I want to calculate the intensity of light at the canopy.
To what degree do the laws of Inverse Square apply to artificial grow lighting layouts?

Inverse Square is a physical method of accounting for photons emitted by a light source as they move away from the source. It is shown as a mathematical equation, $1/r^2$ providing a distance relationship for a point light source as a way to predict the number of photons striking a given surface area at a given distance from the source when the value is known for another point at a different distance from the source. Essentially $1/r^2$ describes how the area illuminated expands as a function of r^2, but the photons emitted are the same. The result is that the intensity of light is reduced by a function of $1/r^2$ at greater distances from the source because the same number of photons are spread over a much larger area. However the $1/r^2$ relationship does not apply well with multiple light sources, fixtures using reflectors, and when the points of measurement are close to the fixture.

Understanding light is not easy

I'd like to start by stating that most subject matter relating to light measurement can get very confusing. The main reason is that photons are not created equally; different wavelengths have different energies, visual sensitivities, and plant absorption sensitivities. This is further complicated by the fact that many articles written on indoor plant lighting are generated by authors whom themselves do not really understand the subject matter. My best advice is to only *consider* articles written by credible sources and to read the articles carefully and slowly. And always remember, you are misinformed until you are completely informed. For these reasons I will do my best to write this article as concisely, to the point, and with a logical progression of the information presented.

Introduction

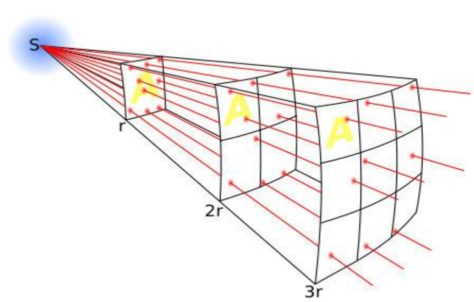
The main reason the indoor grow industry makes us aware of the $1/r^2$ affect is to give us some rudimentary understanding in the hopes that we will give some thought to lighting placement. But there is a serious fault to the $1/r^2$ affect which is further exacerbated for indoor growing applications. The $1/r^2$ relationship applies to a point source of light. For nonpoint sources as the distance from the fixture becomes greater it approximates a point source, but this distance is typically far greater than the indoor gardener would use their lighting fixtures.

$1/r^2$ relationship for a point source

The $1/r^2$ relationship is ideally for a point light source. The diagram below shows how this works. The light source emits a quantity of photons; as the photons travel away from the light source the area of coverage expands, but the photon quantity remains the same. In the diagram, at distance r the area of coverage is A, but at 2r the area of coverage has expanded to 4A, and at 3r to 9A, but the quantity of photons is the same 9 photons shown. From the diagram we can easily deduce that the area of coverage is a function of the r^2. Light intensity is a function of the quantity of photons striking a given surface area so it is easy to see that as the distance increase the intensity decreases as an inverse relationship to the area of coverage resulting in the $1/r^2$ relationship.

Example:

At distance r there are 9 photons passing through area A.
At distance 3r there are still 9 photons, but passing through an area 9A.
At distance r the intensity is **9 photons per area A** and at 3r, 9 photons per area 9A or **1 photon per each area A.** $r^2/(3r)^2 = r^2/9r^2 = 1/9$ as shown in the diagram. At 3r the intensity is $1/9^{th}$ the intensity at r.



