# pco.edge

scientific CMOS camera

low noise
**1.4 electrons**

high resolution
**5.5 megapixel**


high speed
**100 fps**

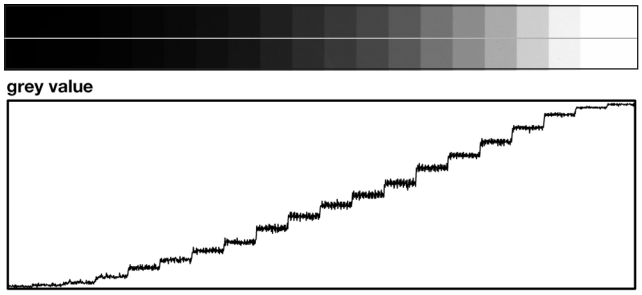
high dynamic range
**22 000 : 1**

The new pco.edge is a breakthrough in scientific imaging cameras, due to its distinctive ability to simultaneously deliver extremely low noise, fast frame rates, wide dynamic range, high quantum efficiency, high resolution and a large field of view - all in one image.

pco.
imaging

1288
EMVA Standard Compliant

# features




The top image shows an extract of a typical pco.edge recording of a grey scale with a 1 : 10 000 dynamic in 20 steps.
The bottom image is a plot of the grey values profile along the centered line through the top image (with gamma 2.2).

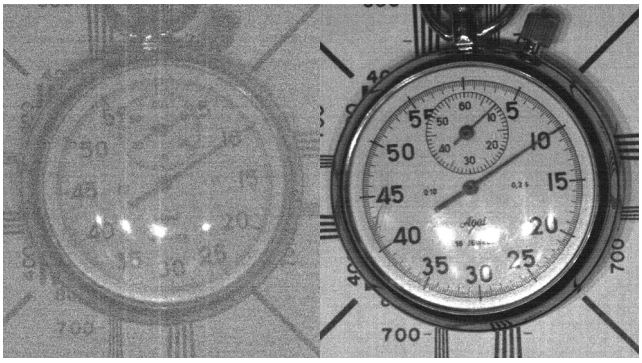
## 22 000:1 dynamic range

Due to the excellent low noise and the high fullwell capacity of the sCMOS image sensor an intra scene dynamic range of better than 22 000 : 1 is achieved. A unique architecture of dual column level amplifiers and dual 11 bit ADCs is designed to maximize dynamic range and to minimize read out noise simultaneously. Both ADC values are analyzed and merged into one high dynamic 16 bit value.

## supreme image quality

The new pco.edge camera (with scientific CMOS image sensor) features outstanding low read out noise of 1.4 electrons ($e^-$) rms. Even at maximum speed of 100 frames/s at full resolution of 2560 x 2160 pixel the noise is less than 2 $e^-$ rms. Moreover the pco.edge provides an excellent homogeneous pixel response to light (PRNU, photo response non-uniformity) and an excellent homogeneous dark signal pixel behaviour (DSNU, dark signal non-uniformity), which is achieved by a sophisticated electronic circuit technology and firmware algorithms. The lower figure shows a comparison of a scientific grade CCD and the new pco.sCMOS image sensor under similar weak illumination conditions. This demonstrates the superiority of pco.sCMOS over CCD with regards to read out noise and dynamic, without any smear (the vertical lines in the CCD image).

The upper image shows the typical fixed pattern noise structures in the dark image of a standard CMOS image sensor, while the lower image shows a corresponding typical sCMOS dark image (same scale).



The left image was recorded by a scientific CCD camera while the right image was recorded by a pco.edge under identical conditions.

## flexibility

User selectable choice of rolling or global shutter mode for exposure provides flexibility for a wide range of applications. The advantages of rolling shutter are high frame rates and low read out noise whereas global shutter provides snapshot images for fast moving objects.

