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DID YOU KNOW?

DISINFECTION WITH UVC LEDS, IT WORKS!

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With our new series of UVC LEDs, we conducted several tens of real-life tests in our lab to showcase and understand their germicidal behavior and efficiency.

In addition to a previous report from independent laboratory SGS proving that the LEDs have an inactivating effect on microorganisms, we aim to optimize our support for a variety of UVC applications to help our customers design in the right model and number of LEDs.

Figure 1 below shows the results of a Petri dish culture of a variety of different bacteria found in a normal public environment, such as a bathroom sink. Samples were taken with a cotton swab and gently swiped onto a nutrient agar solution in the Petri dish. After introduction of the bacteria collection, the surface of the agar in the Petri dish was exposed to UVC light from our VLMU35CR40 – a 37 mW LED with a typical wavelength of 274 nm.

To control the exposure distance and area, a 3D-printed cylindrical case with a height of 30 mm and a diameter of 30 mm was used, which also stamped the shape of the three circles seen below. The LED was soldered on a metal core PCB and driven with a current source of 250 mA to operate within the datasheet specifications.

After exposure to the UVC light, the Petri dish was sealed and placed in an incubation chamber for 72 hours at 30 °C.

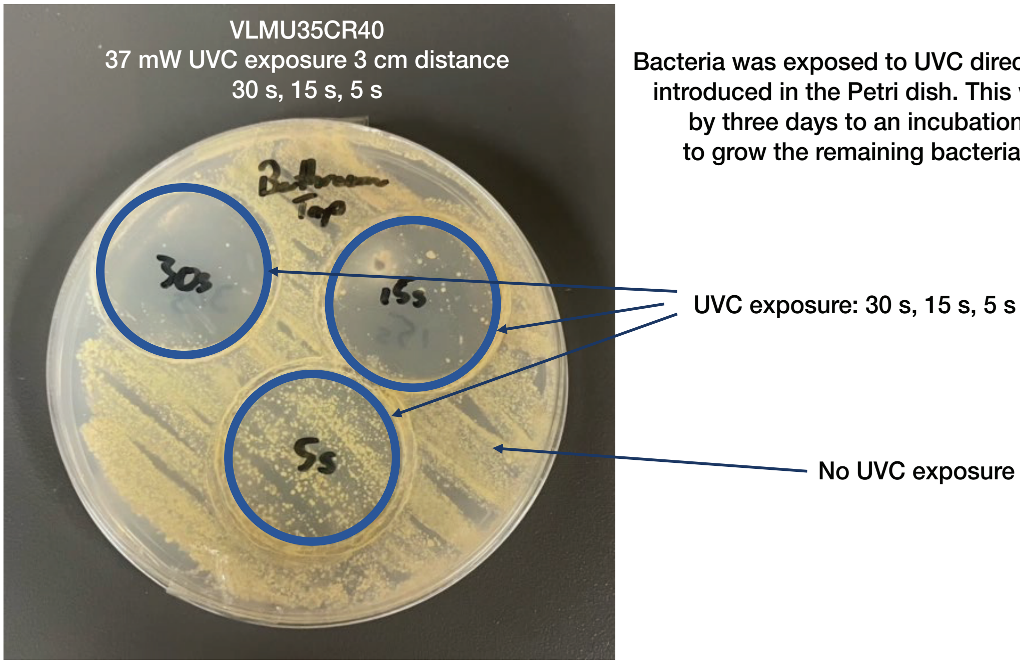

Figure 1 - Petri Dish Result From UVC Exposure

Each yellow dot in the picture is one colony forming unit (CFU) that has grown out of the introduced and surviving bacteria. Outside the three smaller circles, there was no UVC exposure, so the result is a very high density of CFUs. Inside the circles, with increasing UVC exposure times of 5 s, 15 s, and 30 s, the CFUs decrease rapidly, which means that after 30 s of exposure most bacteria were inactivated.

$$H_a = \frac{\Phi_e \times \left[\frac{I_e}{\Phi_e}\right] \times t \times k}{d^2}$$

Datasheet Parameters:

$\left[\frac{I_e}{\Phi_e}\right]$ = Ratio of radiant intensity / radiant power

Φ_e = Radiant power

Application-Specific Parameters:

t = Exposure time

d = Exposure distance

H_a = Absorbed exposure

Germicidal Efficiency Parameter:

k = Microorganism absorbance

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The inactivation of bacteria happens through the amount of energy absorbed by the bacteria. The total amount depends on several variables, such as exposure time, distance, radiant output power, and the wavelength of the LED. The wavelength plays a crucial role since the absorbance efficiency greatly depends on wavelength and peaks at an average of 265 nm. At a decreasing wavelength the efficiency decreases rapidly, e. g. 285 nm results in a 58 % efficiency. [2] [3]

The efficiency curve shown in Figure 2 is an average of the absorbance capability of different microorganisms. The peak absorbance wavelength can vary slightly (± 1 nm) depending on the type of bacteria or virus.

