WE MEET
@ DIGITAL DAYS

DISINFECTION WITH UV-C LEDS

Dominik Köck

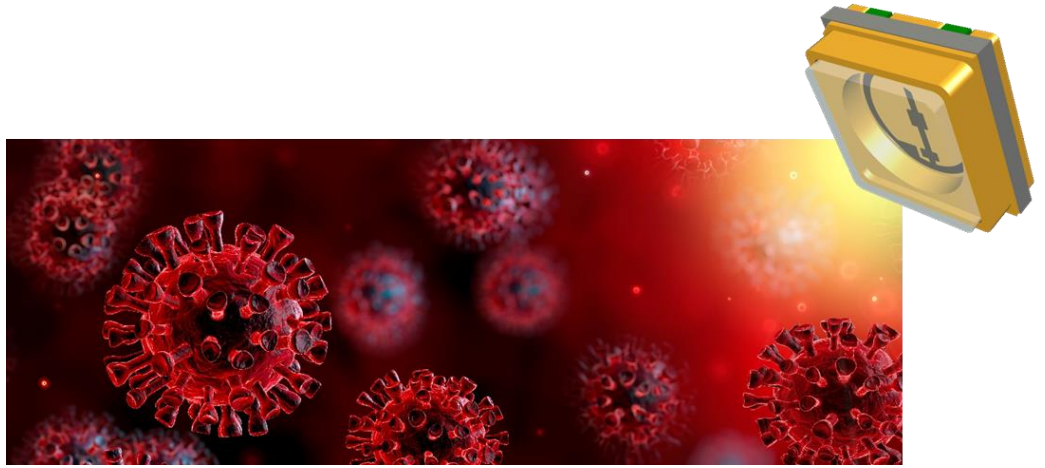
Product Manager Optoelectronics

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

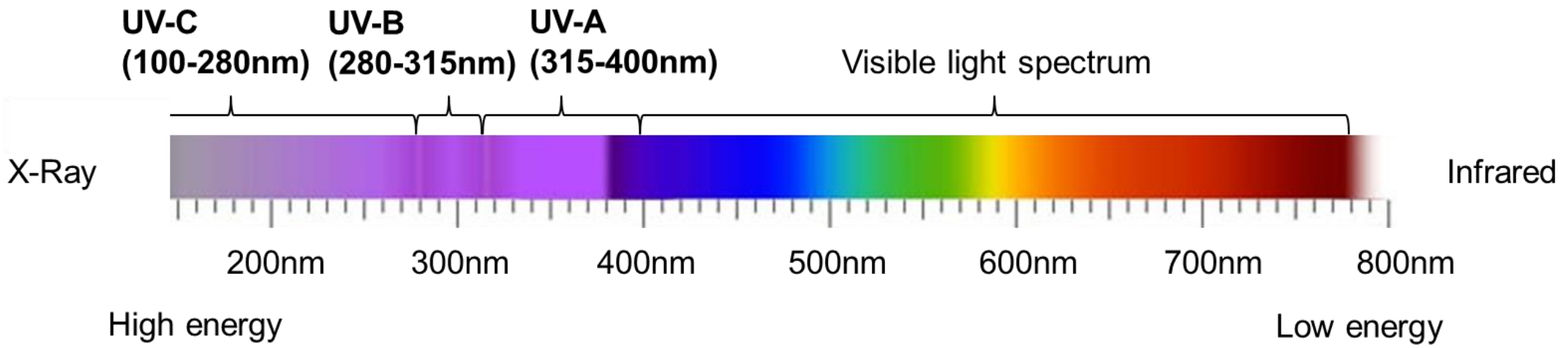
AGENDA

Disinfection with UV-C LEDs

- What is UV light?
  - UV-A, UV-B and UV-C
- Disinfection with UV light
  - Working mechanism
  - Cell inactivation efficiency vs wavelength
  - Dose for disinfection
- Application examples
  - Irradiance calculation examples
- Safety
  - Maximum daily dosis



WHAT IS UV LIGHT?

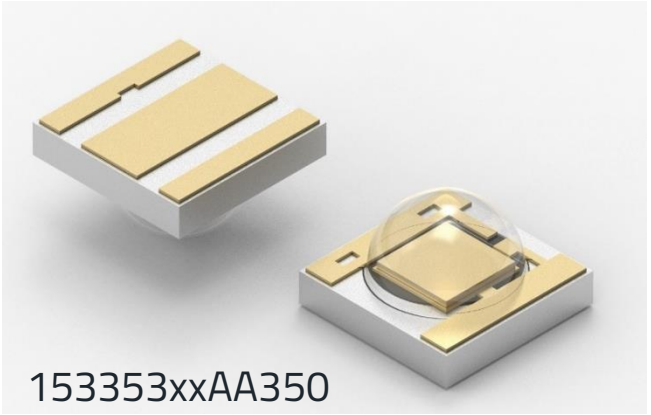


WÜRTH ELEKTRONIC UV LEDS OVERVIEW

Matchcode WL-SUMW

UV-A:

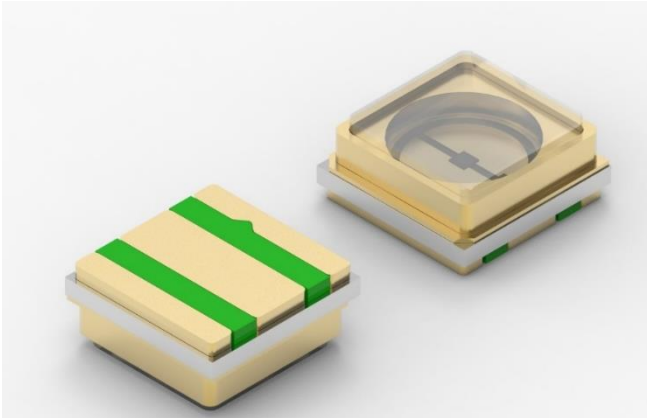
Order Code	λ_P	Viewing angle	Radiant flux
15335340AA350	**405** nm	130°	800-1100 mW
15335339AA350	**395** nm	130°	800-1100 mW
15335338AA350	**385** nm	130°	800-1100 mW
15335337AA350	**365** nm	130°	700-1000 mW



153353xxAA350

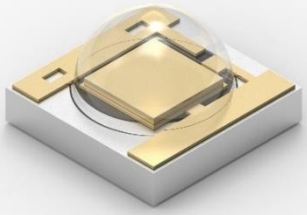
NEW! UV-C:

