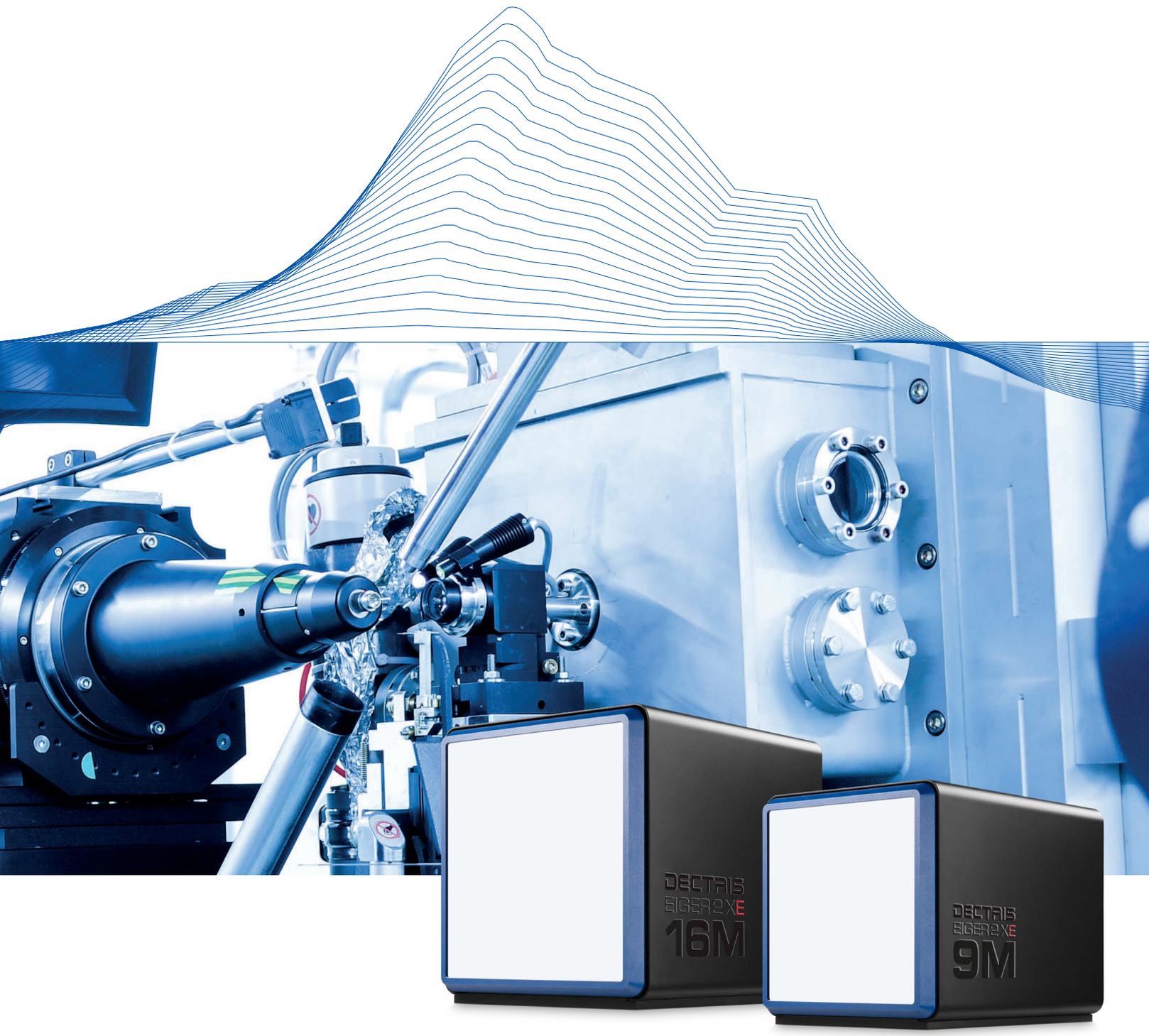
DECTRIS develops and manufactures the most accurate X-ray and electron cameras to spark scientific breakthroughs around the world. While CCD and CMOS cameras capture and integrate X-rays indirectly, DECTRIS hybrid-photon-counting (HPC) detectors count individual photons directly. HPC detectors have transformed measurement methods and data collection strategies at synchrotrons over the last 15 years.

DECTRIS detector solutions are highly beneficial for all X-ray scattering techniques. Our specific solution detector systems can cover a wide angular range, allow for windowless systems in vacuum, tender X-ray detection and/or simultaneous SAXS/WAXS measurements. Customized DECTRIS detector solutions can be found for example at the CoSAXS beamline at MAXIV, at the BioSAS beamline at NSRRC, at the LiX beamline at NSLS-II or at the SAXSMAT beamline at DESY. Join our talk on Thursday to learn more about DECTRIS HPC detectors for SAXS.

If you want to know more about DECTRIS and our detector solutions, check out our website or book an appointment with our colleagues Adela Bekic, Stefan Brandstetter, Nicolas Pilet or Lisa Glatt at the S4SAS conference 2021.

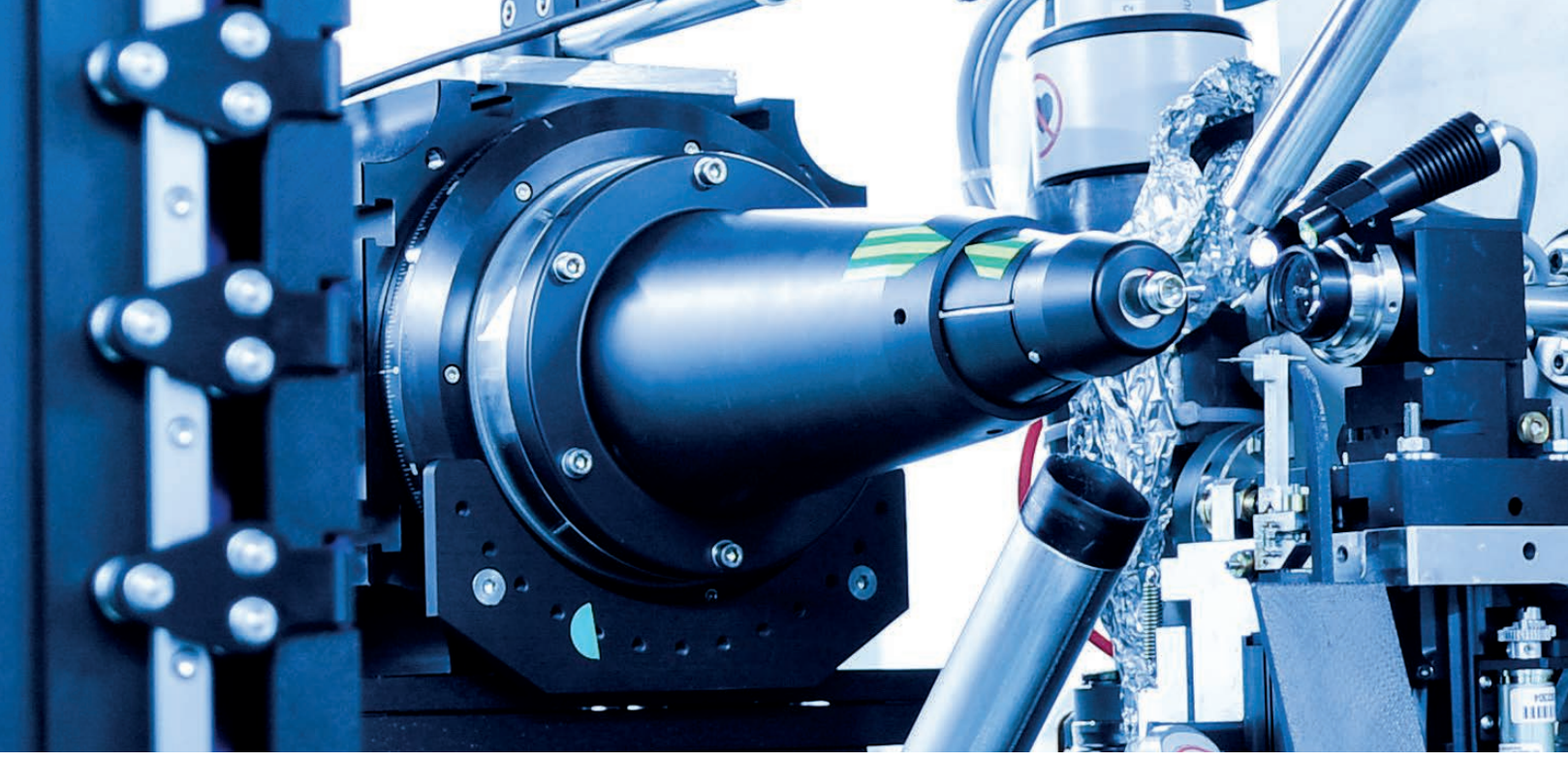
We are looking forward to meeting you at the S4SAS 2021!

DECTRIS
detecting the future



FAST, FASTER,

EIGER2 XE



Fastest large area detectors for 4th generation synchrotrons

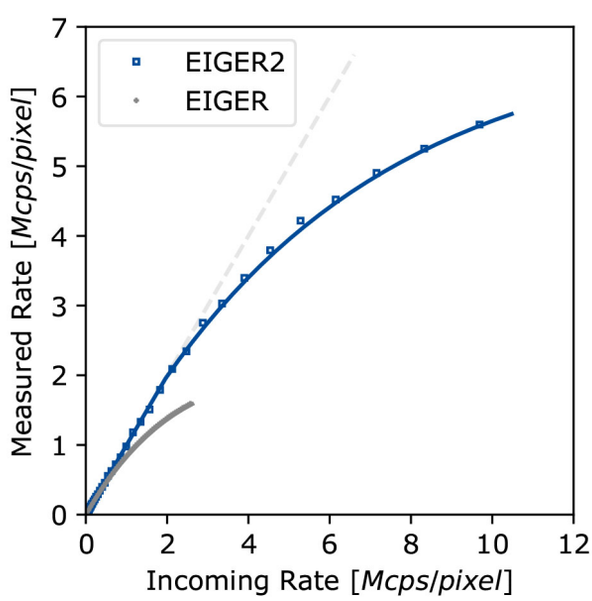
EIGER2 XE detector systems allow endstations to reach new summits in X-ray research. To fully exploit the increasing photon fluxes of the brightest new synchrotron sources, DECTRIS has boosted the EIGER2 X detector series to new extremes. EIGER2 XE 9M and 16M not only provide an unrivalled count rate capability of 10^7 counts/s/pixel and a second energy discriminating threshold but also frame rates above half a kilohertz. Realize your most ambitious projects with an EIGER2 XE detector and prepare your beamline for the future.

Key Advantages

- Hybrid Photon Counting technology
- Count rate capability 10^7 counts/s/pixel
- Two energy discriminating thresholds
- Gateable detection for pump & probe experiments
- Large active area for wide angular coverage

Applications

- Macromolecular crystallography (MX)
- Single crystal diffraction (SCD)
- Small- and Wide-angle X-ray scattering (SAXS/WAXS)
- Powder diffraction (PD)
- Surface diffraction
- Single crystal diffraction (SCD)
- Ptychography
- Time-resolved experiments

