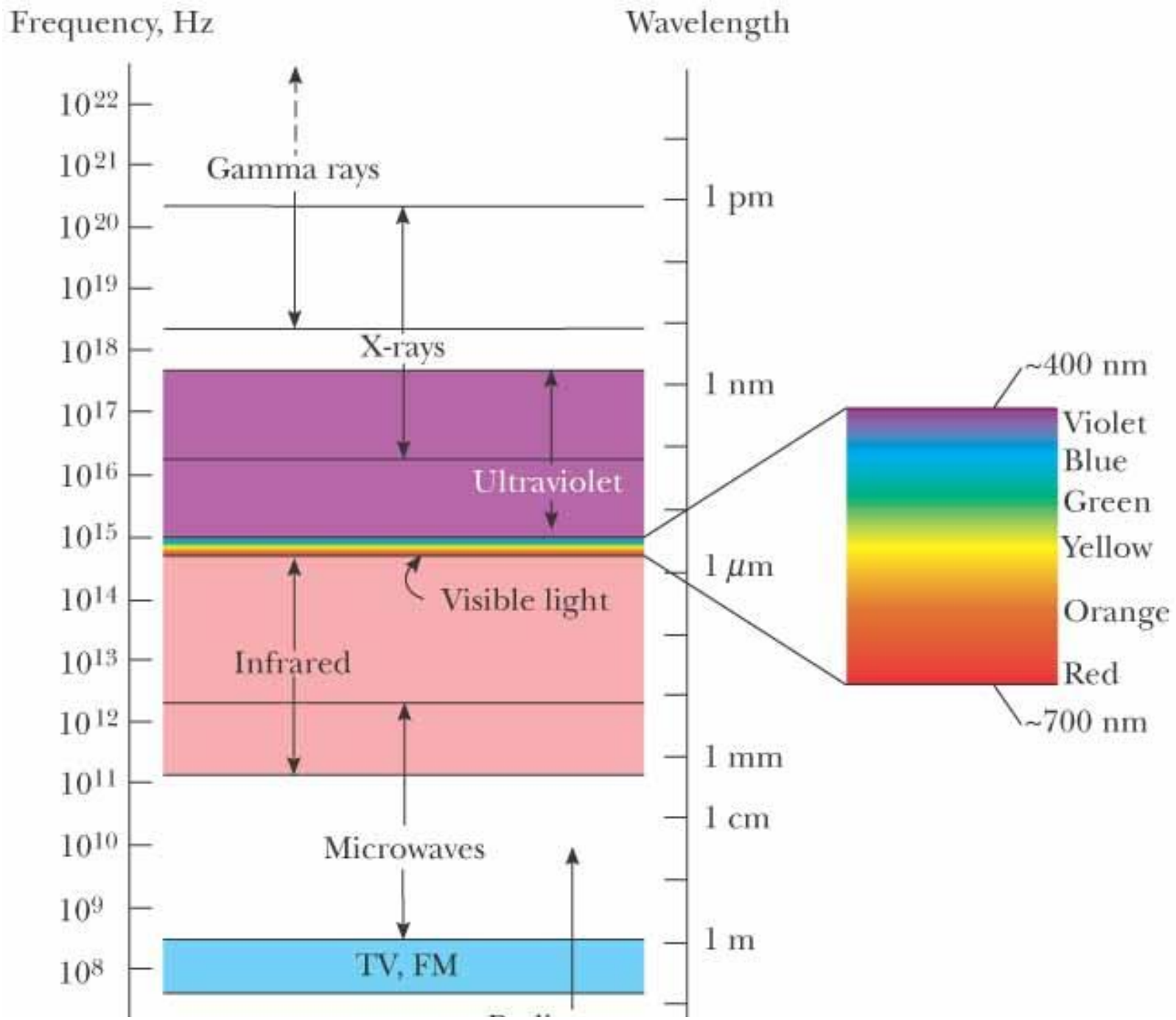
