UVmastercare

Performance test results

Dr Frédéric LUIZI – Expert UV

IoTCo sa
Avenue du Pré Aily, 24
4031 Angleur
info@uvmastercare.com

Table des matières

1. Introduction

The purpose of this document is to present the scientific approach adopted by the UVmastercare team to ensure optimal operation under all conditions. A summary of the results obtained during development and validation tests is presented. Before getting to the heart of the matter, a few words of explanation are in order.

The operation of the UVmastercare, as the name suggests, is based on the emission of ultraviolet radiation. This radiation will kill pathogens such as coronavirus present in the air and on surfaces by degrading their genetic material. Of all ultraviolet radiation, it is the UV-C and more specifically the wavelength of 254 nm that is effective.

Depending on the stability of the pathogen's genetic material, a higher or lower dose will be required for degradation. This dose is measured in mJ/cm². It is a cumulative dose during an exposure. This means that the degradation of the genetic material, and therefore the death of the pathogen, is not instaneous. For example, if a pathogen has genetic material whose stability requires a dose of 5 mJ/cm² to ensure its destruction in 99.9% of cases and is exposed to UV-C light with an intensity of 5 µW/cm² (i.e. the dose emitted during one second), it will then have to be exposed for 1000 seconds (16 minutes and 40 seconds) to reach the desired destruction threshold. If, on the other hand, the same pathogen is exposed to 10 times more powerful UV-C radiation of 50 µW/cm², then only 100 seconds will be needed, i.e. 1 minute and 40 seconds.

The development of an effective device to destroy a specific pathogen therefore requires:

- To know the dose required to effectively eliminate it;
- A good control of the UV-C dose emitted;
- Exposing the pathogen for a sufficient time to ensure the degradation of its genetic material.

This information on the efficacy of the UVmastercare is summarized in the following sections.

2. SARS-COV2 et UV-C

Until recently, to define the UV-C dose required to degrade the genetic material of the coronavirus and therefore to eliminate it, we had to rely on analogies. Indeed, the stability of the genetic material of SARS-COV2 could be deduced from the stability of the genetic material of related viruses. Recently, Italian researchers led by Prof. Bianco have unveiled the specificity of the coronavirus responsible for COVID 19.

These researchers worked on patients infected at different levels. Either patients with mild symptoms, hospitalized patients or patients in intensive care.

In the context of the development of UVmastercare, we did not consider patients with mild symptoms but hospitalized patients. Indeed, it appeared that some asymptomatic patients carry a high viral load. Based on the results of the work of Bianco and his fellow researchers, a dose of 3.7 mJ/cm² UV-C is required to eradicate 99.9% of the SARS-COV2 viruses present in the air or on surfaces.

In order to include an additional margin of safety, two doses were considered for the development of the UVmastercare: 4 mJ/cm2 (scientifically effective dose) et 10 mJ/cm² (safety dose). Once these doses had been defined, it was necessary to ensure that the UV-C emission of the device was perfect.

Knowing that the UV-C radiation emitted by a lamp disperses in all directions, its intensity decreases sharply as soon as one moves away from it. On the basis of the average size of a dentist's office, i.e. between 16 and 25m², different lamp powers were tested to finally select fairly powerful 172W lamps.

UV-C radiation is a light and moreover a light that is not very penetrating. This means that the slightest obstacle to its propagation causes shadowy areas. These areas are partly exposed to radiation due to the reflection of the radiation on certain materials, but in such a case, the path of the light becomes longer and therefore its power decreases rapidly. These phenomena have therefore not been taken into consideration.

A constant in all dentists' offices is the presence of a chair, the source of the aerosols and the epicenter of the possible spread of coronavirus, in the middle of the room. Regardless of the orientation of a UV-C source, it is not possible to avoid significant shadow areas. For this reason, for the development of the UVmastercare, we have chosen to design the device with 2 emission sources and vertical lamps covering the most efficient band from 40 to 200cm, the most exposed height.