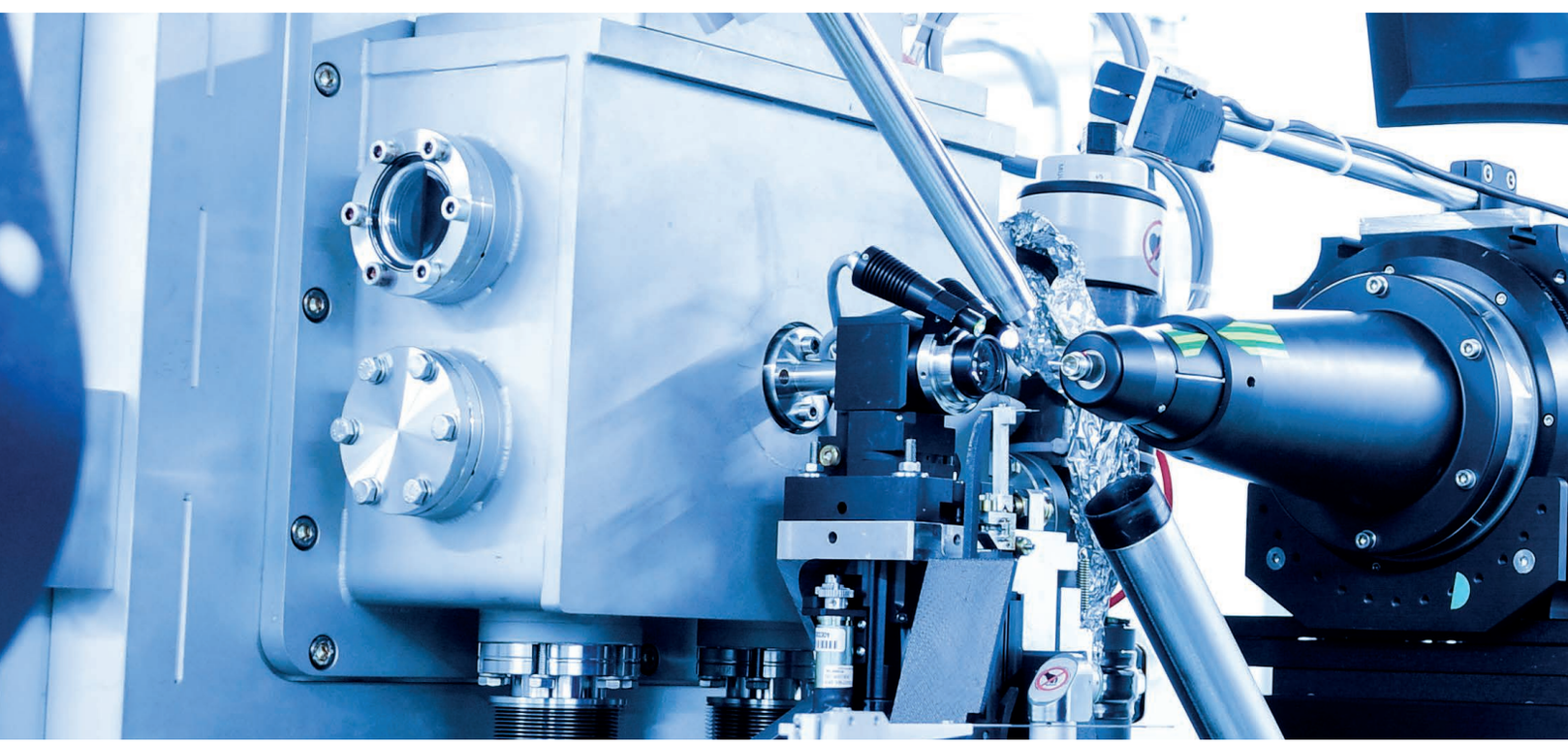


Count rate comparison between EIGER and EIGER2 systems at 12 keV photon energy

Technical specifications

EIGER2 XE	9M	16M
Number of detector modules	3 x 6	4 x 8
Sensitive area, width × height [mm²]	233.1 × 244.7	311.1 × 327.2
Pixel size [µm²]	75 × 75	
Total number of pixels	3108 × 3262 = 10,138,296	4148 × 4362 = 18,093,576
Gap width vertical / horizontal [pixel]	12 / 38	12 / 38
Energy discriminating thresholds	2	
Count rate capability [counts/s/pixel]	10^7	
Point-spread function [pixel]	1 (FWHM)	
Silicon sensor thickness [µm]	450	
Data format	HDF5 / NeXus	
Maximum frame rate [Hz]	550	550 (20s burst), 400 (continuous)
Energy range [keV]	6.0 - 40	
Customer network interfaces	2 x 1 GbE Base-T, 2 x 10 GbE SFP+, 2 x 100 GbE QSFP28	
Dimensions (WHD) [mm³]	340 × 370 × 500	400 × 430 × 500
Weight [kg]	41	55

All specifications are subject to change without notice.



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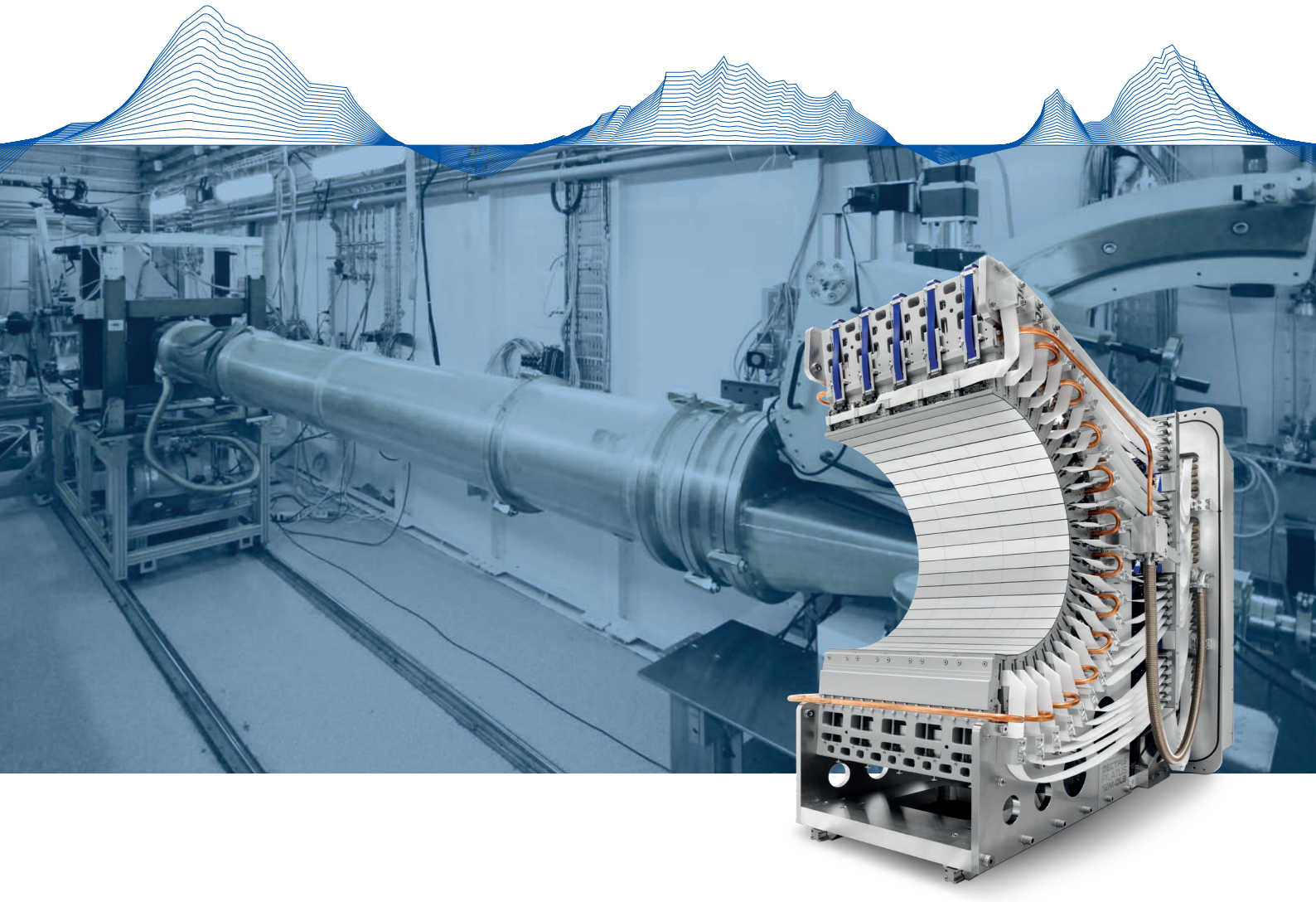
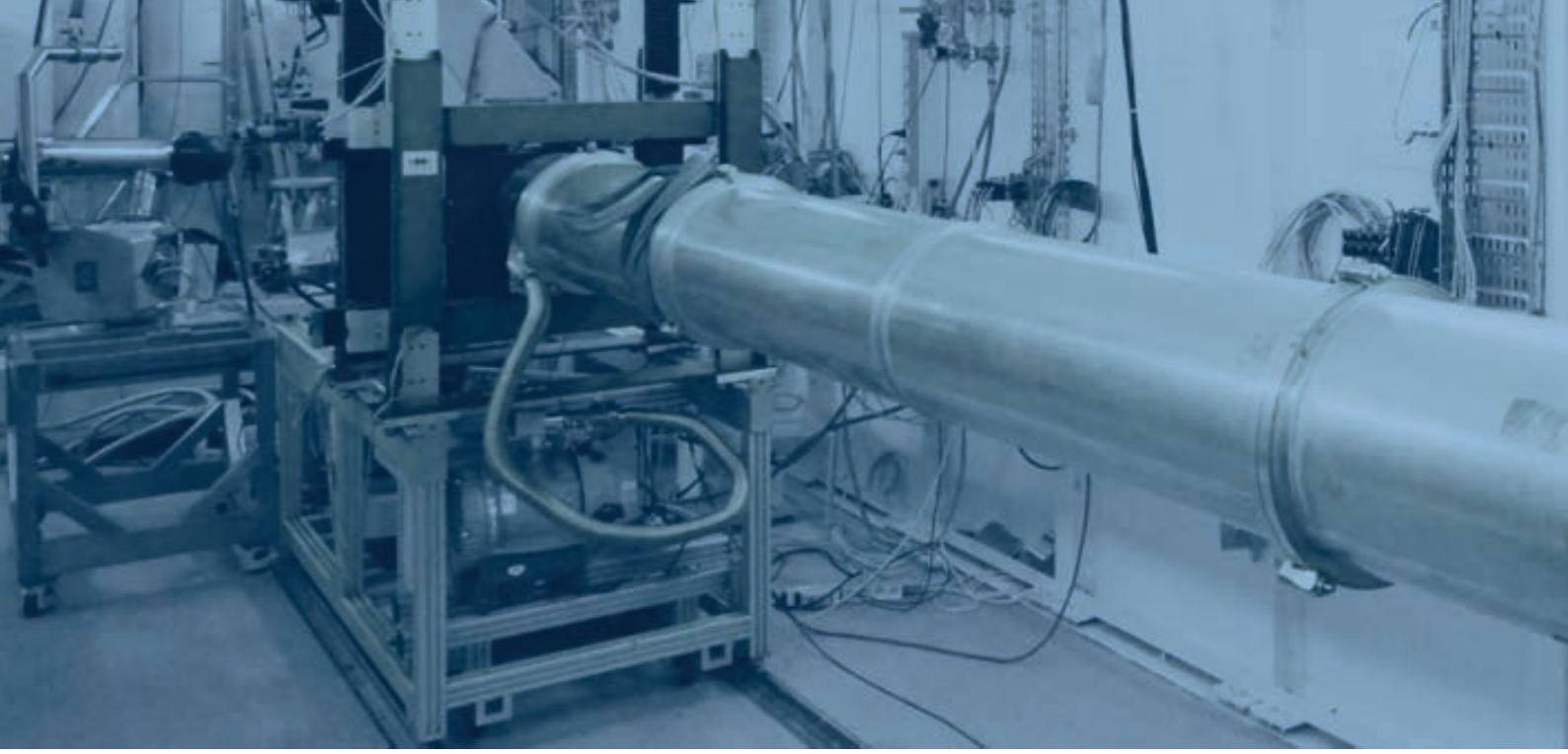
Rev.0 • Printed 07/2019

DECTRIS
detecting the future



SPECIFIC SOLUTIONS

X-ray detection without limits

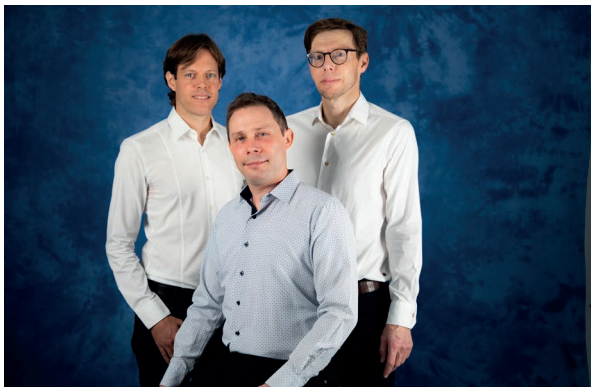


Could your experiments benefit from an X-ray detector that is designed for your needs? If so, unleash the full potential of your experiments with specific solutions: customized detector systems from DECTRIS! In close collaboration with our highly motivated team, you can realize your idea for a specific-solution detector based on the Hybrid Photon Counting PILATUS3 and EIGER2 pixel detectors or the MYTHEN2 strip detector. The detectors shown in this brochure are selected examples of solutions we have previously realized for our customers. If you need a similar - or even an entirely different - detector solution, please contact us to discuss how it can become reality.

