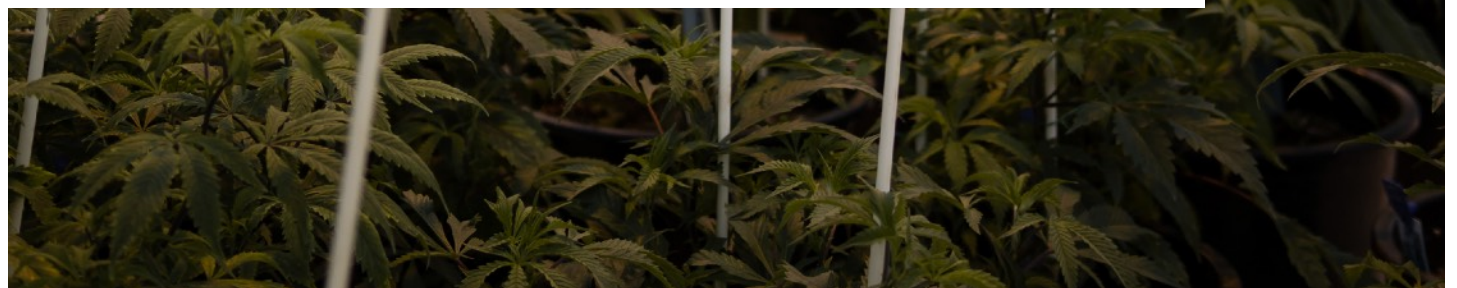




Achieving Industrial Quality Light Measurement on iPhone and iPad

September 2020



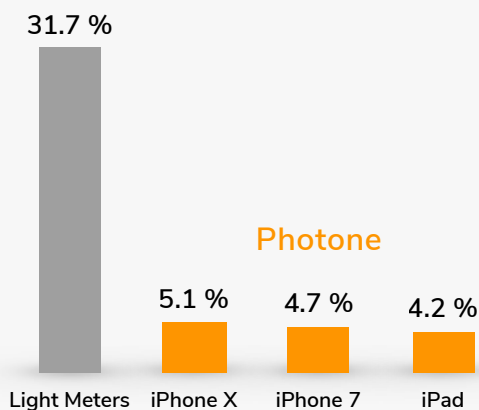
Summary

The Photone iOS app allows to effectively and accurately measure illuminance in Lux or foot-candle and photo active radiation (PAR) in $\mu\text{mol}/\text{m}^2/\text{s}$ using the device's front-facing camera.

Tests with various grow lights prove that Photone repeatedly reaches the best-in-class light measurement **accuracy with errors down to less than a few percent** against professional light meters.

Accuracy Comparison

Compared to various common hardware light meters, Photone is repeatedly achieving the lowest average error rates in measuring grow light illuminance and PAR.



The above error rates are summarized from all measurements within this white paper. They are referenced to an Apogee® SQ-520 Full-Spectrum Smart Quantum Sensor and a PeakTech® 5086 illuminance meter.

Introduction

The right amount of usable light is one of the major factors influencing plant growth. Additional to just enabling healthy plant growth, it is vital for any indoor farming operation to find the right balance between energy input and plant yield output for maximum economic efficiency. Therefore, accurately measuring light intensity and determining how much more or less a plant needs is crucial in every indoor farming application — be it a small home grow or a large scale industrial operation.

