SIS1-x/FMR

HIGH SPEED
FRAMING MODE RECORDER

14-BIT DYNAMIC ◀
UP TO 1 MILLION FPS ◀
IMAGE SEQUENCE CAPTURING ◀

The Scientific Imaging System SIS1-x/FMR is a high resolution camera system, especially designed for high speed image sequence capturing with 14-bit dynamic due to its special image sensor operation modes for extremely fast running processes. Because of a special image sensor with divers opaque masked memory partitions, the system allows image capturing with frame rates up to 1 million frames per second (in the framing mode) while simultaneously preserving the outstanding technical specifications of the Scientific Imaging System.

Features	
Highest Frame Rates ▶	Framing mode for image sequence capturing with frame rates up to 1 million Fps. Due to the utilization of 2048 image lines, the image sensor provides the possibility of much longer image sequences.
Highest Sensitivity ▶	Highest read-out noise of $4e^-$/Pixel/s rms with special “correlated double sampling” signal processing.
14(18)-bit Digitalization ▶	Intensity resolution of 16,384 grayscales, 64 times better than 8-bit systems, important for photometric measurements and structures with low contrast. Averaging of statistical noise with image accumulation offers 15-bit dynamic.18-bit digitalization with 16-bit data transfer for 19-bit dynamic is optional.
Photometric Linearity ▶	Proportionality of measured counts to incoming light intensity better than 0.4%, optimizable to linearities < 0.1% with correction tables.
High Resolution ▶	2 megapixel usable square pixel with the frame transfer CCD image sensors FT18 or FTT1010. 6 megapixel usable square pixel with the Fullframe CCD image sensor Philips FTF3020.
External Timing ▶	Asynchronous image sequence start and external image sequence control by external gate inputs. User-defined, temporal nonlinear image sequence capturing is possible.
Super Pixel Binning ▶	Selectable binning of charges of adjacent pixels onto the CCD chip with single readout increases linearly the signal to noise ratio by reduced spatial resolution.
Anti-Blooming Function ▶	Blooming from one overexposed pixel to adjacent pixels will be avoided by an efficiency of an overexposure factor of >200 relative to the full well capacity.
High Full Well Capacity ▶	Photon statistics $S/N=\sqrt{S}$ determines the signal to noise ratio SNR up from average intensities. High dynamics demand the extremely high e^- capacity of the sensor.
100% Fill Factor ▶	High precision measurements require full sensitivity of the whole image area, because otherwise small image structures result in moiré-effects.
WinSIS-Software ▶	WinSIS6 for WinXP/2000/NT/9x controls all camera functions and integration timing. The concept of intuitive easy-to-use operation for all imaging and processing functions with integrated job creation and macro definition offers a fast realization of complex applications without long training periods. SDK for personal programming.

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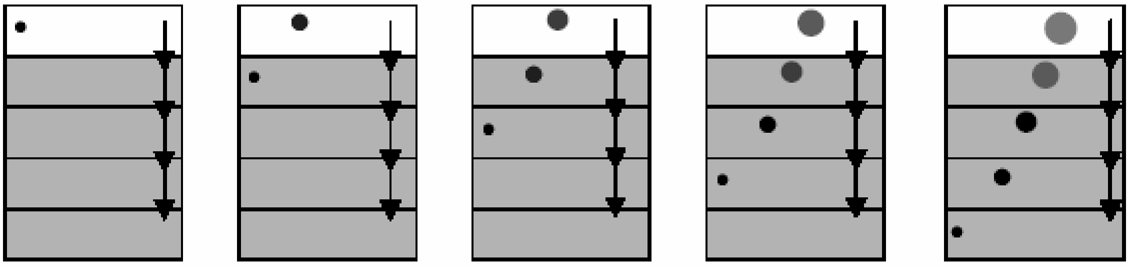
SIS1 – High Speed Framing Mode Recorder

In many scientific and technological applications appear fast processes which have to be acquired and analyzed by imaging. With conventional video-technology the possibilities are limited by the very low refresh rate to record such processes.
Up to now photographic systems were used for the detection of extremely fast moving objects or transient conditions. Besides the very high costs of these systems, this is a cumbersome method because the film development and the extraction of the information need such a long time that an affect on the analysis for optimization of the test parameters is impossible. Not to forget the often necessary and additional effort to digitalize the image information. Special video cameras – particularly cameras with selective readable CMOS image sensors and several output ports – reach high frame rates at pixel frequencies > 60MHz.