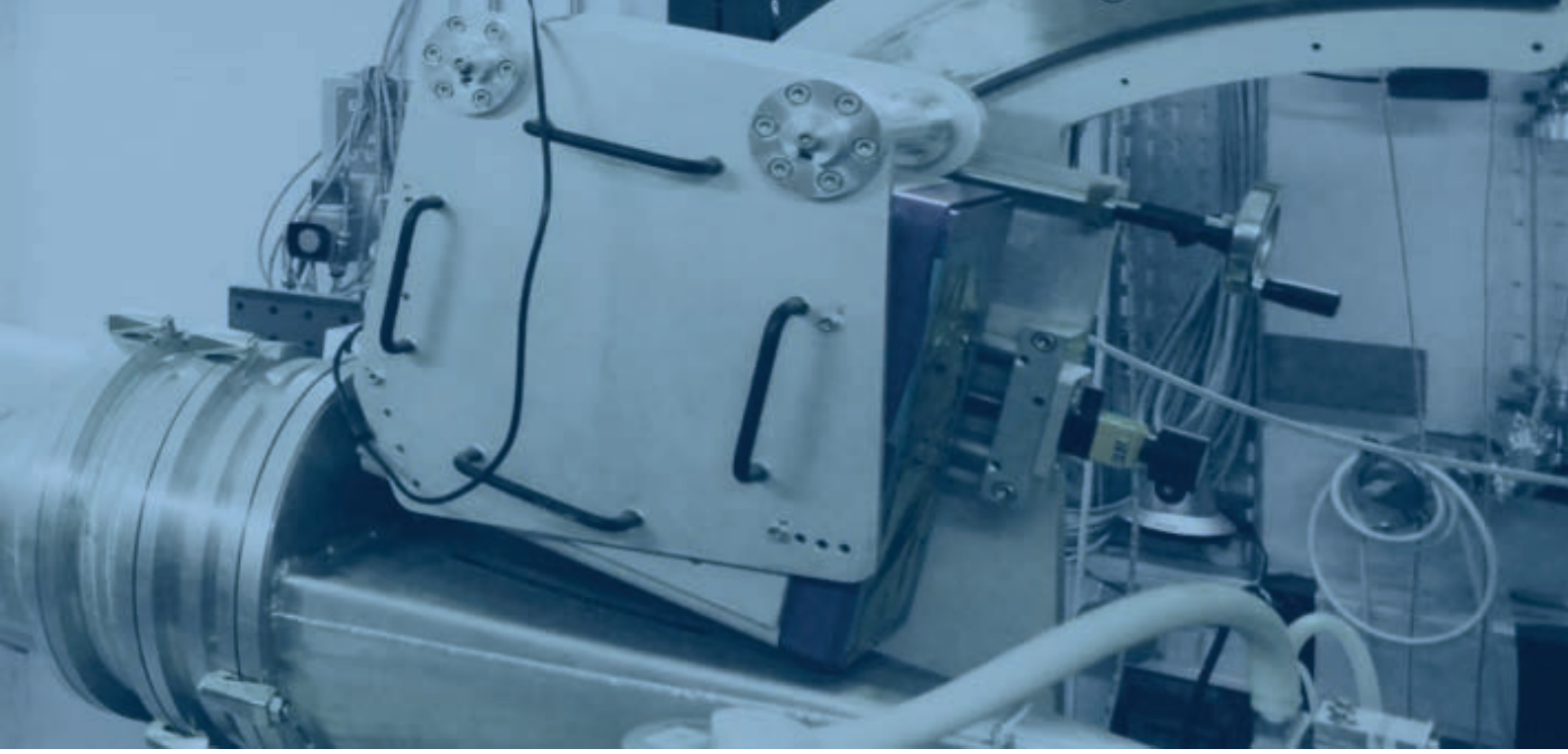
Take advantage of the extensive know-how that DECTRIS has gained throughout its more-than-ten-year history of designing and assembling a large variety of Hybrid Photon Counting detector systems.

Together with our development team, our specific solutions team can realize even the most challenging specific design!

– Custom geometries
– In-Vacuum detectors
– Removable window
– Special energy calibrations



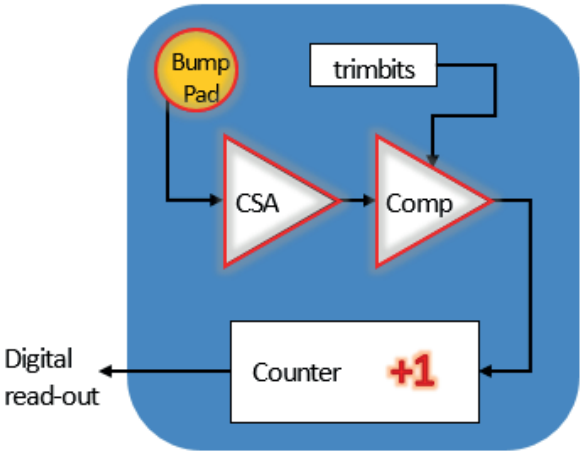
Our specific solutions team



Technology

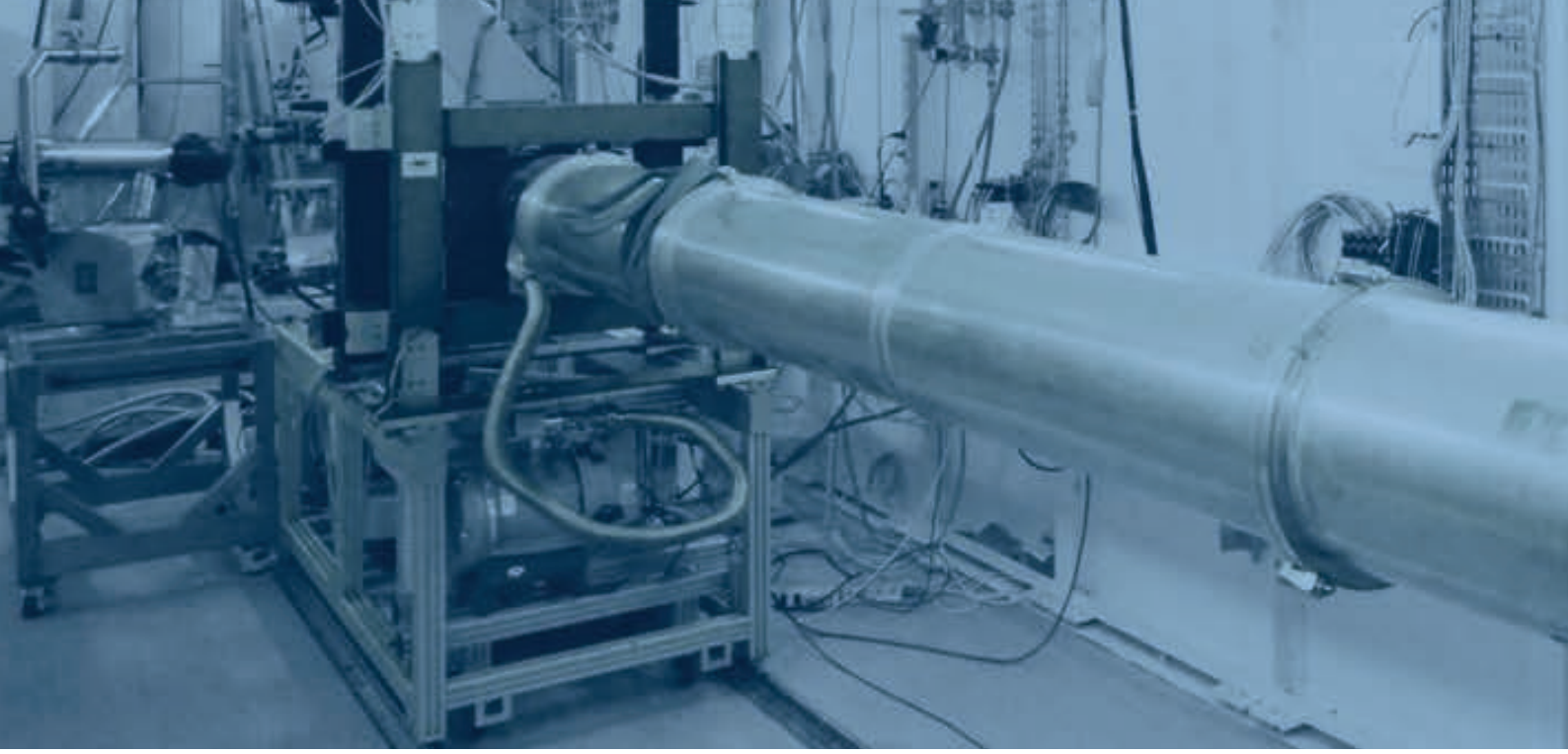
Specific solutions are based on DECTRIS Hybrid Photon Counting technology platforms: PILATUS3 and EIGER2 pixel detectors, as well as MYTHEN2 strip detectors. All X-ray detectors operate in single-photon counting mode and provide outstanding data quality. They feature a very high dynamic range, zero dark signals and no readout noise, thus achieving optimal signal-to-noise ratios even for short readout times and high frame rates. Large active areas with customer-specific geometry are built from multiple identical modules using a modular system concept.

The PILATUS3 detector modular concept enables the construction of detectors in custom geometries and sizes.



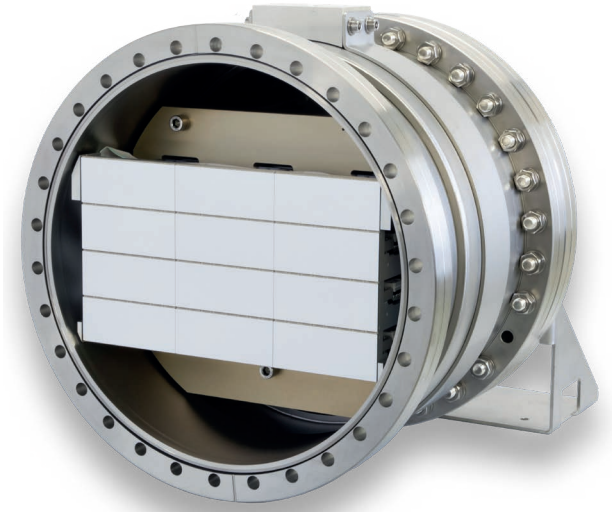
Key advantages

- No read-out noise
- Quantitative signal
- Optimised sensors for large energy range
- Very high dynamic range (from single photon to 10^7 photons/s/pixel)
- Optimal point-spread function
- Custom geometries thanks to modular design



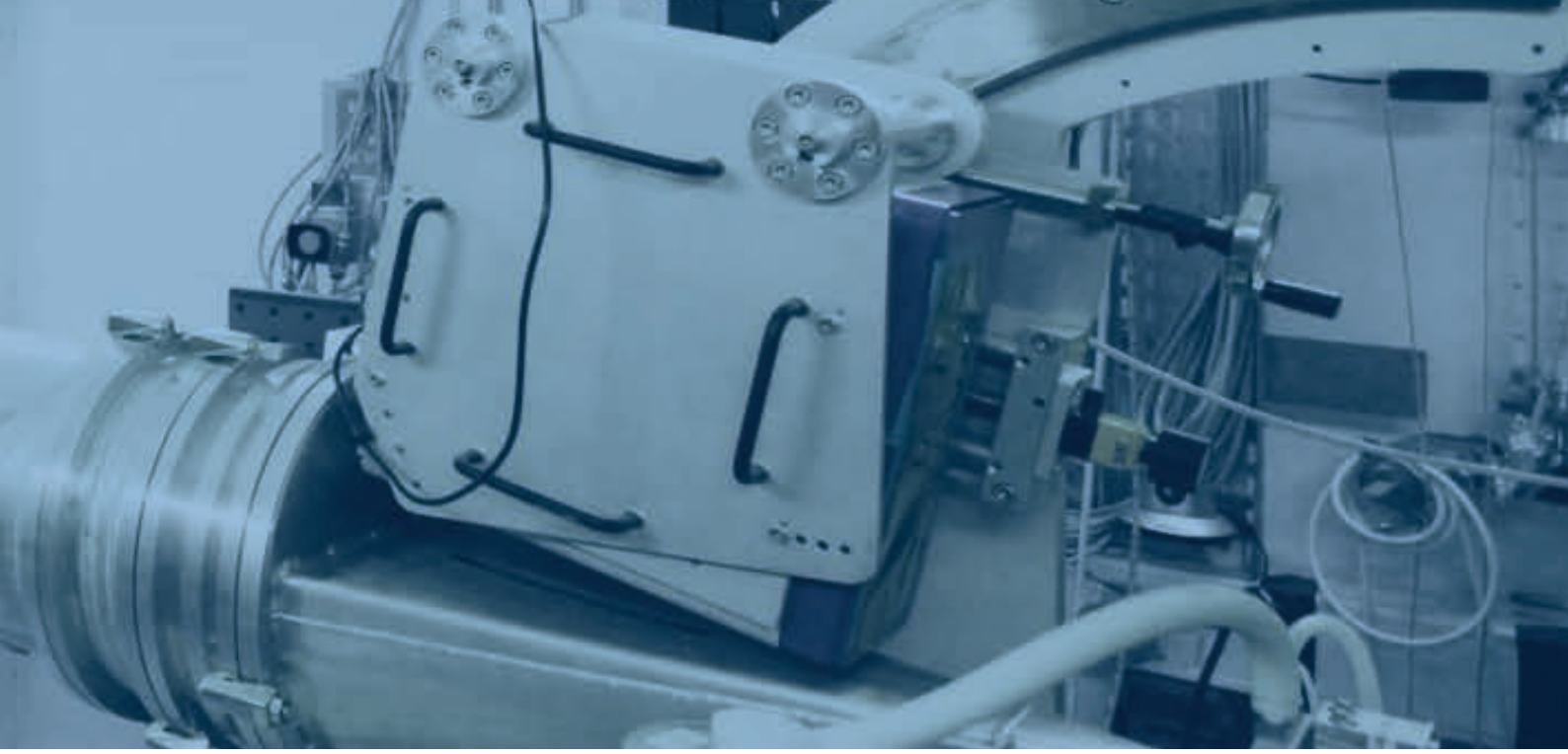
In-vacuum detectors

Do air-scattering or absorption effects limit your experiments? Do your samples need a vacuum environment? Many standard detectors from DECTRIS can be ordered in fully vacuum-compatible versions with water-cooled modules and electronics; these are the PILATUS3 300K(-W) and the EIGER(2) 500K, 1M and 4M. Almost all other detectors can be modified for in-vacuum usage as specific solutions to fit optimally into your setup. Vacuum compatibility to below 10^{-6} mbar can be achieved. The range of detectable X-ray energies can be extended below the specifications of the standard detectors using special, low-energy calibrations.



