PBM FOUNDATION
PHOTOBIOMODULATION HEALS

PBM FOUNDATION, OPTRONICS LABS | UNPUBLISHED

CASE STUDY

SUMMARY

At present, the lack of regulation in the measuring and reporting of photobiomodulation (PBM) device parameters by manufacturers poses a significant issue for both consumers and researchers. Frequently, declared parameters are often derived from incorrect methodology and unregulated, leading to inaccurate and exaggerated specifications.

The current situation poses challenges for both researchers and consumers. Researchers depend on precise device specification reporting to select parameters for research and to ensure that grant funds are not squandered. Likewise, consumers rely on accurate manufacturer specification reporting to make informed choices.

CHALLENGES FOR MEASUREMENT

Photobiomodulation is wavelength, power density and pulse frequency specific.

If photobiomodulation were to be considered therapeutic, comparable to pharmaceuticals, the exact characteristics of light energy used in research needs to be measured in a precise and standardized way for accurate disclosure. This is because the true parameters that triggered therapeutic effects within research studies need to be known.

Forming standardization for light energy measurements is the bedrock which the field of photobiomodulation scientific community requires to grow.

Measurement Issues

There are several challenges in promoting appropriate methodology and equipment for measuring LED parameters. For this the PBM Foundation has partnered with Optronic Labs, a specialist in spectroscopic measurement services and equipment, to help with setting standards and provide LED spectral profile measurements.

- Using inadequate equipment

Manufacturers often use solar power meters, photometers, radiometers – which are either not designed to measure LEDs or are not robust enough to get accurate readings. These types of equipment often lead to readings that are significantly greater than the true value.

Fully-calibrated spectroradiometers from certified manufacturers are required to make accurate measurements.

- Measuring LEDs directly at the source

Currently, most manufacturers measure their LEDs directly at the source instead of accounting for device form factors which could reduce the overall power density, such as plastic sheets or distance.

MULTIPLE DEVICE CASE STUDY:

VIELIGHT NEURO, NEURONIC NEURADIANT, JOOVV

In coordination with Optronic Labs, we tested three photobiomodulation devices, the Vielight Neuro Duo, Neuronic Neuradiant 1070 and Joovv Go 2.0.

The testing was performed by Optronic Labs, using an OL 770VIS/NIR High-Speed Multi-Channel Spectroradiometer equipped with an ND filter wheel and an IS-1 1 inch integrating sphere, equipped with a 1.0mm aperture. The system will be calibrated with a NIST traceable 1000-watt lamp standard of Spectral Irradiance.

Measurement tests will be performed in accordance to how the device is meant to be operated, based on the instructional manual. The measurement tests will accurately simulate what an end user will receive from a surface power density (mW/cm2) and wavelength (nm) perspective.

At present, the two tested characteristics for photobiomodulation device measurements are wavelength and surface power density, otherwise known as irradiance.

- Wavelength (nm) on the electromagnetic spectrum determines the penetration and therapeutic effect.

Wavelength accuracy is an important variable, as the biological effect is dependent on the type of wavelength.

- Surface power density or irradiance (mW/cm2) is the measurement of the intensity or concentration of light energy that lands on a surface area of biological tissue. This in turn determines the depth of penetration and dosage within the tissue area.

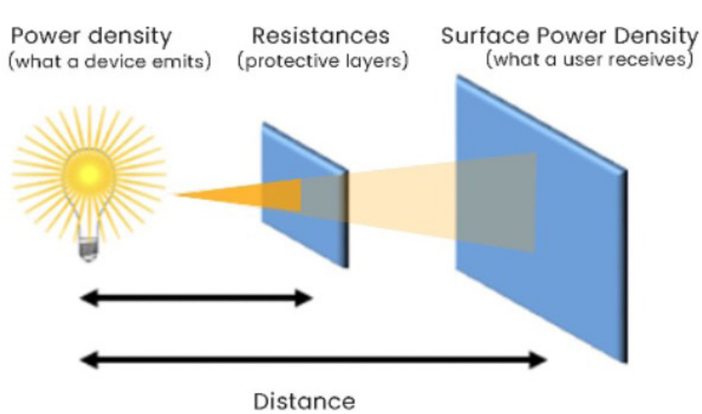


Figure 1: Power density vs surface power density (or irradiance)

In this case study, we give significant consideration to surface power density (irradiance), as it can only be increased through advancing LED technology and optimized form factors, without generating while minimizing heat. As an illustration, in the context of brain photobiomodulation, a high surface power density is crucial to achieve the necessary intensity for penetrating through the scalp and skull.