The calculation of the energy follows the principle of the inverse square law, which is applied for distances more than ten times the light source size.

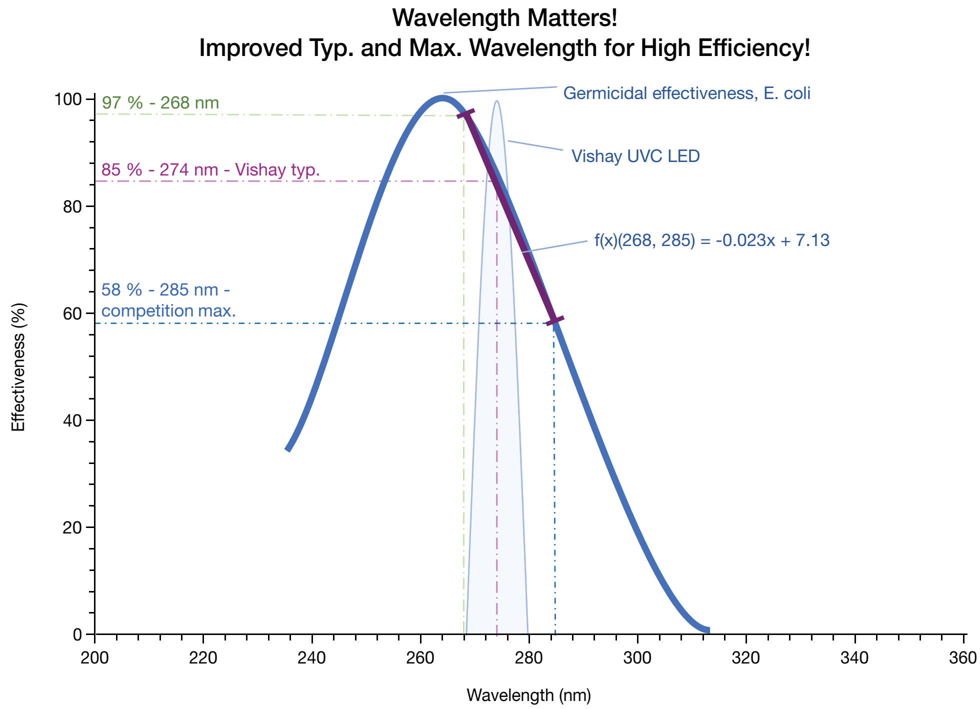

Figure 2 - Absorbance Capability vs. Wavelength

Additionally, here we introduced a wavelength correction factor k, which describes the absorbance efficiency at different wavelengths, simplified with a linear function for a conservative result between 268 nm and 285 nm. The linear function can be seen in Figure 2 overlaying the absorbance curve.

$$k = f(x)[268,285] = -0.023x + 7.134$$

The table below shows the total energy in mJ/cm^2 for the experiment at different times using the above described calculation methods.

Wavelength [nm]	274	274	274
Radiant Power [mW]	37	37	37
[I_e/Φ_e]	0.29	0.29	0.29
Distance [cm]	3	3	3
Time [s]	5	15	30
Absorbed Exposure [mJ/cm^2]	4.96	14.89	29.77

To make individual calculations, the following Excel formula can be used for Absorbed Irradiation Results table below.
= (B3 x B2 x B5)/(B4 x B4) x (-0.023 x (B1 - 268) + 0.97)

Copy the table and place it into A1 of an Excel sheet, then copy – paste the formula in B6, which should deliver the same result as shown here. After that all the values can be modified.

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To put the absorbed irradiation into perspective, we need to compare it with the below data from Figure 2 that shows the amount of energy needed to inactivate different microorganisms. The upper boxplot limit indicates the UVC exposure required to inactivate 99.67 % of the tested samples. To achieve a D90 inactivation, most bacteria require an exposure level of 14.9 mJ/cm^2 or less. Viruses typically need more energy. For a D90 inactivation, an exposure of 62.6 mJ/cm^2 or less is required. Fungi requires the highest amount of energy, typically 224 mJ/cm^2 to cover most types.

Interpreting Figure 2, we can see the expectation for our experiment is a > 90 % reduction at an exposure greater than 14.9 mJ/cm^2, which matches the calculated exposure at 15 s.

Visibly comparing the result in the Petri dish matches with the expectation from the calculations.