Custom geometries

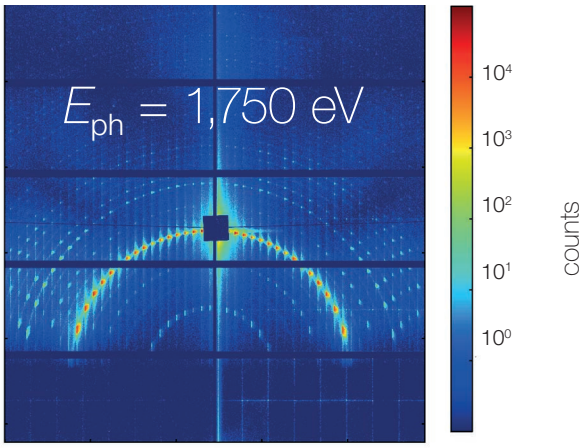
Does your setup impose severe spatial constraints on the detector's geometry and dimensions? Do you need a detector that lets the beam through? The modular concept of DECTRIS detectors allows for various detector geometries, with a planar or even three-dimensional arrangement of the individual modules. Standard housings can be modified, or new housings can be designed from scratch, to meet your requirements on detector shape, sensitive areas and available space.



Special energy calibrations

Are you using soft X-rays? Low energy calibrations down to a minimum threshold energy of 1.6 keV allow to access biological relevant K-edges such as S, Cl, K and Ca.

Do you need more than an image and want to explore the energy dimensions as well? Each pixel has a low-energy threshold and starts counting at energies above the selected threshold value. Special energy calibrations with freely configurable energy threshold patterns can be realized to obtain selectable pixel-wise and/or module-wise energy thresholds for advanced spectroscopy experiments.

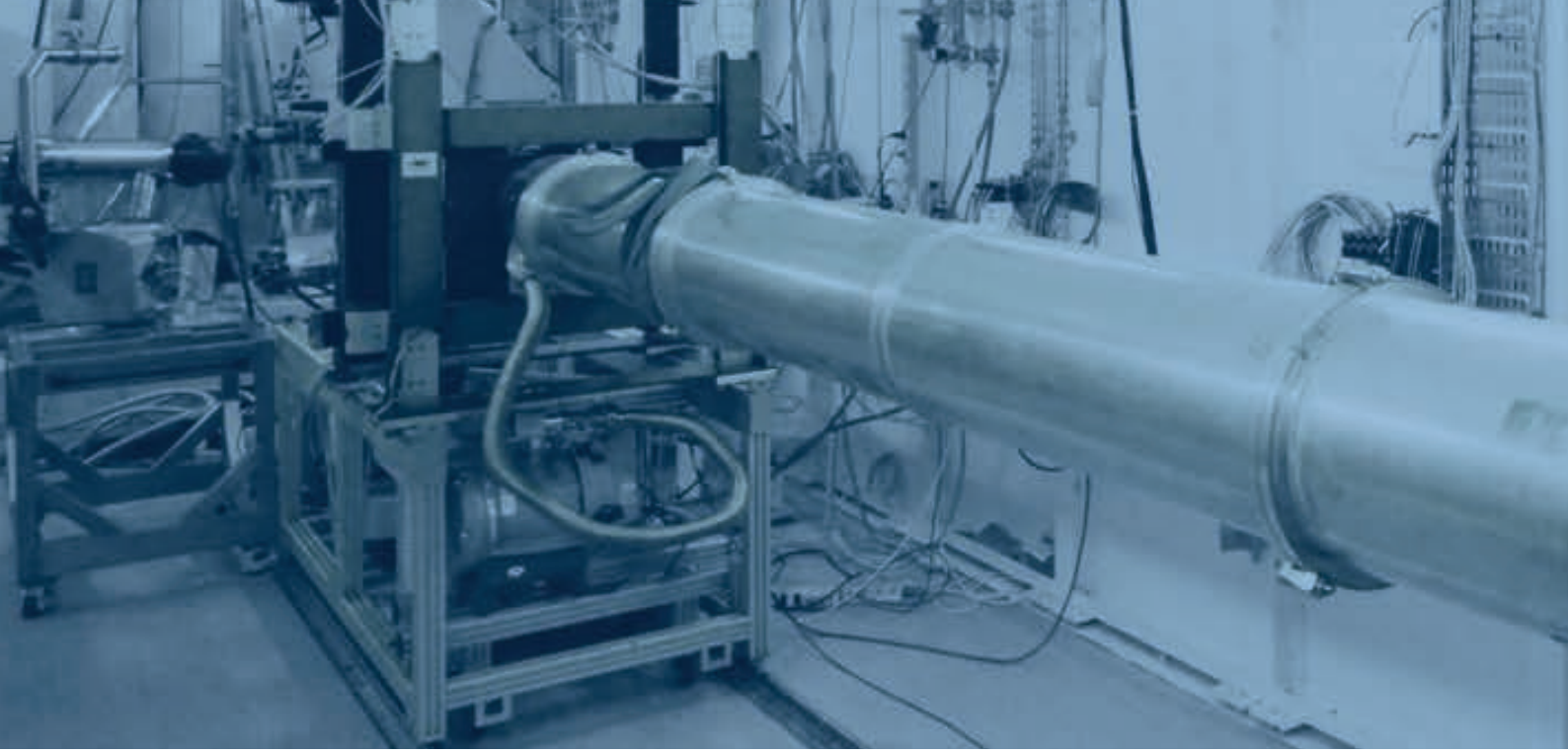


Grazing-Incidence SAXS pattern recorded with the in-vacuum PILATUS 1M detector at a photon energy of 1.75 keV.
Figure courtesy of Michael Krumrey, PTB.

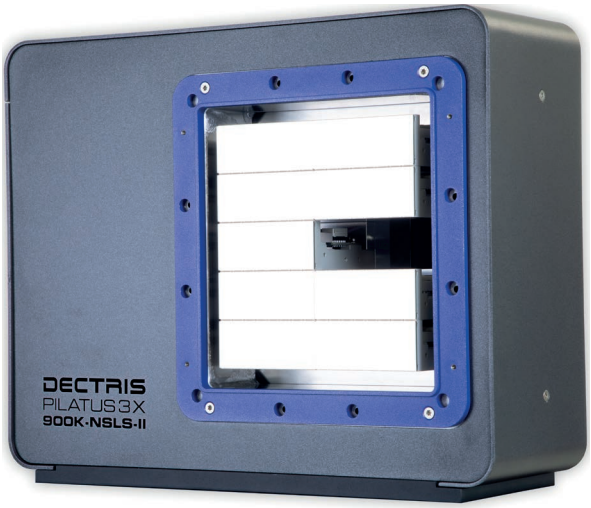
Key advantages

- No air scatter and absorption when the detector is operated in vacuum
- Highest possible data quality with windowless detector operation
- Measurements in the soft X-ray range with special low-energy calibrations
- Sensitive area optimally match your experiment and application
- Detectors can be built with custom geometries and vacuum chambers for smooth integration into your system
- Special energy calibrations for spectroscopy and spectroscopic imaging

„The in-vacuum PILATUS 1M detector has significantly improved our SAXS capabilities, especially for weakly scattering samples and for element-specific measurements at low energies."
Michael Krumrey, Physikalisch-Technische Bundesanstalt, Berlin (Germany)

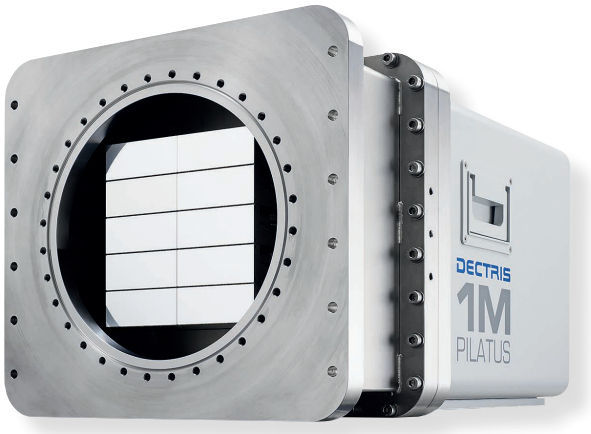


Examples of specific solutions



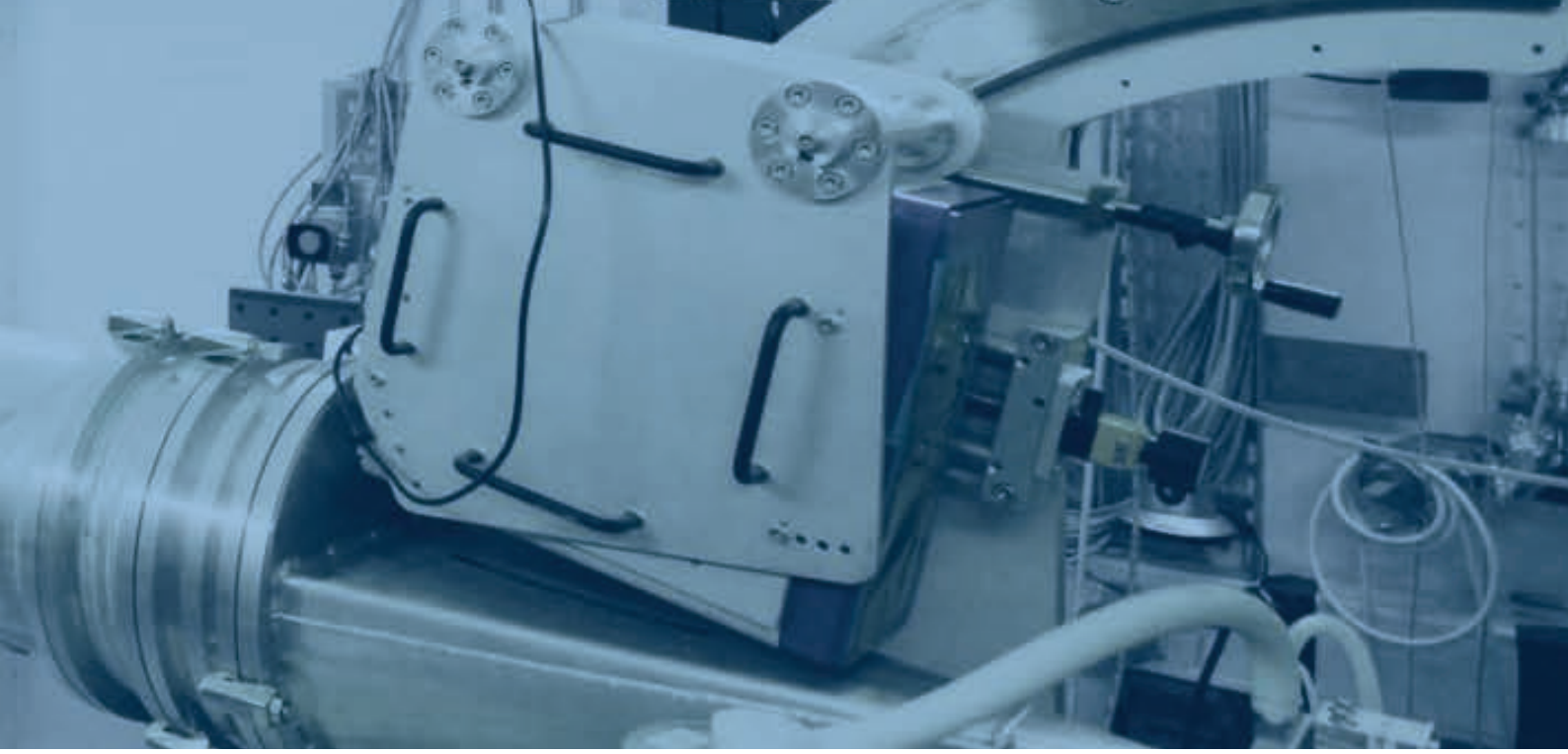
Customized WAXS detectors

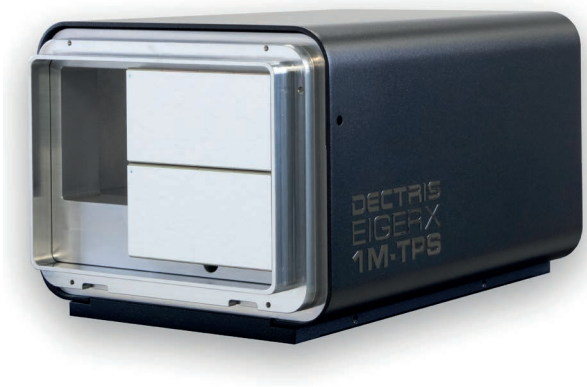
Dedicated geometries allow for the design of a perfect WAXS detector for simultaneous SAXS and WAXS measurement. Missing modules as in the PILATUS3 X 900K-NSLS II (National Synchrotron Light Source II, LiX) and the PILATUS3 X 2M-DLS-L (Diamond Light Source, I22), or ducts on the edge as in the EIGER X 1M-TPS (Taiwan Photon Source, 13A) and the PILATUS3 X 2M PETRA III (PETRAIII), will let the beam through for SAXS detection. The direct beam and small-angle scattering signal pass as close as 3 mm to the active area in a windowless vacuum detector and 5 mm in a detector with a Mylar window.