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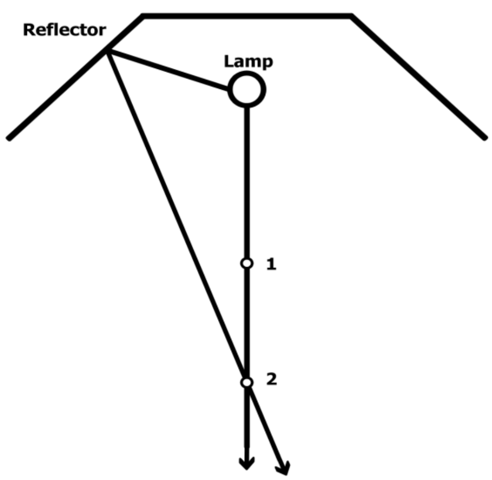
Nonpoint source affects

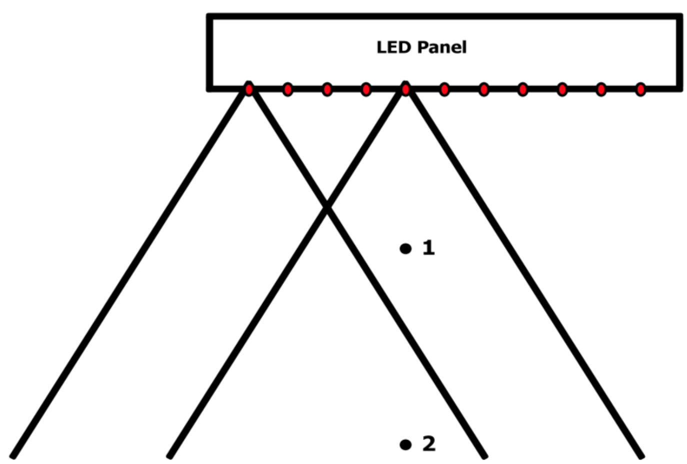
If you have ever taken light intensity measurements under your grow light you very likely did not get a $1/r^2$ relationship, but likely somewhere in between a 1/r and a $1/r^2$ relationship. This has nothing to do with using a proper quantum meter or a standard light meter, but a result of the light fixture not being a true point source. As you get further from the lamp it starts to approximate a point source. An industry rule of thumb is at a distance of 5 times the largest dimension of the fixture the $1/r^2$ relationship starts to hold. The largest dimension would only include the parts that actually emit light from the fixture. This would include all reflector material, but not any housing materials in areas that light is not emitted.

If the largest dimension was 2 feet, then 5 X 2 feet would be 10 feet, so this is the minimum point that the fixture starts to approximate a point source and the $1/r^2$ relationship starts to hold. But keep in mind this is only for measurements that are all taken from a distance of 10 feet or greater.

Real world light fixtures behave more like multiple point sources in close proximity to each other. LED panels are very much that with each individual LED effectively a point source. A lighting fixture will approximate a point source, but only at large distance, much higher than most indoor gardeners would place their lamps. Reflectors in particular skew the $1/r^2$ affect because they bounce photons at radically different angles than the photons emitted directly from the lamp. A reflected photon that could not be detected at a centered position very close to the lamp (point 1) may be detected at the same centered position, but at a greater distance from the lamp (point 2). This is a result of a side reflector bouncing a photon back toward the center at an angle. In the previous example for a point source, the photons only disperse from the center outward. The reflector can bounce photons from one side back toward the center and across to the other side. This is the major contributor in the breakdown of the $1/r^2$ relationship at close distances.

In the case of an LED panel, as you take measurements at different distance from the panel, the photons emitted by the LED directly above the measure point are dispersing from the center. But at the same time the LEDs located off center are emitting photons that may not be detected at a center point close to the panel (point 1), but will be detected at the same center point at a distance further from the panel (point 2).





Measurements taken near the light fixture are capturing photons emitted from multiple points at greatly varying angles. As the point of measurement is taken from greater distances, these angles are reduced and are more similar to each other and this is why it starts to approximate a point source at the greater distances.

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Summary Conclusions

$1/r^2$ is not a critical phenomenon to be overly concerned with in your light set up. It is good to understand it as it will help in understanding any intensity measurements you take. The main objective is to place your light fixtures and the height of the fixture such that it projects the footprint needed while minimizing the light overspray past the crops. Most all of us will find this balance by experimentation and not by performing calculations with parameters that the manufacturers do not provide anyway.

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