white paper

pco.double shutter

special readout mode for fluid dynamics research

DS double shutter

resolution
up to 26 MPixel

interframing time
down to 100 ns

excelitas.com

PCO Camera Range with Double Shutter Feature

Our high-performance camera series with Double Shutter (DS) capability is specifically engineered for fluid dynamics research and demanding industrial measurement applications. The DS technology allows the capture of two sequential images with extremely short interframing times, enabling precise measurements in Particle Image Velocimetry (PIV) experiments. With interframing times ranging from 100 ns to 1 µs, and resolutions from 1.4 MPixel to 26 MPixel, these cameras provide exceptional image quality across a broad range of fields of view and flow speeds, ensuring accurate and detailed velocity measurements for any experimental setup. Whether you need to analyze high-speed flows or capture large-scale turbulence, our DS-capable cameras deliver reliable performance every time.

Camera	pco.edge 5.5 DS	pco.dimax 3.6 DS ST	pco.dicam C1	pco.edge 26 DS	pco.panda 26 DS	pco.pixelfly 1.4 DS
resolution [px]	2560 x 2160	1984 x 1808	2048 x 2048	5120 x 5120	5120 x 5120	1392 x 1040
DS interframing time	100 ns	250 ns	300 ns	350 ns	1 µs	1 µs
single shutter - frame rate	50 fps	2166 fps	106 fps	149 fps	6 fps	13.5 fps
double shutter - frame rate[1]	25 fps	1085 fps	26 fps	74 fps	1 fps	7.3 fps
pixel size [µm]	6.5 x 6.5	11 x 11	6.5 x 6.5	2.5 x 2.5	2.5 x 2.5	6.45 x 6.45
exposure time	10 µs..100 ms	10 µs..10 ms	20 ns..1 ms	6 µs..60 s	6 µs..350 ms	1 µs..60 s
dynamic range	83 dB	60 dB	89 dB	61 dB	66 dB	68 dB
sensor technology	sCMOS monochrome or color	CMOS monochrome	intensified sCMOS	sCMOS monochrome	sCMOS monochrome	CCD monochrome or color
sensor cooling	air or liquid	air or liquid	air	air & liquid	passive	passive
data interface	CLHS FOL	CLHS FOL	CLHS FOL	CLHS FOL	USB 3.1 Gen 1	USB 2.0

[1]In DS mode, the fame rate values correspond to double images.

Double Shutter Mode in PCO Cameras

The outstanding global shutter capabilities of PCO cameras make them the ideal choice for effective double imaging – a key requirement to perform all types of measurements in fluid dynamics applications.

Fluid Dynamics Application Example: Particle Image Velocimetry

Particle Image Velocimetry (PIV) is an optical measurement technique widely used for analyzing fluid flow in a non-intrusive manner. The method involves seeding the flow with tracer particles and capturing two consecutive images within a very short time interval. By analyzing the displacement of particle patterns between the two images, velocity vectors can be computed over small interrogation regions, providing a detailed statistical representation of the flow field.

To accurately resolve the fast motion of particles, high-performance cameras capable of acquiring two images in rapid succession are synchronized with pulsed laser illumination. The laser typically illuminates a thin slice of the flow field called lightsheet, ensuring that only particles within a defined measurement plane contribute to the recorded signal. This time-resolved imaging approach enables high-resolution, planar flow measurements in a wide range of experimental setups. PIV is widely used to study fluid flow in fields such as automotive engineering, aerospace technology, and biomedical research.

Principle of Double Shutter Mode

The double shutter mode is a specialized camera function that allows two exposures to be taken in extremely rapid succession, separated by a precisely defined, very short time interval. This enables accurate time-resolved imaging without the need for high continuous frame rates, making it an ideal technique for capturing motion in fluid dynamics experiments.

Timing of Double Shutter Mode

In contrast to a conventional single shutter mode, the double shutter mode enables two closely timed image acquisitions by overlapping exposure and readout phases.
Figure 1 illustrates the entire double-image acquisition sequence, initiated by a single trigger event:

- After receiving a trigger, the camera starts Exposure A, during which the sensor collects light for the user-defined exposure time t_{expA}.
- Once Exposure A ends, a short interframing time t_{if} allows the system to prepare for the second exposure.
- Exposure B is internally triggered by the camera and begins automatically.
- The duration of Exposure B t_{expB} is equals the readout time of Exposure A t_{readA}, so Exposure B occurs while Exposure A is being read out.
- After Exposure B and its readout phase t_{readB} are complete, the camera is ready for the next cycle.

This mode allows two closely spaced exposures with minimal time between them. The first exposure time is user-controlled, while the second depends on the system's internal timing.
The timing of the intensified pco.dicam camera is slightly distinct: both exposure and interframing time can be freely adjusted within the available range.

