Illumination Distance

Factors Affecting an Illuminator's Usable Distance

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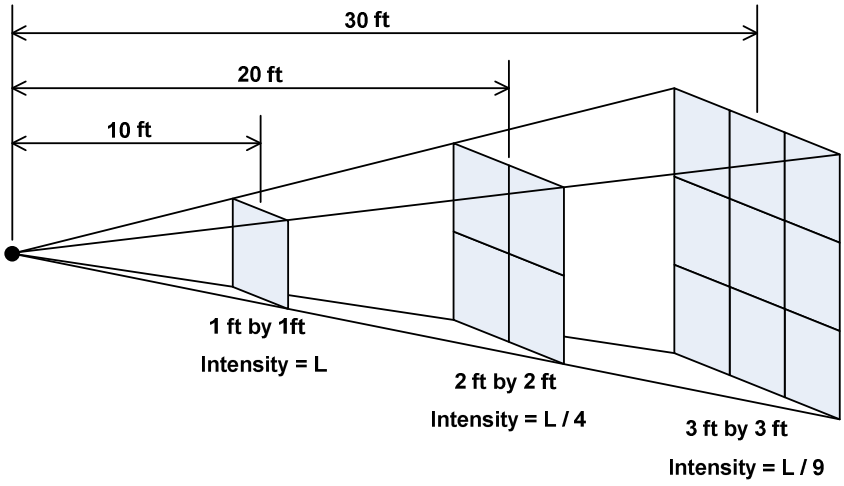
Introduction

One of the most important considerations when specifying illuminators for video security systems is determining the maximum distance at which it will be effective. Unfortunately, the answer involves many factors. Some of these factors are quite straightforward, logical, and easy to quantify. Others are confusing, imprecise, and even subjective. This article attempts to explain these factors as clearly and simply as possible.

Coverage versus Distance

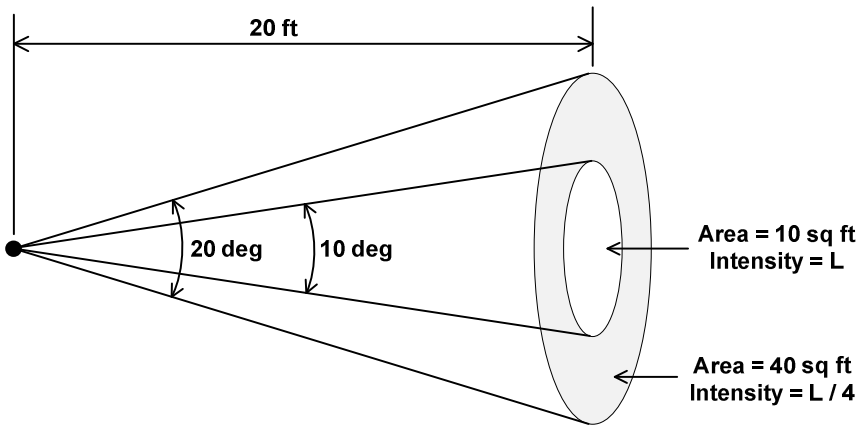
Intuitively, a light source that projects a narrow beam will illuminate a scene at a greater distance than a similar source which has a broad beam. Conversely, the broad beam will illuminate a wider scene, albeit not as brightly or as far away. The principle that governs this relationship is the *Inverse-Square Law*. It states that the intensity of light falls as the square of the distance from the source. It is a mathematical description of simple geometry. Imagine a hypothetical illuminator that projects a square spot of light one foot wide on a flat screen placed at a distance of ten feet. Now move the screen ten feet further away. The projected spot on the screen gets bigger, and less bright. In fact, at twice the distance the square spot gets twice as big – now two feet wide and two feet tall. The same amount of light is spread out over an area of four square feet now. Each square foot gets only one quarter of the light. So the illumination at any point in the spot at twice the distance is one quarter the intensity – one over two squared. This relationship is shown graphically in Figure 1 below.

Figure 1 - Inverse Square Law



A similar argument applies when considering an illuminator's angle of coverage. A 20-degree illuminator covers four times the area compared to a 10-degree illuminator at the same distance, and therefore will be one forth as bright (approximately, all other things being equal). This is shown below in Figure 2.

Figure 2 - Intensity vs. Angle



So to get the most benefit from an illuminator, we need to specify the narrowest illumination angle that will fully cover the camera's field of view. Otherwise, light is wasted and the video image will suffer. Most illuminators must be ordered in fixed angle increments, such as 10-, 30-, or 60-degree coverage. NuOptic's VIS technology allows you to perfectly match the coverage of the illuminator to the coverage of the camera.