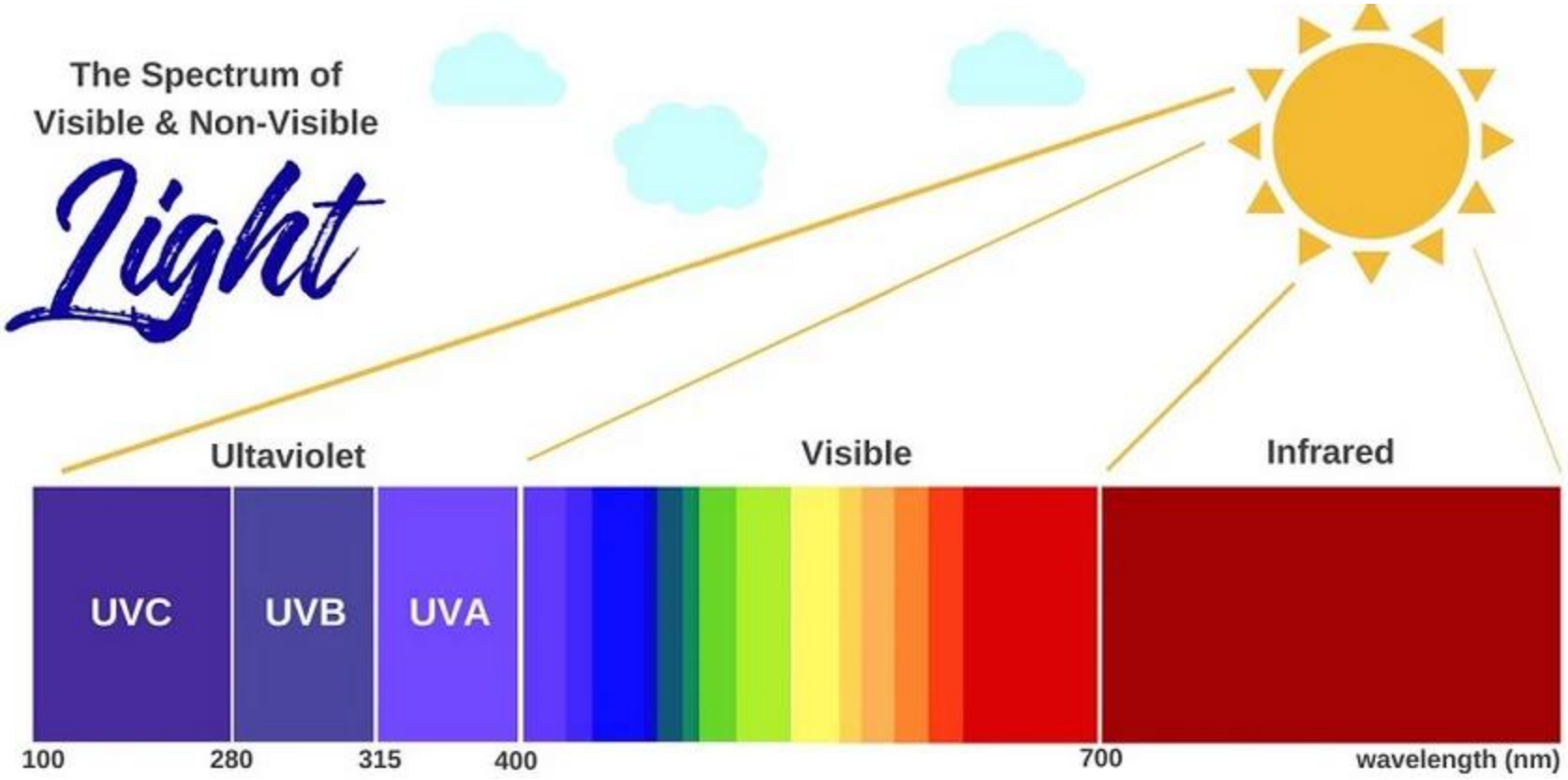
# PH 301