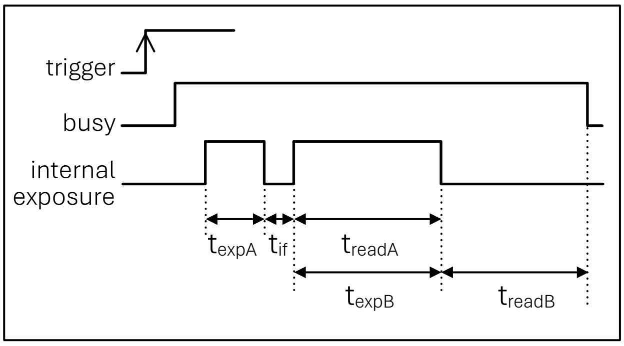

Figure 1: Timing sequence of image acquisition in double shutter mode: the second exposure occurs during the read-out of the first image.

Achieving Clear Image Separation

The interframing time t_{if} defines the transition period between the end of the first exposure t_{expA} and the start of the second exposure t_{expB} (see Figure 2). During this brief phase, the sensor is in a transitional state, meaning that incoming photons may not be assigned clearly to either of the two exposures. This can lead to an undefined state, where the generated photocharge could appear partially in image A, image B, or potentially be missed altogether.

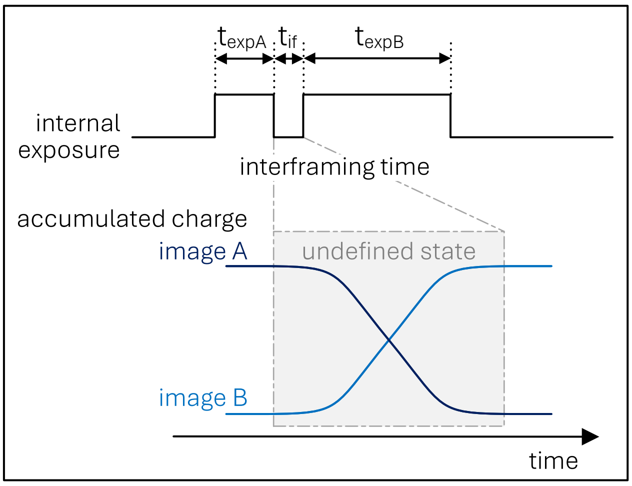

Figure 2: Timing diagram illustrating the undefined state during the interframing time, where charge contribution may overlap between image A and image B.

In PIV, short laser pulses are used to illuminate tracer particles in a flow field so that their displacement between two exposures can be accurately captured. Precise timing of the light signal is essential to avoid issues during the interframing period. As shown in Figure 3, laser pulses should be carefully timed to occur outside this transitional phase. If a pulse happens during the interframing time, it might not be clearly assigned to one exposure. This misregistration can lead to erroneous particle displacement data. By ensuring each laser pulse occurs only during well-defined exposure phases, the signal can be cleanly separated between the two images, avoiding overlap and enabling reliable velocity measurements.

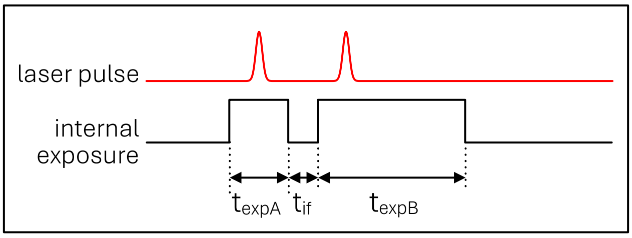

Figure 3: Timing diagram of a sequence of laser pulses in relation to the internal exposure time of the sensor. Laser pulses must be timed outside the interframing period to achieve clear image separation.

Scheimpflug Principle in PIV Setups

In PIV setups, sharp focus across the entire lightsheet is essential for accurate flow measurements. Optical constraints may misalign the illuminated plane with the image sensor, reducing depth of field and detail. Applying the Scheimpflug principle by tilting the lens aligns the focus plane with the measurement plane, expanding the in-focus region for clear particle imaging across the field of view.

The pco.scheimpflug camera adapter provides a precise way to tilt the camera's optical axis by ±18° relative to the sensor plane. This adjustment aligns the focal plane with the measurement geometry, enhancing depth of field and image sharpness without requiring extra optical components.

The adapter features exchangeable lens inserts, ensuring compatibility with a wide range of lenses. It is fully compatible with the pco.edge 26 DS CLHS camera, as shown in Figure 4. Upon request, it can be customized for other camera models.

The pco.scheimpflug adapter is the ideal solution for demanding imaging applications where precision focus across angled or three-dimensional planes is essential.

Figure 4: Illustration of the pco.scheimpflug adapter with a pco.edge 26 DS CLHS camera and a d.fine HR-M 2.8/80 0.09x lens.

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