Fast image capturing for photometric applications requires mostly a high dynamic and linearity according to the dependency of the incoming photons to the digitalized image intensity.
CCD image sensors are appropriate to capture fast processes because of their internal structure and organisation by the utilization of special image sensor operation modes.
With the so called “Framing” operation mode the whole image sensor area is separated into image lines whereat the not to be exposed image areas are masked opaque.
The result is a frame transfer image sensor with several memory partitions whose number equals the total number of the image sensor lines divided by the line number of the single image.

Framing Principle



Exposure 1 with line transfer | Exposure 2 with line transfer | Exposure 3 with line transfer | Exposure 4 with line transfer | Exposure 5 with line transfer

For example: By covering 4/5th of an image sensor photoresistant, 4 frame transfer memory partitions (gray) evolve. With a frame transfer image sensor (in which image area and memory partition are built up equal) it is possible to use 2048 image lines by e.g. separating a 1024 x 1024 image sensor.
The exposure time is normally controlled by a shutter like e.g. a gateable image intensifier or by a pulsed light source. Thereby, the not covered image area can be used as additional image memory, because beside the exposure time no photons reach this always sensitive area. After exposure of the sensitive image lines the image information is transferred by the same number of linetransfers into the covered area according to the line number of the image lines. With one single line transfer always all lines are moved by one line towards the readout register. This process is sequentially repeated image line per image line, as long as the whole image sensor has been exposed. After this the whole image information is read out the same way as during normal mode of the Scientific Imaging System SIS1 to preserve all specifications, like e.g. dynamic of 14/16-bit, the high linearity and the high sensitivity by the low readout noise.

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Framing Features

At the beginning of the capturing the image sensor contents is constantly cleared. Absolute asynchronous start of the image sequence capturing is provided with a starting delay of <1 µs thru an external trigger input. After that the line transfer can be easily adjusted by an external timer due to an external gate input. That fact provides a very flexible realization of various sequential controls.
Particularly it is possible to adopt the image sequence process (for temporal nonlinear events) corresponding to the respective experimental requests. For a user friendly control the line transfer process is performed by the internal Step-On-Clock SOC Sequencer as long as the external sequential control signal is applied. That offers the possibility to easily realize very complex, time dependant processes.
If the sequential control signal is shorter than the simple line transfer time, it is possible to transfer every line separately so that e.g. temporal logarithmic image sequences can be disposed.

The following correlations have to be considered for the maximum possible frame rates:

Max. frame rate [kHz] = 1000/(line transfer time x total frame lines)
Frames/Sequence = image sensor lines/total frame lines

See the chart bellow for examples of maximum possible image sequence rates with the Scientific Imaging System SIS1-p18/HSR (every line includes 1024 pixel). For general specifications consider the information about the SIS1-p18 with Philips FT18 CCD image sensor.

Transfer time for 1 line [µs]	Max. frame rate [KHz]				
	1024 images á 1 image line	256 images á 4 image lines	64 images á 16 image lines	16 images á 64 image lines	4 images á 256 image lines
1	1000	250	62.5	15.625	3.9
2	500	125	31.25	7.8125	1.95
3	250	62.5	15.625	3.9	0.975

Frame rates of a single image are within the MHz-range. To reach an equal pixel scanning frequency with linear sensors, the deployment of a line sensor with approximately 1GHz pixel frequency and 14/16-bit digitalization would be necessary. Today's technology doesn't seem to offer the possibility to realize this. However, this high dynamic is an absolute necessity for photometric applications.