Order Code	λ_P	Viewing angle	Radiant flux
15335327BA250	**275** nm	120°	**3** mW
15335327BA252	**275** nm	120°	**15** mW



15335327BA25x

UV-A APPLICATIONS



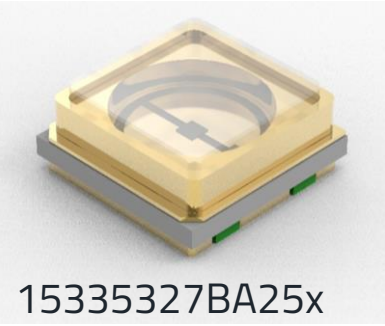
153353xxAA350

Horticulture

Security and counterfeit detection

Curing applications

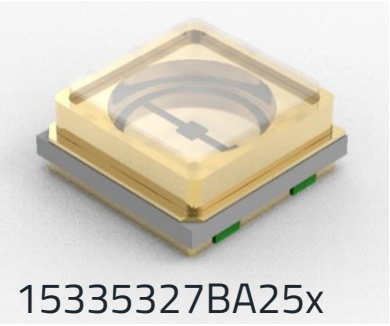
UV-C APPLICATIONS



Surface disinfection

Food industry

UV-C APPLICATIONS



Air purification

Water disinfection

COMPARISON UV-C LIGHT SOURCES

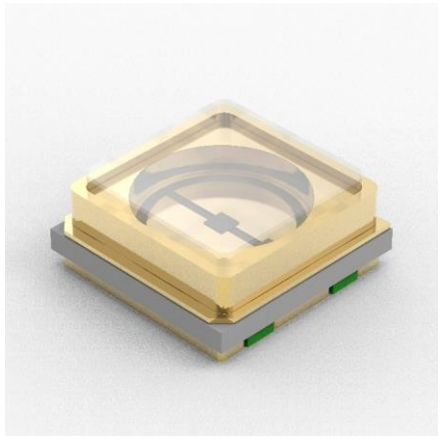
UV-C tube

- \- Long turn-on time
- \- Shock sensitive
- \- Large space requirements
- \- Contains Mercury
- \+ High power

VS.

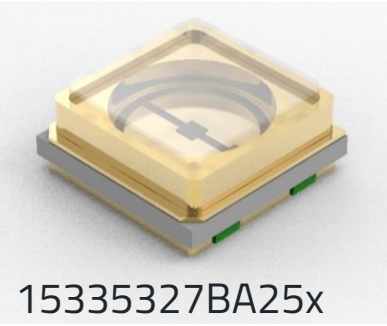
UV-C LEDs

- \+ Instantaneous turn on
- \+ Not shock sensitive
- \+ Space limited application
- \+ No hazardous materials
- \- Comparably low power

