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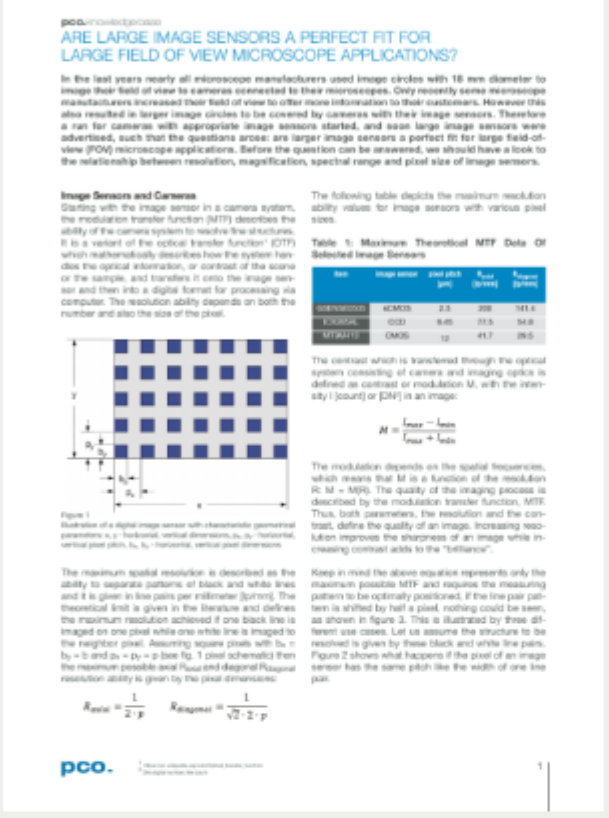
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ARE LARGE IMAGE SENSORS A PERFECT FIT FOR LARGE FIELD OF VIEW MICROSCOPE APPLICATIONS?

In the last years nearly all microscope manufacturers used image circles with 18 mm diameter to image their field of view to cameras connected to their microscopes. Only recently some microscope manufacturers increased their field of view to offer more information to their customers. However this also resulted in larger image circles to be covered by cameras with their image sensors. Therefore a run for cameras with appropriate image sensors started, and soon large image sensors were advertised, such that the questions arose: are larger image sensors a perfect fit for large field-of-view (FOV) microscope applications. Before the question can be answered, we should have a look to the relationship between resolution, magnification, spectral range and pixel size of image sensors.

Image Sensors and Cameras

Starting with the image sensor in a camera system, the modulation transfer function (MTF) describes the ability of the camera system to resolve fine structures. It is a variant of the optical transfer function1 (OTF) which mathematically describes how the system handles the optical information, or contrast of the scene or the sample, and transfers it onto the image sensor and then into a digital format for processing via computer. The resolution ability depends on both the number and also the size of the pixel.

The following table depicts the maximum resolution ability values for image sensors with various pixel sizes.

Table 1: Maximum Theoretical MTF Data Of Selected Image Sensors

Item	Image sensor	pixel pitch [µm]	R_{axial} [lp/mm]	$R_{diagonal}$ [lp/mm]
pco.edge 5.5	sCMOS	6.5	77	54.5
pco.pixelfly	CCD	6.45	77.5	54.8
MT9J003	CMOS	1.2	41.7	29.5

The contrast which is transferred through the optical system consisting of camera and imaging optics is defined as contrast or modulation M, with the intensity I [count] or [DN] in an image:

$$M = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

The modulation depends on the spatial frequencies, which means that M is a function of the resolution R: M = M(R). The quality of the imaging process is described by the modulation transfer function, MTF. Thus, both parameters, the resolution and the contrast, define the quality of an image. Increasing resolution improves the sharpness of an image while increasing contrast adds to the "brilliance".

Figure 1
Illustration of a digital image sensor with characteristic geometrical parameters x, y - horizontal, vertical dimensions, p_x, p_y - horizontal, vertical pixel pitch, b_x, b_y - horizontal, vertical pixel dimensions

The maximum spatial resolution is described as the ability to separate patterns of black and white lines and it is given in line pairs per millimeter [lp/mm]. The theoretical limit is given in the literature and defines the maximum resolution achieved if one black line is imaged on one pixel while one white line is imaged to the neighbor pixel. Assuming square pixels with $b_x = b_y = b$ and $p_x = p_y = p$ (see fig. 1 pixel schematic) then the maximum possible axial R_{axial} and diagonal $R_{diagonal}$ resolution ability is given by the pixel dimensions:

$$R_{axial} = \frac{1}{2 \cdot p} \qquad R_{diagonal} = \frac{1}{\sqrt{2} \cdot 2 \cdot p}$$

Keep in mind the above equation represents only the maximum possible MTF and requires the measuring pattern to be optimally positioned. If the line pair pattern is shifted by half a pixel, nothing could be seen, as shown in figure 3. This is illustrated by three different use cases. Let us assume the structure to be resolved is given by these black and white line pairs. Figure 2 shows what happens if the pixel of an image sensor has the same pitch like the width of one line pair.

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Are Large Image Sensors A Perfect Fit for Large Field of View Microscope Applications?

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