In-vacuum SAXS detector

DECTRIS has developed a vacuum-compatible version of most of its standard detectors. Complete detectors in vacuum, or remote detector heads used together with a detector electronics unit (DEU) in air, allow you to achieve the vacuum that you need for each experiment. A removable window option allows for complete prevention of parasitic scattering. The PILATUS3 100K-M detector has a very compact detector head design and a DEU in air, which allow you to reach 10^{-6} mbar easily with reasonable pumping power.



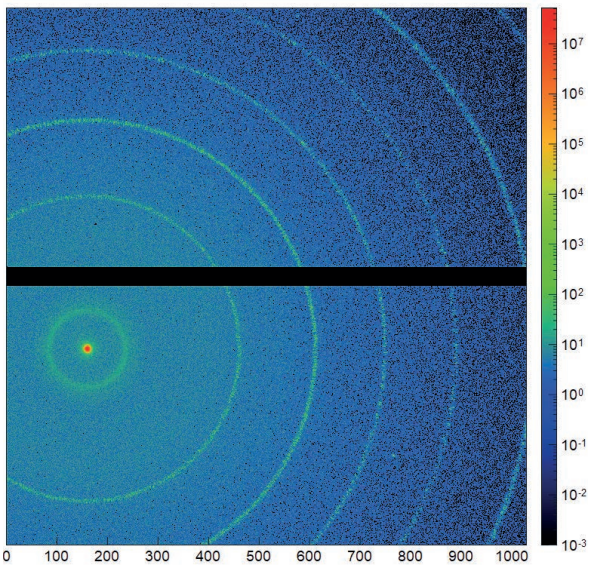


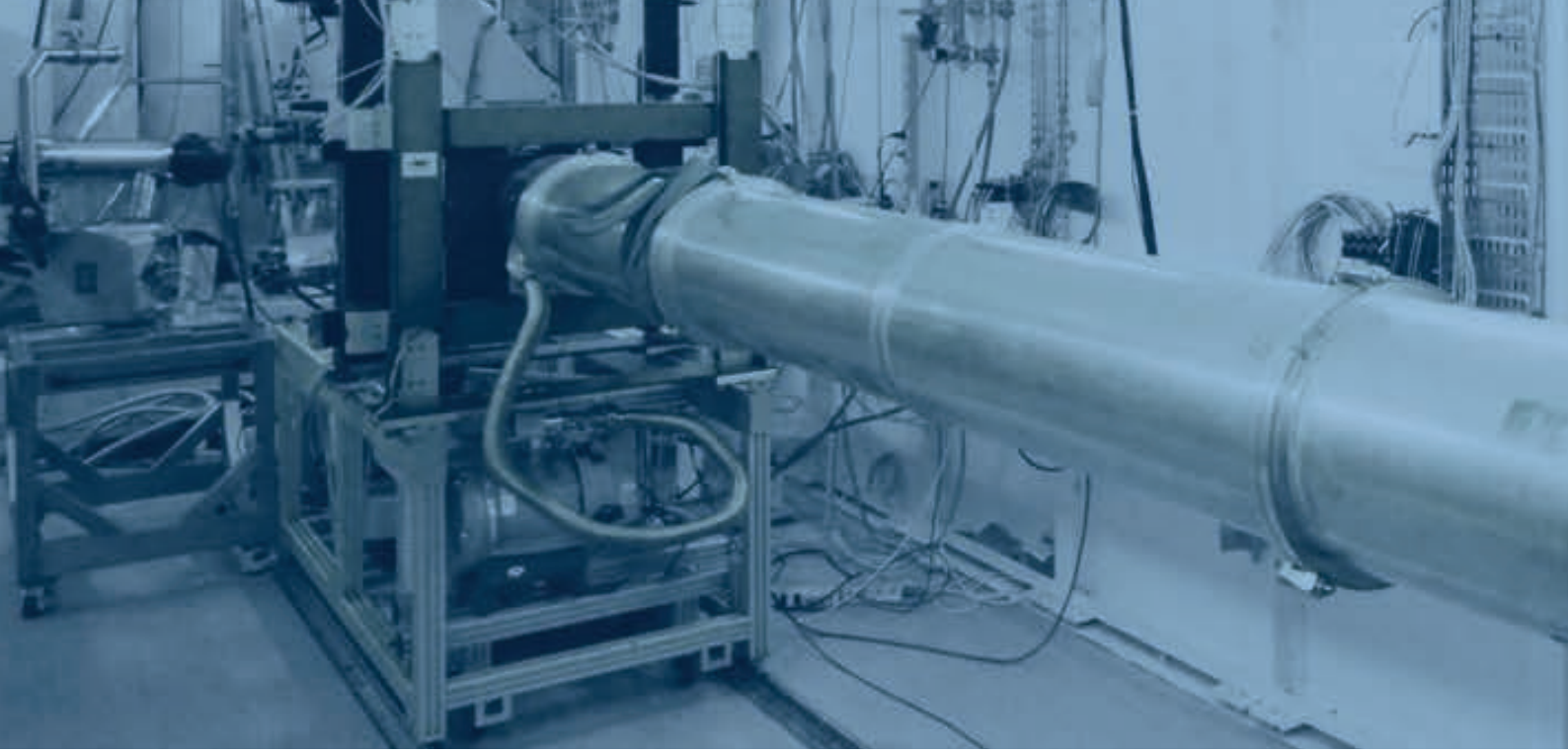
Lateral flight tube on WAXS detector

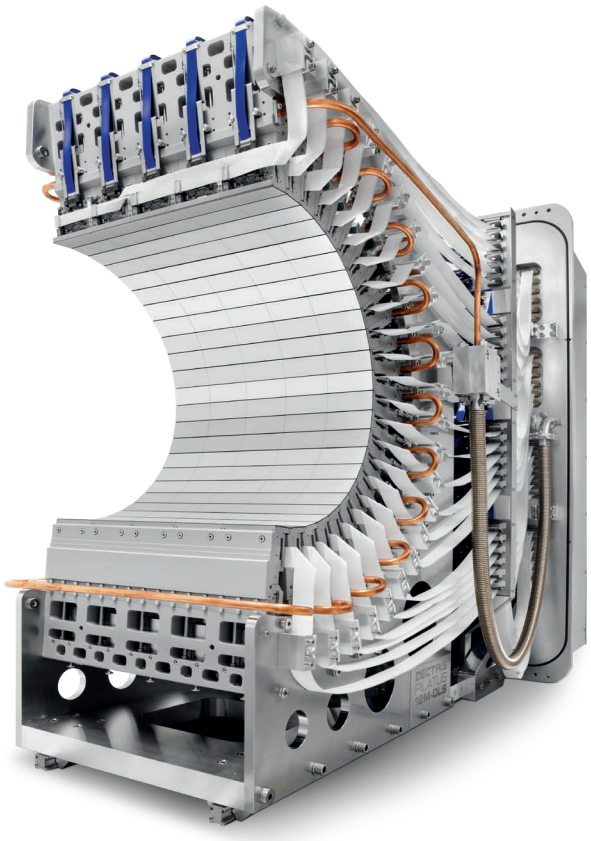
Dedicated geometries can also be based on the EIGER2 modules. Their 75 µm x 75 µm pixels enable high-resolution WAXS detection together with coverage of a large q-range. The removable window option and vacuum compatibility, when added to the flight tube of the EIGER X 1M-TPS, allow the straight beam to pass less than 3 mm from the active area to reach the SAXS detector upstream. The flight tube has been designed to fit the beamline geometry optimally. The upstream SAXS detector of this beamline is an EIGER X 9M specially adapted to vacuum, which extends the high resolution and large q-range to the SAXS regime.

EIGER2 R 1M without window, the ultimate WAXS detector

WAXS scattering of lanthanum hexaboride (LaB_6) measured in a Xeuss3.0 SAXS/WAXS instrument from Xenocs. Thanks to direct detection and a small pixel size, the sharp scattering rings are captured with high angular resolution. The large sensitive area of the EIGER2 R 1M enables the acquisition of multiple rings in a single image. Wide-angle scattering data acquisition benefits greatly from the unprecedented dynamic range of the EIGER2 series, that enables beamstopless operation in laboratory. This allows the direct beam intensity and the scattered signal to be measured by the same detector. The absence of a Mylar window prevents any parasitic scattering and enables sample scattering detection, down to very small angles.







Long-wavelength PX system

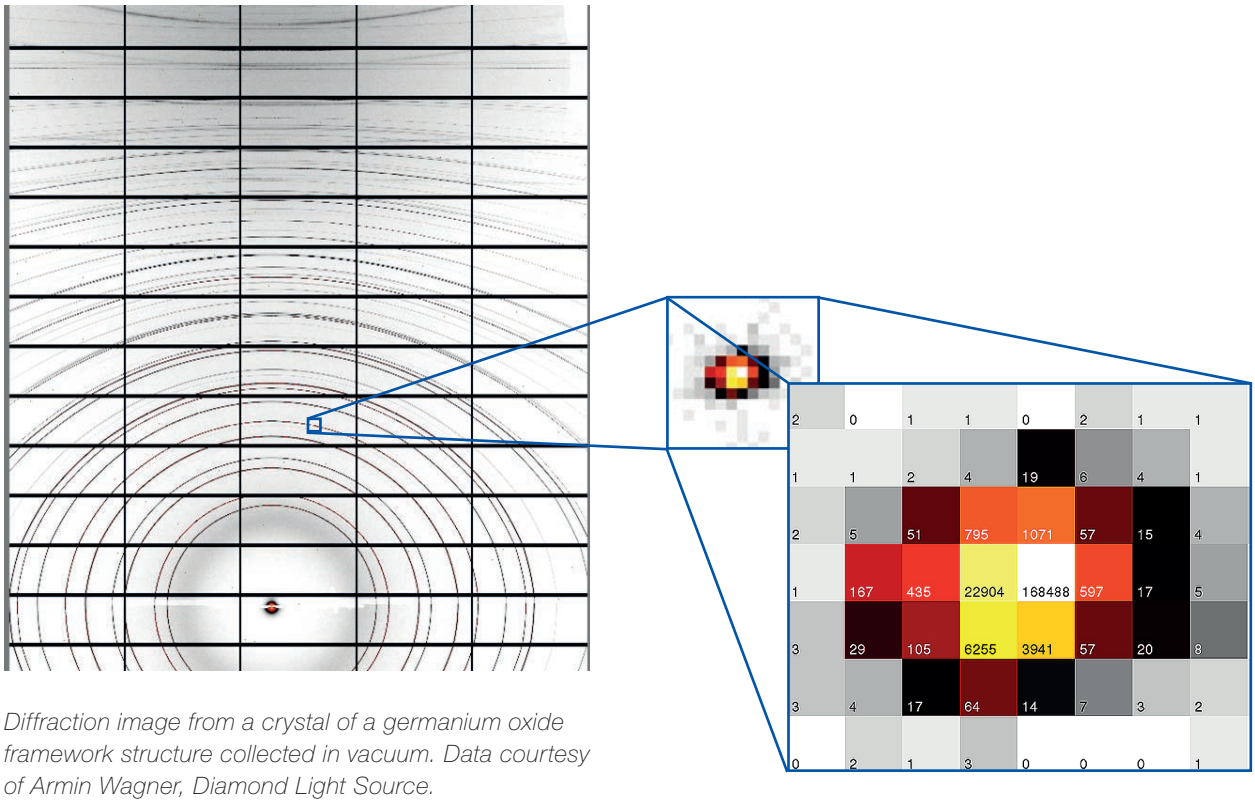
The use of long wavelengths for anomalous phasing has long been hampered by strong air absorption and large scattering angles, but a PILATUS 12M specific solution, built by DECTRIS in close collaboration with the I23 team of Diamond Light Source, successfully overcomes these limitations. Placing the sample and detector in vacuum eliminates air absorption and scattering. The semi-cylindrical shape of the detector covers a 2θ range of ± 100° and makes it possible to collect low- and high-resolution data simultaneously. [1], [2], [3]

The PILATUS 12M-DLS detector consists of 120 PILATUS detector modules mounted on a high-precision frame to form a semi-cylindrical shape. With an active area of 0.34 m^2, this is the largest PILATUS detector ever built. This iconic detector can detect X-rays with energies down to 2.3 keV, and it is vacuum-compatible down to a pressure of 10^{-6} mbar.

[1] A. Rozov *et al.* "Importance of Potassium Ions for Ribosome Structure and Function Revealed by Long-Wavelength X-Ray Diffraction." Nature Communications 10(1), 2519 (2019)

[2] P. S. Langan *et al.* "Anomalous X-Ray Diffraction Studies of Ion Transport in K+ Channels." Nature Communications 9(1), 4540 (2018).