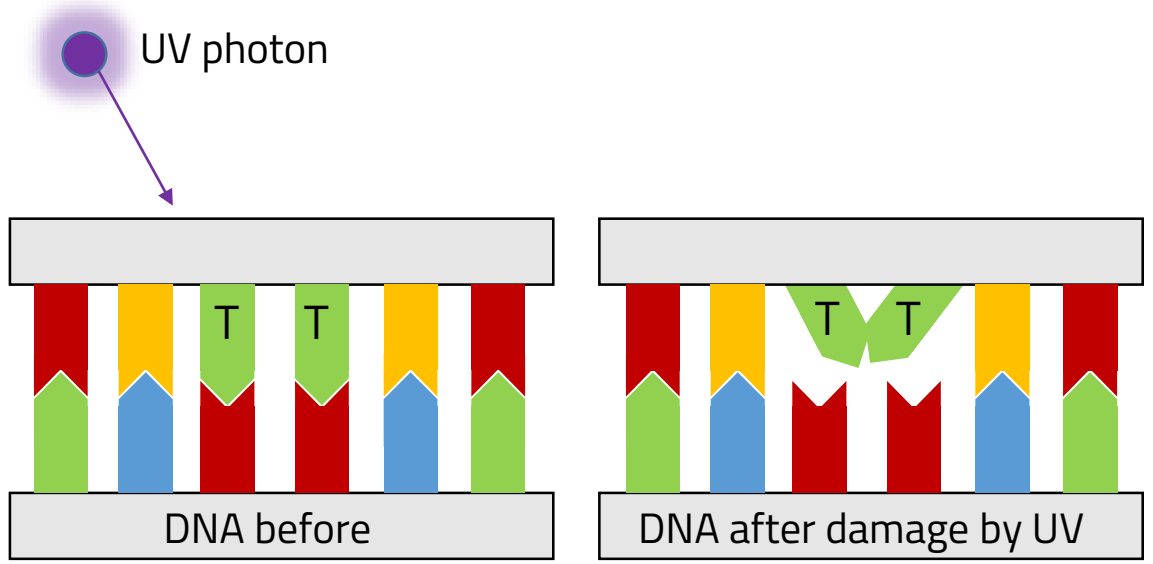


UV-C DISINFECTION

Working mechanism

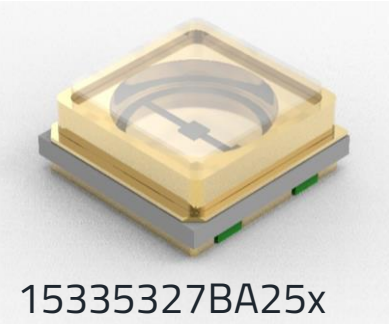


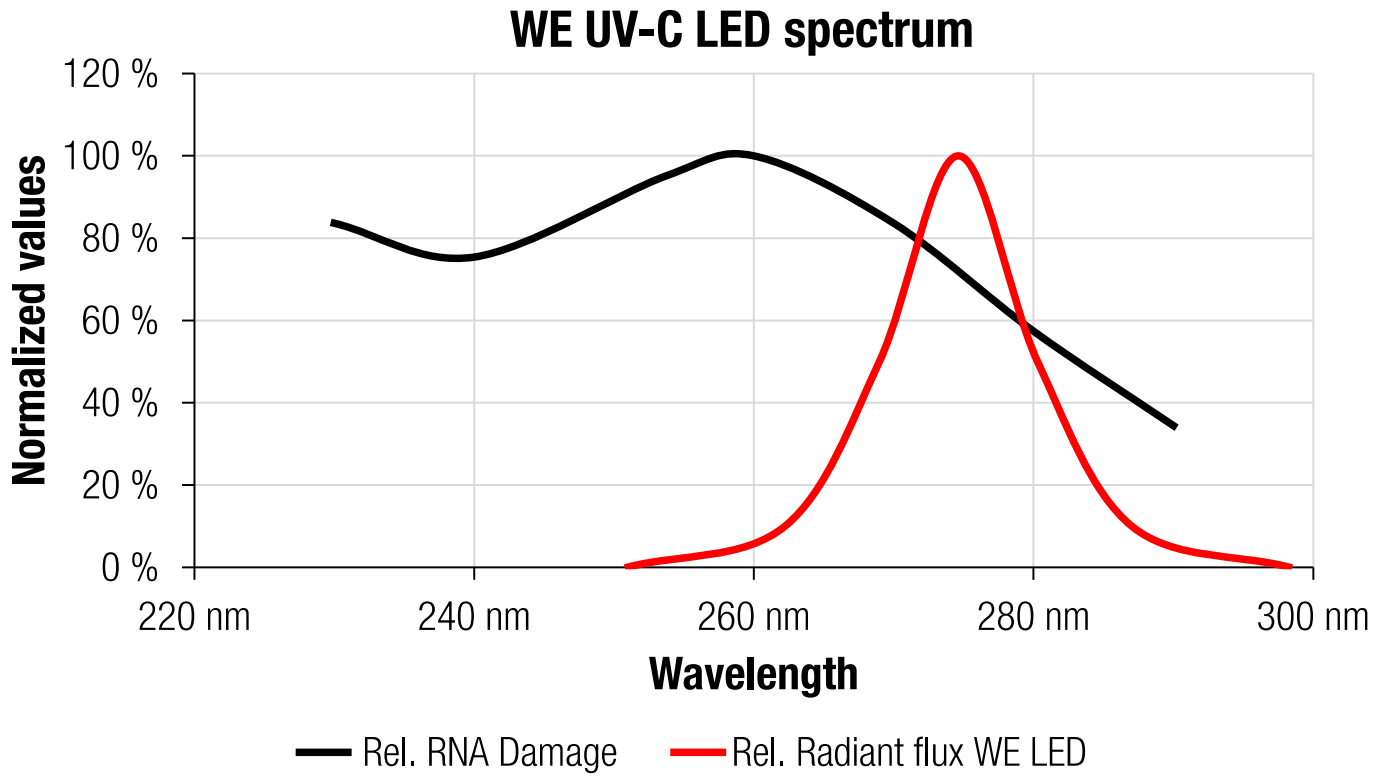
- UV-C radiation splits chemical bonds between nucleic acids of DNA
- Formation of Thymine Dimers
- DNA can not be duplicated in cell divsion anymore
- Similar mechanism for RNA of viruses



UV-C DISINFECTION

Wavelength dependence

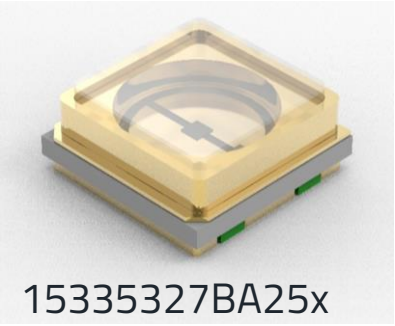


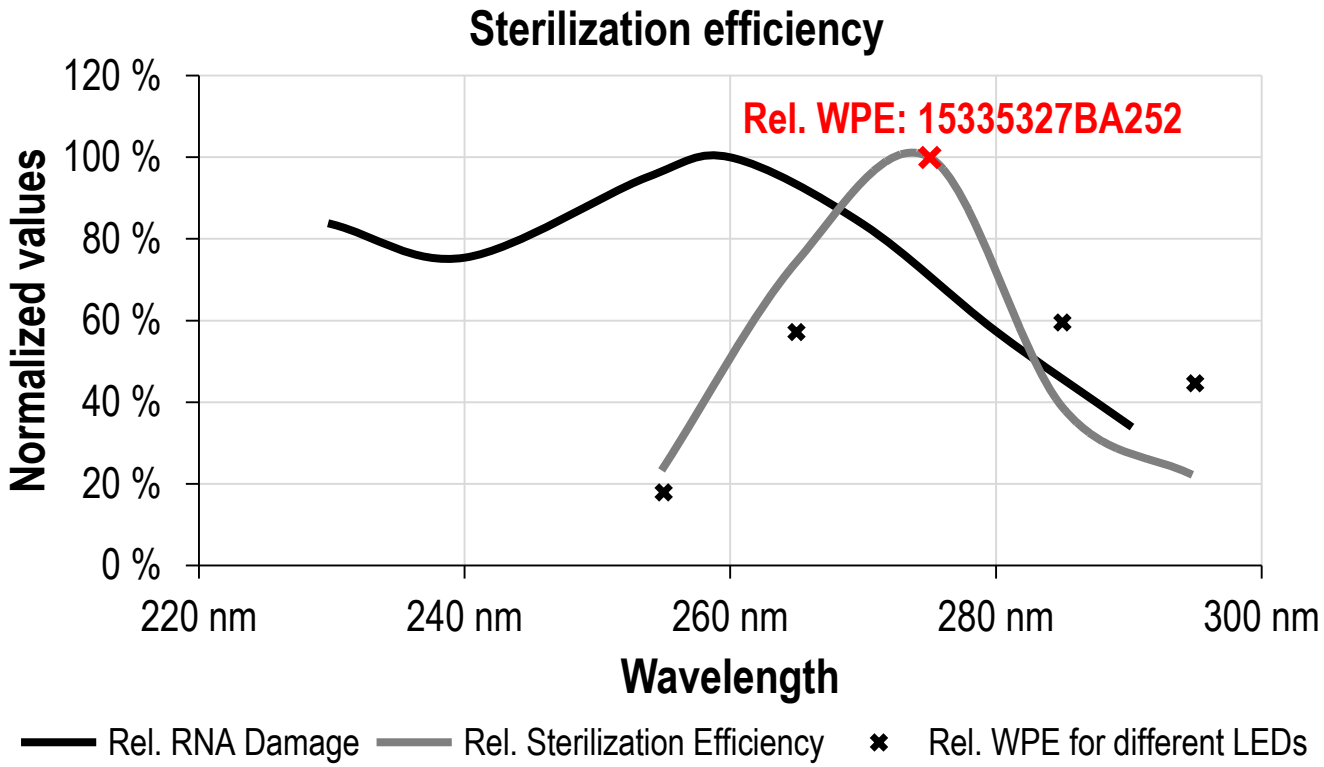


[1] *S. Beck et al. (2016) Comparison of UV-Induced Inactivation and RNA Damage in MS2 Phage across the Germicidal UV Spectrum. Appl. Environ. Microbiol.*