# ENGINEERING OPTICS

## Lecture_6_UV Light_COVID-19


Frequency, Hz
Wavelength
$10^{22}$
$10^{21}$
$10^{20}$
$10^{19}$
$10^{18}$
$10^{17}$
$10^{16}$
$10^{15}$
$10^{14}$
$10^{13}$
$10^{12}$
$10^{11}$
$10^{10}$
$10^{9}$
$10^{8}$
Gamma rays
X-rays
Ultraviolet
Visible light
Infrared
Microwaves
TV, FM
1 pm
1 nm
1 $\mu$m
1 mm
1 cm
1 m
~400 nm
Violet
Blue
Green
Yellow
Orange
Red
~700 nm

# Ultraviolet Radiation




**UV radiation covers wavelength range of 100-400 nm, which is a higher frequency & lower wavelength than visible light. It comes naturally from sun, but it can also be created by artificial sources used in industry, commerce, & recreation.**

# Ultraviolet Radiation

- As sunlight passes through atmosphere, all UV-C & approx. 90% of UV-B radiation is absorbed by ozone, water vapour, oxygen, & carbon dioxide.

- UV-A radiation is less affected by atmosphere. Therefore, UV radiation reaching Earth's surface is largely composed of UV-A with a small UV-B component.

- Amount of UV radiation from sun that hits Earth's surface depends on several factors, sun's height in sky, latitude, cloud cover, altitude, thickness of ozone layer & ground reflection.

- Reductions in ozone layer due to human-created pollution increase amount of UV-A & UV-B. This can impact human health, animals, marine organisms, & plant life.

- In humans, increased UV exposure can cause skin cancers, cataracts, & immune system damage. [10 am – 4 pm, UV index is high]

www.who.int/health-topics/ultraviolet-radiation#tab=tab_1

# UV Water Treatment

- **To kill microorganisms, UV rays actually strike the cell. It penetrates outer cell membrane, passes through cell body & disrupts its DNA preventing reproduction.**

- **UV treatment does not alter water chemically; nothing is added except energy. Sterilized microorganisms are not removed from water. UV disinfection does not remove dissolved organics, inorganics or particles in water.**

- **Degree of inactivation by UV radiation is directly related to UV dose applied to water. Dosage, a product of UV light intensity & exposure time ($\mu ws/cm^2$).**

- **UV does not effectively disinfect some organisms (most molds, protozoa, & cysts of Giardia lamblia & Cryptosporidium) since they require a higher dose.**

# SARS-Cov-2; Optics & Photonics Technology

- **Severe Acute Respiratory Syndrome (SARS)-Coronavirus (Cov)-2 [Feb. 11, 2020]**

**Viruses are named (ICTV: International Committee on Taxonomy of Viruses) based on their genetic structure to facilitate development of diagnostic tests, vaccines, & medicines.**

- **High-quantum efficiency multispectral cameras**
- **Visible-light laser diodes**
- **LEDs**
- **Infrared bolometer arrays (infrared-based thermometers for measuring forehead temperature: Noncontact patient screen)**
- **Narrowband optical filters**
- **Wideband multispectral optical spectrometers**

**IR thermometers are based on single detectors or arrays of MEMS-based microbolometers or semiconductor diode detectors. Far-infrared: 8 -14 μm**

