WHITE PAPER

Lightfinder

Outstanding performance in difficult light conditions

September 2021

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1 Summary

Axis Lightfinder technology gives a network camera extreme light sensitivity. In very low light, where other cameras would switch to night mode and gray-scale video, cameras with Lightfinder remain in day mode and continue to deliver color images. In surveillance situations, color may be the critical factor for the identification of a person, an object, or a vehicle.

Lightfinder adds value not only in the darkest scenes, but in any place where light levels are lower than typical indoor lighting. As it needs less light to produce a good image, a Lightfinder camera can, for example, employ a shorter exposure time and thereby keep blur and noise to a minimum.

Lightfinder's low-light capabilities are exemplified in this white paper through images from a studio with extremely well-controlled lighting. At a light intensity of 1.5-5 lux, the scene appeared very dark to the human eye, but the camera showed the scene as being deceptively bright. When the light intensity was lowered, the human eye lost color vision and details at around 0.5 lux, while the camera kept on delivering bright colors. Even down to 0.02 lux, when the people on-site experienced it as practically pitch black, with only the lightest objects faintly discernible, the camera still provided a color image.

Lightfinder technology constitutes a fine-tuned combination of first-class optical components, such as a high-quality lens and a specially selected image sensor optimized for surveillance. Digital image processing algorithms are embedded in the system-on-chip. As all these building blocks of Lightfinder regularly improve, Lightfinder, too, is constantly evolving. The concept of Lightfinder 2.0 represents a step in this evolution, with increased light sensitivity, more life-like color reproduction, and custom tuning for advanced users.

Lightfinder builds on extensive know-how in color processing, filtering, and tuning. Lightfinder and Axis Zipstream technology are tuned together for extra careful compression, which preserves image details while still producing video at a low average bitrate and reduced storage costs.

2 Introduction

Lightfinder is Axis technology that enables a network camera to provide high-quality color video even in extremely low light conditions. The technology is the result of a unique combination of the right sensor and the right lens, together with optimized image processing algorithms on a state-of-the-art chip.

Network cameras with Lightfinder are beneficial in all demanding low-light video surveillance applications such as parking lots, city surveillance, campuses, and construction sites, where color video may substantially enhance the possibility to effectively identify people, vehicles, or incidents.

This white paper describes the fundamentals and the key benefits of the Lightfinder technology. Image quality is exemplified through Lightfinder video snapshots from a low-light scene with controlled lighting. For a thorough technological understanding, however, we will start by discussing the basics of light, light detection, and light measurements.

3 Let there be light – a background

Light consists of discrete bundles of electromagnetic energy, called photons. These have different energy levels, or wavelengths. Within the visible light energy interval, different wavelengths represent light of different colors. The figure below shows some of the energy ranges in the electromagnetic spectrum.

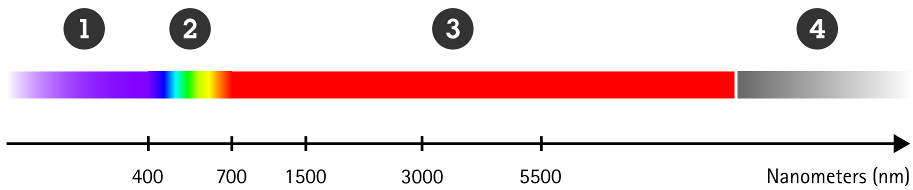

Figure 1. Part of the electromagnetic spectrum, with energy ranges marked in wavelengths (nanometers). The energy ranges from left to right are: (1) Ultraviolet light, (2) Visible light, (3) Infrared light, (4) Microwave.

Note that the infrared energy range is further divided into the following; Near infrared, Short wave infrared, Middle infrared, Long wave infrared and Far infrared.

3.1 Light detection

The human eye can detect light (photons) of wavelengths between approximately 400 nm and 700 nm (the visible spectrum). The eye has two types of light detector, rods and cones, which are optimized to measure light of different intensities and wavelengths. The cones provide color vision, but they require strong light (a good number of photons) in order to detect anything. The rods, however, can detect very low levels of light (just a few photons are enough), but since they cannot distinguish between wavelengths, they provide no color information. This is why the human eye loses its color vision when the lighting drops: the cones pick up nothing, but the rods still do.

In a digital camera, the equivalent to the eye's rods and cones are the millions of photo-sensitive spots (pixels) on the image sensor. Apart from detecting visible light photons, a digital camera sensor also benefits from the ability to detect photons of slightly longer wavelengths (700-1000 nm) in the near infrared (near-IR) part of the spectrum. Near-IR light is normally present in both sunlight and artificial light.