From a technological point of view, not all UV-C lamps are the same. They can be based on different technologies leading to a conversion between the energy consumed (watts consumed) and the irradiance in UV-C sometimes very different. The technology selected for the UVmastercare is the low-pressure amalgam technology which is recognized as the technology with the highest UV-C efficiency.

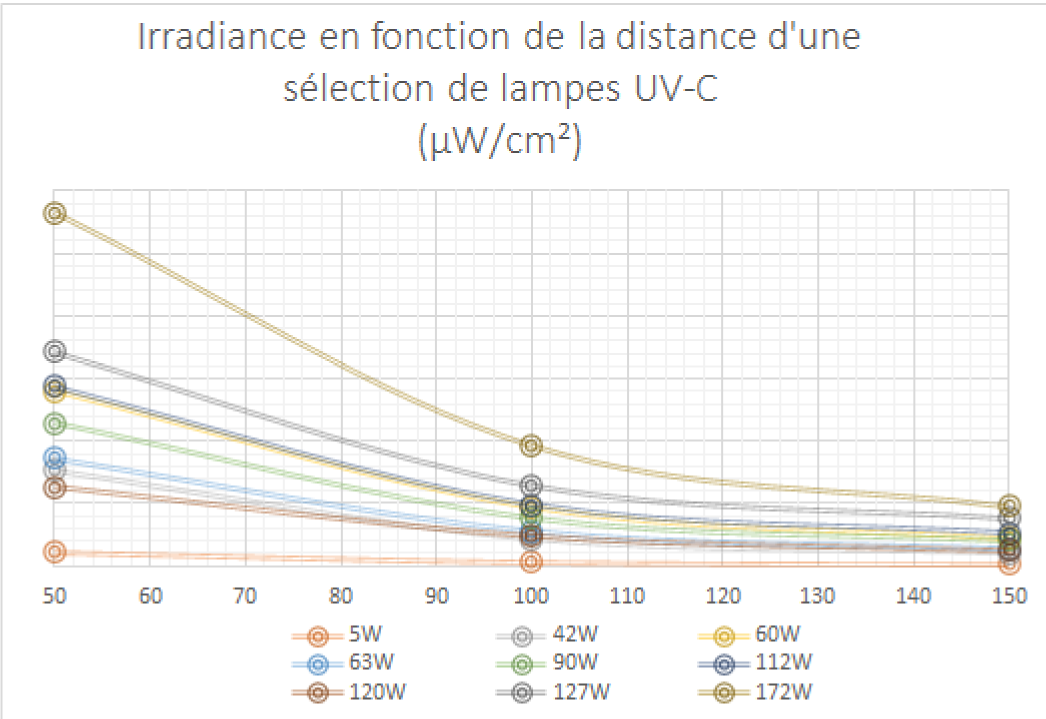
On the basis of all these characteristics, the control of UV-C emission has been optimized. This ensures that the SARS-COV2 genetic material remains in good working order during the time it takes for the genetic material to degrade. The emission of UV-C radiation over time varies as a function of temperature. At low temperature, the mercury gas at the origin of the radiation does not ionize sufficiently to guarantee a good emission. A heating time is therefore taken into account in the calculation of the treatment times to reach a required dose.

3. Measurement results of the UVmastercare device

On the basis of all the parameters described in the previous point, the key results of the developments carried out are summarized below.

a. The choice of lamps

In order to best meet the defined specifications, a multitude of UV-C lamps of different technologies and power were tested. Below, we can see the evolution of irradiance (µW/cm²) at three distances from the lamps, i.e. 50cm, 1m and 1.5m. On the basis of these analyses, the choice was made for the UVmastercare on 172W lamps.