Power versus Light Output

Illuminators are specified according to their input power – usually by their maximum or worst-case input power. This is useful for planning the line voltage or low voltage power source that must be provided to the illuminator. On the other hand, a particular power rating is not very helpful in determining whether an illuminator will provide sufficient light for the application. Also, products from different manufacturers with the same coverage angle and power specifications may have significantly different light output. One product may use newer, more efficient LEDs; or it may have more efficient optics or driver circuitry. These differences may even be seen between product lines from a single manufacturer.

We can at least state the obvious: two illuminators provide twice the light of one when covering the same area from the same distance. It is also safe to assume that an illuminator rated at twice the power will provide approximately twice the light as a lower power illuminator from the same manufacturer's product line. A NuOptic 80 Watt VIS-1080 does indeed produce approximately twice the light output as the 40-watt VIS-1040. How much further can the higher powered illuminator be placed from the target? Here we can use the inverse

square law: twice the light power will have the same brightness at the square root of two times the distance – approximately 1.4 times the distance.

Required Image Quality

Of course the purpose of illumination for video security is to provide a useful image in conditions where there is not enough natural illumination. The image may be needed for direct viewing by an operator, for video recording, or for both purposes.

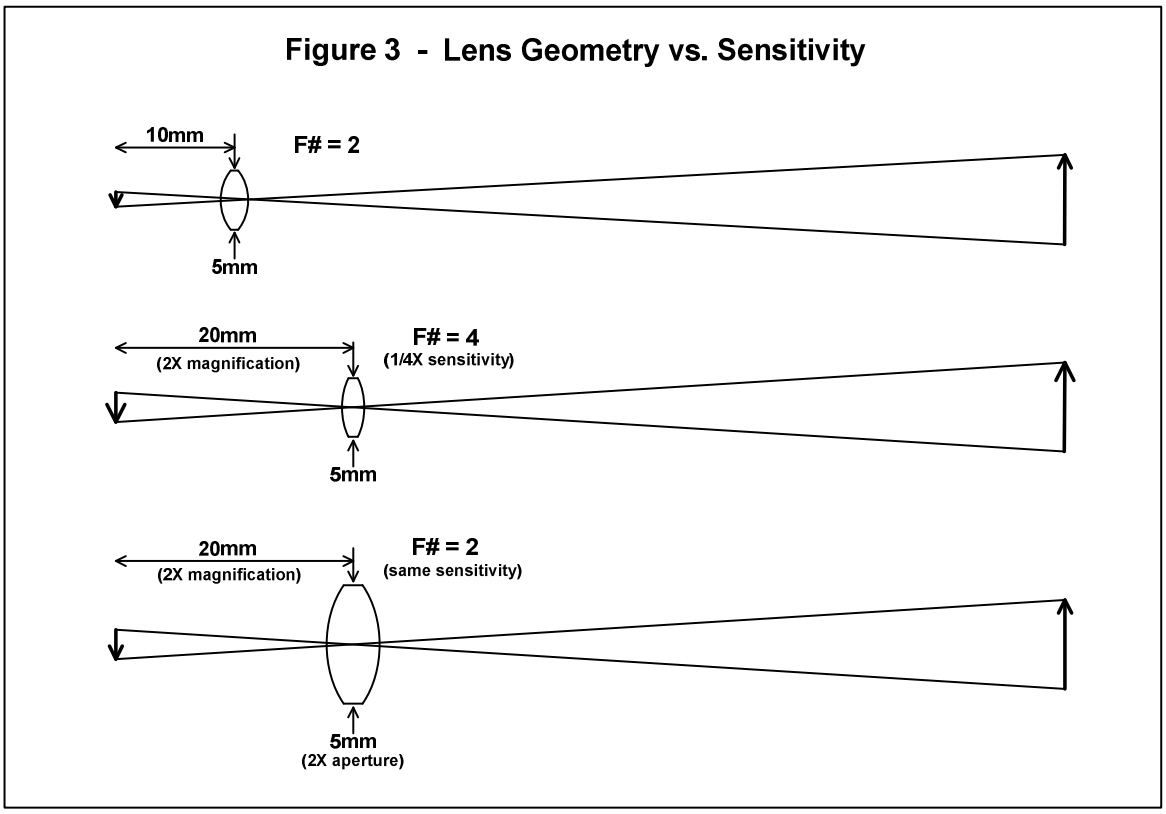
The goal may be merely to determine activity, such as a car entering a parking lot or an intruder climbing a fence. On the other hand, the goal may be to identify the make and model of the car, or the clothing and facial features of the intruder. The latter goal dictates a less grainy, lower noise image. An illuminator that can work perfectly well at the required distance in the first case may not necessarily provide enough light at the same distance in the second case.