When visible light levels are very low, a digital camera (a day-and-night camera with a removable IR-cut filter) can still use the available near-IR light to produce images. However, this light has no color information, so at very low levels of visible light, both the human eye and a typical day-and-night camera can only provide greyscale images.

A camera with Lightfinder, however, retains its color vision and keeps producing color images even when the lighting diminishes to levels way below where the human eye can make out colors.

Lightfinder cameras can also be supplemented with IR illuminators and use the cameras' night mode instead. The greyscale IR images in night mode can be tremendously useful, for example in video analytics applications, but in many use cases, day-mode video with its colors and natural look is undoubtedly more attractive.

Figure 2. Snapshot from a nighttime video where a Lightfinder camera makes optimal use of the existing light.

3.2 Light intensity in lux

Light intensity can be photometrically quantified as illuminance, or luminous flux per unit area. The quantity of illuminance is based on the absolute, radiometric intensity (irradiance measured in W/m^2) of the light. However, illuminance also incorporates weighting according to the human eye's sensitivity function, a standardized model of human visual brightness perception at different wavelengths. This means that illuminance represents the light intensity as perceived by the human eye. Illuminance is measured in lux (lx), with one lux equaling one lumen per square meter.

Illumination in natural scenes is often complex, with shadows and highlights giving different lux readings in different parts of the scene. One lux reading does not indicate the light condition of the scene overall, nor does it say anything about the direction of the light. That said, light intensity measurements do provide a valuable tool for estimating light conditions and comparing different scenes. The table below lists typical lux values for a range of lighting conditions.

Table 3.1 Lux values for various conditions.

Light intensity	Description
0.05 – 0.3 lux	Clear night with a full moon
1 lux	Candle at 1 m
80 lux	Office building hallway
500 lux	Office light
10,000 lux	Full daylight
100,000 lux	Strong sunlight

3.3 Light sensitivity specified as minimum illumination

Many manufacturers specify the light sensitivity of a network camera as the minimum level of illumination needed to produce an acceptable image. Whereas such specifications are helpful in making light sensitivity comparisons for cameras produced by the same manufacturer, similar comparisons between products from different manufacturers should be made with caution. Since there is no global standard for how to measure the minimum illumination, different manufacturers use different methods and have different criteria as to what constitutes an acceptable image.

4 Key elements of Lightfinder

Lightfinder technology constitutes a successful combination of fine-tuned, high-quality optical components and advanced image processing on a system-on-chip designed specifically for surveillance. As these building blocks regularly improve, so too does Lightfinder technology evolve.

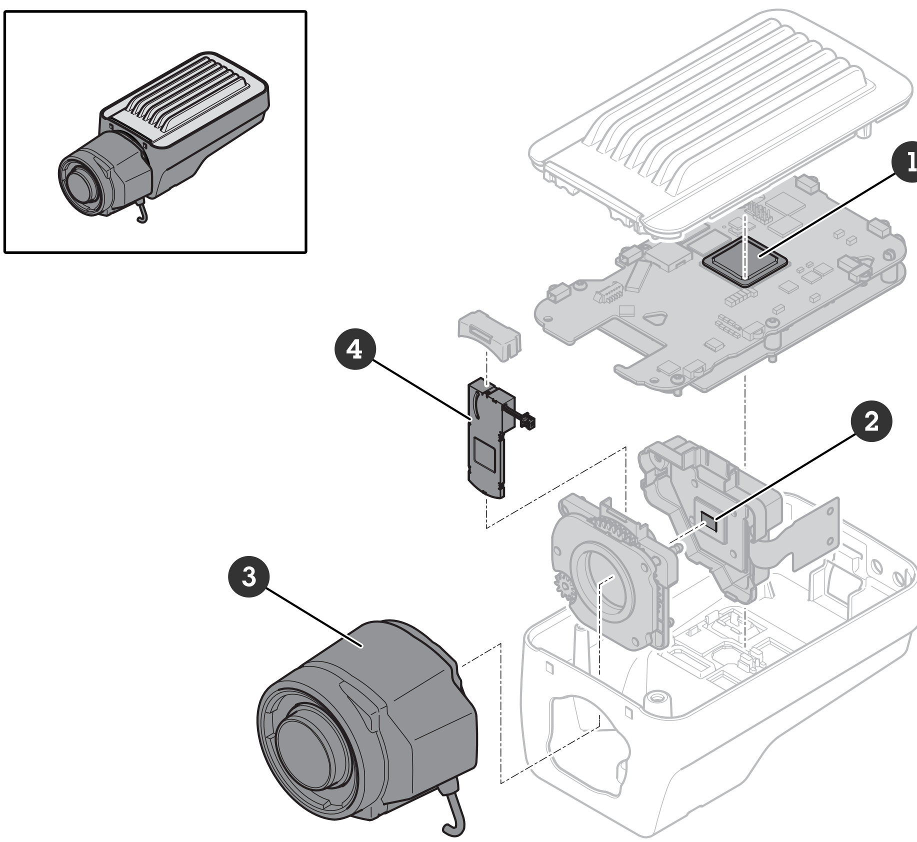

Figure 3. Exploded view of an Axis network camera. The highlighted components are those optimized in Lightfinder technology: (1) system-on-chip with embedded image signal processing (ISP) module, (2) image sensor, (3) lens, and (4) filters.

