WHITE PAPER

Lighting for Network Video

Lighting Design Guide

AXIS COMMUNICATIONS

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1. Introduction

When selecting a network camera for day or night surveillance, there are several elements impacting image quality that are important to understand. This guide is intended to give a basic overview of those elements, to give an understanding of how lighting affects the image, and of the factors that need to be taken into consideration for creating favorable lighting in dark environments.

2. What is light?

Light is fundamental to network video. It is light reflected from the scene being viewed that allows images to be visible both to the human eye and to the camera. So the performance of any network video system depends not only on the camera and lens, but also on the quantity, quality, and distribution of available light.

Light is energy in the form of electromagnetic radiation. The light's wavelength (or frequency) determines the color and type of light. Only a very narrow range of wavelengths is visible to the human eye, i.e. from approximately 400nm (violet) to 700nm (red). However, network video cameras can detect light outside the range of the human eye, allowing them to be used not only with white light, but also with Near Infrared light (715-950nm) for night surveillance.

The behaviour of light varies according to the material or surface it strikes, where it is either reflected, diffused, absorbed or (more commonly) subjected to a mixture of these effects. Most surfaces reflect some element of light. Generally, the paler the surface, the more light it reflects. Black surfaces absorb visible light, while white surfaces reflect almost all visible light. Infrared is not always reflected in the same way as visible light. The way infrared is reflected depends on the nature of the material – see the reflectance chart on page 7.

3. What is color?

The processes by which the human eye and brain "see" color are very complex, so the definition of color presented here is of necessity greatly simplified.

Light at wavelengths visible to the human eye is interpreted by the brain as colors; from 400nm (violet) to 700nm (red). All other visible colors are between these wavelengths - indigo, blue, cyan, green, yellow and orange, as seen in e.g. a rainbow. When viewed together, these wavelengths appear as white light.

A green leaf looks green because it reflects green wavelengths present in white light. If you look at it under a red light it will appear black, because the lighting contains no green. The same applies when you buy a colored item of clothing - you might take it to the door or window to check how it looks in daylight. This is because interior lighting contains a slightly different mixture of wavelengths from the light outside, and consequently alters the apparent color of the garment.

The exact same can be said for network video. The color output of an illuminator affects the color seen by the camera, as in e.g. the yellowish light seen under sodium street lighting. To provide true color network video images, white light illuminators need to provide color-corrected illumination matched to the visible spectrum.

Colored objects reflect light selectively. They reflect only the wavelengths (i.e. colors) that you see, and absorb the rest. A red flower, for instance, contains pigment molecules that absorb all the wavelengths in white light other than red, so that red is the only color it reflects.

At wavelengths lower than the visible spectrum, the radiation becomes ultraviolet (UV), which burns the skin (tanning) and is therefore unsafe for network video. At wavelengths higher than the visible spectrum, the radiation becomes infrared (IR).

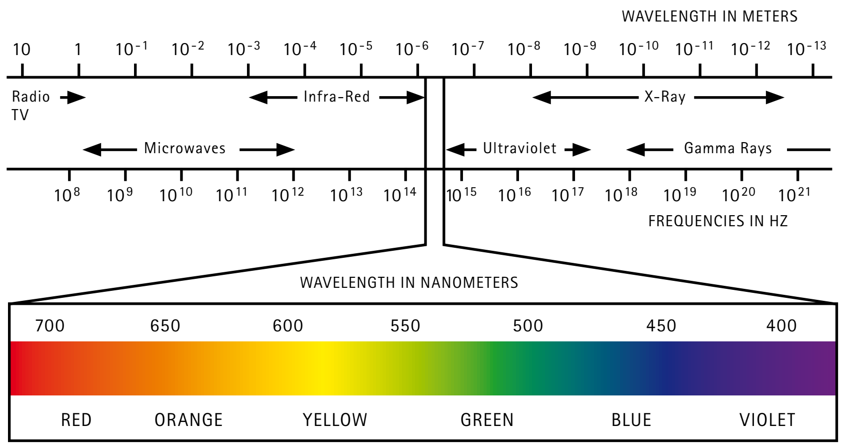


Figure 1: The wavelengths of visible spectrum

4. What is infrared light?

Infrared light (IR) is light at higher wavelengths that the human eye can see. The infrared light used for network video lighting is at wavelengths slightly greater than the visible spectrum, i.e. between 700 and 1100nm. This IR range is also known as Near Infrared (NIR) light.

