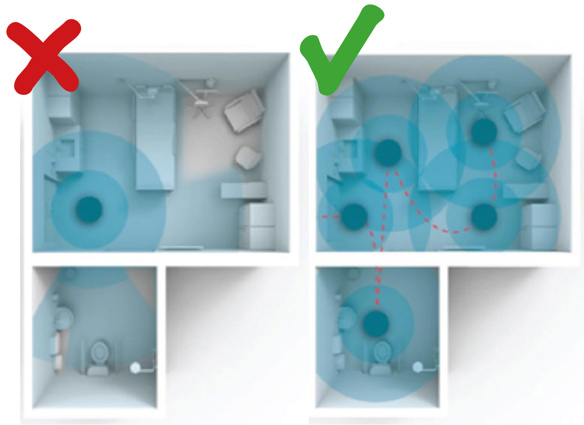
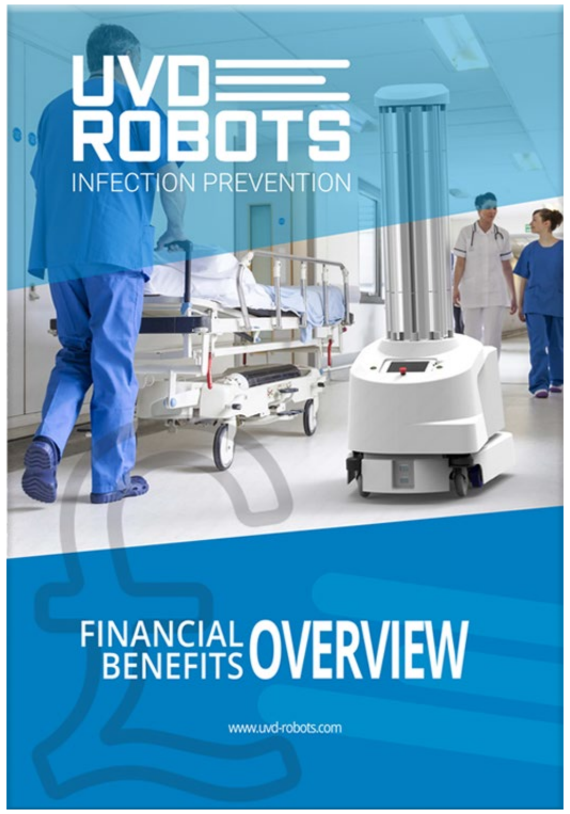
IMPLEMENTING CORRECT UV-C ROOM DISINFECTION PRACTICES

There can be no doubt that the only effective way to carry out a UV-C disinfection involves the continuous repositioning of the UV-C device. This of course comes at a significant price - the associated labour costs of having to pay a member of staff to physically move the device. Or does it?



FINANCIAL BENEFITS OVERVIEW

from UVD Robots (below) shows how utilising robotic technology for UV-C room disinfection can drastically reduce the associated labour costs without sacrificing efficacy.



WHAT DOES A PHYSICIST SAY?

John Erland Østergaard, PhD, M.Sc. Physics
Chief Technology Officer & Co-Founder of Blue Ocean Robotics

> *"You cannot change the fundamental laws of physics governing light behaviour, and UV-C is light. The issues of shadow and distance must be considered when applying UV-C light as a disinfectant. There are two options open to solve these issues, moving the UV-C source yourself, or getting a robotic platform to move it for you."*