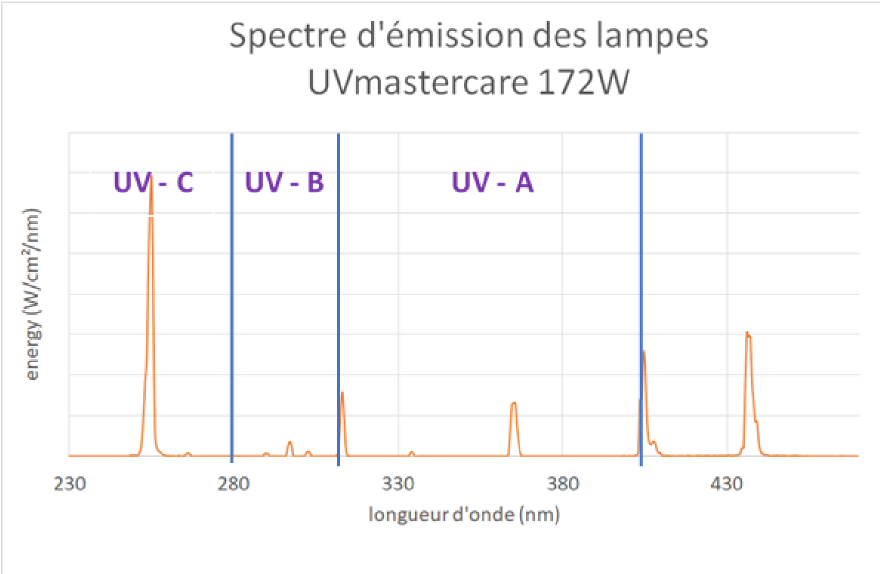
Irradiance depending on the distance of a selection of UV-C lamps

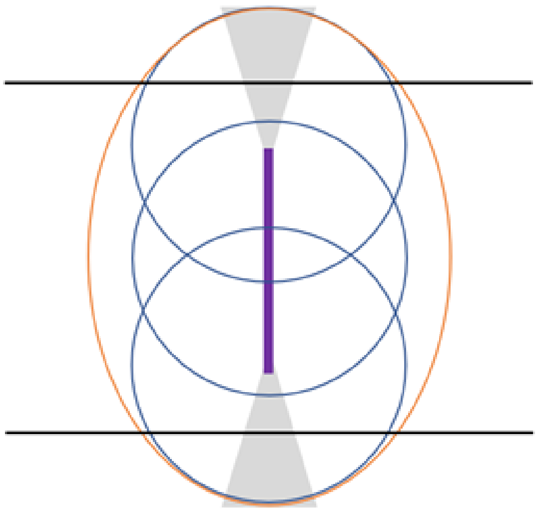
b. The emission spectrum

Once the model of lamp was selected, we called upon the analysis laboratory of CERTECH, Research Center at the service of companies located in Seneffe, Belgium, to confirm the quality of the emitted spectrum.

The graph below clearly shows that the main emission peak is well within the UV-C wavelength range and more precisely centered on 254 nm, the most efficient wavelength to degrade genetic material.

There is also an emission peak at 400 and at 440nm. These two peaks are visible to the human eye and reduce accidents by making the UVmastercare visible when in operation.





c. Emission height and efficiency

In order to optimize the positioning of the UVmastercare lamps, we have validated the hypothesis illustrated in the figure opposite. The vertical violet bar represents a UV-C lamp. The three blue circles represent the radiation emitted at the same distance from the top, middle and bottom of the lamp. The orange oval shape represents the cumulative irradiance of the different emission points. The two black horizontal lines represent the height range within which the irradiance is optimal.

In the case of the UVmastercare, the length of the lamp is 80 cm positioned on its base at a height of 80 to 160 cm. Therefore, the optimal height range is from 40 cm to 200 cm.