Some industry groups have proposed more incremental levels of image quality needed for security applications, for example, Detection, Classification, Recognition, and Identification. Another, coming from thermal imaging technology, uses Detection, Orientation, Recognition, and Identification, with somewhat different criteria for each level. See the references for more information.

Effect of Camera Sensitivity

The quality of the video image in low light conditions is strongly dependant on the sensitivity of the camera. The sensor itself is a key contributor. The size of the sensor has decreased over time, which decreases sensitivity simply because it gathers less light. At the same time, technological advantages have made these smaller devices more sensitive. The end result is that modern cameras are significantly better despite their smaller format.

The lens is the other main contributor to camera sensitivity. Clearly, a lens with a larger aperture will gather more light. The actual parameter that indicates the “speed” of the lens is its F-number. This number is the ratio of the focal length to the aperture of the lens. This means that a telephoto lens of the same aperture as a wide angle lens will result in a camera system that is less sensitive, and therefore requires a brighter scene. To be as sensitive as the wide angle lens, the telephoto must have a larger aperture – maintaining the same F-number. This relationship is shown graphically in Figure 3 below.



Lux – Unit of Measure

Video security cameras usually have a specification called a lux rating. *Lux*, abbreviated lx, is the International System of Units (SI) measure of the photometric intensity of light. It can be thought of as the strength of light as seen by the human eye.

- A full moon on a clear night produces about 0.3 lux
- An overcast, dark day produces about 100 lux
- A bright overcast day produces about 1000 lux
- Direct sunlight can range from about 30,000 to above 100,000 lux

A camera's lux rating is the actual available light intensity at which the camera can produce a usable image. Modern cameras often have ratings well below 1 lux. Unfortunately, as was discussed previously, there are differing interpretations as to what constitutes a "usable image." It is important to understand whether a lux rating produces image quality sufficient for your application, i.e. for detection or for recognition.

Further discussion of cameras and lenses is beyond the scope of this paper. Please refer to your camera documentation or manufacturer's website.

Infrared Light

Since lux is a measure of light intensity as seen by the human eye, it is not very useful for light that is invisible to the human eye. A rigorous radiometric measure of infrared light intensity is watts per square meter. Unfortunately, few products are specified in terms of radiometric units, and few video professionals are familiar with such terminology.

A less-than-rigorous measure of light that is sometimes used for infrared systems is “equivalent lux.” This is simply the amount of IR illumination that will give a similar signal from a day/night camera as one lux of visible light. It is not a rigorous metric since different cameras can have different relative sensitivities between white and IR light. The advantage of “equivalent lux” is that it is a convenient extension from familiar visible light systems.

More information about infrared illumination and day/night cameras can be found in a separate NuOptic white paper devoted to these topics.

Distance Specifications

It is of course necessary for illuminator manufacturers to provide distance specifications for their products despite all of these competing and confounding factors. Some manufacturers are more rigorous than others in documenting their methodology. NuOptic’s approach to generating distance specifications is to benchmark our products against the other most popular illuminators in the industry. These specifications are therefore useful for both product comparison and system planning.

For our white light products, this benchmarking results in a scene lux reading of approximately 3.5 lx. This light level should provide quite good image quality, minding the camera sensitivity caveats described previously. For our infrared products, the benchmarking results in an “equivalent lux” reading of about 19. Given the lack of rigor of “e-lux” as a measure, the number itself is less important than the assurance that we strive to provide the useful apples-to-apples distance specifications. As with the white light specs, the IR light level should provide good image quality with modern day/night cameras.

Final Recommendations

As you can see, the factors affecting usable illumination distance are numerous and interrelated. Published distance specifications need to be considered in light of these factors, rather than taken strictly at face value. Customers are urged to consult an industry professional when selecting illuminator products and planning their system.

We hope that the information provided here and in other NuOptic white papers can form a starting point for better understanding of video security systems in general and illuminators for video security in particular.

References

Technical Guide for Lenses – Computar_Lens_Tech_0208.pdf

DCRI White Paper Series #1: Defining the Right Level of Image Quality Needed for your Video Surveillance Systems – Bosch Security Systems

“Analysis of Image Forming Systems” – John Johnson, in Image Intensifier Symposium, AD 220160