Surface power density is different from power density. Despite sharing the same unit of measurement (mW/cm2), surface power density is superior because it considers form factor variables – which might add distance or additional resistance, which can vary greatly between devices.

> "A HIGH SURFACE POWER DENSITY IS CRUCIAL TO ACHIEVE THE NECESSARY INTENSITY FOR PENETRATING THROUGH THE SCALP AND SKULL"

Surface power density is more important than total power (W). Total power can be increased by using many weak, generic LED diodes to reach a high value, given that each tiny power can contribute to the total sum. In the context of dosage, increasing the time can also lead to a higher dosage vs total power.

We will also use comparisons to the power density of peak sunlight for perspective. Sunlight has an estimated power density of 135 mW/cm2, otherwise known as the "solar constant."

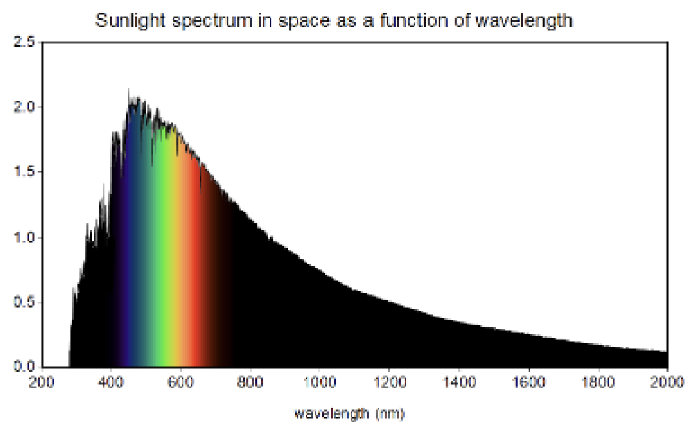


Figure 2: Spectral power density or irradiance of sunlight (https://www.wtamu.edu/~cbaird/sq/2013/07/03/what-is-the-color-of-the-sun/) Sunlight spectrum in space as a function of wavelength.
Public Domain Image, image source:
Christopher S. Baird, data source: American Society for Testing and Materials Terrestrial Reference.

OVERALL RESULTS

Table 1
Calculated Values

	Helmets		NeURO			
Measurement position	Suyzeko	Neuronic	Back Left	Back	Back Right	Front
Peak Wavelength (nm)	811	1059	810	810	808	811
Integrated value over 60nm window (mW/cm²)						
781nm-841nm	4.74					182.06
1031nm - 1091nm		6.22				
780nm - 840nm			316.70	333.24	277.25	183.69
778nm - 838nm					282.43	

SUYZEKO NIR HELMET

The Suyzeko NIR helmet is a photobiomodulation helmet developed by Suyzeko, located in Shenzen, China. Suyzeko offers their helmet platform to vendors for private-labeling and customization. It can be found on AliExpress or on their website. Multiple vendors resell a customized version of their helmet platform, including Neuronic, MitoMind and Weber Medical.

Suyzeko declares a surface power density (irradiance) of 24 mW/cm2 on their website.

The specifications declared by Suyzeko can be found on their website: https://tinyurl.com/Suyzeko-Brain-Health-LED-Light

However, calibrated surface power density measurements by Optronic Labs only found 4.74 mW/cm2. This may be due to several factors, such as

1. Using improper measuring equipment
2. Measuring LEDs directly at the source, without accounting for protective layers and distance.

Based on wavelength accuracy measurements, its peak wavelength is 811nm.

Table 1 and Table 2 illustrate the measured differences in power density and wavelength for the Suyzeko helmet.

Suyzeko NIR Helmet	Declared Power Density (mW/cm^2)	Measured Surface Power Density (mW/cm^2)	Measured Difference (%)
Device Power Density	24	**4.74**	-81%
Sunlight Power Density (Solar Constant)		135	
Difference between device power density and sunlight power density		-97%	

Table 1: Measured Surface Power Density results of the Suyzeko NIR Helmet. The results shows a -81% difference in declared power density vs measured surface power density. Compared to peak sunlight power density (or solar constant), the device is 96% weaker than peak sunlight.

Suyzeko NIR Helmet	Declared Wavelength (nm)	Measured Wavelength (nm)	Difference (nm)
Peak Wavelength	810nm	811nm	1nm

Table 2: Measured Peak Wavelength of the Suyzeko NIR Helmet. The difference is 1nm between the declared wavelength and measured wavelength.