As the camera can "see" some infrared light that is invisible to the human eye, there are various alternatives as to how this can be displayed on a computer screen. Usually the image is shown in black and white, with the scene appearing as it would if the human eye could see infrared light. Other false colors can also be used to show the content of infrared light compared to visible light. This is sometimes used in scientific imaging.

Applications that require covert surveillance, or which must otherwise avoid even low levels of visible lighting are ideal for infrared light.

5. Color or monochrome images?

The first question to answer when setting up night time surveillance lighting is whether to go for color or monochrome images. Color is preferable in many cases, but care must be taken to provide true color, which can be achieved by using a color-corrected illuminator. Consider the yellow light provided by low pressure sodium street lighting - using incorrect white light can actually impair performance and lead to inaccurate color rendition – a camera is only as good as the available light.

Infrared should be the method of illumination in all cases where white light would be too intrusive or where covert surveillance is required. Infrared lighting can also illuminate at greater distances than white light at the same power level.

6. Brightness and glare

Brightness is the subjective perception of luminance from a given area. Glare is the result of excessive contrast between bright and dark areas within the field of view. This problem is greater in darkness, when contrast between bright and dark areas make it difficult for the human eye (and network video cameras using infrared) to adjust to changes in brightness.

7. Light and surfaces

Light at wavelengths visible to the human eye is interpreted by the brain as colors; from 400nm (violet) to 700nm (red). All other visible colors are between these wavelengths - indigo, blue, cyan, green, yellow and orange, as seen in e.g. a rainbow. When viewed together, these wavelengths appear as white light.

7.1. Diffusion

A diffusing material scatters light passing through it. The direction and type of light changes as it passes through the material.

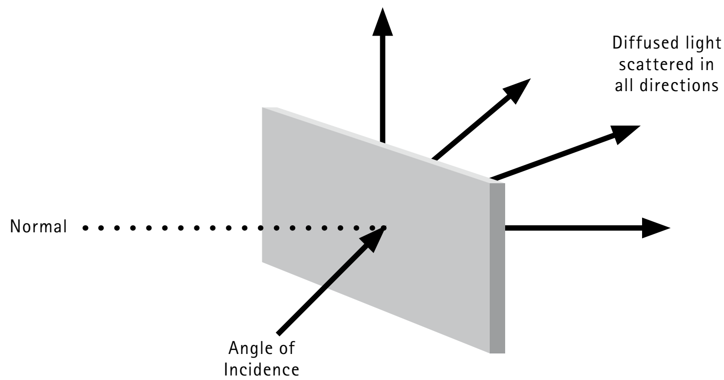


Figure 2: Light diffusion

7.2. Reflection

When light hits a surface it can bounce back as a reflection. The quality of the surface affects the type of reflection. Highly textured surfaces scatter light, due to tiny irregularities in the material, whilst a flat surface such as a mirror provides a more focused reflection.

7.2.1. Specular reflectance

If a surface reflects light like a mirror – it is said to have specular reflectance. With specular surfaces, the angle of incidence is equal to the angle of reflectance.

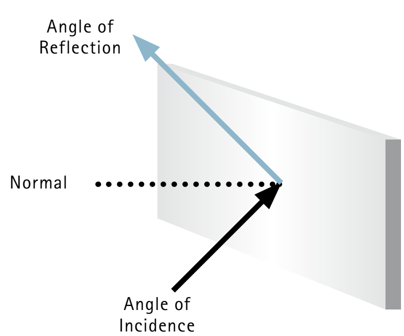


Figure 3: Specular reflection

7.2.2. Diffuse reflectance

Diffuse reflection surfaces bounce light in all directions due to tiny irregularities in the reflective surface. For example, a grained surface will bounce light in different directions. A diffuse reflective surface can scatter light in all directions in equal proportions.

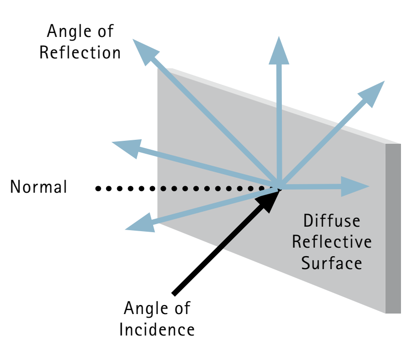


Figure 4: Diffuse reflection

7.2.3. Retro-Reflection

In this type of reflection the surfaces bounce light back in the direction it came from. Traffic signs and vehicle number plates have retro- reflective surfaces.