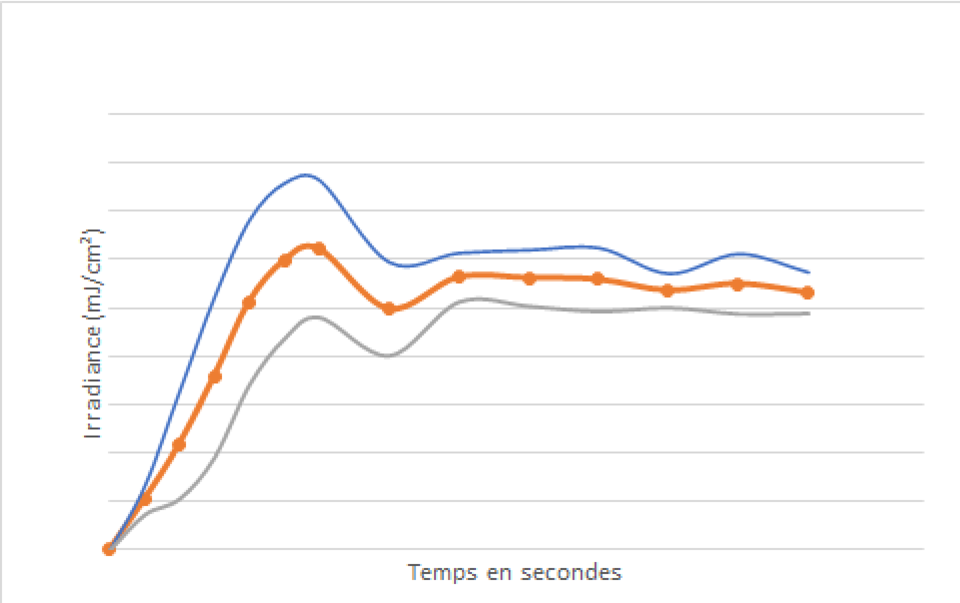
Experimental measurements have confirmed these values with a variation in the order of 30% within a radius of 50cm from the lamp, decreasing to 20% within a radius of 1m, to 10% within a radius of 1.5m and to less than 5% within a radius of 2m and more. The evolution of this variability comes from the shadow effect of the device itself (its foot and base) at the smallest distances. However, as the irradiance is much higher at these distances, the UVmastercare's effectiveness in the height range is guaranteed.

d. The impact of the treatment duration

When switched on, the UVmastercare lamp will be at room temperature. During our validations, in 10 minutes of treatment, we have shown that it can go up to temperatures above 80°C and even up to 93.2°C for the maximum measured. These temperature peaks do not have a negative impact on the performance of the lamps.

On the other hand, the temperature after ignition is to be taken into consideration. Indeed, the mercury vapour arc that is generated within the tube is not generated instantly. As a result, the UV-C radiation emitted is not optimal as soon as the lamp is switched on.

As shown in the graph below, the irradiance increases gradually until it reaches a peak. It then stabilizes over time. The variability of the different batches of 172W lamps tested always at the same distance was especially marked during the first 2 minutes of operation. For this reason, we do not take the first minute after switching on into consideration when simulating the processing time. This helps to smooth out the variability and to avoid announcing times that do not ensure the required dose.



The dose required to ensure the disinfectant effect is the result of the irradiance emitted by the UVmastercare during a certain time. As we have seen previously, the eradication of Coronavirus requires a dose of 3.7 mJ/cm², which we have rounded up to the next unit, i.e. 4 mJ/cm². If a single UVmastercare lamp generates 250 µW/cm² at a distance of 1m, the calculation of the exposure time is as follows:

- Treatment time (seconds) at 1m = 60 seconds (heating time) + 4.000 µJ/cm² / 250 µW/cm² at 1m

  Or, T (sec) = 60 + (4.000 /250)

  = 60 + 16

  = 76 secondes (1 minute 16 seconds)

e. The impact of distance

The radiation emitted by the UVmastercare lamp as by all UV lamps corresponds to a number of UV-C photons (light particles of the biocidal wavelength) which are distributed in space as they move away from the source. It is easy to understand that the further away they move, the more this same number of photons emitted during one second for example, must cover a surface growing in all dimensions. Therefore, the decrease of the UV-C dose with respect to distance is not a linear relationship but rather a logarithmic one.