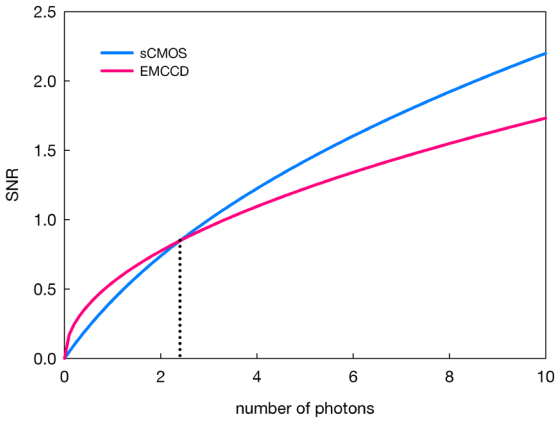
## free of drift

The new pco.edge camera features + 5 °C stabilized Peltier cooling, allowing for a continuous operation free of any drift phenomena in image sequences.

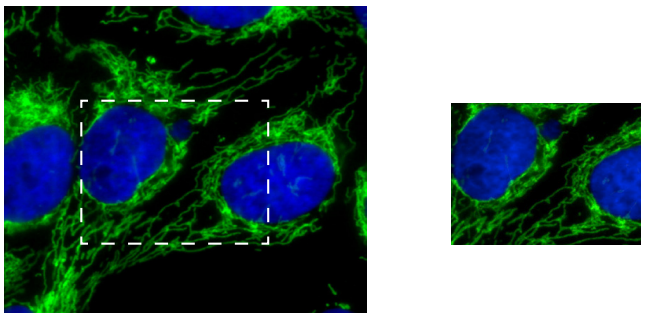
# features

## reaching emCCD domain

In the past emCCD image sensors featuring on-chip amplification were developed to detect the lowest level of light. However, amplification, while reducing read out noise, comes at the expense of dynamic range. Both features are not possible simultaneously in emCCD sensors. In addition, the amplification process generates excess noise, which reduces the effective quantum efficiency ($QE_{eff}$) of the emCCD sensor by the factor of two (e.g. the 90 % QE of a back illuminated emCCD sensor has an $QE_{eff}$ of 45 %). The excess noise present in emCCDs makes the pco.sCMOS the sensor of choice at light conditions above 2 photons per pixel (@ 60 % QE, assuming a cooled sensor with dark current = 0). Furthermore, available emCCD sensors are limited in resolution and frame rate.




The graph shows the signal-to-noise (SNR) curves of a typical emCCD camera (gain = 1000) and a sCMOS camera vs. number of photons.



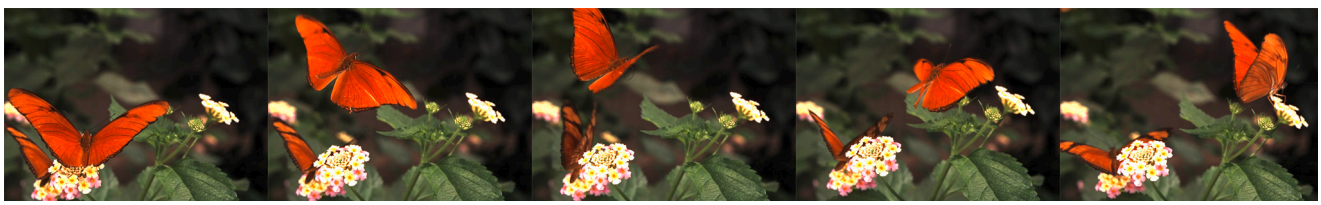
The two images show in comparison the field of view of a 5.5 Mpixel resolution vs. a 1.3 Mpixel resolution, courtesy of Dr. Stefan Jakobs, Dept. of NanoBiophotonics, MPI for Biophysical Chemistry

## high resolution

A 5.5 Mpixel resolution in combination with a moderate chip size (21.8 mm diagonal, 6.5 µm pixel pitch) benefits microscopy applications with low magnification factor and large field of view, thereby reducing processing times and increasing throughput. The figure compares the potential of the new field of view of the pco.edge to the 1.3 Mpixel image resolution which is widely used in microscopy applications for scientific cameras.