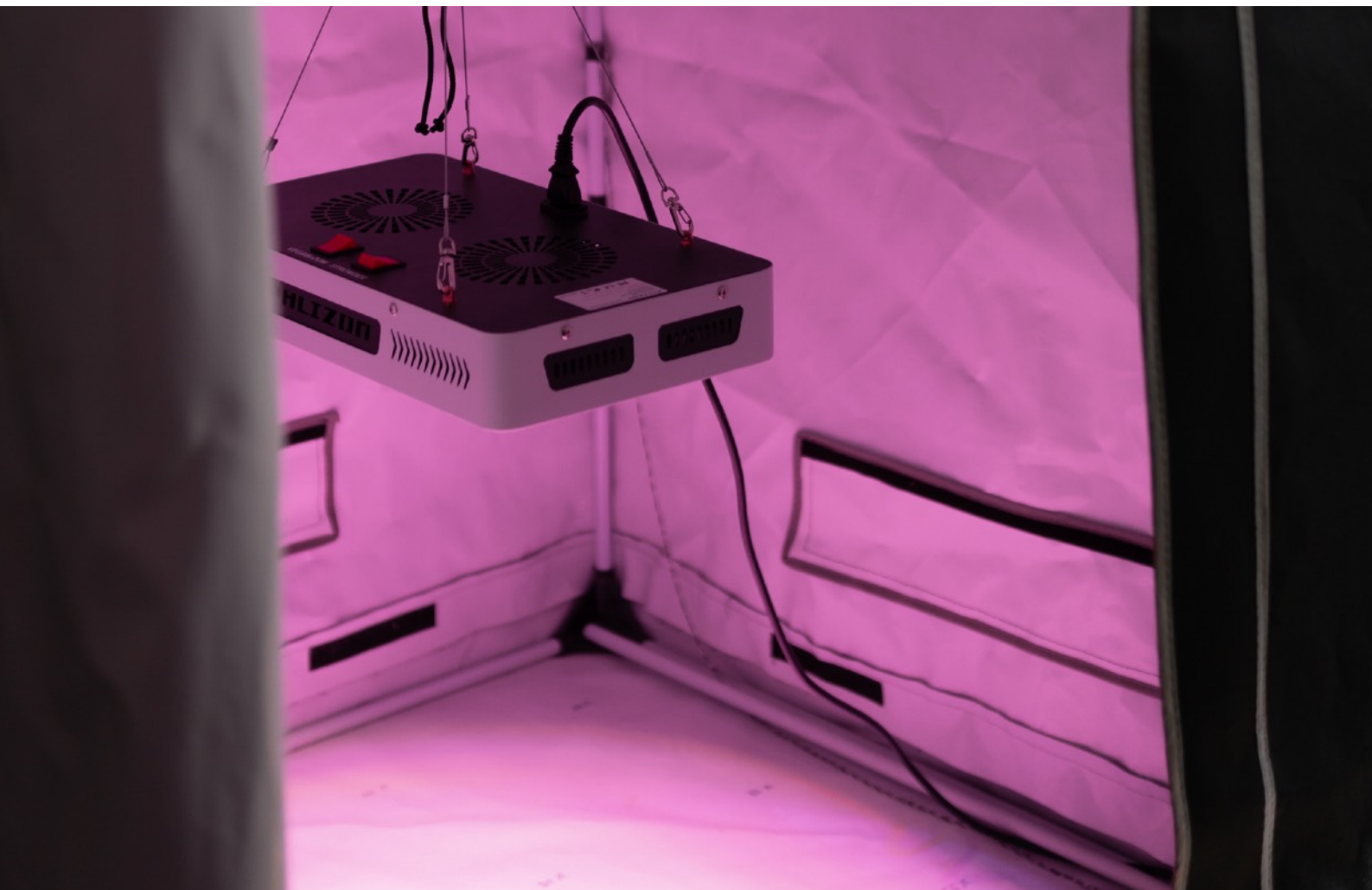
Traditionally, measuring light required specialized and often expensive hardware light meters covering just this single purpose. We were able to change this: The Photone iOS app is able to achieve industrial-grade light measurement on a smartphone or tablet. This white paper describes Photone's accuracy in further detail, how we verify this claim of accuracy, and how to maximize accuracy in your own usage.

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Setup and Methodology

To create a stable, reproducible environment, all measurements are taken in a light-proof box with white interior. To adjust the light intensity, the distance from the light fixture to the measurement device is varied to cover a broad measurement range.