# SARS-Cov-2; Molecular Diagnosis

- **Symptoms: Sore throat, Dry cough, Muscle ache, Fatigue**

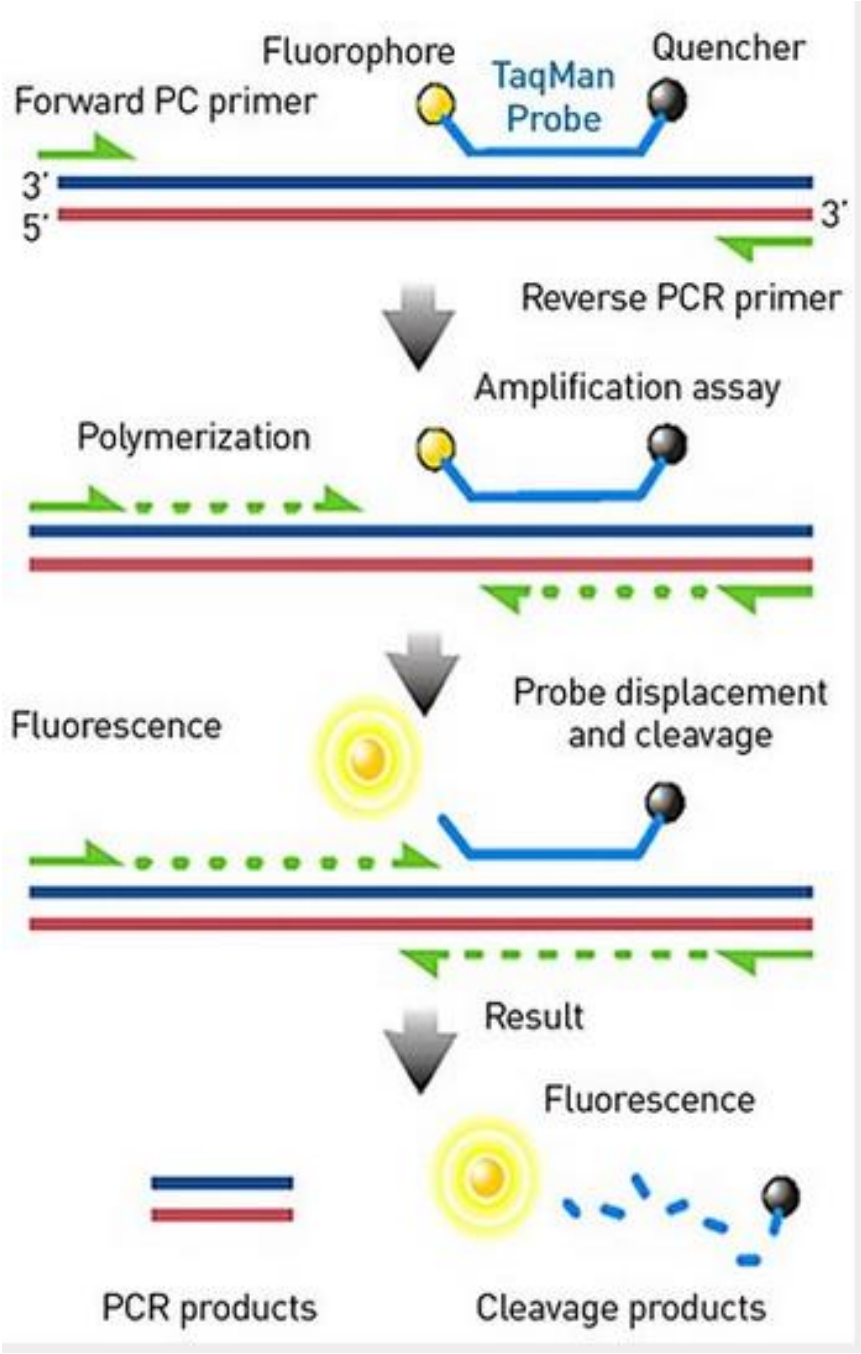
**Real-time reverse Transcription Polymerase Chain Reaction (RT-PCR)**

- **RT-PCR uses sensitive spectroscopic methods to detect extremely small quantities of viral genetic material from a patient's nasal or throat swab.**
- **Specimen collection ⟹ Sample processing**
- **Real-time RT-PCR works by copying specific nucleic acid sequences with that sample, using probes – nucleic acid primers – that selectively bind very specifically to the RNA sequences present in SARS-Cov-2 virus.**
- **Probes are tagged with molecules of fluorescent dye.**

RT-PCR instrument

- **Enzymes are then used to copy nucleic acid sequences bound to probes.**
- **Sample is thermally cycled roughly 40 times between 37°C & 95°C.**
- **If target nucleic acid sequences are present, they are amplified twofold with each cycle.**
- **It is optical technology that puts “real-time” in RT-PCR.**
- **As amplification enzymes create duplicate copies, fluorescent molecules are released into buffer solution.**
- **Overall fluorescence is measured in real-time after each cycle, increasing as the no. of amplicons increases for positive samples.**
- **By measuring intensity buildup during thermal cycling, the virus is detected & amount of virus present (viral load) can be estimated.**