After the light is collected and focused by a high-quality lens, it reaches the image sensor, which is a key part of any digital camera. The sensor is an electro-optical component, consisting of an array of light-sensitive photon detectors, which convert light into electric signals. All Lightfinder products are equipped with a specially selected, highly sensitive CMOS sensor with optimal characteristics for surveillance.

Equally important as the image sensor are the digital image processing algorithms embedded in the ISP module of the system-on-chip. The chip is designed specifically for video surveillance and is manufactured according to the latest available ASIC technology, ensuring the maximum number of digital building blocks. The algorithms will, in real time, remove noise, recover colors, and clarify each image, to produce the most usable video from even the smallest sensor signal. However, the preservation of image content is always prioritized over extensive filtering, which could remove crucial details. It is especially important in surveillance that image algorithms do not destroy the forensic information in the scene. The algorithms must be well-behaved and predictable and should never introduce extra information in the image in the process of making it look "nicer".

By carefully evaluating everything in the optical path and optimally tuning all digital algorithms, it is possible to achieve outstanding camera performance in most light conditions, with low light being the ultimate challenge. In Lightfinder products, the lens and the sensor are matched with other optical components, typically lens filters, to maximize light sensitivity and resolution, while still avoiding artifacts. Lightfinder and Axis Zipstream technology are tuned together for extra precise compression, which will preserve image details while still producing video with a low average bitrate, as well as reducing storage costs.

5 Key benefits of Lightfinder

Lightfinder enables the camera to reproduce colors in scenes with very little light, but it also provides high-quality video with low noise and a minimum of motion blur. This is because the extreme light sensitivity enables a short exposure time.

5.1 Color video for accurate identification in extremely low light

In very low light, where other day-and-night cameras would switch to night mode and grayscale video, cameras with Lightfinder remain in day mode and continue to deliver color video. Color in surveillance video can be of the utmost importance for effective identification of people, vehicles, or incidents. By providing the operator with the possibility to quickly and accurately report the color of clothing or cars, Lightfinder can enable rapid intervention and precise identification.

5.1.1 Lightfinder examples at different light levels

In order to exemplify the low-light capabilities of Lightfinder, this section includes images from video sequences filmed by a Lightfinder camera in a studio with extremely well-controlled lighting.

AXIS Q1645 Network Camera, equipped with an extra light-sensitive F0.9 lens, was positioned 10 m from an arrangement of colorful objects. The camera used an exposure time of 1/30, which would have been enough to capture moving objects as well. WDR was turned off.

The first figure shows the scene as reproduced by the camera at light levels between 1.5 lux (measured around the tricycle) and 5 lux (measured around the mannequins' waists). It should be noted that the human eye (also 10 m from the objects, next to the camera) perceived this scene as significantly darker than suggested by the image, even after the eye had been allowed sufficient time to adapt. The eye could still discern colors, but the light levels could be described as "uncomfortably low".

Figure 4. A studio scene with a light intensity between 1.5 lux (on the tricycle) and 5 lux (at mannequin waist height). The Lightfinder camera delivered clear colors and a deceptively bright image. The human eye could also discern color, but perceived the scene as being very dark.

The following three images show cropped images of the same scene filmed with the same setup, but at progressively lower light levels. At around 0.5 lux the human eye lost color vision, while the Lightfinder camera continued to reproduce bright colors. In fact, the Lightfinder camera kept its color vision, although fairly subdued, all the way down to the lowest tested light levels of 0.02-0.08 lux. At these levels, the human eye could perceive neither colors nor details, and the scene appeared practically pitch black, with only the lightest objects faintly discernible.

Figure 5. 0.2 lux – 0.7 lux measured on the objects. The Lightfinder camera provides bright colors. To the human eye, color vision was questionable, and mainly light surfaces could be discerned, with very little detail.

Figure 6. 0.1 lux – 0.3 lux measured on the objects. The Lightfinder camera provides a less sharp, but still very detailed, color image. The human eye could not discern the darker surfaces and perceived no details or colors.