One of the reference lights mounted within the light-proof box

Reference Meters

Best-in-class reference meters have been used to ensure the Lux, foot-candle and PAR measurements are as accurate and reliable as they can get.

Illuminance Meter

To measure illuminance in Lux and foot-candle, a PeakTech® 5086 JIS C 1609:1993 Class A certified meter with a specified accuracy of $\pm 3\%$ is used.



PAR Meter

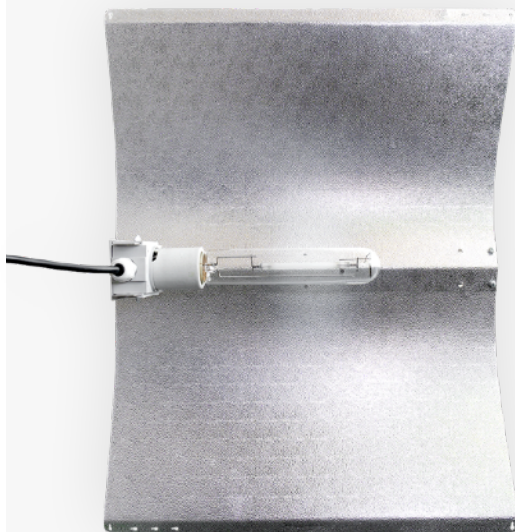
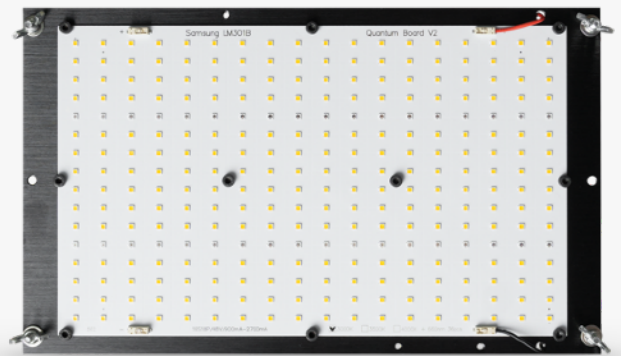
To measure photosynthetically active radiation (PAR) in $\mu\text{mol}/\text{m}^2/\text{s}$, an Apogee® SQ-520 quantum PAR sensor covering the whole 400nm - 700nm spectrum range with an accuracy of $\pm 5\%$ is used.