**[T. M. Baer & C. E. Baer, Opt. Phot. News 31 (May, 2020)]**




**In "TaqMan" real-time polymerase chain reaction, a nucleic-acid probe molecule, tagged with a fluorescent molecule & an accompanying quencher, attaches to the stretch of DNA or RNA being copied.**

**With each round of amplification, fluorescent molecule is released into the buffer solution & separated from the quencher, allowing amplification of targeted genetic sequence-such as one from SARS-CoV-2 to be detected via fluorescence in real-time.**

- **Real-time RT-PCR instruments employ narrowband visible laser diodes or LEDs as excitation sources & semiconductor diodes or photo-multipliers with narrow band-pass optical filters for detection.**

- **These instruments are fully automated & can process 96 to 384 samples in parallel in one hour.**

- **False negative rate of this approach is currently estimated at roughly 30%. Repeated testing can reduce this.**

- **Imaging of lungs of COVID-19 patients: High-resolution computed tomography (CT) scans.**

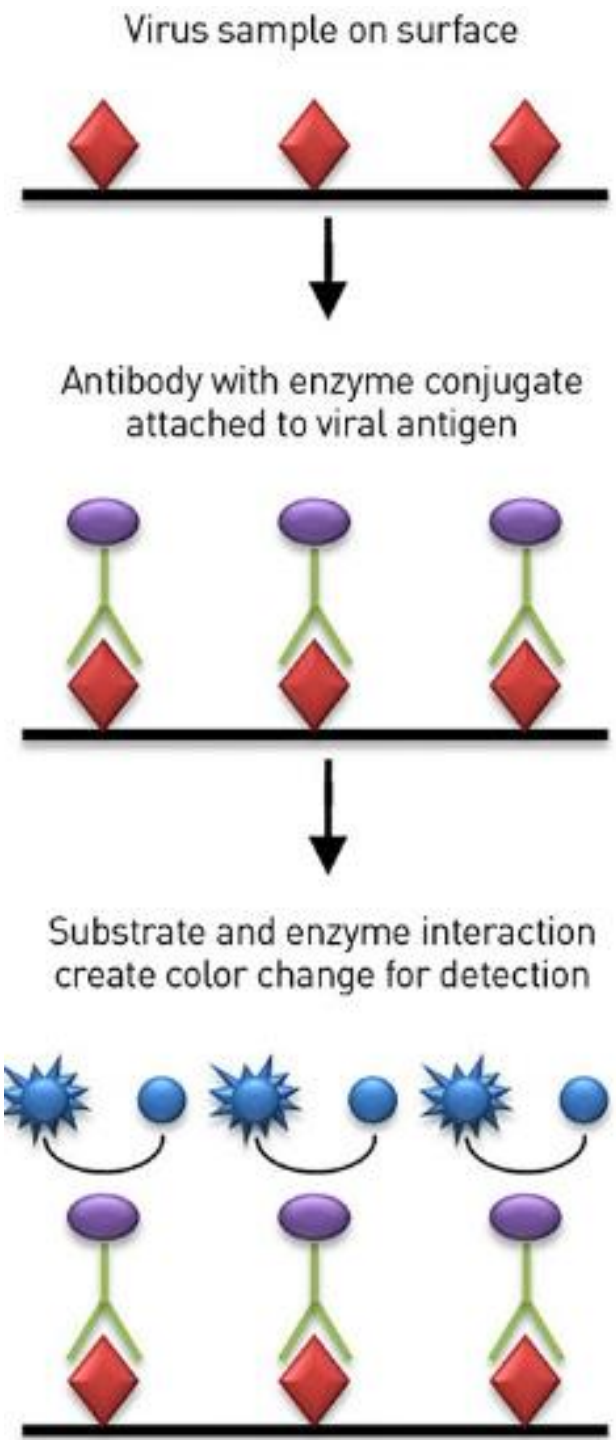
- **Oxygen-saturation meter: It measures percentage of oxygenated hemoglobin in blood. Oxygen-saturation percentage is measured from the ratio of the absorption at 665 nm & 894 nm (LED). Battery-powered device.**