UV-C DISINFECTION

Optimal wavelength





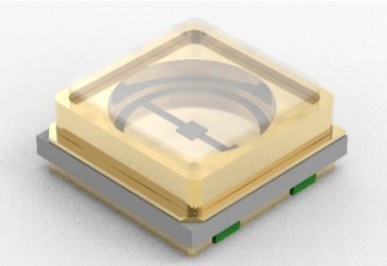
275nm LED combines:

- **Ability to damage RNA**
- **High output power and Wall-Plug-Efficiency (WPE)**
- **Technology maturity**

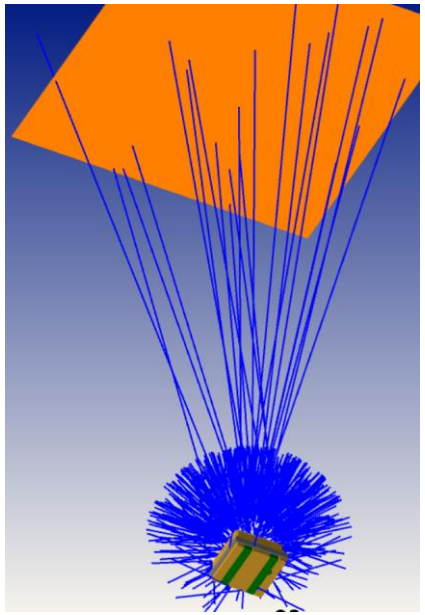
[1] *S. Beck et al. (2016) Comparison of UV-Induced Inactivation and RNA Damage in MS2 Phage across the Germicidal UV Spectrum. Appl. Environ. Microbiol.*

UV-C DISINFECTION

Ray files for optical simulations

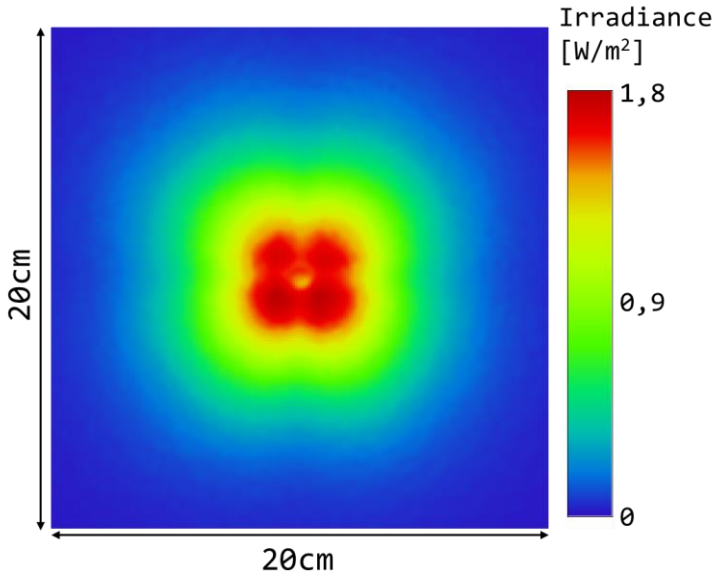


RAY Ray file for UV-C LED



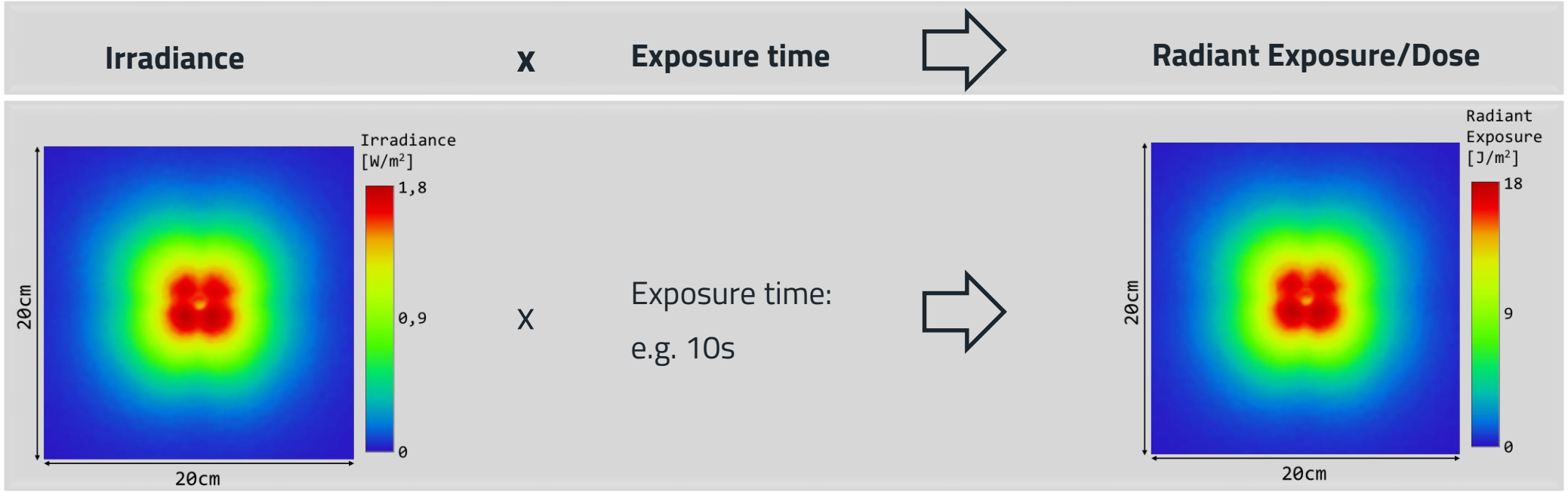
Simulation

Irradiance @4cm distance for 15335327BA252



BACKGROUND

Irradiance and Dose



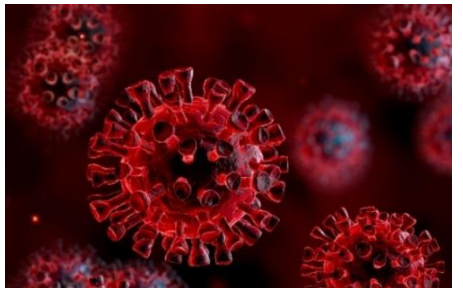
Dose	Percentage of germs inactivated
D90	90 %
D99	99 %
D99.9	99.9 %
D99.99	99.99 %