As illustrated in point a, it is this evolution of the dose as a function of distance that has led us to choose powerful lamps that ensure maximum treatment at distances suitable for the treatment of dental practices.

For example, in a standard dental practice of 20m² (4 x 5m), the placement of two UVmastercare on the diagonal of the room on either side of the treatment chair will result in a distance between the UVmastercare of about 3m. The diagonal of such a room measures 6.2m. So, we will typically have 1.6m from one corner, then the first UV, 3m then the second. The circle of irradiance around each of the devices before their overlapping effects will be 1.5 to 1.6m. At a distance of this order, the dose generated by the UVmastercare will still be of the order of 150 µW/cm². To reach the prescribed dose, the time will be 60 + (4.000 / 150), i.e. 87 seconds (1 minute and 27 seconds). To reach the proposed precautionary dose of 10mJ/cm², the time will be 60 + (10.000 / 150), i.e. 127 seconds or 2 minutes and 7 seconds).

To cover the entire room, it will then take up to 318 seconds, i.e. 5 minutes and 18 seconds.

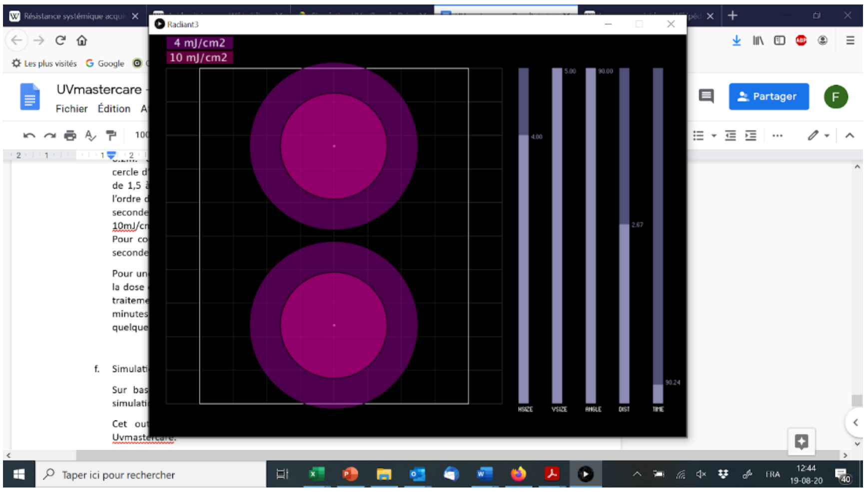
For an Osram type lamp, which is only 36W in the most powerful configuration, the dose emitted at 1.6m will only be of the order of 30 µW/cm² according to our tests. In this case, the treatment time to reach the precautionary dose will be 60 + (10,000 / 30), i.e. 393 seconds or 6 minutes and 33 seconds. To cover the entire room, the time will no longer be counted in a few minutes but in several tens of minutes.

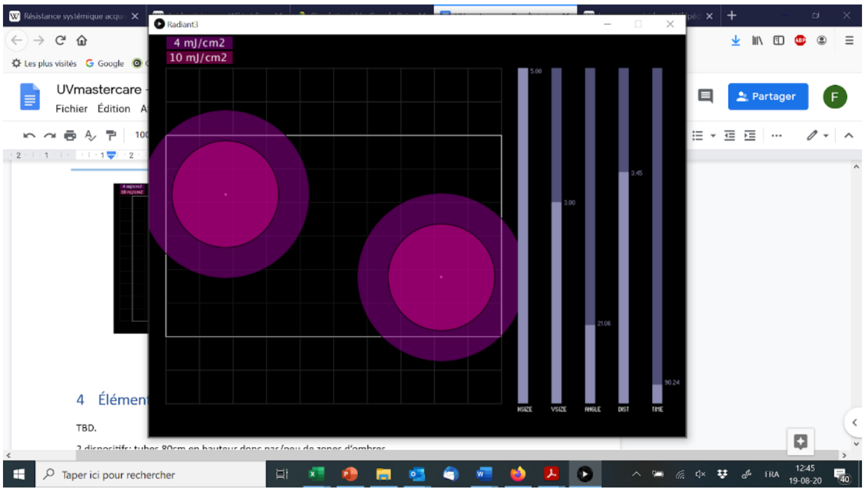
f. Simulations

On the basis of all the parameters listed above, we have developed a simulation tool to help calibrate the treatment time required for each dental practice.