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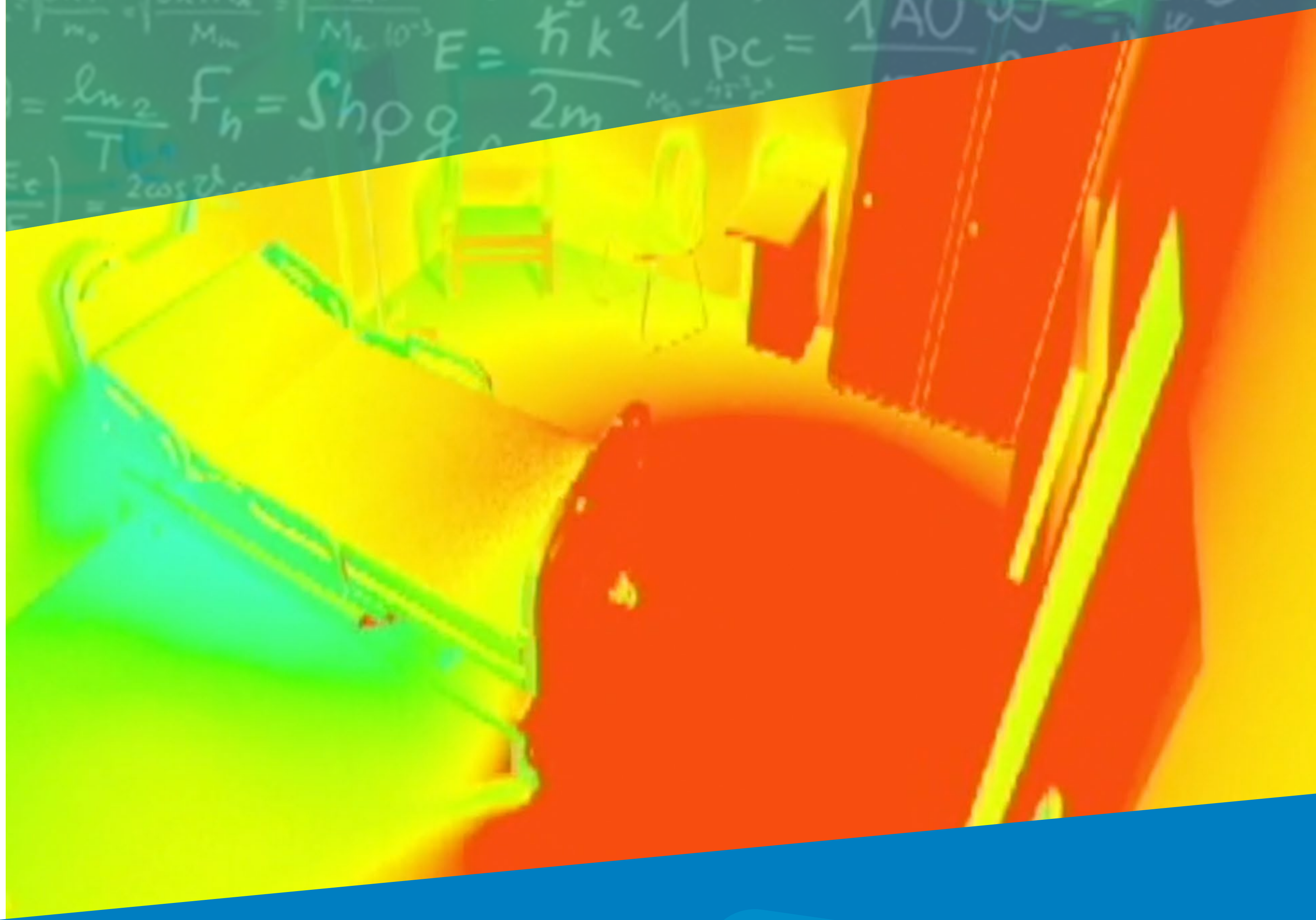
INFECTION PREVENTION



PHYSICS

THE ENEMY OF UV-C DISINFECTION

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physics

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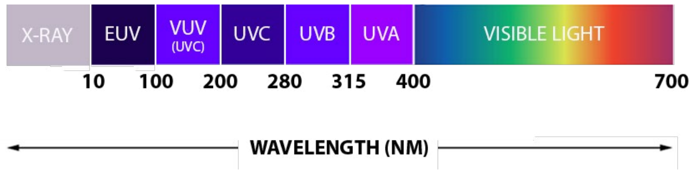
noun

the branch of science concerned with the nature and properties of matter and energy. The subject matter physics includes mechanics, heat, light and other radiation, sound, electricity, magnetism, and the structure of atoms.