D90 DOSES

D90 Doses for different germs

Germ type	Information on the germ	D90 Dose (J/m^2)	Lamp type
Virus			
Corona virus [2]	Corona viruses such as SARS-CoV-2	6-117540 Median: 37	Low pressure
Hepatitis virus [3]	Causes Hepatitis	40	Low pressure
Influenca [4]	Responsible for "The Flu"	20	Low pressure
Adenovirus [5]	Causes the "Common Cold"	390	Low pressure
Bacteria			
Salmonella typhimurium [6]	Can cause food poisoning	39	Low pressure
Escherichia coli [7]	Can cause food poisoning	43 (275nm)	LED
		41 (254nm)	Low pressure
Legionella pneumophila [8]	Can form in water supplies	17	Low pressure
Fungi			
Aspergillus niger [9]	Can form "black mold"	1160	Low pressure

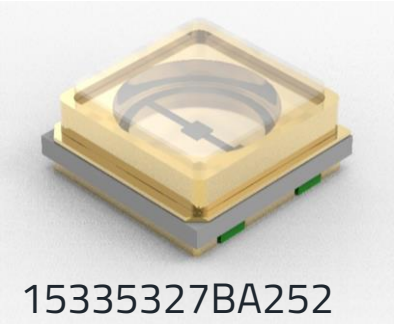
German water desinfection norm [10]**: 400J/m²**