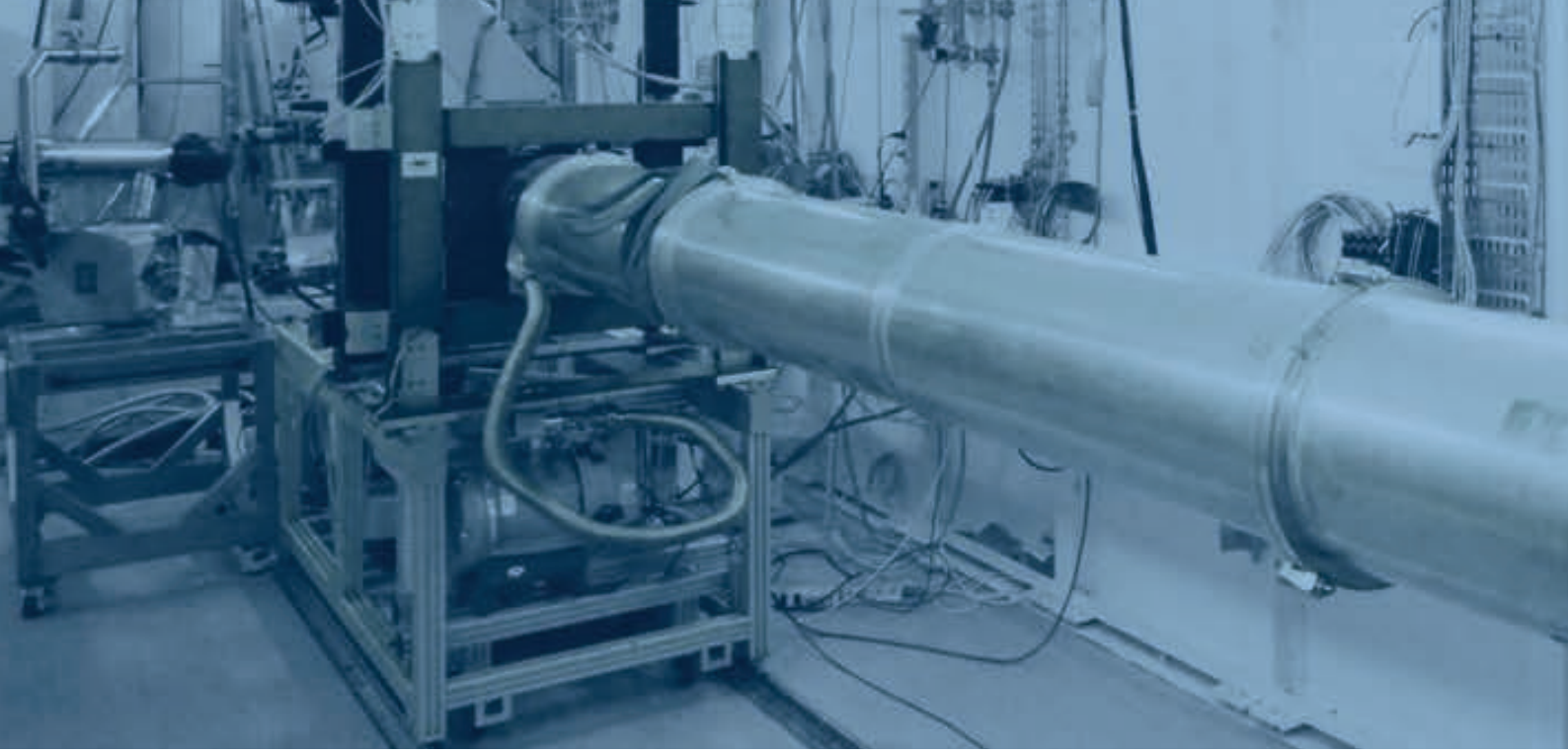
[3] H. P. Austin *et al.* "Characterization and Engineering of a Plastic-Degrading Aromatic Polyesterase." Proceedings of the National Academy of Sciences 115(19), E4350 (2018)

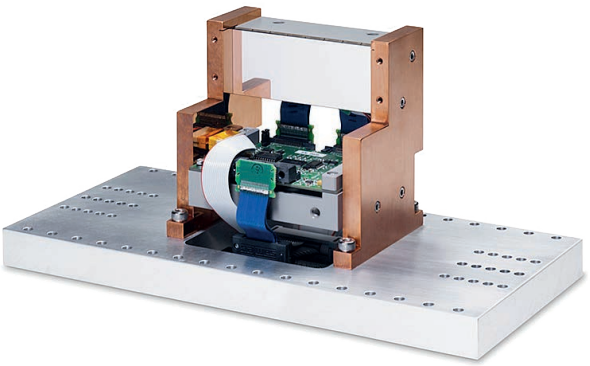


Diffraction image from a crystal of a germanium oxide framework structure collected in vacuum. Data courtesy of Armin Wagner, Diamond Light Source.

"Long-term experience with PILATUS detectors at DLS, their high data quality and huge scientific success, encouraged us to start the ambitious in-vacuum low-energy PILATUS 12M development project with DECTRIS. Most important for realizing a complex beamline project, DECTRIS proved to be a very competent and reliable partner and remained on schedule."

Armin Wagner, Diamond Light Source, Oxfordshire (UK)





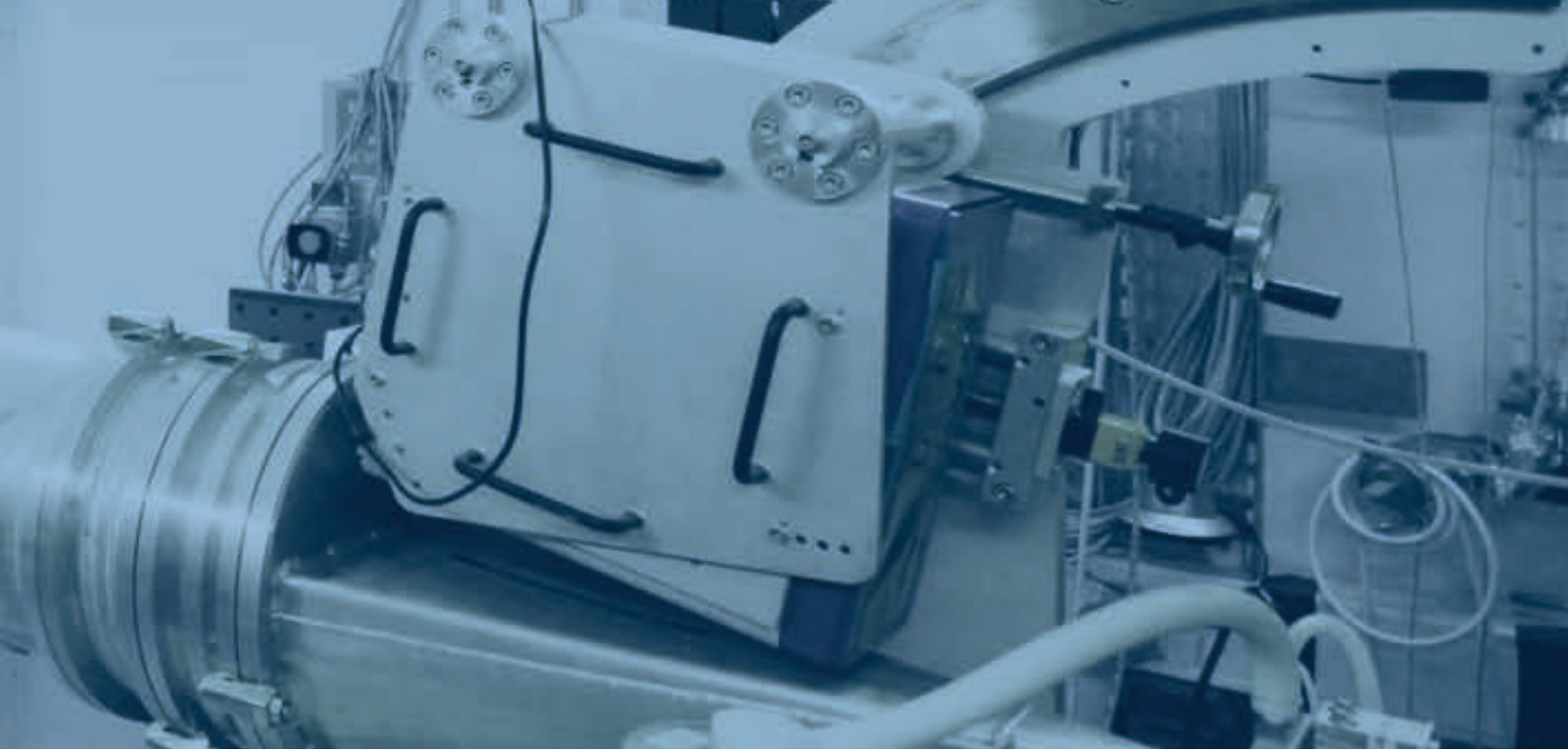
In-vacuum PILATUS 100K detector for the inelastic X-ray-scattering spectrometer at SPring-8

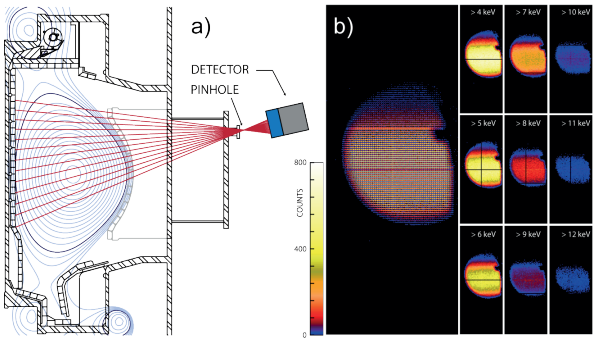
The PILATUS 100K module is split into two parts to meet the stringent space requirements for the in-vacuum experiment setup. Inelastic X-ray scattering is synonymous with extremely low signals. By shortening the standard module to 30 mm and making use of a 1000 µm silicon sensor, it is possible to simultaneously maximize the solid angle and the quantum efficiency at 16 keV photon energy for the SPring-8 BL43LXU medium-resolution spectrometer [1].

[1] A. Q. R. Baron "RIKEN Quantum NanoDynamics Beamline (BL43LXU): The Next Generation for Inelastic X-Ray Scattering." SPring-8 Information 15(1), 14 (2010)

EIGER X 1M-MAX IV

The EIGER X 1M-MAX IV is a highly compact design for the X-ray emission spectrometer SCANIA-2D at the Balder beamline at MAX IV. The detector consists of a short detector head, with all connectors on the side of the housing and also featuring a separate electronics box. This custom design makes the photon-counting detector compatible with the limited space that is available inside the spectrometer. It allows the Rowland circle below the beam to have its maximum radius, while leaving free space for *in-situ* environments above the beam. In addition, defined mounting points are placed on the housing; these hold fiducial markers for optical detection of the exact detector position in three dimensions.





„Our collaboration with DECTRIS led to significant improvements in the high-resolution X-ray spectroscopy of hot tokamak and stellarator plasmas. Thanks to the implementation of noise-free single photon counting detectors from DECTRIS in our X-ray imaging crystal spectrometers it is now possible to perform Doppler measurements of the ion temperature and plasma flow velocity profiles with much higher temporal and spatial resolutions than was previously feasible“

Manfred Bitter, Princeton Plasma Physics Laboratory, Princeton (USA)

Spectral X-ray imaging with pixel-wise energy calibration:

A special X-ray imaging camera based on the PILATUS3 100K has been built by the Princeton Plasma Physics Laboratory (PPPL) to image the intensity of different emission lines simultaneously [1].
DECTRIS assisted PPPL in setting up a special energy calibration, in which each pixel in a sub-array of 3 x 3 pixels can be set to a different threshold, e.g. as shown, between 4 keV and 12 keV in steps of 1 keV. This creates a combination of imaging and energy resolution that makes it possible to distinguish the emissions of different elements [2].

[1] N. A. Pablant et al. “Novel Energy Resolving X-Ray Pinhole Camera on Alcator C-Mod.” Review of Scientific Instruments 83(10), 10E526 (2012)
[2] L. F. Delgado-Aparicio et al. “Simulation, Design, and First Test of a Multi-Energy Soft x-Ray (SXR) Pinhole Camera in the Madison Symmetric Torus (MST).” Review of Scientific Instruments 89(10), 10G116 (2018)

In-vacuum detector for X-ray plasma spectroscopy

This PILATUS3 900K-IPP detector system was designed for the Institute of Plasma Physics (IPP) in Hefei, China. The detector head, comprising nine PILATUS3 modules, is part of a new X-ray imaging crystal spectrometer (XICS) for the detection of X-rays ranging from 3.1 keV (Ar emission) to 13 keV (Kr emission) for the EAST Tokamak. The fast readout time of only 0.95 ms and the high frame rate of 500 Hz, which are enabled by the PILATUS3 technology, provide real-time feedback for the experiment.

Technical specifications of the detector modules

Specific solutions can be based on PILATUS3, EIGER, MYTHEN and EIGER2 Hybrid Photon Counting detector modules.

	PILATUS3	EIGER2	MYTHEN
Detector type	pixel detector	pixel detector	strip detector
Pixel size/strip pitch [µm²]	172 × 172	75 × 75	50
Sensitive area (width × height) [mm²]	83.8 × 33.5	77.1 × 38.4	64 × 8
Number of pixels/strips per module	487 × 195	1,028 × 512	1,280
Maximum frame rate [Hz]	500	2,000	1,000
Readout time [ms]	0.95	continuous readout	0.089
Sensor options [µm]	Si: 450, 1,000 CdTe: 1,000	Si: 450 CdTe: 750	Si: 320, 450, 1,000
Lowest threshold energy (low-energy calibration) [keV] *X-ray energies down to 4 keV are available only with 320 µm x 4 mm sensors	Si: 2.3 (1.6) CdTe: 8 (6)	~ 2.7	6 (4.5*)

All specifications are subject to change without notice.