Figure 4: The Neuradiant 1070 device by Neuronic

THE NEURONIC NEURADIANT 1070

The Neuronic Neuradiant is a photobiomodulation helmet built on Suyzeko's helmet platform but features a different wavelength. This exercise is meant to illustrate the differences in surface power density between devices, even when the helmet platform and LED technology is similar.

Neuronic offers their helmet for retail through their website.

Neuronic declares a power density (or irradiance) of 20-40 mW/cm2 on their website.

The specifications declared by Neuronic can be found on their website: https://neuronic.online/products/1070nm-helmet

However, calibrated surface power density measurements by Optronic Labs only found 6.22 mW/cm2. This may be due to several factors, such as

1. Using improper measuring equipment
2. Measuring LEDs directly at the source, without accounting for protective layers and distance.

Based on wavelength accuracy measurements, its peak wavelength is 1059 nm versus 1070nm declared.

Table 3 and Table 4 illustrate the measured differences in power density and wavelength for the Neuradiant 1070 helmet.

Neuronic Neuradiant 1070	Declared Power Density (mW/cm^2)	Measured Surface Power Density (mW/cm^2)	Difference (%)
Device Power Density	20-40	**6.22**	-79%
Sunlight Power Density (Solar Constant)		135	
Difference between device power density and sunlight power density		-95%	

Table 3: Measured Surface Power Density results of the Neuradiant 1070. The results shows a -79% difference in declared power density vs measured surface power density. Compared to peak sunlight power density (or solar constant), the device is 95.39% weaker than peak sunlight.

Neuronic Neuradiant 1070	Declared Wavelength (nm)	Measured Wavelength (nm)	Difference (nm)
Peak Wavelength	1070	1059	11

Table 4: Measured Peak Wavelength of the Neuradiant 1070. The difference is 11nm between the declared wavelength and measured wavelength.

THE VIELIGHT NEURO DUO 3

The Vielight Neuro Duo is a photobiomodulation helmet developed by Vielight Inc. Vielight pioneered the field of home brain photobiomodulation technology and their devices are featured in the most published clinical research to date.

Vielight declares a power density (or irradiance) of 75 (frontal diode) and 100 mW/cm2 (rear modules) on their website.

The specifications declared by Vielight can be found on their website: https://www.vielight.com/devices/

However, calibrated surface power density measurements by Optronic Labs found an average total of 277.5 mW/cm2. This may be due to several factors, such as 1) using improper measuring equipment.

Based on wavelength accuracy measurements, its peak wavelength is 810 nm.

Table 5 and Table 6 illustrate the measured differences in power density and wavelength for the Neuradiant 1070 helmet.

Figure 5: The Vielight Neuro 3

Vielight Neuro Duo	Declared Power Density (mW/cm^2)	Measured Surface Power Density (mW/cm^2)	Measured Difference (%)
Back Left Module	100	316	+216%
Back Center Module	100	333	+233%
Back Right Module	100	277	+277%
Front	75	184	+145%
Total Average		**277.5**	
Sunlight Power Density (Solar Constant)		135	
Difference between device power density and sunlight power density		+105.6%	

Table 5: Measured Surface Power Density results of the Vielight Neuro 3. The results shows a +105.6% difference in declared power density vs measured surface power density. Compared to peak sunlight power density (or solar constant), the device is 105.6% stronger than peak sunlight.

Vielight Neuro Duo	Declared Wavelength (nm)	Measured Wavelength (nm)	Difference (nm)
Back Left Module	810nm	810	0
Back Center Module	810nm	810	0
Back Right Module	810nm	808	-2
Front	810nm	811	1

Table 6: Measured Peak Wavelength of the Vielight Neuro. The difference is close to zero.

DISCUSSION

For photobiomodulation, wavelength and power density (or irradiance or intensity – mW/cm2) are two crucial factors for determining biological outcomes. However, this field is quagmired by the lack of testing standards for the measurement of wavelength and power density.

This exercise illustrates an important a crucial problem in the field of photobiomodulation, where researchers are basing their experiments on parameters declared by manufacturers, which can be, in the case of Suyzeko and Neuronic, overexaggerated and by Vielight, understated.

- Testing Equipment

Presently, this industry is facing an issue due to a lack of education and misinformation.

Often, the incorrect go-to measurement device is a solar power meter. As the name implies, this helps estimate the power of sunlight or full spectrum light typically used in the plant growing industry or solar energy industry. LED measurements performed by solar power meters are exaggerated and inaccurate.