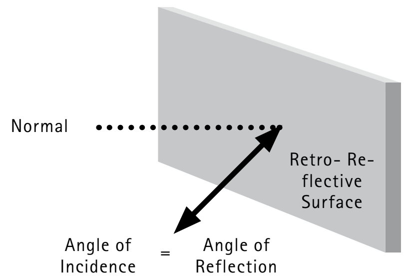


Figure 5: Retro-reflection

7.3. Reflectance levels

Reflectivity is a measure of the reflected power compared to incident power. Objects reflect light at different intensities, and energy not reflected is absorbed and converted to heat. Objects with low reflectivity absorb a lot of energy – which is why e.g. a brick wall feels warm in sunlight. See below.

It is important to remember that the camera does not use the ambient light on a scene as detected by a light meter, but instead the amount of light reflected by objects in the scene.

7.4. Absorption

Some surfaces actually absorb light. Colored surfaces absorb some light and reflect the rest – which is why they appear a particular color. A black surface absorbs most of the light falling on it. The light energy is usually turned into heat, so dark materials heat up easily.

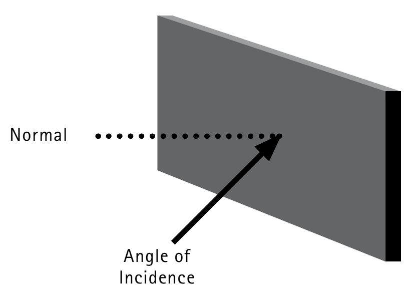


Figure 6: Light absorption

8. Light sources

8.1. Incandescent lamps (including halogen)

Incandescent bulbs were the first bulbs developed and are highly inefficient, wasting 90% of input energy as heat, making them hot to touch. Halogen bulbs provide a minimal increase in efficiency but still waste up to 85% of the input energy as heat. For network video purposes, incandescent bulb life is limited and they are very inefficient.

8.2. Fluorescent lamps

Use of these lamps for network video purposes is limited, due to the "pulse" effect perceived when the scene is viewed with a network video camera. These lamps are generally low power and designed mainly for internal fitting. As they have a large diffused source, the light output is difficult to focus and control.

8.3. HID (High Intensity Discharge) lamps

These are efficient, provide good color rendition and have a long life – up to 12,000 hours. HID lamps could well be used in network video, but they suffer from long start-up times (2-3mins) and cannot be turned on again immediately after being turned off.

8.4. LEDs

Light Emitting Diodes are the fastest growing lighting solution for network video applications. Their efficiency is typically 80-90%, with the greatest efficiency coming from LEDs producing red light. The LEDs are often chosen in network video applications because of their advantages, which include extremely low electrical consumption; low operating temperatures and continuity of color throughout the unit's operating life.

Unlike traditional bulbs, LEDs are also highly durable, insensitive to vibration, and their hard casing makes them difficult to break. They are also capable of emitting light at a given wavelength without the need for a filter and are quick start devices.

LEDs offer the lowest possible running costs (less than 100 watts for the highest power units) with the longest operating life - up to 100,000 hours (10 years).

In comparison, fluorescent bulbs typically last 10 000 hours and incandescent bulbs 1000 hours.

9. Network video lighting - which wavelength?

White light: A mixture of light at 400-700nm provides true white light.

Practical uses:
> Illuminate an area for the network video system
> Improve the overall level of illumination for personnel
> Provide a welcoming environment for authorized personnel
> Deter crime by illuminating a secure area upon intrusion
> Can be used with monochrome, color, and day/night cameras

Infrared:
> 715-730nm. Overt IR produces a red glow like a red traffic light.
> 815-850nm. Semi-covert IR with a faint red glow.
> 940-950nm. Covert IR - invisible to the human eye.

Practical uses of infrared:
> Provides discreet or covert illumination for network video
> Minimizes light pollution
> Provides very long distance illumination
> Can be used with monochrome or day/night cameras

10. Light and safety

As white light is visible to the human eye we have a natural protection against overexposure to white light. The iris and the eyelids close to reduce the input of visible light. If this is not enough, we simply turn away from the light. As we cannot see infrared light, our eyes cannot automatically adjust to over-exposure. However, infrared does produce heat – which can be used as a safety measure. If you can feel the heat of the IR unit - do not look at the source. Even the most powerful IR units, at angles of 10 degrees, are eye safe beyond distances of 2 meters.

11. Beam patterns

To provide illumination for network video, the angle of illumination should be adjusted so as to light the whole scene adequately. Modern Adaptive Illumination™ units allow the angle of illumination to be adjusted onsite, to suit the specific scene requirements. Lighting that is too narrow will produce "white out" or glare in the middle of the scene, with some areas not correctly illuminated.