Light Equipment

Commonly used grow lights for indoor farming have been used to create a relevant real-world usage scenario.

Full Spectrum LED

For all full spectrum LED measurements, a 120W Quantum Board equipped with 3000K full spectrum Samsung LM310B LEDs is used.

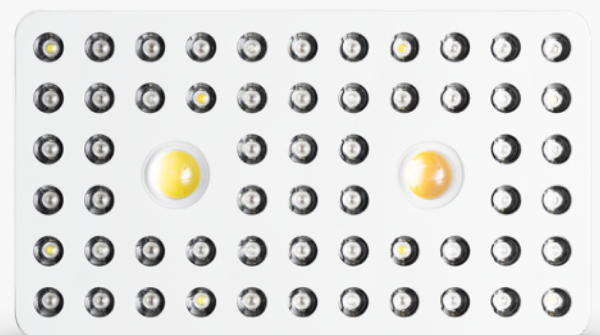


High Pressure Sodium

As for conventional grow lights, a Philips SON-T PIA 400W Green Power 2000K High Pressure Sodium (HPS) bulb mounted in an adjustable reflector is used.

Red / Blue LED

To cover commonly used red / blue LED fixtures, a Phlizon 1000W LED light is used for all red / blue LED measurements.



SETUP AND METHODOLOGY

Light Meter Comparison

Common light meters were tested in the same conditions to compare the performance of the Photone App to the more expensive, specialized equipment.

PeakMeter® MS6612

An all-in-one digital light meter covering lux and foot candle for about \$30.



Uni-T UT383

An affordable, well made digital light meter in one single package with a price tag of around \$20.

MASTECH® MS6610

A wide-range lux meter with remote photo detector with a price tag of around \$30.

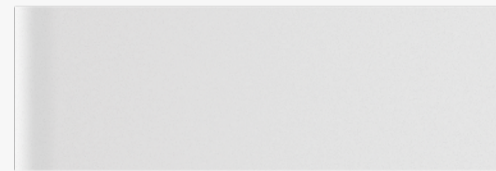


Photone App

All the following measurements were taken with a freshly installed version of Photone on the specified devices. All steps to maximize accuracy mentioned in this white paper were executed.

Diffuser Accessory

To ensure even light dispersion, paper diffusers made from regular, matte white 80g/m² multi-purpose printer paper are used. On the iPhone, a paper strip is wrapped around the top and taped on the backside. On the iPad, a piece of paper is taped over the front-facing camera.



Devices

Three devices are used: An iPhone X, iPhone 7 and an iPad Pro 9.7". Each device is running on iOS 13.7.

Photone

App version 2.0.0 is used throughout this test. However, all measurements will be applicable to newer versions as well.



Measurements

Each measurement includes illuminance readings in Lux and PAR measurements in $\mu\text{mol}/\text{m}^2/\text{s}$. Foot-candle readings are proportional to lux and therefore, the same accuracy is achieved.

Results Interpretation

The measurement results are categorized and visualized to provide a simple overview.

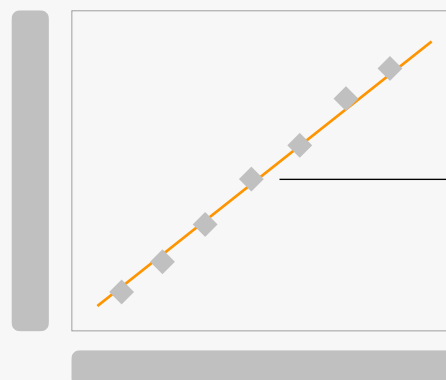
Measurement range
from low to high

Low	100 - 1'000 Lux 10 - 100 $\mu\text{mol}/\text{m}^2/\text{s}$
Mid	1'000 - 10'000 Lux 100 - 1'000 $\mu\text{mol}/\text{m}^2/\text{s}$
High	10'000 - 150'000 Lux 1'000 - 3'000 $\mu\text{mol}/\text{m}^2/\text{s}$



