

OVERVIEW

If you search for the definition of fluence you will find different definitions from different references. The [wiki page](#) that mentions it equates it to "radiant exposure," and just relates it to irradiance, watts per surface area integrated over time. That's not the way it is defined by those using it in the UV water treatment and air disinfection industries. A better reference is at the following link. See the definitions for Fluence and Fluence Rate at the top of page 2:

<https://iuvanews.com/stories/pdf/archives/170101BoltonEtAl2015.pdf>

These confirm the following definitions:

Fluence Rate: Total radiant watts collected onto a spherical surface from any direction, divided by the sphere cross sectional area, not the sphere surface area. The units of fluence rate are watts/area.

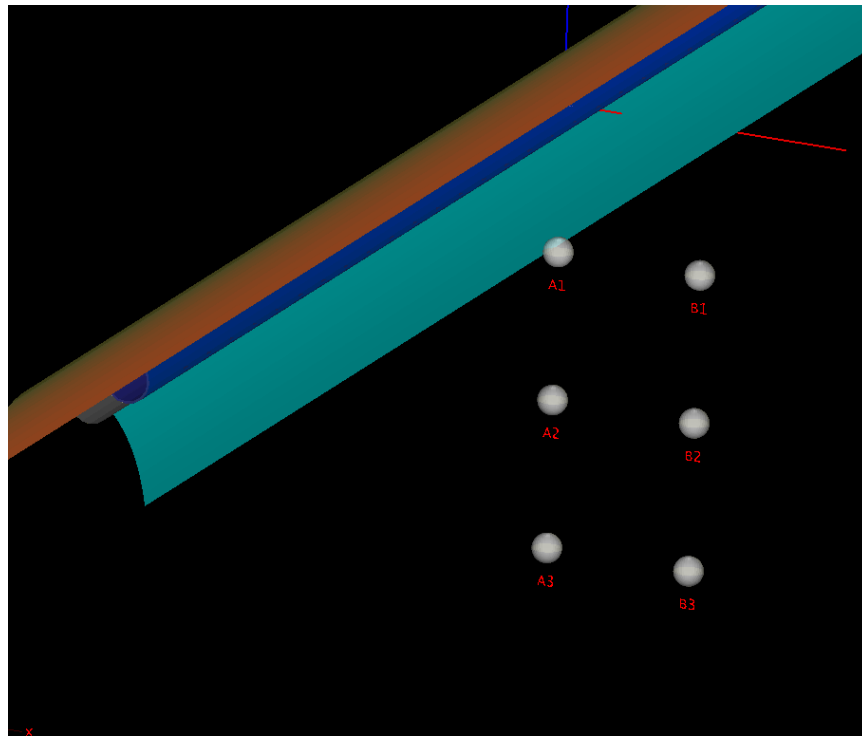
Fluence: Fluence is the fluence rate multiplied by time in seconds to get joules/area.

COMPUTING FLUENCE RATE IN PHOTOPIA

Photopia does not yet support the direct calculation of fluence or fluence rate values like it does for irradiance. Direct calculations of a grid of fluence rate values is however, in development and will be supported soon. In the meantime, fluence rate can still be computed in stand alone Photopia, but it requires a particular model setup and some data post processing.

Follow these steps to compute fluence rate values:

1. Draw or import a spherical object on a "transmissive" layer. The size should be relatively small, but not too small, as you will then need a very high number of rays to get stable values for the radiant watts intersecting the sphere. To start, try a sphere radius of 10mm.
2. Array the sphere into the locations at which you want to measure the fluence rate.
3. Create a unique layer name for each sphere in your model. Then select each sphere in the CAD view and change its layer property in the property control on the right side of the screen, to be one of the unique layer names. It is best to follow a logical naming convention such as Sphere_A1, Sphere_A2, Sphere_B1, Sphere_B2, etc., with the letters and numbers indicating columns and rows in a grid. Separating the spheres is necessary since you'll need to view the radiant watts incident onto each sphere in the "RADIANT WATT INTERACTION WITH SYSTEM" section of the Photometric Report.