**[T. M. Baer & C. E. Baer, Opt. Phot. News 31 (May, 2020)]**

# Measuring Immunity: ELISA

- **Optical instruments are also used to test whether a person has been exposed to SARS-Cov-2 virus & has developed an immune response.**
- **These instruments use a technique called an Enzyme-Linked Immunosorbent Assay (ELISA) to measure presence of antibodies specific to SARS-Cov-2 virus in a patient's blood-serum sample.**
- **In a typical assay, an antigen found on the virus surface is immobilized on the bottom of a sample well, which is optically transparent.**
- **Antibodies in serum sample are attached to an enzyme (horseradish peroxidase) & allowed to incubate on the surface containing immobilized antigen.**
- **Any antibodies specific for SARS-Cov-2 antigen bind target & become immobilized on surface of optical window. Unbound, nonspecific antibodies are washed off.**

**[T. M. Baer & C. E. Baer, Opt. Phot. News 31 (May, 2020)]**




**Schematic of ELISA, which measures presence of specific antibodies in a COVID-19 patient's sample.**

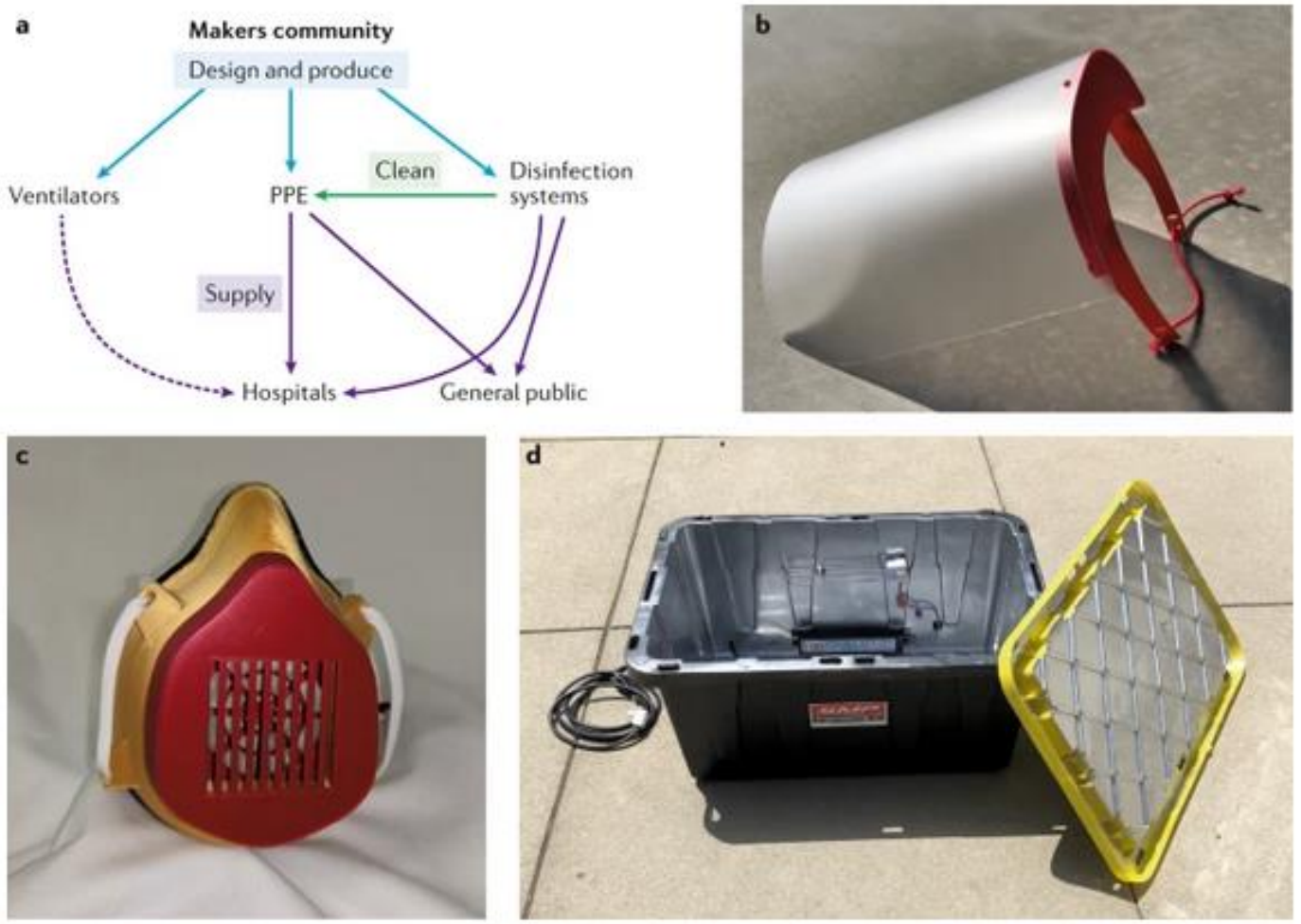
**Technique relies on a colorimetric change in sample generated by an enzyme attached to antibodies specific to SARS-CoV-2 virus.**