## high speed

The new pco.edge offers in fast mode a frame rate of 100 frames/s (fps) at full resolution of 2560 x 2160 pixel. As in many CMOS based cameras the frame rate increases significantly if smaller regions of interest (ROI) are used. The reduction of the image area works as well in favour of the frame rate of CCD sensors, but here unwanted regions still need to be read out at the expense of the total readout speed. The typical frame rate for a 1.3 Mpixel scientific CCD camera (6 $e^-$ read out noise) is 10 fps. The new pco.edge camera provides at 1.3 Mpixel resolution (< 2 $e^-$ read out noise) a frame rate of 210 fps in comparison.



Resolution 640 x 480 pixel @ 460 frames/s (color version)

# technical data

## image sensor

| | |
|---|---|
| type of sensor | scientific CMOS (sCMOS) |
| image sensor | CIS2051 |
| resolution (h x v) | 2560 x 2160 pixel |
| pixel size (h x v) | 6.5 µm x 6.5 µm |
| sensor format / diagonal | 16.6 mm x 14.0 mm / 21.8 mm |
| shutter modes | rolling and global (snapshot) |
| MTF | 76.9 lp/mm (theoretical) |
| fullwell capacity | 30 000 e⁻ |
| readout noise | < 1.4 e⁻ rms @ 33 fps (rs[1], ssc[2])<br>< 2.0 e⁻ rms @ 100 fps (rs[1], fsc[2])<br>< 3 e⁻ rms @ 50 fps (gs[1], fsc[2]) |
| dynamic range | 22 000 : 1 (86.9 dB) |
| quantum efficiency | 57 % @ peak |
| spectral range | 370 nm .. 1100 nm |
| dark current | 2 e⁻/pixel/s (rs[1]) @ 5 °C<br>240 e⁻/pixel/s (gs[1]) @ 5 °C |
| DSNU | < 2 e⁻ rms |
| PRNU | < 2 % (uncorrected) |
| anti blooming factor | 1 : 10 000 |

## camera

| | |
|---|---|
| frame rate | 100 fps @ 2560 x 2160 pixel (rs[1], fsc[2])<br>50 fps @ 2560 x 2160 pixel (gs[1], fsc[2]) |
| exposure/shutter time | 500 µs .. 2 s (rs[1])<br>10 µs .. 100 ms (gs[1]) |
| dynamic range A/D | 16 bit (ssc[2, 3])<br>12 bit (fsc[2, 3]) |
| A/D conversion factor | 0.46 e⁻/count |
| pixel scan rate | 95.3 MHz (ssc[2]) / 286 MHz (fsc[2]) |
| pixel data rate | 190.7 Mpixel/s / 572 Mpixel/s |
| region of interest | selectable |
| non linearity | < 1 % |
| cooled image sensor temperature | + 5 °C (@ + 25 °C ambient) |
| cooling method | Peltier with forced air (fan) |
| trigger input signals | frame trigger, sequence trigger |
| trigger output signals | exposure, busy |
| data interface | dual Camera Link (full, 10 taps) |
| time stamp | in image (1 µs resolution) |

[1] rs = rolling shutter / gs = global shutter
[2] ssc = slow scan mode - 16 bit / fsc = fast scan mode. The fast scan mode is always visually lossless compressed to 12 bit due to speed limitations given by the Camera Link interface.
[3] The high dynamic signal is simultaneously converted at high and low gain by two 11 bit A/D converters and the two 11 bit values are sophistically merged into one 16 bit value.