Absolute average error over all measurements taken within the specified measurement range

Measured value:
What the device
actually measured



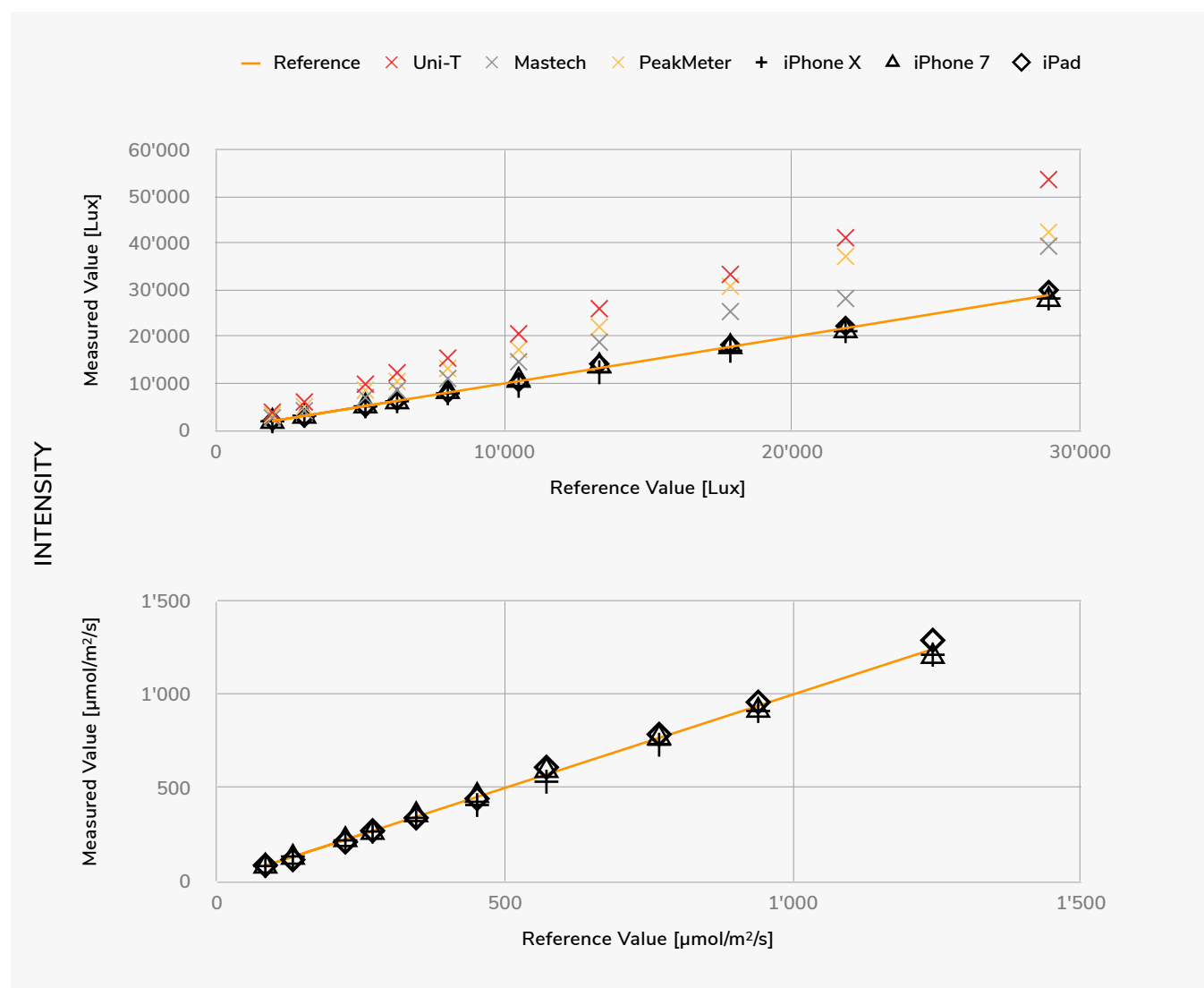
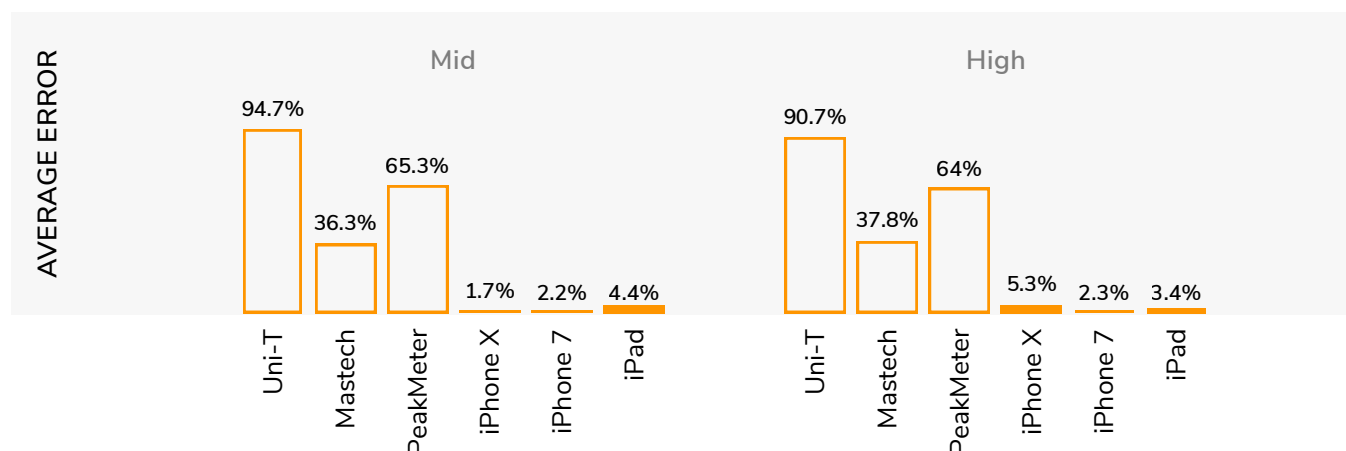
Reference line: 100%
accuracy