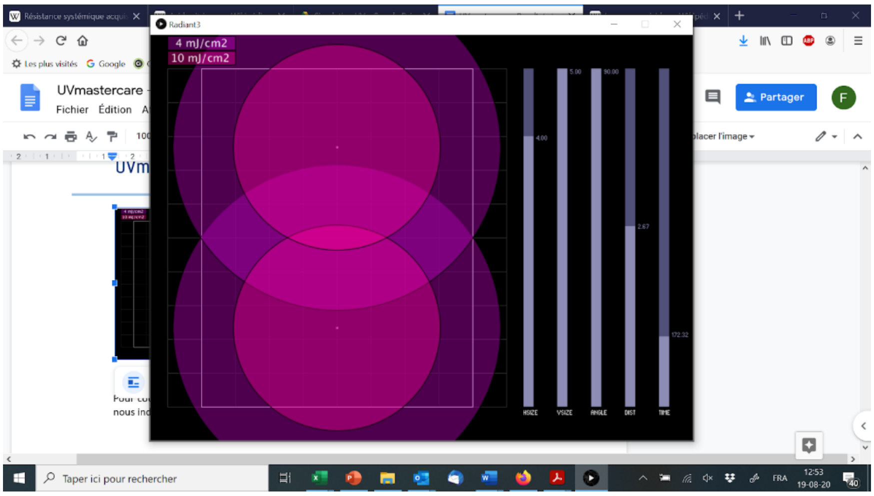
This tool allows us to take into account the dimensions of the practice and the positioning of the Uvmastercare.

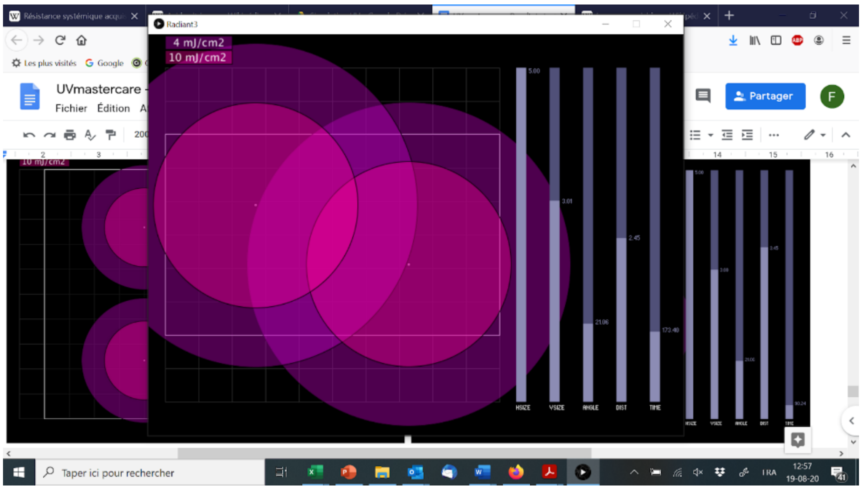
In the two examples below, we can see the simulation of the effect of two UVmastercare after 90 seconds of treatment positioned in two different practices, the one on the left measuring 4 x 5 m with the two UVs placed on the central axis in the length and the one on the right measuring 5 x 3 m with the two UVs placed on the diagonal.