While expensive, spectroradiometers are the correct measuring device to use for LED spectral measurements. Spectroradiometers are specialized instruments used for the precise measurement of the spectral characteristics of light emitted by LED (Light Emitting Diode) sources. These instruments are crucial for several purposes in LED measurement and characterization.

SPECTRAL ANALYSIS

Spectroradiometers are used to break down the emitted light from LEDs into its constituent wavelengths across the entire visible spectrum. This allows for a detailed analysis of the spectral distribution, revealing the power density of each wavelength.

- Surface Power Density

Surface power density, often referred to as irradiance, is a measure of the power of electromagnetic radiation (such as light energy) incident on a unit area of a surface. In other words, it is the intensity of light energy that lands on a user's skin before penetration and absorption by tissue.

It quantifies the amount of power per unit area that is received by a surface. Surface power density is typically expressed in units of watts per square meter (W/m^2) or other appropriate units for the specific type of radiation being measured.

Surface power density is a fundamental parameter for understanding how electromagnetic radiation interacts with and affects surfaces in various fields of science and technology. It helps determine the energy, intensity, or heating effects of radiation on a given area and is a key factor in designing and optimizing systems that utilize or interact with electromagnetic radiation.

Surface power density can be increased only through several factors:

-More technologically advanced LED technology

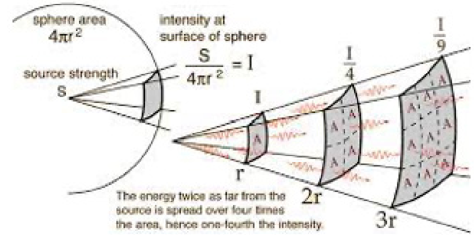
-Optimized form factor that minimizes distance and resistances

- Inverse Square Law of Light

Distance is an important variable to be cognizant of when it comes to photobiomodulation, due to the inverse square law of light.

The inverse square law of light, also known as the inverse square law of illumination, is a fundamental principle in physics and optics that describes how the intensity or brightness of light (or any other form of electromagnetic radiation) diminishes with increasing distance from a point source of light. This law can be expressed as follows:

In simpler terms, the inverse square law states that as you move farther away from a light source, the intensity or brightness of the light decreases inversely proportional to the square of the distance. This means that if you double the distance from a point light source, the illuminance on a surface at that new distance will be reduced to one-fourth (1/4) of the original intensity.



We will consider the factors discussed above when examining the potential reasons why the Suyzeko and Neuronic helmet, which share the same platform, have a lower surface power density than their declared power density.

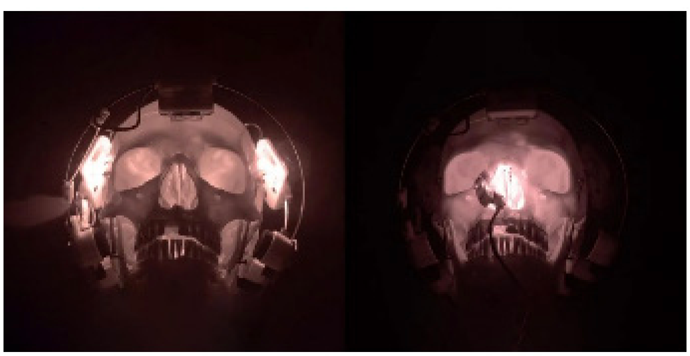
1. Suyzeko and Neuronic are directly measuring at the source of the LED, without accounting for the silicon sheet or plastic, which absorbs light energy.
2. The Suyzeko/Neuronic helmet platform has several centimeters of distance between the LED circuit board and the silicon sheet due to heat generated. This reduces the intensity of light energy, due to the inverse square law of light.

THE VIELIGHT NEURO HEADSET

The Vielight Neuro headset has a significantly higher measured surface power density than declared on their spec sheets. The power densities emitted are on par with lasers without the safety concerns.

1. The Vielight Neuro is designed with a form factor that minimizes distance between the LED and user's scalp, maximizing contact and reducing the inverse square law of light.
2. The Vielight Neuro LED's modules are likely superior and more technologically advanced, being able to generate significant amounts of power density while at full contact with the scalp.

Vielight may be self-declaring a lower power density due to conservative measurements with narrowband spectrum measurements.



CONCLUSION

This case study demonstrates the need for measuring standards and certification to be imposed in this industry, so that researchers and consumers can be equipped with an independent measure of the true value of device parameters and spectral profiles of photobiomodulation equipment.