# UV for COVID-19

- UV light could be used to disinfect public areas such as public transport, aeroplanes, & sports arenas. Sterilization of surfaces.
- To kill COVID-19 virus, very high levels of UV light is required, which is very costly.
- Handheld UV light device: A high performance UV LED emitting a high intensity of UV light. Limitation: transparent electrode material
- Solution: To develop high performance portable diodes that can have a current applied to them for light transmission. They needed to be transparent to UV light.
- MATERIAL: ??
- Transparent conductors (Japanese): Strontium niobate

# How the makers are helping?

[A M Armani *et al*., Nat. Rev. Mat. 5 (2020) 403]




**(a) Overview of multi-faceted contributions of maker community to COVID-19 pandemic. Dashed arrow indicates a supply line that is still not fully established. (b) 3D-printed face shield, (c) 3D-printed face mask, & (d) disinfection box using UV light.**

# COVID-19

**Disinfection plays a key role in safety & well-being of healthcare workers & broader society.**

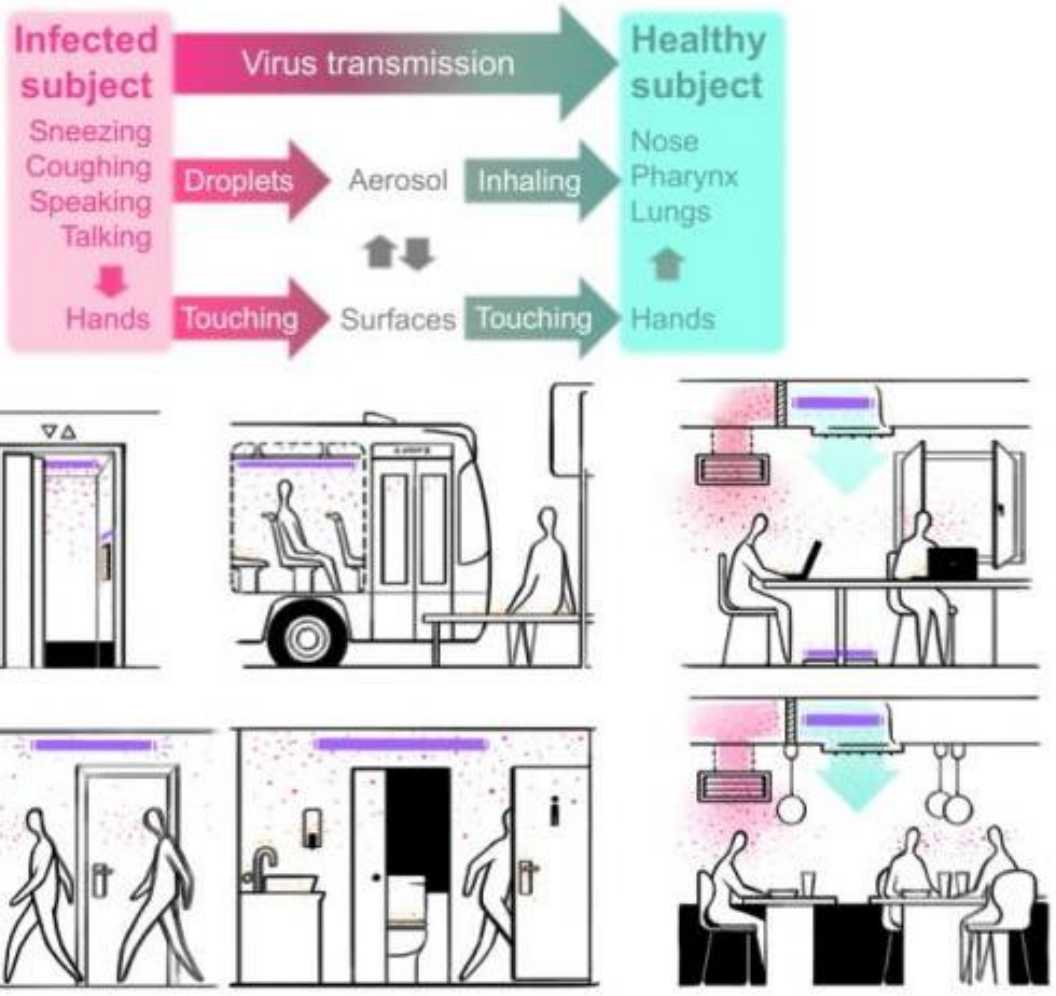
**UV Disinfection Lamps (254 nm)**

**UV Sterilization Box**

- **A UV-C light (100-280 nm) sanitizer acts by penetrating thin wall of a small microscopic organism & destroying its nucleic acids. This disrupts DNA structure & either kills it or renders it unable to reproduce - & therefore harmless.**

- **Exposure to UV-C light poses known threats to human health.**

**Quartz UV germicidal lamp used to disinfect a train in Moscow Metro transit system.**




**Antimicrobial UV-C light sources could be placed in a variety of locations associated with viral spread, such as ventilation systems & other areas. Lamps could then be operated without a direct optical path to humans, or while rooms are not in use, to help reduce virus propagation without endangering human health.**

**[S. Wills, Opt. Phot. News 31 (June, 2020)]**

- **Light in "far UV-C," between 207 & 222 nm, is also effective at killing microorganisms—yet "studies to date suggest that these wavelengths do not cause the human health issues" associated with the 254-nm radiation of germicidal lamps.**

