

WHITE PAPER

Sensor size and image quality in 4K cameras

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1 Summary

Cameras with 4K resolution and large sensors combine a high resolution with large pixels. This combination provides better image quality than other 4K cameras, especially in low light.

2 Introduction

To be able to capture good surveillance footage, a camera must have a high-quality image sensor that provides a resolution that matches the purpose of the surveillance. The resolution is determined by the number of pixels on the sensor and a matching lens. But the size of the pixels also has a significant impact on image quality. The pixels can be larger if a larger sensor is used.

This white paper explains the impact of sensor size on image quality and provides a comparison between sensor sizes of 4K cameras from Axis.

3 How does a digital image sensor work?

The image sensor is a key component of any digital camera. The image sensor registers the light in all parts of the scene and converts it to electric signals. These signals provide the information that is needed for the camera to, after some additional amplification and processing, reproduce a digital image of the scene.

Light is made up of photons, which are discrete bundles of energy. If the light intensity in a scene increases, for example when the sun breaks through the clouds, it means that a higher number of photons will travel toward the camera.

The camera's image sensor is made up of millions of photodetectors (photo-sensitive spots), commonly known as pixels. Each pixel absorbs photons and converts them to electrons, essentially converting the incoming light into an electronic signal. A pixel keeps capturing photons throughout a defined period of time which is the camera's exposure time, or exposure interval. After that period of time, the pixel is read out and its charge is measured. A new exposure interval begins and the pixel can capture new photons again.

Each pixel has a certain size and can hold only a certain number of photons before it becomes saturated. If the exposure time is long, or the scene is too bright, pixels may reach their saturation point before the exposure time is up: they are full and can't capture any more photons. The saturation of pixels will cause overexposure in the image.

3.1 Impact of different resolutions

As the surveillance industry has continued to move to higher resolutions, manufacturers have usually tried to keep the same sensor size to avoid the higher cost of using a larger sensor. This means they need to fit more photodetectors in the same sensor area, making each pixel smaller and able to capture less light. The charge after each exposure interval will consequently be lower and the electric signal from each pixel will need more amplification before it can be used to form the image. The signal-to-noise ratio in small pixels is generally lower due to the lower signal.

So, simply by increasing the number of pixels in a sensor of the same size, you will get better resolution, but you may also get images with lower quality. This is especially true in low light scenes, where image noise tends to be more disturbing. If you instead increase the size of the sensor, each photodetector can capture more photons and generate a stronger signal with less noise.

4 Implications of larger pixels

Compared to another 4K camera that is the same in all other aspects, the camera with a larger sensor combines the high resolution with large pixels, which provides better image quality, especially in low light.

To benefit from using a larger sensor, the whole design of the camera must be tailored to accommodate the sensor. An obvious example is that the lens must fit to the new size and match the resolution of the sensor. This makes the camera physically larger.

4.1 More signal, less noise

The signal-to-noise ratio, SNR, is a measure that compares the level of a desired signal to the level of the background noise. In a sensor with larger pixels, each pixel captures more photons during a given exposure interval. This provides a higher level of desired signal, and thus, a higher SNR. With less noise from the sensor, the camera can produce images that are clearer and crisper.

When each pixel can capture a larger number of photons, the digital image signal that it produces will be stronger. This is true in all scenes, but especially so in low-light scenes or in the low-light areas of a scene, since those would usually require more amplification and thus contain more noise. So, using larger pixels means less noise and better low-light performance in the whole image.

4.2 More photon-absorption capacity, more dynamic imaging

With larger pixels, each pixel can hold more photons before becoming saturated. This enables the camera to capture a wider dynamic range within one exposure. However, the size of the pixels also makes it possible to decrease the exposure time since they allow the camera to capture enough photons in a shorter time. A shorter exposure time is often desired since it can provide more freedom to control the image result. For example, a shorter exposure enables better capturing of scenes with fast movements, keeping motion blur low.

The possibility for each pixel to reproduce a wider dynamic range within one exposure should not be confused with overall WDR (wide dynamic range) imaging techniques. These normally incorporate varieties of multiple exposures and may be necessary in order to capture scenes with extreme dynamic range.

5 Sensor sizes in Axis 4K cameras

Axis offers cameras of various sensor sizes, including several that combine 4K resolution with a large sensor. With pixels that are more than four times larger than those in most other 4K cameras, the cameras with large sensors effortlessly produce high-resolution footage that is clear and crisp even in low light. They combine the high resolution of 4K with the premium sensitivity of the best low-light cameras.

Figure 1. Comparing sensor sizes and pixel sizes between a selection of 4K network cameras. The sensor size and pixel size of Axis premium 4K cameras with large sensors are more than four times larger than those of typical or industry premium 4K cameras.

- 1 Sensor size
- 2 Pixel size
- 3 Axis premium 4K 4/3" sensor
- 4 Industry premium 4K 1/1.8" sensor

5 *Typical 4K 1/2.5" sensor*

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