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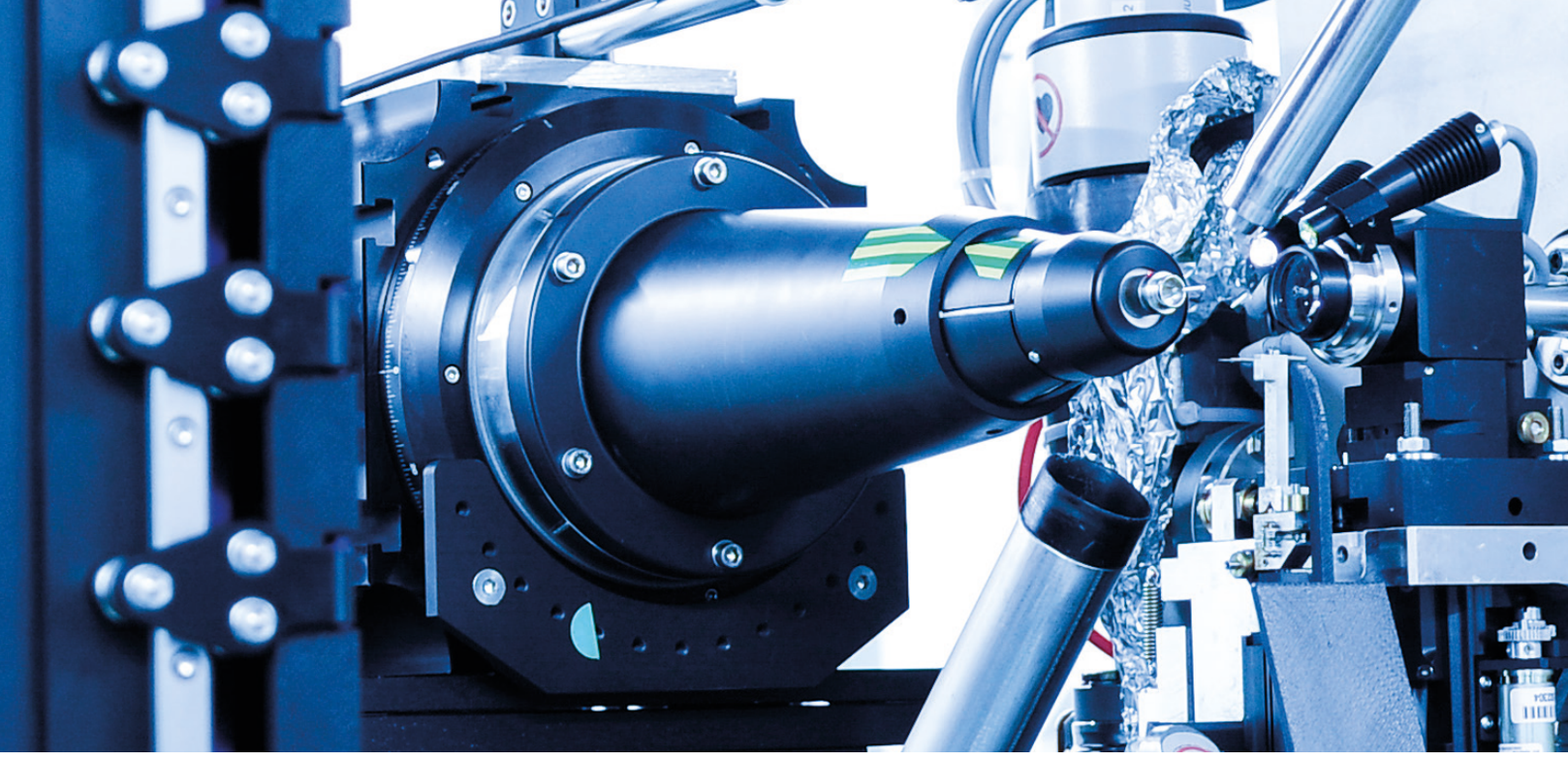
DECTRIS
detecting the future

EIGER2 X

Discover the true potential of your beamline



Latest Technology for 4th Generation Synchrotrons

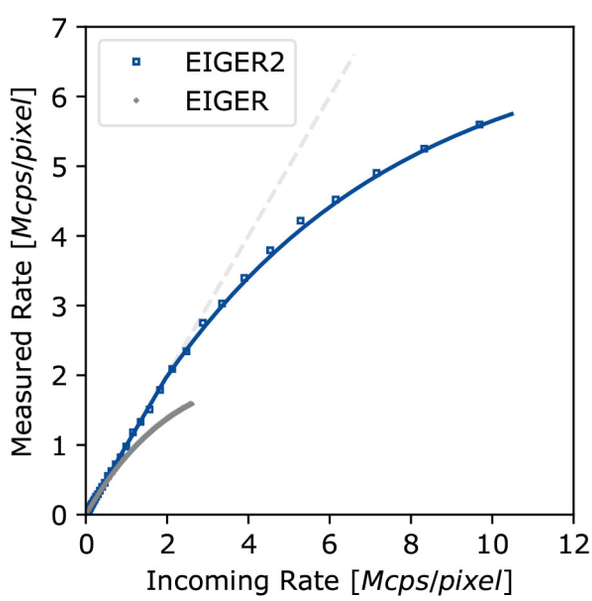
Research is driven by excellence and innovation. Most ambitious projects are realized by modern and powerful tools. Synchrotrons keep getting brighter. To fully exploit the increasing photon fluxes, DECTRIS presents the new EIGER2 detector series. With a count rate capability of 10^7 counts/s/pixel, a second energy discriminating threshold and non-paralyzable counters through DECTRIS retrigger functionality, EIGER2 detectors prepare your beamline for the future.

Key Advantages

- Hybrid Photon Counting technology
- Count rate capability 10^7 counts/s/pixel
- Two energy discriminating thresholds
- Gateable detection for pump & probe experiments
- Large active area for wide angular coverage

Applications

- Macromolecular crystallography (MX)
- Single crystal diffraction (SCD)
- Small- and Wide-angle X-ray scattering (SAXS/WAXS)
- Powder diffraction (PD)
- Surface diffraction
- Single crystal diffraction (SCD)
- Ptychography
- Time-resolved experiments

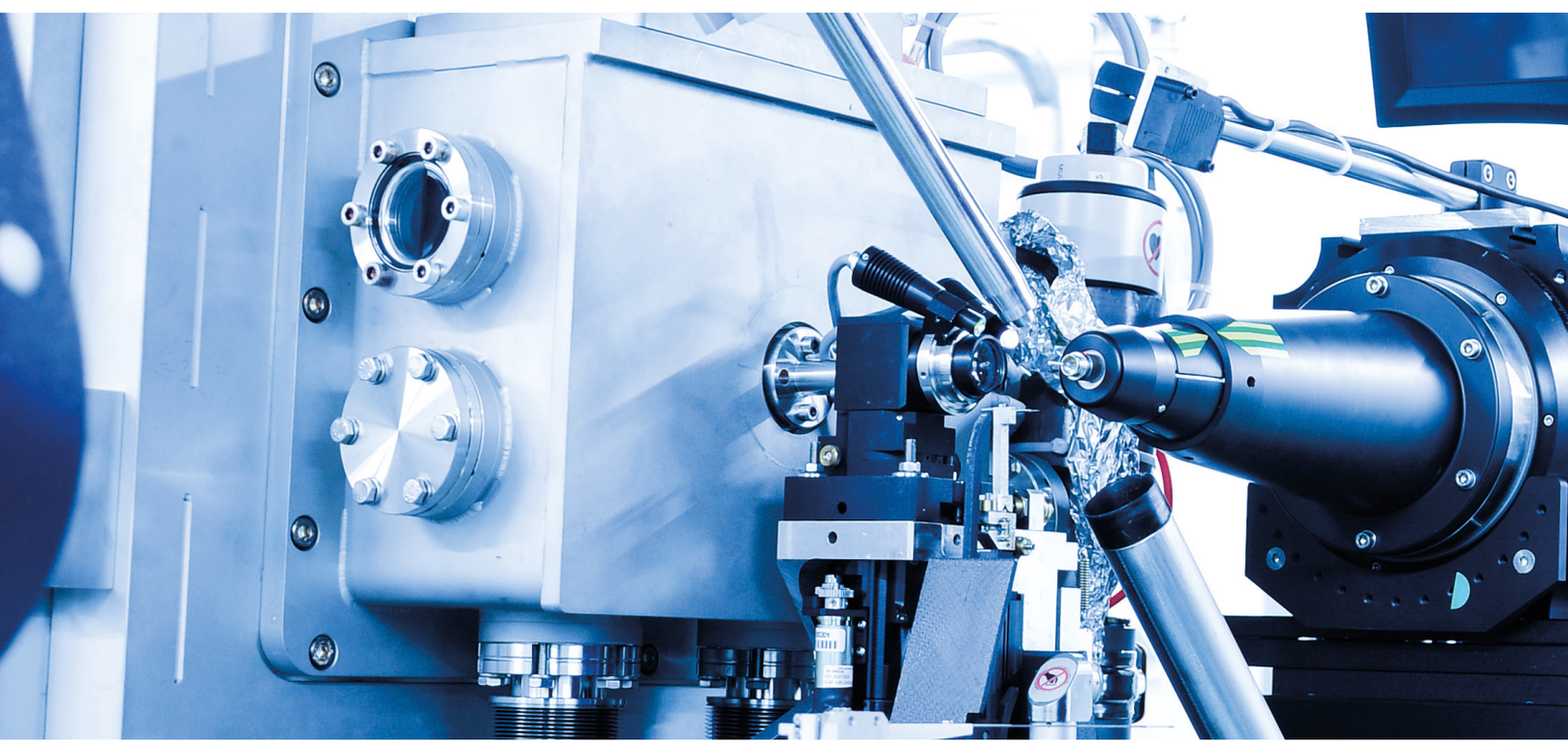


Count rate comparison between EIGER and EIGER2 systems at 12 keV photon energy

Technical specifications

EIGER2 X	500K	1M	4M	9M	16M
Number of detector modules	1	1 × 2	2 × 4	3 × 6	4 × 8
Sensitive area, width × height [mm²]	77.1 × 38.4	77.1 × 79.65	155.1 × 162.15	233.1 × 244.65	311.1 × 327.15
Pixel size [µm²]			75 × 75		
Total number of pixels	1028 × 512 = 526,336	1028 × 1062 = 1,091,736	2068 × 2162 = 4,471,016	3108 × 3262 = 10,138,296	4148 × 4362 = 18,093,576
Gap width vertical / horizontal [pixel]	- / -	- / 38	12 / 38	12 / 38	12 / 38
Inactive area [%]	0.0	3.6	5.8	6.6	6.9
Energy discriminating thresholds			2		
Count rate capability [counts/s/pixel]			10^7		
Frame rate [Hz] [Hz]	2000	2000	500	230	130
Point-spread function [pixel]			1		
Silicon sensor thickness [µm]			450		
Data format			HDF5 / NeXus		
Dimensions (WHD) [mm³]	114 x 92 x 242	114 × 133 × 240	235 × 237 × 372	340 × 370 × 500	400 × 430 × 500
Weight [kg]	3.3	3.9	15	41	55

All specifications are subject to change without notice.



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DECTRIS®

detecting the future

PILATUS 3
S AND X SERIES

Hybrid Photon Counting Detectors for Everyone

Two performance classes to match the needs of any beamline

synchrotron

Hybrid Photon Counting X-ray detectors of the PILATUS3 S and X series meet the requirements of both advanced synchrotron instruments as well as cutting edge beamlines. With ample performance for any standard application, the PILATUS3 S series makes Hybrid Photon Counting technology accessible to virtually any synchrotron beamline and budget. A PILATUS3 S detector is the optimal choice for scientists looking for excellent data from a fast detector without requiring ultimate frame rates.

The PILATUS3 X series excels with frame rates up to 500 Hz and sub-millisecond readout times, enabling novel experimental strategies. Region of interest readout, a new feature of the PILATUS3 X series compared to its PILATUS3 predecessors, enables taking advantage of highest frame rates with even the largest models. The PILATUS3 CMOS readout ASIC features DECTRIS instant retrigger technology, which enables non-paralyzable counting, enhanced high-rate-counting performance, reduced readout time and allows for highly accurate count-rate correction. DECTRIS instant retrigger technology overcomes the intrinsic count-rate limitations of previous photon-counting detectors.

Superior data quality is the key benefit of all PILATUS3 detector systems and is achieved through various unique features: the absence of readout noise and dark current, a sharp point-spread function, and a high dynamic range and counter depth of 20 bits (~1 million counts). State-of-the-art CMOS ASICs and readout electronics enable fast data acquisition. In its standard configuration, PILATUS3 now features 450 µm silicon sensors for enhanced quantum efficiency.