- **Reason may be that light in far UV-C penetrates less than a few μm into biological materials. That's too short a distance to pierce nonliving protective layers of skin & eye into living cells beneath. But it's more than sufficient to bore into tiny bacteria & viruses.**

- **LED arrays emitting hundreds of milliwatts have been developed with liftetimes of 1000 hours & electrical efficiencies around 10%.**

- **Arrays of these diodes can generate significant UV power levels to decontaminate surfaces. Recent lab results indicate that exposure times of about 1 minute were sufficient to kill bacteria & viruses with a 1-W-average-power device located about 1 meter above a contaminated surface.**

**[T. M. Baer & C. E. Baer, Opt. Phot. News 31 (May, 2020)]**

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Biomedical Optics EXPRESS

# Lightweight UV-C disinfection system

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**Abstract:** UV-C exposure is an effective disinfectant for a range of bacteria and viruses. As such, UV-C treatment, in combination with a chemical wipe, is a common cleaning protocol in medical facilities. Given the increase in severe bacterial and viral agents in society, having access to environmentally friendly disinfectant methods is of increasing interest. In response, we designed, constructed, and validated a UV-C disinfection system from readily accessible components. To improve the UV-C intensity, the enclosure interior was coated with chrome paint. The system is validated using *Bacillus cereus*, a gram-positive endospore-forming bacteria.

# e-book on Prevention and Control of Covid-19

**A free e-book is available for online reading (but not for download).**

**https://www.worldscientific.com/doi/pdf/10.1142/11834**

**Wenhong Zhang, Editor-in-Chief**
**Huashan Hospital of Fudan University, China**

**World Scientific Publishing Co. Pte. Ltd. (2020)**

# Reality check: COVID-19 & UV Disinfection

https://physicsworld.com/a/reality-check-covid-19-and-uv-disinfection/