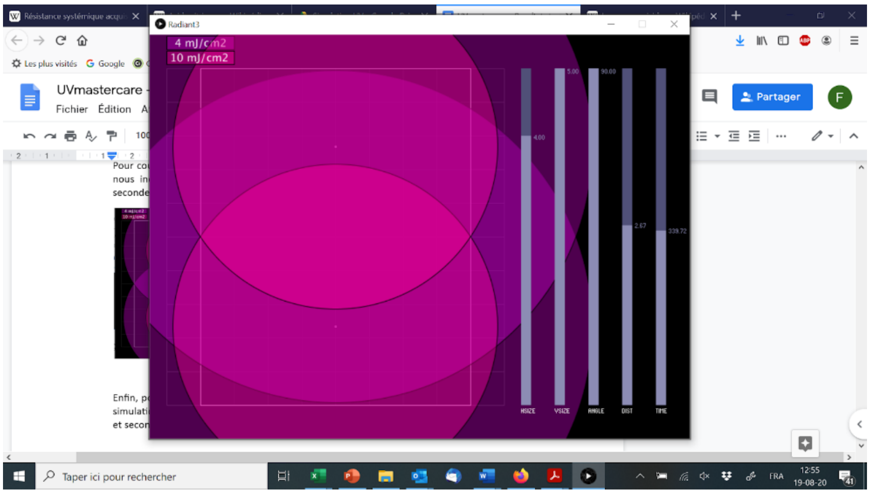


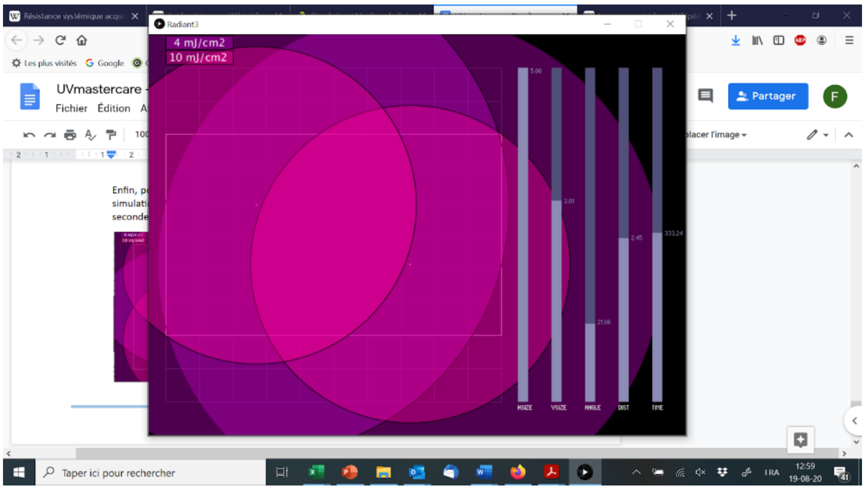
In order to cover all of these two cabinets with a dose of 4 mJ/cm², the simulations below indicate that it will take 172 seconds (2 minutes and 52 seconds) and 173 seconds (2 minutes and 53 seconds) respectively.





Finally, to cover all of these two cabinets with a precautionary dose of 10 mJ/cm², the simulations below indicate that it will take 340 seconds (5 minutes and 40 seconds) and 333 seconds (5 minutes and 33 seconds) respectively.





In the table below, we show some typical dental office configurations and the time required to reach a complete treatment either at 4mJ/cm² (scientifically effective dose) or at 10mJ/cm² (ultra-safe dose).

Length (m)	width (m)	Time for 4mJ/cm²		Time for 10mJ/cm²	
		Sec	Min	Sec	Min
3	3	118	1'58	194	3'14
3	3	124	2'04	219	3'39
3	4	160	2'40	305	5'05
5	3	132	2'12	243	3'03
5	4	168	2'48	325	5'25
5	5	214	3'34	438	7'18

It can be seen that for the vast majority of practices, the treatment time to reach the precautionary dose of 10mJ/cm², 6 minutes will suffice. It should be noted that 6 minutes is the time that had been defined in the specifications as the dose that would allow a dentist to treat a patient comparable to that received before the COVID 19 crisis and therefore without loss of profitability. In fact, beyond 6 minutes between two patients, the number of patients that can be seen in a day decreases.