Measurements

Reference value: What
should be measured

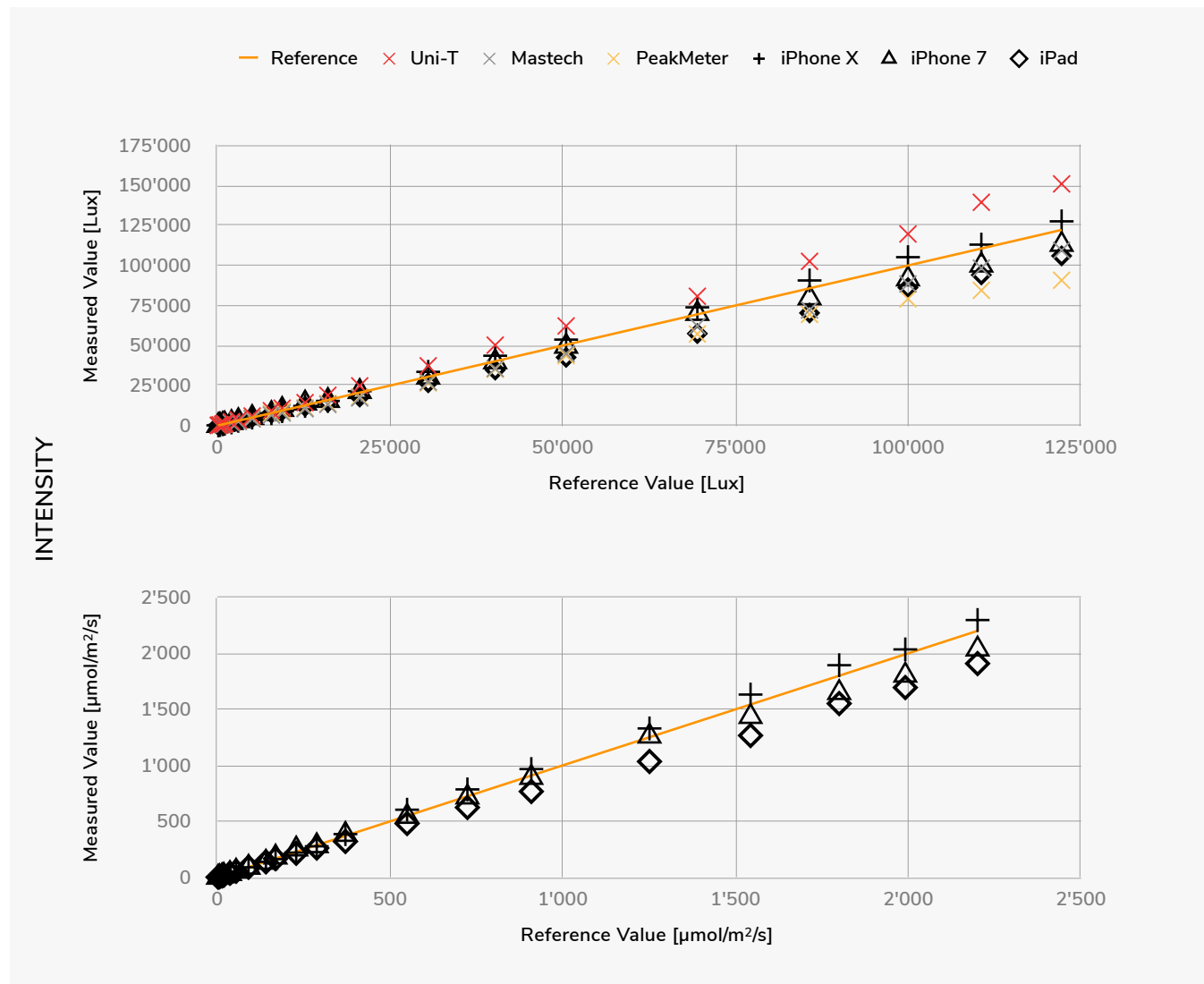
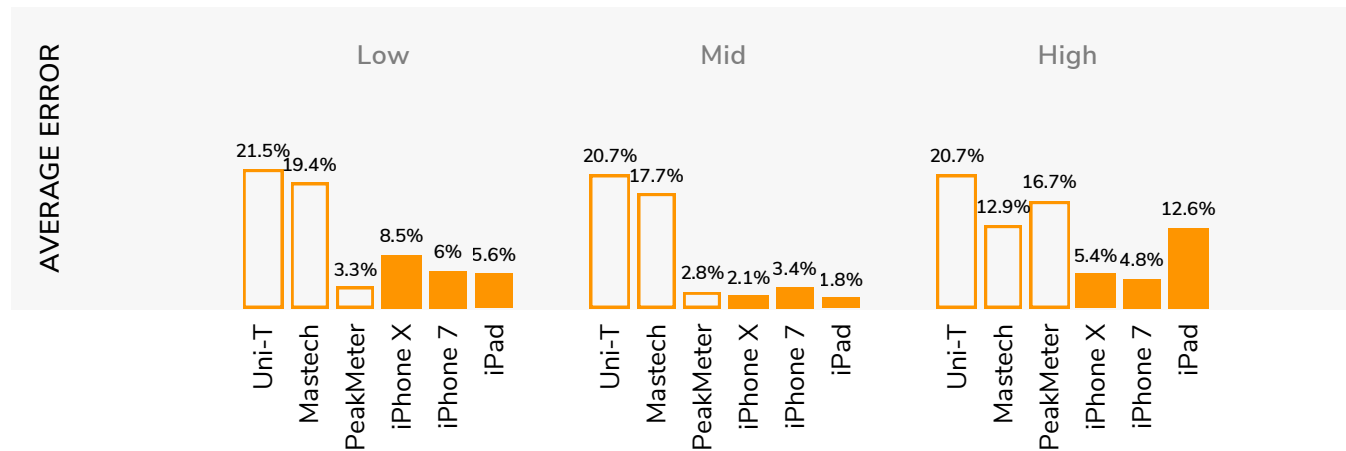
MEASUREMENTS