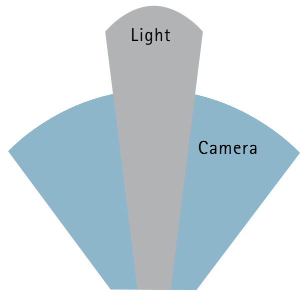


Figure 7: Lighting is too narrow for camera field of view

Lighting that is too wide means "wasted" light and reduced viewing distance.

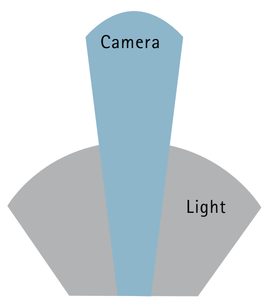


Figure 8: Lighting is too wide for camera field of view

Many installations use varifocal lenses, and ideally there should be the same level of flexibility as regards lighting, so as to maximize system performance. Flexible illuminators for video surveillance, such as those in Axis' portfolio, offer a range of output angles - allowing you to select the angle that covers the exact field of view and provides the best images. Adjustment is quick and convenient, and the available angles are easily selectable.

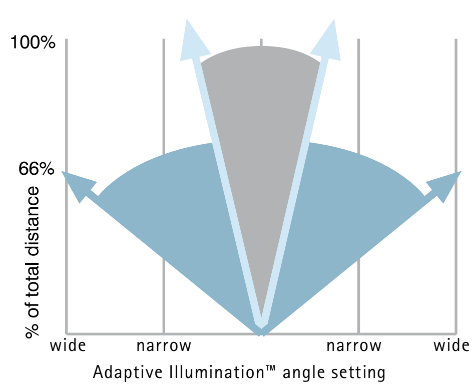


Figure 9: Adaptive illumination to cover many angles of view

12. The inverse square law

The amount of light available at a particular distance is inversely proportional to the square of the distance from the light source. As light obeys this inverse square law, we'll now look at how this law is applied.

As light travels away from the point source it spreads both horizontally and vertically, with less light at greater distance. In practice, this means that if an object is moved from a given point to another point twice as far from the light source, it will then receive only ¼ of the light (2 x distance2 = 4).

Taking this further, if an object 10m from a light source receives 100 Lux, moving the object to 40m from the source means it will receive only 1/16th of the light (4 x distance2 = 16) resulting in the object receiving only 6.25 Lux. The inverse-square law applies to both white light and infrared light in the same way.

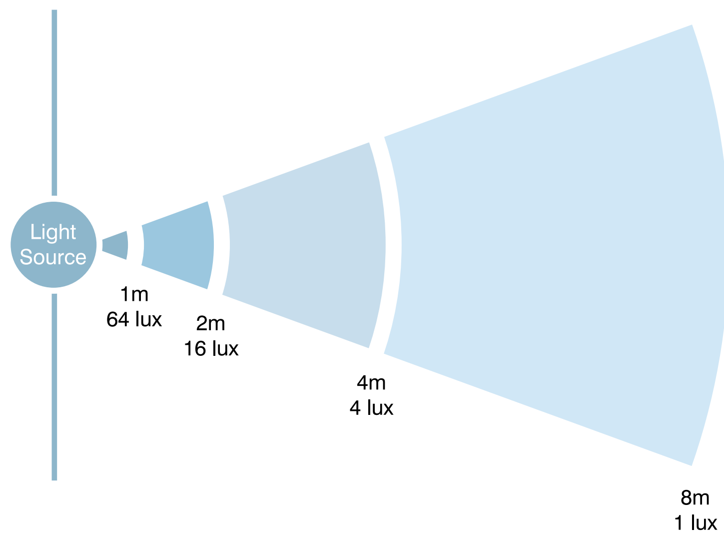


Figure 10: The inverse square law

13. Illumination distances for Axis products

The chart shown below is a guide to selecting an appropriate Axis infrared illuminator for the camera's horizontal angle of view and the distance to the object from the illuminator. Note that the solid area denotes optimum usage. The shaded area denotes less-than-optimum usage.