Array of 6 spheres in Photopia model

4. Assign each sphere layer the CLEAR001 transmissive material. This material allows rays to pass right through the spheres, so they do not interfere with their paths and they emit away from the luminaire. Photopia will still track the watts incident onto the spheres with this material, however.
5. Set the lamp watts to be in mW so that the value is 1000 times higher than the value in watts. This is helpful since a small # of watts will interact with each sphere and the values shown in the report are not listed with any decimal places. Then run the raytrace with at least 10,000,000 rays. If your results show little or no watts onto spheres that should have non-zero values, then you might need to enter the lamp output in micro-watts, thus scaling your original lamp watts by 1,000,000. If you do this, then divide the incident energy onto each sphere by 1000 to continue the calculations in mW.
6. View the Photometric Report and you'll see the radiant watts interacting with the spheres in this table:

RADIANT WATT INTERACTION WITH SYSTEM

Attenuated (%)	Absorbed (%)	Incident (%)	Layer Name
0 (0.0%)	0 (0.0%)	37941 (26.2%)	Illuminance Planes
0 (0.0%)	66 (0.0%)	65369 (45.1%)	LAMP-TUV-335W-XPT-HO-254NM1
0 (0.0%)	3 (0.0%)	2985 (2.1%)	LAMP-TUV-335W-XPT-HO-254NM2
0 (0.0%)	56 (0.0%)	56 (0.0%)	LAMP-TUV-335W-XPT-HO-254NM3
0 (0.0%)	0 (0.0%)	0 (0.0%)	LAMP-TUV-335W-XPT-HO-254NM4
0 (0.0%)	11150 (7.7%)	111496 (76.9%)	Reflector
0 (0.0%)	1 (0.0%)	708 (0.5%)	Sphere A1
0 (0.0%)	0 (0.0%)	349 (0.2%)	Sphere A2
0 (0.0%)	0 (0.0%)	178 (0.1%)	Sphere A3
0 (0.0%)	0 (0.0%)	110 (0.1%)	Sphere B1
0 (0.0%)	0 (0.0%)	204 (0.1%)	Sphere B2
0 (0.0%)	0 (0.0%)	161 (0.1%)	Sphere B3
0 (0.0%)	11276 (7.8%)	219558 (151.4%)	Total

The mW incident onto each sphere are shown in red. This section of the report can be copied and pasted into Excel to extract the numbers.

7. First divide all the sphere mW values by 2 since each ray that is incident upon it will contribute its energy twice and it enters one side and exits the other.
8. Compute the fluence rate according to the definition. This is best done in a spreadsheet, like the example provided. This spreadsheet allows you to enter the sphere radius, mW incident onto each sphere and the total lamp mW, as a reference. It then computes the fluence rate in several different units.
9. If you need “fluence” values, then you multiply the fluence rate values by the exposure time in seconds. Determining the exposure time of air or water particles at different locations in space is not trivial however and requires CFD calculations as well.

UVC LUMINAIRE PERFORMANCE REQUIREMENTS

For room air disinfection applications, the most relevant performance metric is fluence rather than surface irradiation. Fluence quantifies the energy onto a particle incident from all directions. It is defined as the total watts onto a sphere from all directions divided by the sphere cross sectional area, not the sphere surface area. It has the same units as irradiance, W/area, but irradiance is the watts/area onto a flat surface.

Achieving effective disinfection in the air depends on a lot of factors beyond your luminaire intensity distribution, but one of the most important other factors is how well the air is mixed. So there needs to be active air circulation mechanisms included with the system as well. Assuming well mixed air, the fluence values necessary to disinfect vary depending on the references you'll see. Most that I've seen however, are in the micro-watt/cm² range. I've seen values as low as 5 micro-watts/cm², but [this reference](#) lists values between 30-50 micro-watts/cm². Those are probably reasonable values to strive for within a reasonable distance from the luminaires.

CONVERSION FACTORS

Photopia currently provides output in W/m². You can convert to other units with the following scale factors:

Conversion from W/m² to mW/cm²: multiply by 0.1

Conversions from W/m² to μW/cm²: multiply by 100

OTHER REFERENCES

See the following additional resources from various industry organizations for more information on UV disinfection and safety.

CIE UV Documents

The CIE has a range of documents related to using UV energy for disinfection and the safety of such systems. They have released 2 of these documents for free and have others available on their website.

CIE 187:2010 UV-C Photocarcinogenesis Risks from Germicidal Lamps

CIE 155:2003 Ultraviolet Air Disinfection

Read more on the [CIE Website](#).

IUVA - International Ultraviolet Association

With a mission of "advancing the sciences, engineering & applications of ultraviolet technologies to enhance the quality of life & protect the environment," the IUVA is a great resource to get involved with if your products are related to using UV energy, especially for disinfection. They have an annual conference, coordinate research, and contribute expertise to standards committees.

In January, Ryan gave a presentation at a NIST/IUVA conference on "Simulating the Performance of UV Systems", which you can find on our website in [our list of Presentations](#).

Read more on the [IUVA Website](#).

IESNA – Illuminating Engineering Society

[IESNA Photobiology Committee Report on GUV](#)

[Designing a UV-C Germicidal System](#)