Red / Blue LED



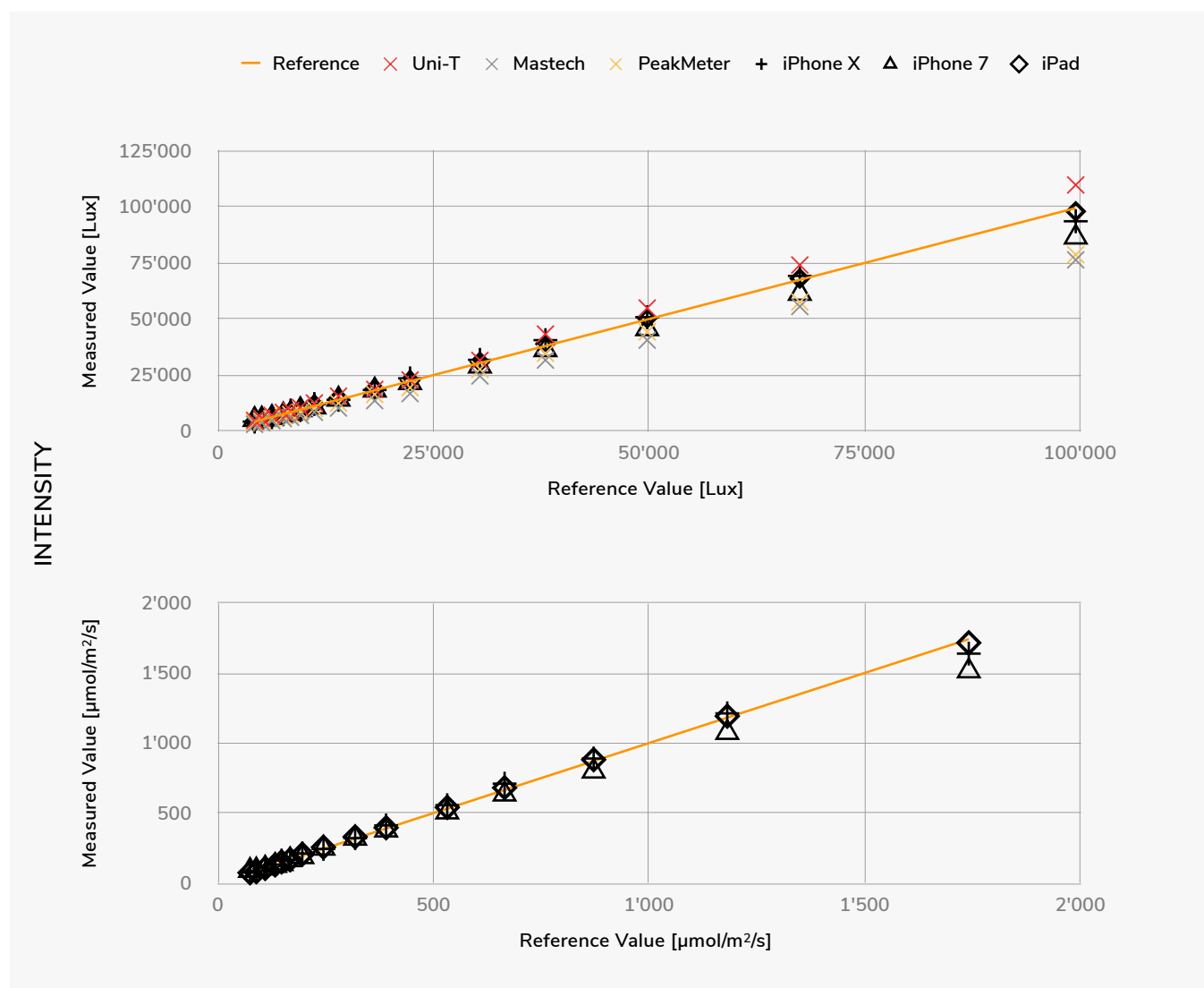
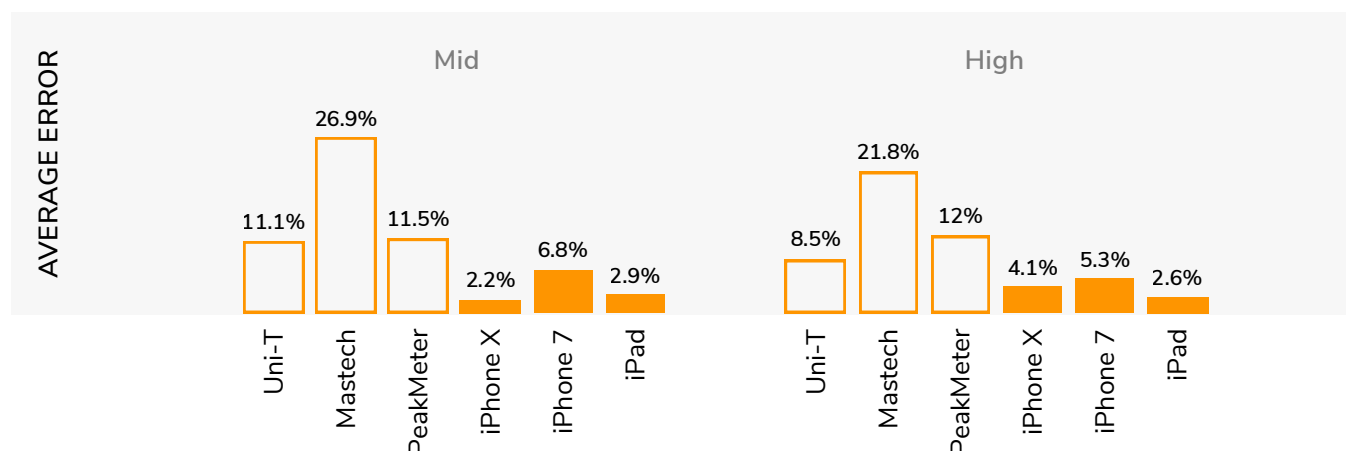
MEASUREMENTS

Full Spectrum LED



MEASUREMENTS

High Pressure Sodium



Factors Influencing Accuracy

Multiple factors affect the measurement chain, spanning all the way from the light source to the actual camera sensor. It is therefore crucial for accurate measurement to take those factors into account.

Diffuser Material and Position

Diffuser material in the right thickness and as uniform in color and density as possible is optimal. Furthermore, the material should ideally be readily available. Photone is therefore engineered to work with a diffuser made out of regular, matte white printer paper. The diffuser is ideally detachable for easy handling and can be attached in the same way repeatedly.