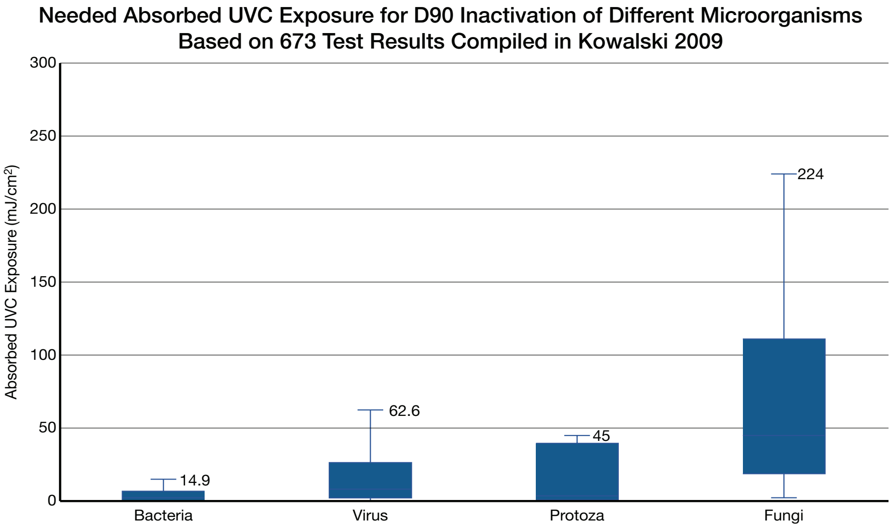

Figure 3 - Energy Needed for Inactivation of Different Microorganisms [1]

These results can be used to design different applications and can be scaled up or down according to distance, exposure time, and target microorganism.

Recent studies for the inactivation of different types of coronaviruses have shown that an upper limit of 10.6 mJ/cm^2 for a 90 % reduction can be assumed for existing and future variants of SARS-Cov-2 [4]. Therefore coronaviruses are all well within the range of the above discussed limits.

As a rule of thumb, we can state that viruses tend to need a higher amount of energy than most bacteria. Fungi need a significantly higher amount of energy for inactivation. The environment in which the microorganisms are located also influences the result and consequently the exposure requirements. Increasing energy needs are seen in air < surfaces < water -> air, surfaces, water. [1]

To ensure the efficiency of applications, we recommend in any case to create an official third-party lab test report such as SGS. The results shown in this report are reference values for application estimations.

Application Examples

Button Sterilization – Small Area – Low Power – Long Exposure

Wavelength [nm]	274	280	285
Radiant Power [mW]	3	3	3
$[I_e/\Phi_e]$	0.34	0.34	0.34
Distance [cm]	1	1	1
Time [s]	60	60	60
Absorbed Exposure [mJ/cm^2]	50.94	42.52	35.50

A low power LED such as the VLMU35CL20 with a typical output power of 3 mW can be used for targeted sterilization such as lighting on a button from a relatively short distance. With increasing distance, the time would also need to be increased according to the inverse square law. The table shows three different types of UVC LEDs with different wavelengths, which can be found in the market by different suppliers. The effect of the wavelength results in a significant difference of the absorbed energy, while all other parameters stay the same.

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Air Sterilization – High Power – Short Time

Wavelength [nm]	274	274	274
Radiant Power [mW]	148	148	148
[I_e/Φ_e]	0.29	0.29	0.29
Distance [cm]	1	2	3
Time [s]	1	1	1
Absorbed Exposure [mJ/cm²]	35.72	8.93	3.97

The next example application could be a flow through air unit, where the critical part is that the exposure time is relatively short. Higher power can be realized with multiple LEDs, such as 4 x VLMU35CR40 with typical 37 mW that results in a total radiant power of 148 mW. The table shows the absorbed energy result for three different distances and showcases the drastic effect exposure distance has on a system and the absorbed energy levels.

Surface Sterilization – Different Power LEDs

Wavelength [nm]	274	274	273
Radiant Power [mW]	37	21.5	13.5
[I_e/Φ_e]	0.29	0.29	0.26
Distance [cm]	3	3	3
Time [s]	30	30	30
Absorbed Exposure [mJ/cm²]	29.77	17.30	10.01

The above table compares three different LEDs from the Vishay portfolio – VLMU35CR40 (37 mW), VLMU35CT20 (21.5 mW), and VLMU35CB20 (13.5 mW) — at typical parameters from their respective datasheets. In general, the higher power LEDs have a better efficiency in input / output power, as well as a better cost / performance ratio. However, depending on the application design, such as PCB, case design, and heat management, it can also be beneficial to use multiple lower power LEDs.

Notes:

[1] Kowalski, Wladyslaw (2009). Ultraviolet Germicidal Irradiation Handbook: UVGI for Air and Surface Disinfection

[2] Application Note: UVC Sterilization

[3] Did You Know? Wavelength Matters

[4] Ultraviolet irradiation doses for coronavirus inactivation – review and analysis of coronavirus photoinactivation studies

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