WHAT IS UV-C LIGHT?

Ultraviolet (UV) light is a component of the electromagnetic spectrum that falls in the region between visible light and X-Rays.

This invisible radiation includes the wavelength range of 100 nm to 400 nm. UV light can be further subdivided and categorized into separate regions:



100 nm to 200 nm
Far UV or vacuum UV
(these wavelengths only propagate in a vacuum)

200 nm to 280 nm
UV-C - useful for disinfection and sensing

280 nm to 315 nm
UV-B - useful for curing, tanning and medical applications

315 nm to 400 nm
UV-A (or "near UV") - useful for printing, curing, lithography, sensing and medical applications

Now we have established UV-C as a form of light, we must also accept that UV-C is governed by the exact same laws as visible light. Most importantly for disinfection purposes - **shadow** and **intensity over distance.**

THE PHYSICS OF UV-C LIGHT - SHADOW

Most people know that light travels in all directions in straight lines and objects in the path of light cast a shadow (see Fig. 1). That being said, it's important to revisit the issue and understand the challenges shadowing creates when using light for disinfecting.

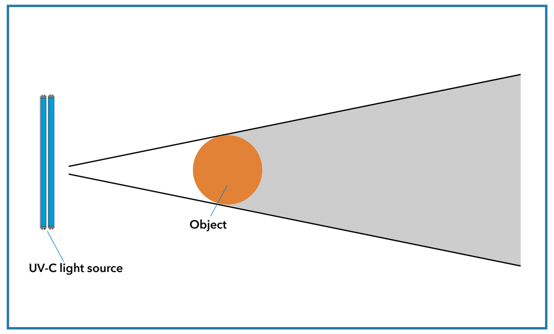


Fig 1. Objects in the path of light cast a shadow

By far, the most powerful source of UV-C radiation in the solar system is the Sun. The amount of UV-C generated by the Sun every second, is higher than all of the artificially generated UV-C in the history of UV-C disinfection combined (see Fig. 2).

Imagine being on holiday in Spain mid August and the dangers of spending too much time in the Sun. Sunburn is a well known result of over exposure to UV light. Now, have you ever stopped to think why you cannot get sunburn at night? The answer is simple! The part of The Earth facing the sun blocks the light from the part facing away from the Sun. Otherwise known as day and night (see Fig. 2).

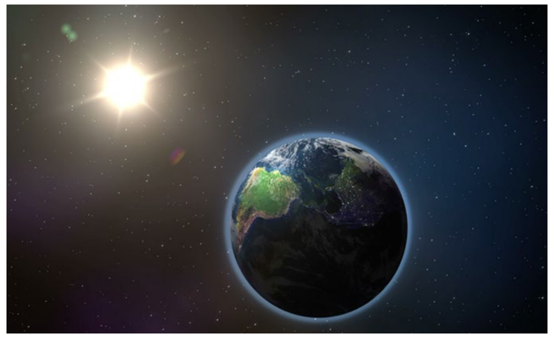


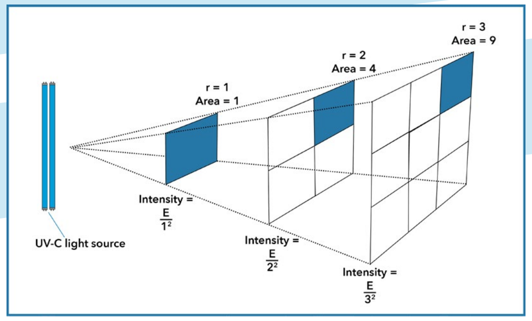
Fig 2. The Earth casts a shadow on itself (night)

If we now apply this fundamental law of physics to a patient room or operating theatre scenario, how can we expect a man made device to accomplish what the Sun cannot? The only effective approach to avoid shadowing in a healthcare setting, is to reposition the light source (UV-C device) as many times as necessary.