Screen Protector

Screen protecting films or glasses are commonly used to protect smartphone screens from scratches and shattering. Some screen protectors cover the front-facing camera as well and therefore influence the measurement. Initial out-of-the-box device calibration might not be ideally suited for every kind of screen protector. However, every screen protector can be counteracted by individually calibrating the device.

FACTORS INFLUENCING ACCURACY

Measurement Range

Photone's accuracy is tested and guaranteed in the range of 100 - 150'000 Lux, 9 - 13935 FC, and 0 - 3000 $\mu\text{mol}/\text{m}^2/\text{s}$. Measurement results outside this range may decrease in the level of accuracy.

Maximizing Accuracy

Three essential ingredients are required to achieve maximum accuracy:

1. Usage of a proper diffuser
2. Steady measurement conditions
3. Individual device calibration

Diffuser

A diffuser is required to spread the light evenly before it reaches the camera's image sensor. The ideal diffuser is made out of matte white printer paper as specified within the app. The diffuser must lay flat on top of the front-camera and must be free from any dirt or other element blocking the light transmission.

HOW TO

Build a Diffuser

The crafting process for a diffuser is described within the Photone app. It is as simple as cutting a piece of paper to the proper size, wrapping the paper around the top of the smartphone, and taping it together. Such a diffuser is detachable and can be used only when a measurement is taken.

MAXIMIZING ACCURACY

Steady Measurement Conditions

A repeatable, steady measurement environment is crucial when taking measurements for comparison between each other. For instance when a light bulb is measured repeatedly over its lifetime to detect when a replacement makes the most economic sense or when a light footprint of a grow room is laid out. Important factors are position – both in location and in height – and light reflections, influenced mostly by surrounding walls.

HOW TO

Create Steady Measurement Conditions

Marking the measurement location with tape or a marker pen allows to measure from the same spot repeatedly. Additionally, a cardboard box, stool, or other aid can be used to keep the same distance from the light at every measurement. To keep reflections steady, it is advised to note how the room was set up, such as leaving the door open or closed.

MAXIMIZING ACCURACY

Calibration

Calibration resembles the fine-tuning of the whole measurement chain for each individual device. The need for calibration is in the nature of varying influencing factors – even down to manufacturing tolerances of the camera. Proper calibration counteracts each influencing element from the light falling onto the diffuser until it is sampled as a digital pixel in the image.

HOW TO

Calibrate

You can calibrate using a reference meter that measures lux, fc, or PAR / PPFD, calibrate using the sun, or calibrate using a known reference such as your light manufacturer's specification. All of this is supported within the Photone app and the calibration process is fully guided to be as simple as possible.

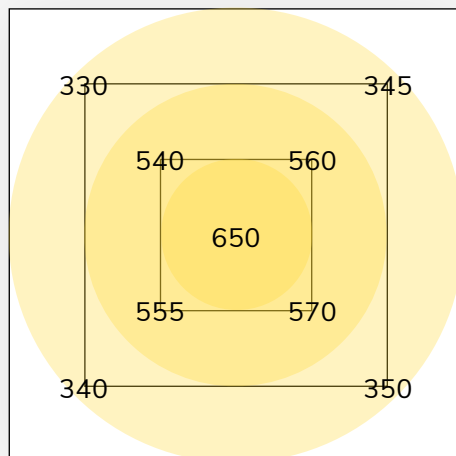
Verifying Accuracy

In order to verify measurement accuracy, a known reference for comparison is required. The accuracy can either be verified using illuminance or PAR.

KNOWN REFERENCE

Sun

Fortunately enough, bright and clear mid-day sun can always be used as its expected lux measurement is known: 120'000 lux for direct sunlight and 20'000 lux when pointed at clear blue sky.



KNOWN REFERENCE

Light Specification

Most grow light manufacturers provide a light footprint chart indicating PAR values in $\mu\text{mol}/\text{m}^2\text{s}$ at a certain distance. Distances of 12", 18", or 24" are commonly used. In order to validate accuracy, the manufacturer's measurement scenario must be reproduced and measured with Photone.

KNOWN REFERENCE

Reference Meter

The ideal option is the comparison to a professional, certified, and calibrated illuminance or PAR meter. One thing to look out for is to measure at the same distance and with light falling directly from the top.



About Us

We are a small team from Switzerland dedicated to empowering everyone to take accurate light measurements without costly specialized equipment.

We began tinkering with the idea of accurately measuring light with a smartphone camera in early 2016 and released the very first version of the Photone app for iOS in 2019. We focus relentlessly on improving Photone to provide the best possible light measurement ever achieved on iPhone and iPad.

Download

The Photone mobile App is available as a free download on the [App Store](#).