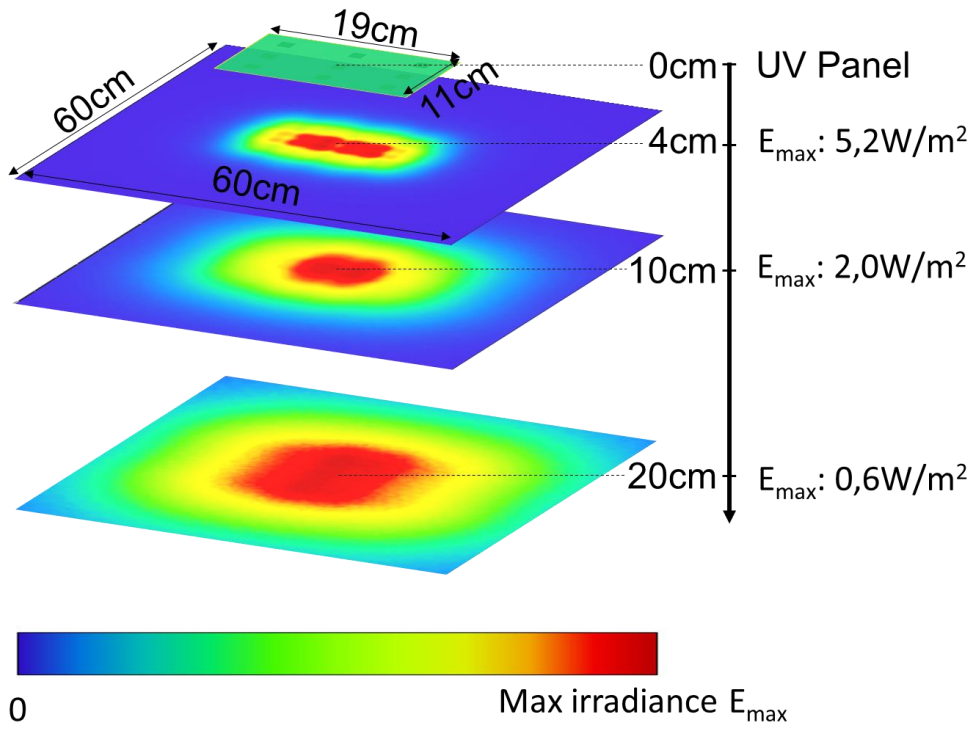


ACHIEVING A DOSE

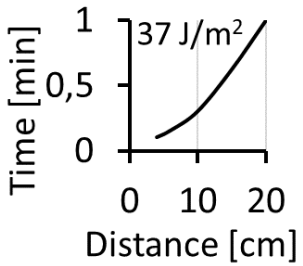
Surface disinfection

Schematic of UV panel with 9 LEDs



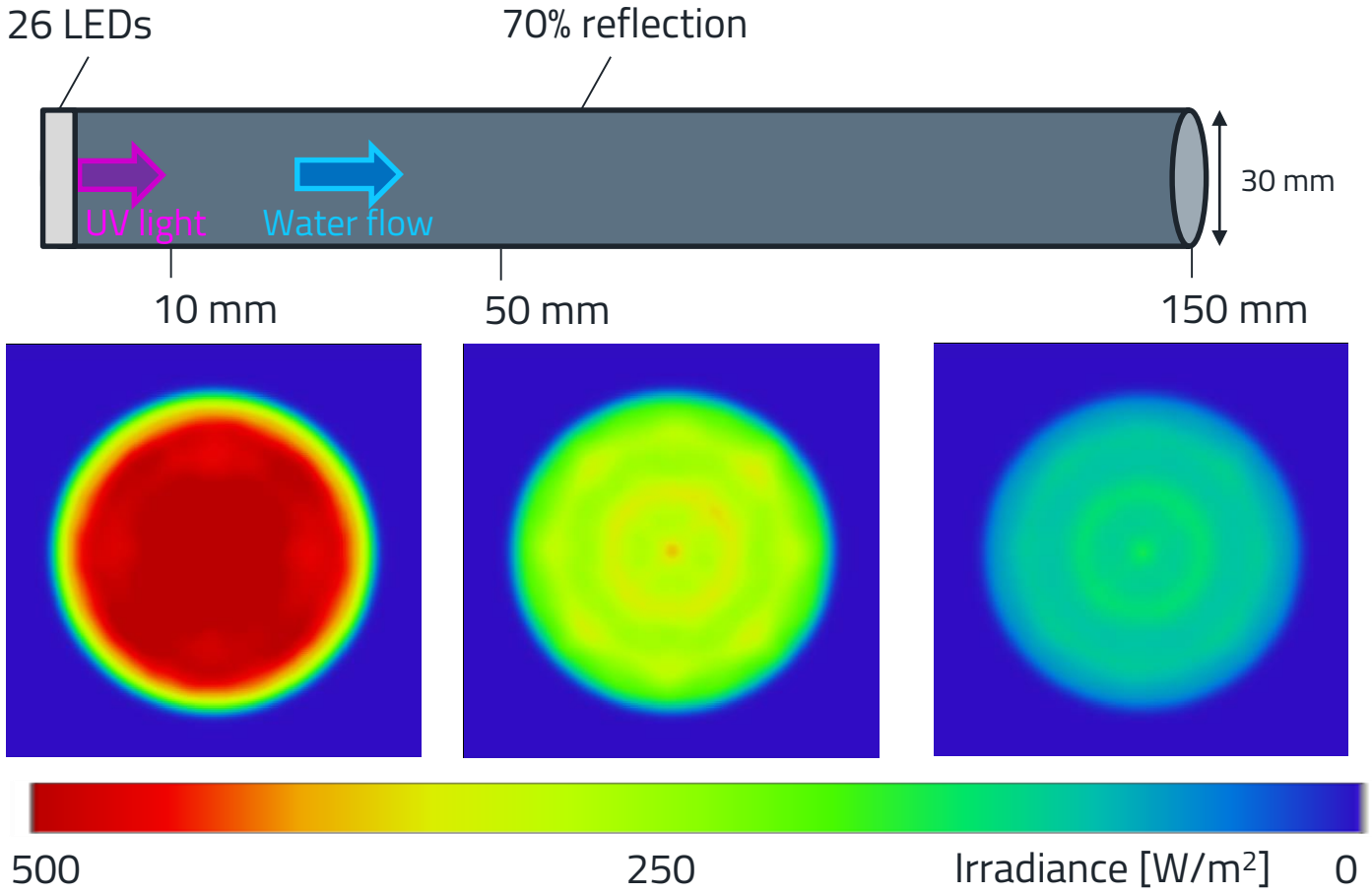


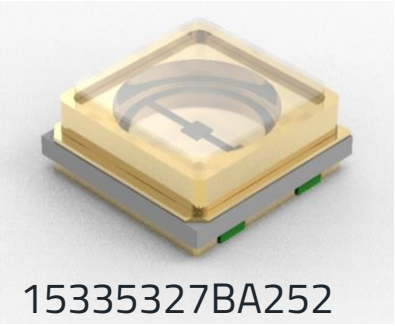
Dose 37 J/m²	Dose 400 J/m²
0.1 min	1.3 min
0.3 min	3.3 min
1.0 min	11.1 min

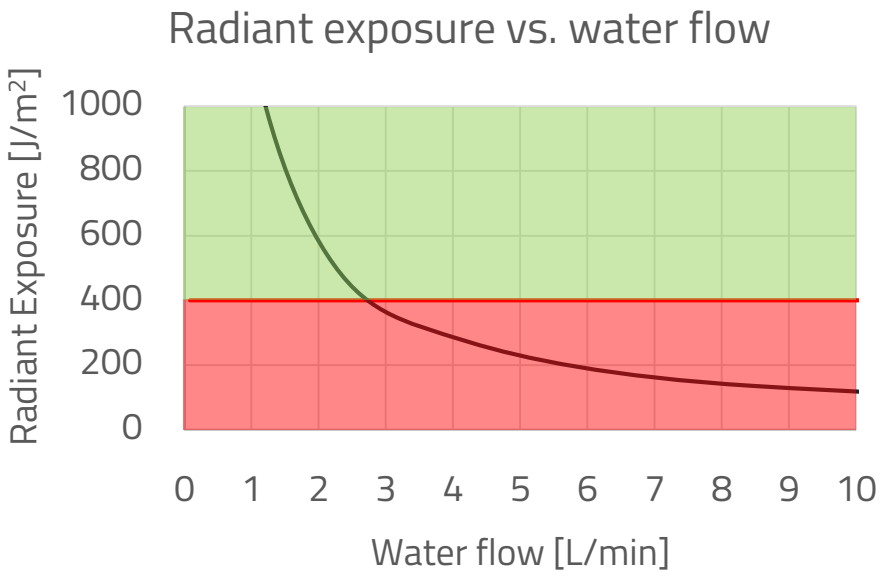


ACHIEVING A DOSE

Water disinfection



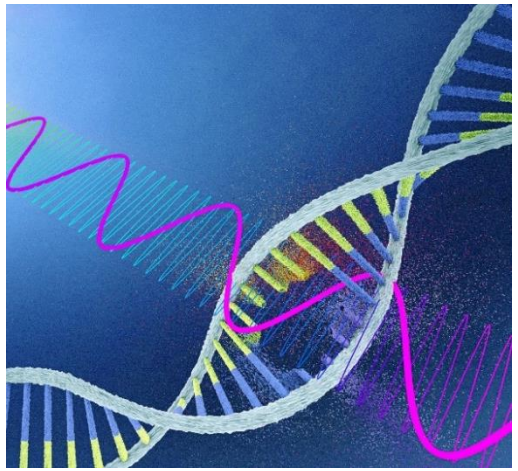




UV SAFETY

- Eyes and skin can be damaged with UV radiation
- UV-C radation is especially dangerous
- Wear protective equipment!
- Attach warning labels to your applications!
- Include appropriate safety measures for your application!
- Maximal allowed dose per 8h work day for 275nm: **30J/m^2** [11]