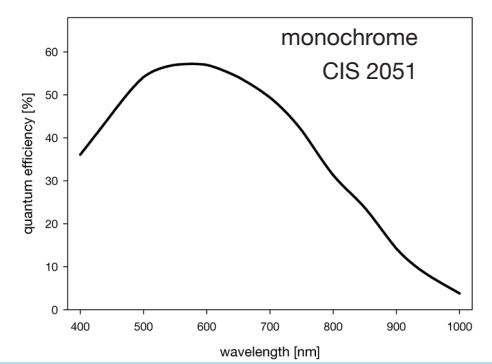
## general

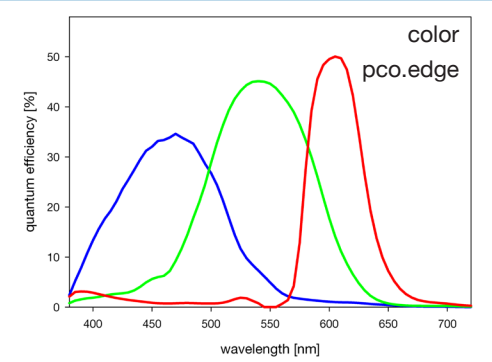
| | |
|---|---|
| power supply | 12 .. 24 VDC (+/- 10 %) |
| power consumption | 20 W |
| weight | 700 g |
| ambient temperature | + 10 °C .. + 40 °C |
| operating humidity range | 10 % .. 80 % (non-condensing) |
| storage temperature range | - 10 °C .. + 60 °C |
| optical interface | F-mount & C-mount |
| CE / FCC certified | yes |

## frame rate table

| | fast scan[2] | | slow scan[2] | |
|---|---|---|---|---|
| typical examples | rolling sh. | global sh. | rolling sh. | global sh. |
| 2560 x 2160 | 100 fps | 50 fps | 33.3 fps | 16.7 fps |
| 1920 x 1080 | 200 fps | 100 fps | 66.7 fps | 33.3 fps |
| 1600 x 1200 | 180 fps | 90 fps | 60 fps | 30 fps |
| 1280 x 1024 | 210 fps | 105 fps | 70 fps | 35 fps |
| 640 x 480 | 450 fps | 225 fps | 150 fps | 75 fps |
| 320 x 240 | 900 fps | 450 fps | 300 fps | 150 fps |

## quantum efficiency



# technical data

## software

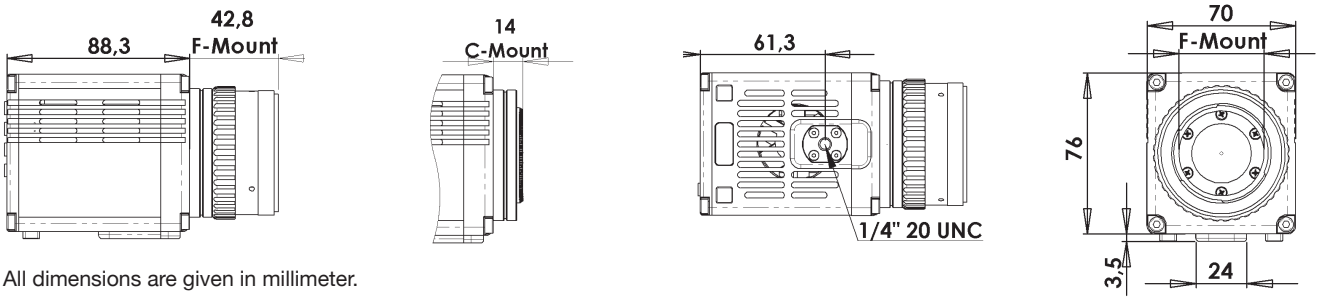
Camware is provided for camera control, image acquisition and archiving of images in various file formats (WindowsXP and later). A free software development kit (SDK). including a 32bit dynamic link library, for user customization, integration on PC platforms is available. Drivers for popular third party software packages are also available.
(Please visit www.pco.de for more information)

## options

monochrome & color versions available; custom made versions (e.g. water cooling, fan-less, deep cooled...)

## dimensions

F-mount and c-mount lens changeable adapter.