Figure 7. 0.02 lux – 0.08 lux measured on the objects. The Lightfinder camera provides a dark image with subdued but discernible colors. The human eye could only vaguely discern the lightest surfaces and perceived no details or colors whatsoever.

5.2 Other benefits related to exposure time and aperture size

The extreme light sensitivity of a Lightfinder camera can be beneficial not only in the darkest scenes, but in any scene where light levels are lower than in a typical indoor office. Needing less light to produce a good image, a Lightfinder camera could either use a shorter exposure time, which minimizes noise and blur, or it could use a smaller lens aperture which has other advantages.

For example, Lightfinder makes it possible to:

- reduce motion blur (by using a shorter exposure time)
- reduce noise (also using a short exposure time)
- use longer telephoto lenses (which generally requires a shorter exposure time for a good result)
- increase depth of field (by using a smaller aperture in the lens)
- reduce noise (by using less digital gain)
- improve WDR performance (which means less noise) in the dark parts of the image

Exposure time is the period of time during which the camera sensor captures photons (and converts them to electric signals), before the resulting electron count for each pixel is measured and used to form an image. All sensor pixels are then cleared, and the photon capturing starts again.

Low-light scenes generally require longer exposure times for the sensor to capture enough photons to produce a usable image. If the exposure time is too short and the image becomes too dark, it is possible to brighten it digitally, but not without increasing the noise. With a long exposure time, however, any fast-moving objects may become blurry in the image as they move across the sensor during the exposure interval. This phenomenon is called motion blur, a common problem in scenes with limited light.

Figure 8. A long exposure time may cause visible motion blur. In this snapshot, the license plate might have been readable if a shorter exposure time had been used.

Since Lightfinder allows for shorter exposure times, it can reduce motion blur. This is especially important if a high resolution is required (resolving details of the moving object). Other ways of reducing motion blur include placing the camera further away from the moving object or using a wide-angle lens. In these cases, a moving object will move over a smaller number of pixels on the sensor, even though it has the same velocity.

Another advantage of Lightfinder is that it can be used to increase the depth of field in an image, because it may be possible to use a smaller lens aperture. In low light, it is desirable to use a larger aperture so as to collect more light during the exposure time. However, due to the laws of physics governing optics and ray-tracing, the larger aperture also gives a shorter depth of field, that is, a shorter part of the scene can be in focus simultaneously. With Lightfinder, the exposure time can be shorter, which allows the use of a smaller aperture and thereby a greater depth of field.

6 Lightfinder 2.0

As of May 2019, an increasing number of new Axis network cameras are equipped with Lightfinder 2.0. Available on cameras that use the ARTPEC-7 system-on-chip, this concept represents a step in the evolution of Lightfinder.

6.1 Benefits

Owing to a complete redesign of the image processing pipeline, Lightfinder 2.0 provides even sharper images with less artifacts. Apart from improving the general light sensitivity of the camera, Lightfinder

2.0 also enables more accurate color reproduction, improved white balance, and increased possibilities to lift shadows and dark objects.

Lightfinder 2.0 also comes with new settings for controlling temporal and spatial filtering. This is especially valuable for advanced users who need to optimize the image for specific analytics applications.

6.2 Example

The following image is a snapshot from a surveillance video test of an Axis camera with Lightfinder 2.0. There seems to be nothing extraordinary about the image – if you don't know how dark the scene really was. The person who can be spotted in the image, standing under the bridge, measured the light intensity at only 0.05 lux. Lightfinder 2.0 reproduces this very dark site as if it were bathed in daylight.

Figure 9. A sharp, bright, color image delivered by a Lightfinder 2.0 camera, even though the light intensity was only 0.05 lux under the bridge.

In comparison, the next image shows a snapshot of the same scene in which the image has been manipulated to visualize what the human eye might see. To a person standing next to the Lightfinder

2.0 camera, the area under the bridge appeared very dark, although some details were still possible to distinguish.

Figure 10. This is what people at the scene were able to see. The image has been manipulated to visualize the darkness as experienced by the human eye.

The next image is from the same scene, but captured on a contemporary smartphone. Naturally, smartphones don't optimize images for surveillance purposes, but the fact that the area under the bridge was rendered completely black gives a general idea of how dark the scene actually was.

Figure 11. The same scene captured on an iPhone8.

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About Axis Communications

Axis enables a smarter and safer world by creating solutions for improving security and business performance. As a network technology company and industry leader, Axis offers solutions in video surveillance, access control, intercom, and audio systems. They are enhanced by intelligent analytics applications and supported by high-quality training.

Axis has around 4,000 dedicated employees in over 50 countries and collaborates with technology and system integration partners worldwide to deliver customer solutions. Axis was founded in 1984, and the headquarters are in Lund, Sweden

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