Approximate maximum illumination distances - per camera angle and per illuminator model (distances not to scale)

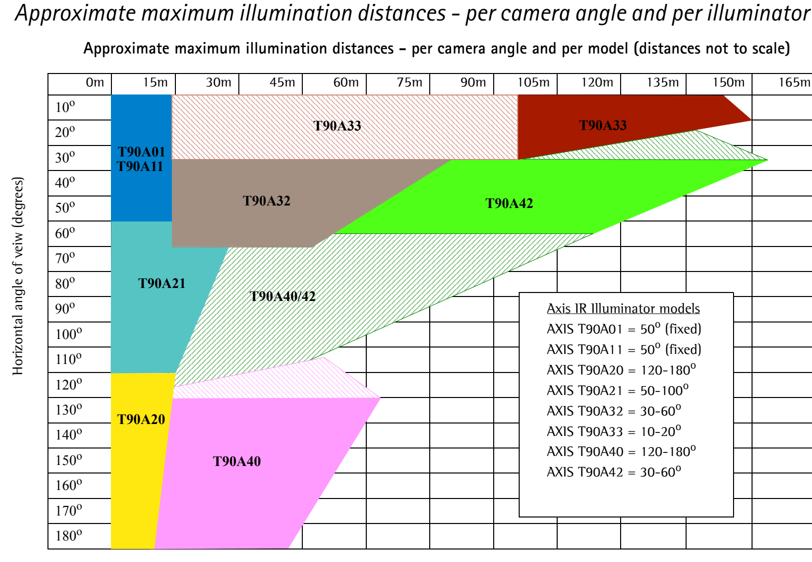


Figure 11: IR Illuminator selection chart

14. Using multiple illuminators

The inverse-square law explains how the amount of light drops over distance, but it can also be used to calculate how many additional illuminators are needed to achieve specific increases in distance.

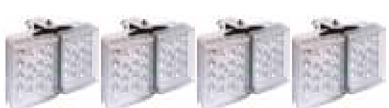
If the distance from a single illuminator is doubled - then the amount of the light is reduced to 25%. So to illuminate at twice the distance possible with one illuminator (keeping the same power at the scene) then 4 illuminators will be needed (22 = 4). Similarly, to achieve 3 times the distance of one illuminator, 9 illuminators will be required (32 =9).

The inverse square law can also be used to calculate the effect of using multiple illuminators, by taking the square root of the change in available light at source. For example, using 4 illuminators will produce a 2-fold increase in distance (√4 = 2), and using 25 illuminators will result in a 5 fold increase in distance (√25 = 5).

TIP 1! It is not always necessary to use multiple illuminators to achieve increases in distance. Illuminators with narrower angles or more powerful illuminators may both provide the required additional increase in distance.

TIP 2! If you only need to illuminate a particular object at a particular distance, using e.g. a zoom lens, then there is also the option to place a small illuminator close to the object. An example of an application of this type is a gate or door at a site perimeter, relatively far from the site's buildings and other infrastructure.

1 UNIT = 1 x DISTANCE



4 UNITS = 2 x DISTANCE

No. of Illuminators	Distance Multiplier
1	1
2	1.4
3	1.7
4	2
5	2.2
6	2.4
7	2.6
8	2.8
9	3

TIP 3! Doubling the illumination distance requires 4 x the power.

TIP 4! Doubling the number of illuminators provides a 1.4 x increase in distance.

15. Measuring light

15.1. White light

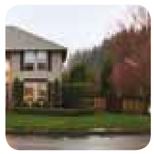
White light is measured in lux, the SI unit of illuminance, which also takes into account the area the light is spread over. 1 lux = 1 lumen per square meter.

The foot candle is still widely used as a unit of measurement: 10 lux ≈ 1 foot candle.

White light at the scene can be measured by the simple use of a light meter. Typical lux light levels are:

Bright sunny day =
10,000 - 100,000 lux

Street lighting =
5 lux



Overcast day =
1,000 - 10,000 lux

Full moon =
0.1 lux

Twilight =
1 - 100 lux

Bright, clear starlight =
0.01 - 0.0001 lux

Figure 13: Light intensity for various scenarios

15.2. Infrared

As lux is a measurement of visible light, and by definition infrared produces invisible light, lux cannot be used to measure infrared power. The most common form of measurement for infrared light is mW per square meter, a simple statement of energy output from a light source over a given area.

16. The need for even illumination

The most important aspect in designing any lighting system is achieving even illumination. Both the human eye and the network camera/lens need to handle dramatic differences in the amount of light within the field of view.

When driving at night on an empty road at night you can see clearly using only the headlights from your own car. However, when a car approaches from the opposite direction, although the light on scene actually increases, your night vision will still be impaired, as there is now a very strong light around the centre of the scene causing the iris in your eye to close. The same thing happens with a network video camera – a bright spot within the image will cause the lens to close and reduce night-time performance. To achieve the best images at night, the illumination must be evenly distributed, using lighting products designed for this purpose.