The framing-technology is particularly qualified for linear motions because of its lamellar image shape (aspect ratio depends on the necessary number of images). The wide image distance can be adjusted in the direction of motion. This offers an optimal spatial utilization of the image sensor area for the motion sequence.
With the SIS1-x/FMR it is possible to view and analyze the images in real time. The included, extremely powerful software provides vast analysis features whereby online regulations of the test conditions are also possible.
In addition, you can capture sequences of this image series at repeatable processes or you can add up the image sequence intensities for signal averaging.

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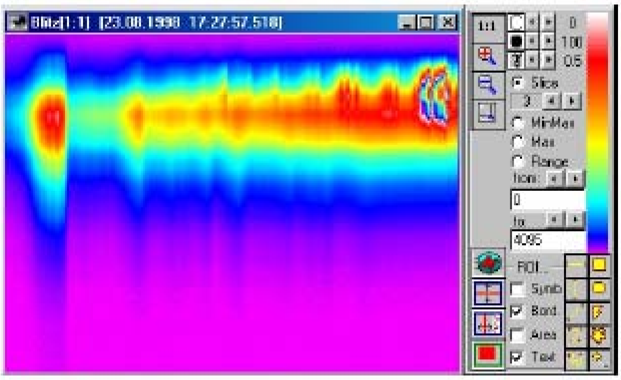
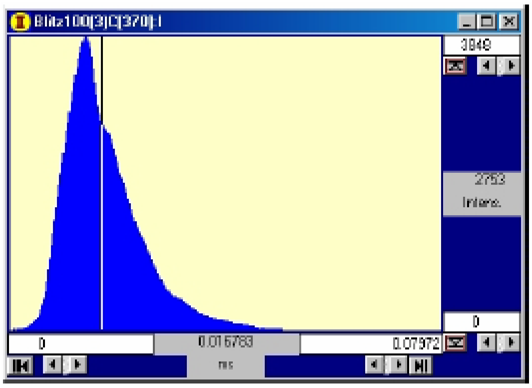
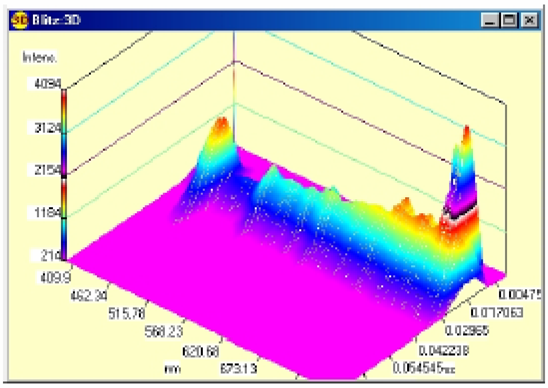
Kinetic Spectroscopy

An important special case is the kinetic spectroscopy. Depending on entrance slit height of the spectrometer the created spectral intensity-spread of the analyzed light is displayed on one or a few lines of the image sensor. Spectral changes can be measured down to the submicroseconds-period with high spectral resolution. With appropriate good spatial resolution and good diffused light performance of the spectrometer it is not necessary to cover the image sensor for fixing the image area. The image height is flexible and e.g. the entrance slit height could be adjusted to the available light intensity.



Here the temporal and spectral performance of the light emission of a flash light is shown as an example. The entrance slit height of the used flatfield-spectrometer is realized by the direct injection of an optical fiber with a diameter of 0.005mm which illuminates the first two image lines of the image sensor so no further covering is necessary. The x-direction is the wave length axis which is given by the spectral dispersion of the flatfield pattern. The y-direction is the time axis from 0 to 0.08ms with a temporal resolution of 250ns/line. It is easily possible to recognize the starting delay and the spectral time performance of the different emission processes during flash light discharge.





The analysis was made with the powerful image processing program WinSIS6.
Above, the spectral curves at different times are shown as intensity profile. On the right hand side a three-dimensional view is shown. Of course all data can be exported in ASCII-format whereby many other applications are supported.

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