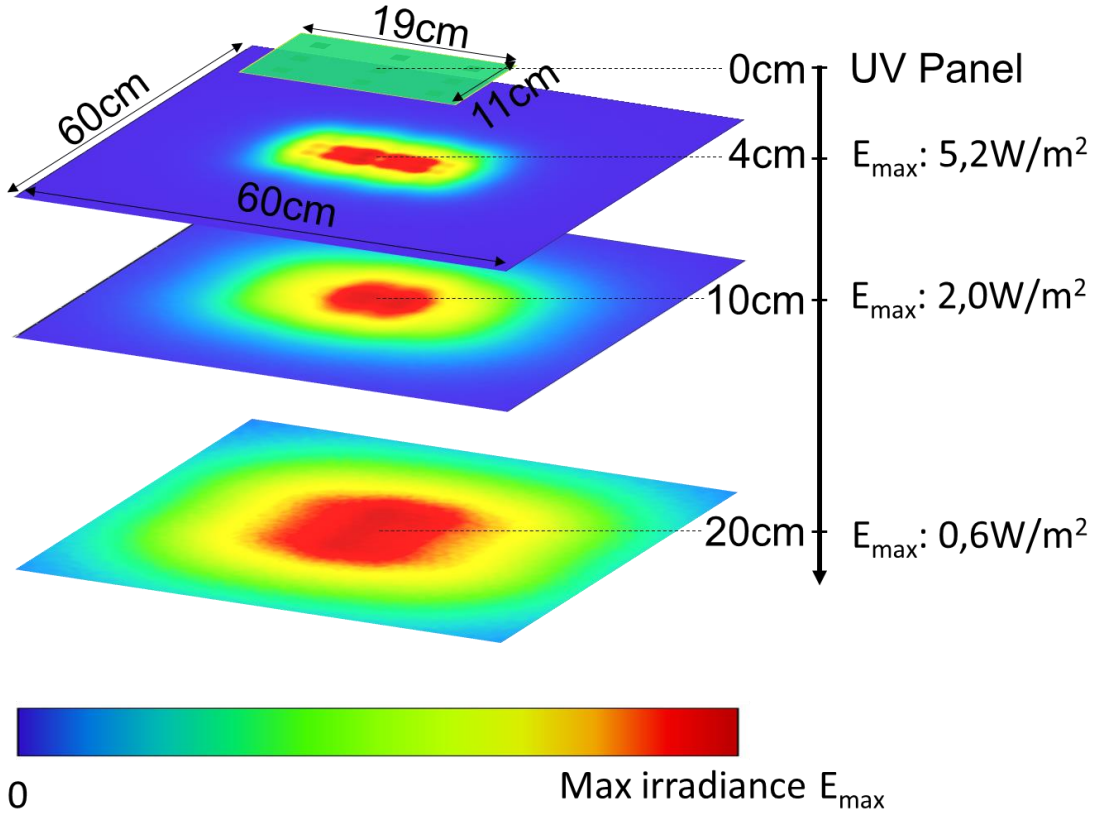
Warning! UV-C radation



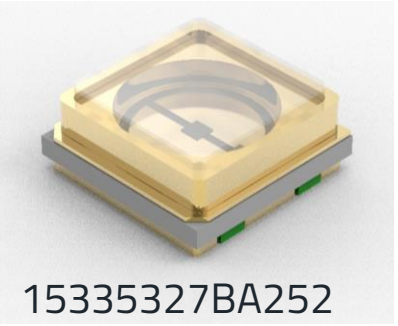
[11] DIRECTIVE 2006/25/EC

UV SAFETY

Example simulation



Schematic of UV panel with 9 LEDs



15335327BA252

Dose 30 J/m²
6 s
15 s
50 s

Short exposure to UV-C LEDs' light can already exceed the daily limit!

HOMEPAGE

Ray files available under Downloads

WL-SUMW SMT Ultraviolet Ceramic LED | Optoelektronik | Würth Elektronik Produktkatalog (we-online.de)

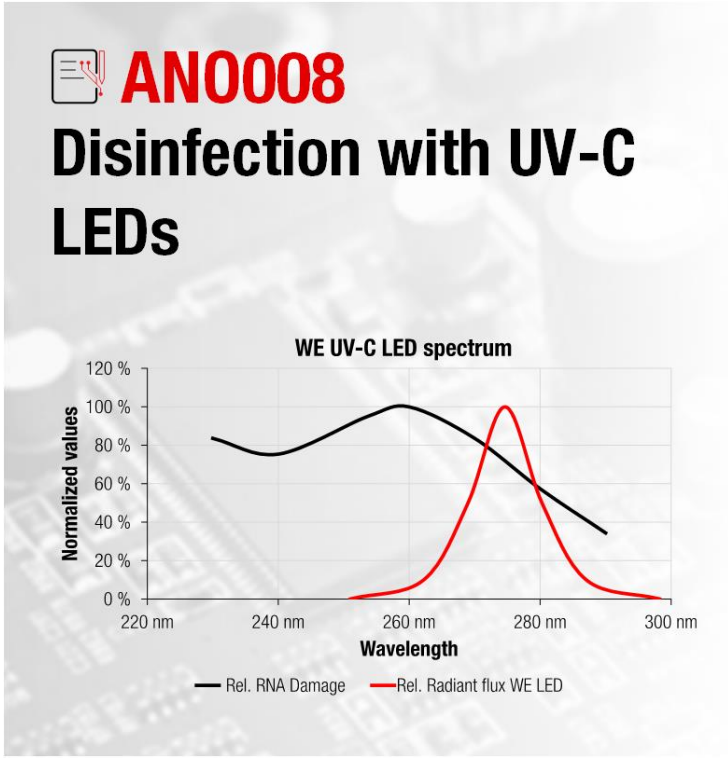
		Artikel Nr.	Daten-blatt	Simu-lation	Downloads	$\lambda_{Peak\ typ.}$ (nm)	$\Phi_{e\ min.}$ (mW)	$\Phi_{e\ typ.}$ (mW)	$\Phi_{e\ max.}$ (mW)	$V_{F\ typ.}$ (V)	Chiptechnologie	Muster
NEU		15335327BA250	SPEC	RE	25 DATEIEN	275	1.5	3	–	6.5	AlGaN	1
NEU		15335327BA252	SPEC	RE	25 DATEIEN	275	8	15	–	6	AlGaN	1
		15335337AA350	SPEC	RE	25 DATEIEN	365	700	–	1000	3.8	AlInGaN	1
		15335338AA350	SPEC	RE	25 DATEIEN	385	800	–	1100	3.5	AlInGaN	1
		15335339AA350	SPEC	RE	25 DATEIEN	395	800	–	1100	3.5	AlInGaN	1
		15335340AA350	SPEC	RE	25 DATEIEN	405	800	–	1100	3.5	AlInGaN	1