17. Specifying the correct camera

17.1. Sensitivity

This describes a camera's sensitivity to light and essentially measures the minimum light level needed to produce acceptable images, although this value is very subjective. An image may be acceptable to one person and totally unacceptable to another.

Sensitivity is typically measured in lux, with camera manufacturers stating the minimum lux level needed to provide acceptable pictures. However, this statement does not usually specify if the minimum lux figure represents the minimum light on scene, at the lens, or at the camera chip. For Axis cameras, this value always applies to the light on scene.

Although lux claims tend to be overstated, and although minimum lux only describes a cameras performance with visible light, this lux value is still the only easily available measure of a camera's sensitivity.

TIP 1! There is no such thing as a zero lux camera – every camera needs light to produce high quality images. Even the most light-sensitive camera will produce higher signal/lower noise pictures when there is more light available. The exception is thermal cameras, which create images based on the heat that radiates from a vehicle or person, allowing the cameras to produce images also in complete darkness.

TIP 2! For more information about light sensitivity, you can also refer to Axis' white paper - **In the best of light** - available at www.axis.com/corporate/corp/tech_papers.htm.

18. Specifying the correct lens

18.1. F-stop

The f-stop (aperture) of a lens determines how much light passes through it to the camera chip. In simple terms, the lower the f-stop, the more light passes through the lens, although the quality and manufacture of the lens also affects the amount of light that can pass. The table below shows the impact of using different aperture lenses in a network video system:

f/Number	Light passed in %	Amount of light needed to achieve 1 lux at sensor
f/1 •	20%	5 lux
f/1.2	15%	7.5 lux
f/1.4 •	10%	10 lux
f/1.6	7.5%	13.3 lux
f/1.8	6.25%	16 lux
f/2 •	5%	20 lux
f/2.4	3.75%	30 lux
f/2.8 •	2.5%	40 lux
f/4 •	1.25%	80 lux

• = a full f-stop

Figure 14: F-stops and light levels required to achieve 1 lux at the sensor

TIP! For most camera sensors, the lower the f-Stop of a lens, the more light will pass to the sensor.

For a zoom lens, the best f-stop is only achievable at the wide setting. As the lens is zoomed, the aperture closes, which affects how much light is needed on scene to produce good images at low light levels.

18.2. Transmission

The efficiency of a lens is measured by its transmission. Passing through the lens, some of the light will be lost as a result of the lens material, thickness and coating characteristics. A lens with a higher efficiency will pass a higher percentage of the light. Whilst the f-stop of a lens describes how much light the lens will pass, it is not a measure of its overall efficiency.

TIP! The transmission of a lens changes with wavelength. For example, one lens may pass 95% of visible light and 80% at 850nm infrared, whilst another may pass 95% of visible light and 50% at 850nm infrared. When specifying the lens, consider the wavelength of light it will be used with. Also note that glass lenses tend to be more efficient than plastic lenses.

18.3. Corrected lenses

Infrared Corrected lenses

Infrared corrected lenses are designed to remove the problem of focus shift between day and night light, using specialist glass and coating technology to minimize light dispersion. Focus shift is caused by the different wavelengths of light. Each individual wavelength focuses at a different point after passing through the lens.

Color corrected lenses

Light sources, including the sun, produce a broad spectrum of lighting. White light as we know it is simply the range of the lighting spectrum visible to humans. As a result, a lens must control which light passes through to the camera, so as to create an image accurate to the images as perceived by the human eye. Many cheap lenses do not efficiently match their color passing with the visible spectrum, so as a result they provide inaccurate color images. Color corrected lenses pass only visible light and focus each individual color at the same point - providing true color and sharp images.

Most color-corrected lenses are not suitable for use with infrared lighting, although there are some exceptions.

All images in this white paper courtesy of Raytec - www.rayteccctv.com

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About Axis Communications

Axis is an IT company offering network video solutions for professional installations. The company is the global market leader in network video, driving the ongoing shift from analog to digital video surveillance. Axis products and solutions focus on security surveillance and remote monitoring, and are based on innovative, open technology platforms.

Axis is a Swedish-based company, operating worldwide with offices in more than 20 countries and cooperating with partners in more than 70 countries. Founded in 1984, Axis is listed on the NASDAQ OMX Stockholm under the ticker AXIS. For more information about Axis, please visit our website at www.axis.com

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