THE PHYSICS OF UV-C LIGHT - INTENSITY OVER DISTANCE

THE INVERSE SQUARE LAW

Just like shadow, another law of light that complicates the use of UV-C as a room disinfectant is intensity over distance. The loss of light intensity over distance can be easily calculated using the inverse square law.



We know that UV-C intensity at 1m is 100% therefore, the light intensity at 2m will fall to 25% (a quarter). At 3m the intensity drops further to 11% (a ninth) and at 4m, intensity is only **6.25%**.

The inverse square law dictates that when we want to reach the same level of UV-C intensity (or germicidal effect) achieved at 1m distance, it is necessary to radiate for 9 times longer from 3m distance and 16 times longer from 4m distance.

In 2017, an experiment to measure the intensity of light from a UV-C device in a local hospital was conducted by Blue Ocean Robotics. Light intensity was measured using a Spectrophotometer with the maximum intensity shown in red (see below). The experiment clearly proved how light intensity is significantly affected by distance even, in a small single patient room. Figs. 3 and 4 illustrates how light intensity drastically drops over distance when radiating from a single position. It was concluded that complete coverage of the single room with maximum UV-C illustrated in Fig. 5 was only achievable when the results from 6 separate positions were combined.

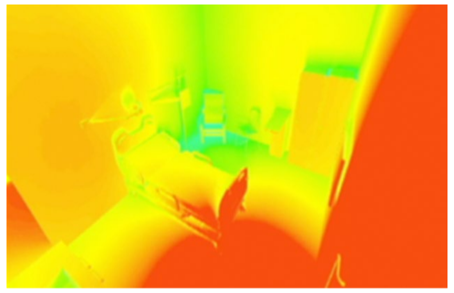


Fig 3 - Maximum intensity is limited to within 1m distance of the UV-C device

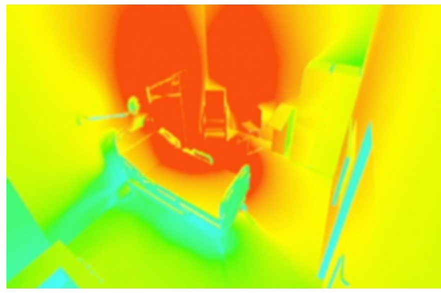


Fig 4 - Changing position of the UV-C device only changes the area of maximum intensity but does not expand it

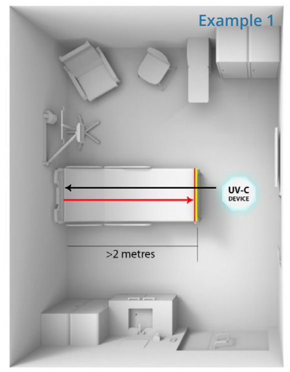
Fig 5 - Complete coverage achieved when combining results from 6 separate positions

> *"What about reflection to avoid shadowing when it comes to UV-C disinfection"*
>
> Without doubt, the most controversial discussion point when dealing with UV-C disinfection

THE PHYSICS OF UV-C LIGHT - REFLECTION

UV-C has a very short wavelength which means approximately 95% of the energy is absorbed by many types of molecules present in modern plastics and paints. Only 5% of the UV-C energy can be utilized for disinfecting objects in shadow from direct UV-C rays.

In a realistic healthcare environment reflection is often combined with distance as the examples 1 and 2 illustrate. In order to radiate UV-C on to the blind side of a hospital bed rail, the light must first travel to the wall in order to be reflected. This means that the 95% loss of energy due to reflection is not the only loss of energy to consider. Additionally, the loss of intensity as per the inverse square law must be calculated:



EXAMPLE 1 RIGHT

Calculation of UV-C radiated onto the blind side of hospital bed rail (marked in red).

Distance light travels is approx. 4 metres = UV-C light intensity is approx. 6.25% (a sixteenth).
Energy reflected off the wall = 5% (95% absorbed).

Total UV-C radiated onto blind side of hospital bed rail = 5% of 6.25% = **0.3%**

Conclusion with example 1:

1 minute direct UV-C at 1 metre = 300 minutes of reflected UV-C