All dimensions are given in millimeter.

## camera views



Further information can be found on www.pco.de & www.pco-scmos.com

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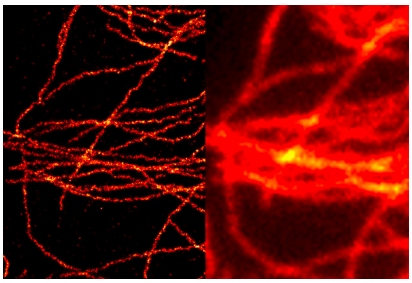
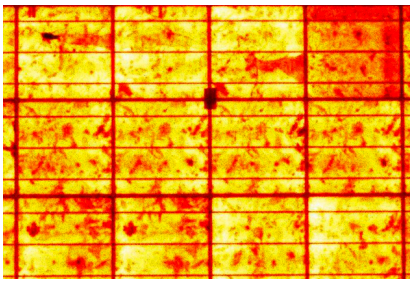
# applications

### life science



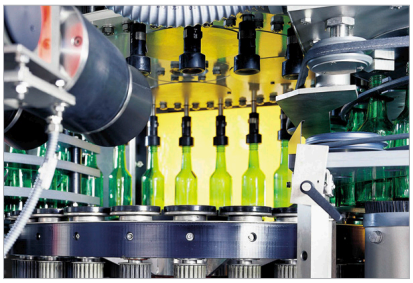
A widefield (right) and a GSDIM super-resolution (left) microscopy image of tubulin fibers, courtesy of Leica Microsystems, Germany

### physical science



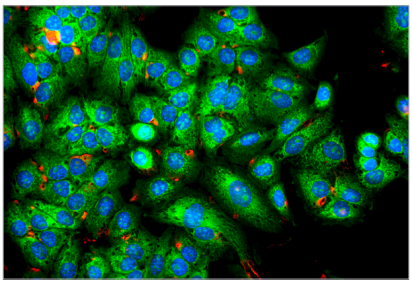
Electroluminescence of a solar cell panel to measure and visualize defects of the cells, recorded with the pco.edge camera, PCO, Germany

### industry



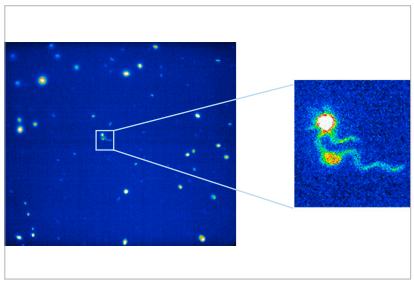
Bottle inspection measuring at a high dynamic range, courtesy of Krones AG, Regensburg, Germany

### life science



Human liver cancer cells, which have been stained with different probes for membranes, nuclei and permeability, courtesy of TILL Photonics, Germany

### life science



A widefield microscopy image of small bacteria obtained with the pco.edge camera, where the enlarged area shows the stained flagella, courtesy of Prof. Dr. Wirth, Microbiology, University of Regensburg, Germany

### TV / Broadcasting

A high speed image of a horse race finish in full HD. The 200 fps at full HD together with the supreme image quality are useful features of the pco.edge for slow motion applications.

## application areas

■ Live cell microscopy ■ Single molecule detection ■ Super resolution microscopy ■ TIRF microscopy / waveguides ■ Spinning disk confocal microscopy ■ Genome sequencing (2nd and 3rd gen) ■ FRET ■ FRAP ■ Lucky astronomy / imaging ■ Adaptive optics ■ Solar astronomy ■ Fluorescence spectroscopy ■ Bio- & Chemi - luminescence ■ High content screening ■ Photovoltaic inspection ■ X-ray tomography ■ Ophthalmology ■ Flow cytometry ■ Biochip reading ■ Machine vision ■ TV / Broadcasting ■ Spectral (hyperspectral) imaging ■ Laser Induced Breakdown Spectroscopy (LIBS)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