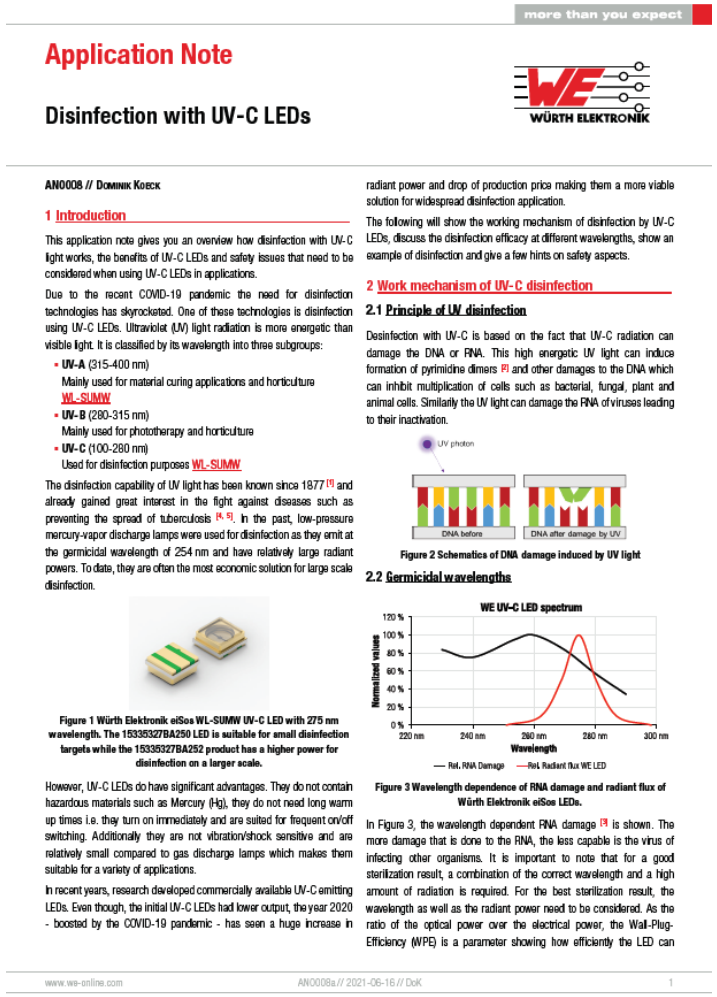
FURTHER INFORMATION

Application Note

DE: www.we-online.de/ANO008

EN: www.we-online.com/ANO008





more than you expect

Application Note

Disinfection with UV-C LEDs

WÜRTH ELEKTRONIK

ANO008 // Dominik Koeck

1 Introduction

This application note gives you an overview how disinfection with UV-C light works, the benefits of UV-C LEDs and safety issues that need to be considered when using UV-C LEDs in applications.

Due to the recent COVID-19 pandemic the need for disinfection technologies has skyrocketed. One of these technologies is disinfection using UV-C LEDs. Ultraviolet (UV) light radiation is more energetic than visible light. It is classified by its wavelength into three subgroups:

- **UV-A** (315-400 nm)
  Mainly used for material curing applications and horticulture
  WL-SUMW
- **UV-B** (280-315 nm)
  Mainly used for phototherapy and horticulture
- **UV-C** (100-280 nm)
  Used for disinfection purposes WL-SUMW

The disinfection capability of UV light has been known since 1877 [1] and already gained great interest in the fight against diseases such as preventing the spread of tuberculosis [4, 5]. In the past, low-pressure mercury-vapor discharge lamps were used for disinfection as they emit at the germicidal wavelength of 254 nm and have relatively large radiant powers. To date, they are often the most economic solution for large scale disinfection.

Figure 1 Würth Elektronik eiSos WL-SUMW UV-C LED with 275 nm wavelength. The 15335327BA250 LED is suitable for small disinfection targets while the 15335327BA252 product has a higher power for disinfection on a larger scale.

However, UV-C LEDs do have significant advantages. They do not contain hazardous materials such as Mercury (Hg), they do not need long warm up times i.e. they turn on immediately and are suited for frequent on/off switching. Additionally they are not vibration/shock sensitive and are relatively small compared to gas discharge lamps which makes them suitable for a variety of applications.

In recent years, research developed commercially available UV-C emitting LEDs. Even though, the initial UV-C LEDs had lower output, the year 2020 - boosted by the COVID-19 pandemic - has seen a huge increase in radiant power and drop of production price making them a more viable solution for widespread disinfection application.

The following will show the working mechanism of disinfection by UV-C LEDs, discuss the disinfection efficacy at different wavelengths, show an example of disinfection and give a few hints on safety aspects.

2 Work mechanism of UV-C disinfection

2.1 Principle of UV disinfection

Desinfection with UV-C is based on the fact that UV-C radiation can damage the DNA or RNA. This high energetic UV light can induce formation of pyrimidine dimers [2] and other damages to the DNA which can inhibit multiplication of cells such as bacterial, fungal, plant and animal cells. Similarly the UV light can damage the RNA of viruses leading to their inactivation.

Figure 2 Schematics of DNA damage induced by UV light

2.2 Germicidal wavelengths

Figure 3 Wavelength dependence of RNA damage and radiant flux of Würth Elektronik eiSos LEDs.

In Figure 3, the wavelength dependent RNA damage [3] is shown. The more damage that is done to the RNA, the less capable is the virus of infecting other organisms. It is important to note that for a good sterilization result, a combination of the correct wavelength and a high amount of radiation is required. For the best sterilization result, the wavelength as well as the radiant power need to be considered. As the ratio of the optical power over the electrical power, the Wall-Plug-Efficiency (WPE) is a parameter showing how efficiently the LED can

www.we-online.com ANO008a // 2021-06-16 // DoK 1

LITERATURE

[1] S. E. Beck, R. A. Rodriguez, M. A. Hawkins, T. M. Hargy, T. C. Larason and K. G. Linden, "Comparison of UV-Induced Inactivation and RNA Damage in MS2 Phage across the Germicidal UV Spectrum," *Applied and Environmental Microbiology,* 16 02 2016.

[2] M. Heßling, K. Hönes, P. Vatter and C. Lingenfelder, "Ultraviolet irradiation doses for coronavirus inactivation – review and analysis of coronavirus photoinactivation," *GMS Hyg Infect Control.,* 2020.

[3] C. Bowker, A. Sain, M. Shatalov and J. and Ducoste, "Microbial UV fluence-response assessment using a novel UV-LED collimated beam system," *Water Research,* pp. 2011-2019, 2011.

[4] D. Battigelli, M. Sobsey and Lobe, "The inactivation of hepatitis A virus and other model viruses by UV irradiation," *Water Sci. Technol.,* p. 339–342, 1993.

[5] G. Abraham, "The effect of ultraviolet radiation on the primary transcription of Influenza virus messenger RNAs," *Virology,* 1979.

[6] R. Rodríguez, S. Bounty and K. Linden, "Long-range quantitative PCR for determining inactivation of adenovirus 2 by ultraviolet light," *Journal of Applied Microbiology,* p. 1854–1865, 2013.

[7] X. Hu, S. Geng, X. Wang and C. and Hu, "Inactivation and photorepair of enteric pathogenic microorganisms with ultraviolet irradiation,," *Environmental Engineering Science,* p. 549–553, 2012.

[8] S. Cervero-Aragó, R. Sommer and R. and Araujo, "Effect of UV irradiation (253.7 nm) on free Legionella and Legionella associated with its amoebae hosts," *Water Research,* p. 299–309, 2014.

[9] M. Clauß, "Higher effectiveness of photoinactivation of bacterial spores, UV resistant vegetative bacteria and mold spores with 222 nm compared to 254 nm wavelength," *Acta hydrochimica et hydrobiologica,* p. 525–532, 2006.

[10] "Zur Sicherung eines regelkonformen Betriebs von UV-Desinfektionsgeräten nach DVGW-Arbeitsblatt W 294," DVGW Deutscher Verein des Gas- und Wasserfaches e.V., 2012.

[11] DIRECTIVE 2006/25/EC