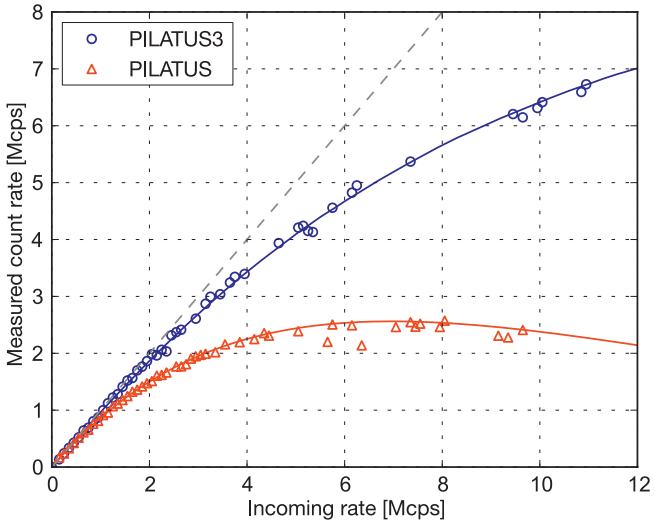
DECTRIS instant retrigger technology

DECTRIS instant retrigger technology is a photon-counting method that results in non-paralyzable counting and achieves accurate high-rate-counting performance.

Conventional single-photon counting X-ray detectors are susceptible to counting losses and counter paralyzation. Counting losses are caused by pile-up of charge pulses generated by photons impinging too closely spaced in time. Count rate correction is applied to compensate for the counting loss. However, at high photon rates, pile-up can cause paralyzation of a conventional counting detector.

In PILATUS3 S and X detectors, the instant retrigger technology detects pulse pile-up, retriggers the counting circuit and effectively overcomes counter paralyzation. The non-paralyzable counting achieved by DECTRIS instant retrigger technology allows for enhanced count rate correction and improves data quality at high count rates. Photon rates of more than 10^7 photons per second in a single pixel can be accurately measured with PILATUS3 detectors. Furthermore, global count rates of more than 2 x 10^8 photons per second and mm^2 can be achieved.

Visit our website **www.dectris.com** for a detailed description of DECTRIS instant trigger technology.



Measured data (symbols) and theoretical curves (solid lines) of count rate characteristics of PILATUS3 (blue) and PILATUS (red). Data acquired at beamline X05DA of Swiss Light Source, 10.0 keV X-ray energy, 5 keV threshold.

Improved Applications

PILATUS3 detectors ideally match the ever increasing brightness and flux of present and future 3rd generation synchrotron sources. The unprecedented count rate capabilities are compatible with the strongest diffraction and scattering intensities and eliminate count rate limitations in applications like small-molecule crystallography or X-ray reflectometry. The high local and global count rates allow data with excellent statistics to be taken with short exposure times. High frame rates and an overflow-free 20 bit counter seamlessly complement these properties.
This enables advanced high-flux diffraction experiments such as *in situ* virus crystallography. Many applications require the determination of the primary beam intensity. PILATUS3 detectors in synchrotron-based ptychography or in SAXS instruments enable the direct measurement of the primary beam intensity.

The high frame rates supported by the PILATUS3 X series can be used to speed up experiments and enable novel strategies, while the short readout time improves the duty cycle and hence the efficiency of data collection. This is of major advantage in applications that require the acquisition of large data sets such as SAXS, ptychography or sample alignment and characterization by grid scanning techniques. Thanks to the new Region Of Interest (ROI) feature, even the largest PILATUS3 X models offer highest frame rates.

Key advantages
- Count rates up to 10 Mcts/sec/pixel
- Direct detection of X-rays in single-photon-counting mode
- No readout noise
- No dark current
- Excellent point-spread function
- Overflow-free 20 bit counter
- Room temperature operation

Advantages S Series
- Maximum frame rate of 25 Hz
- Readout time of 2.03 ms
- Upgradable to X series

Advantages X Series
- Frame rates up to 500 Hz
- Readout time of 0.95 ms
- Region of interest readout

Applications
– Macromolecular crystallography (MX)
– Single-crystal diffraction (SCD)
– Surface diffraction
– Small and wide-angle X-ray scattering (SAXS/WAXS)
– X-ray powder diffraction (XRPD)
– Coherent X-ray imaging
– Time-resolved experiments

Detector options
In addition to the standard configuration with 450 µm silicon sensors, all PILATUS3 detectors are also available with 1000 µm silicon sensors for improved quantum efficiency at high X-ray energies. The water cooled models PILATUS3 X 300K and 300K-W offer optional vacuum compatibility. This option allows operation of the detector in vacuum, e.g. in the flight tube of a SAXS instrument. The vacuum compatible 300K and 300K-W detectors are also available with 320 µm thick sensors and special calibrations for low energy applications. Based on PILATUS3 technology, DECTRIS can realize Specific Solutions. In this case all modules are placed in vacuum and custom geometries can be realized.

The PILATUS processing unit (PPU) provides an efficient complement to PILATUS3 detector systems. Dedicated software packages running on a high-end server ensure stable data acquisition at sustained high rates without challenging your beamline IT infrastructure. The PILATUS3 X systems 1M, 2M, and 6M include a PPU mini. All PILATUS3 S and X systems can be upgraded with a PPU L or XL for additional computing and storage resources.

	Sensor thickness [µm]		
X-ray energy	**320**	**450**	**1000**
5.4 keV	94 %	94 %	>80 %
8.0 keV	97 %	98 %	96 %
12.4 keV (1Å)	72 %	84 %	97 %
17.5 keV	37 %	47 %	76 %
22.2 keV	20 %	27 %	50 %

Table 1: Quantum efficiency of PILATUS sensors measured in cooperation with PTB at the BAM beamline at BESSY II.

PILATUS3 S detector series technical specifications

PILATUS3 S	1M	2M	6M
Number of detector modules	2 × 5	3 × 8	5 × 12
Sensitive area: width × height [mm²]	168.7 × 179.4	253.7 × 288.8	423.6 × 434.6
Pixel size [µm²]	172 × 172		
Total number of pixels: hor. × ver.	981 × 1043	1475 × 1679	2463 × 2527
Gap width: hor. / ver. [pixel]	7 / 17		
Inactive area [%]	7.2	8.0	8.5
Defective pixels	< 0.03%		
Maximum frame rate [Hz]	25		
Readout time [ms]	2.03		
Point-spread function	1 pixel (FWHM)		
Threshold energy [keV]	2.7 - 18		
Counter depth	20 bits (1,048,576 counts)		
Power consumption [W]	165	250	580
Dimensions (WHD) [mm³]	265 × 286 × 455	384 × 424 × 456	590 × 603 × 455
Weight [kg]	25	46	92
Module cooling	Water-cooled		
Electronics cooling	Air-cooled		
Standard configuration	450 µm silicon sensor		
	detector, detector server, water-cooling unit		
Detector options	1000 µm silicon sensor		
	PPU mini, L or XL		

PILATUS3 S detectors can be upgraded on-site with minimal downtime to X Series detectors. This enables the full performance and features of the corresponding PILATUS3 X detector.

PILATUS3 X detector series technical specifications

PILATUS3 X	100K-A	200K-A	300K	300K-W	1M	2M	6M
Number of detector modules	1 x 1	1 x 2	1 x 3	3 x 1	2 x 5	3 x 8	5 x 12
Sensitive area: width × height [mm²]	83.8 x 33.5	83.8 × 70.0	83.8 × 106.5	253.7 × 33.5	168.7 × 179.4	253.7 × 288.8	423.6 × 434.6
Pixel size [µm²]	172 × 172						
Number of pixels: hor. × ver.	487 x 195	487 × 407	487 × 619	1475 × 195	981 × 1043	1475 × 1679	2463 × 2527
Gap width: hor. / ver. [pixel]	0	– / 17	– / 17	7 / –	7 / 17	7 / 17	7 / 17
Inactive area [%]	0	4.3	5.5	0.9	7.2	8.0	8.5
Defective pixels	< 0.03%						
Maximum frame rate, full frame [Hz]	500	500	500	500	500	250	100
Maximum frame rate, ROI [Hz]	–	–	–	–	500	500	500
Readout time [ms]	0.95						
Point-spread function	1 pixel (FWHM)						
Threshold energy [keV]	3.5 - 18	3.5 - 18	2.7 - 18	2.7 - 18	2.7 - 18	2.7 - 18	2.7 - 18
Counter depth	20 bits (1,048,576 counts)						
Power consumption [W]	30	30	36	36	165	250	580
Dimensions (WHD) [mm³]	156 x 115 x 284	156 x 155 x 284	158 x 193 x 262	280 x 62 x 296	265 x 286 x 455	384 x 424 x 456	590 x 603 x 455
Weight [kg]	4.5	5.4	7.5	7.0	25	46	92
Module cooling	Air-cooled	Air-cooled	Water-cooled	Water-cooled	Water-cooled	Water-cooled	Water-cooled
Electronics cooling	Air-cooled	Air-cooled	Water-cooled	Water-cooled	Air-cooled	Air-cooled	Air-cooled
Standard configuration	450 µm silicon sensor						
	detector, detector server	detector, detector server	detector, detector server, water-cooling unit		detector, detector server, water-cooling unit, PPU mini		
Detector options	1000 µm silicon sensor						
	PPU mini, L or XL	PPU mini, L or XL	PPU mini, L or XL	PPU mini, L or XL	PPU L or XL	PPU L or XL	PPU L or XL
	–	–	vacuum compatibility 320 µm silicon sensor		–	–	–

All data are subjects to change without notice

Hybrid Photon Counting (HPC) technology

Hybrid pixel detection

Hybrid pixel detectors directly convert X-rays into an electronic signal. Other types of X-ray detectors rely on intermittent steps to capture and convert X-rays. CCD and CMOS active pixel detectors, for instance, have to convert X-rays to visible light first. Scattering of light in the phosphor screen required for conversion smears out the signal and decreases spatial resolution. Fiber-glass optics transduce the light on the chip, which causes further loss and distortion of signal. These intrinsic design limitations of CCD and active pixel detectors are absent in hybrid pixel detectors.

Direct detection of X-rays with hybrid pixel technology offers superior spatial resolution and high detection efficiency. In a hybrid pixel detector every pixel is comprised of two components: a sensor pixel and a readout pixel (fig. 2). X-ray photons are directly converted into electric charge in the sensor pixel. The readout pixel processes and counts this electric signal. Sensor and readout pixel have a direct, electronic connection that is unique for every hybrid pixel and prevents spread and loss of signal. This makes every hybrid pixel a virtually independent X-ray detector and leads to lowest point spread, highest sensitivity and ultimate speed.

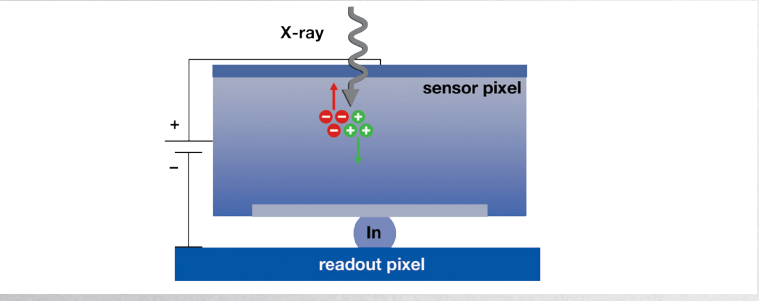


Figure 2: Principle of direct detection of X-ray photons in a solid-state sensor.

Single-photon counting

Free electric charge is released in the sensor pixel upon absorption of X-rays. The X-ray signal is processed by the readout pixel in single-photon-counting mode, which offers various advantages over integrating the signal. In an integrating detector, charge is accumulated during exposure. Throughout integration, an intrinsic dark current is added to the accumulated charge. Dark current increases noise and diminishes data quality. In a single-photon-counting detector, the signal is determined by counting individual events of charge released by X-ray absorption: The charge is amplified in the readout pixel and, if the signal exceeds an adjustable threshold, an absorption event is digitally counted. This way, single-photon-counting technology completely abolishes dark current as a source of detector noise and enables superior data quality. Furthermore, single-photon counting occurs on the fly during exposure, achieving earliest possible digitization and a subsequent fast and noise-free digital readout. Therefore, readout noise is entirely absent in single-photon-counting detectors.

Features

Optimal signal-to-noise ratio

PILATUS3 Hybrid Photon Counting detectors are inherently free of dark current and readout noise (fig. 3). The absence of any detector noise guarantees data with an excellent signal-to-noise ratio. Compared to conventional detectors, this allows for either superior data collection at similar exposure times or equally good data with shorter acquisition times, equivalent to lower dose to the sample. A noise-free detector provides largest benefit when recording weak signals from poorly diffracting samples or at highest resolution.

Excellent point-spread function

With hybrid pixel technology and direct conversion of X-rays into charge pulses, PILATUS3 detectors spread virtually no intensity between pixels. This enables a sharp point-spread function of one pixel (FWHM) and offers a variety of benefits (fig. 4). Closely spaced signals, even of largely differing intensity, can be accurately resolved and measured. Sharper signals reduce overlap with scattering or other background intrinsic to the experiment, thereby improving the signal-to-noise ratio.

High dynamic range

A counter depth of 20 bits (~1 million counts) combined with the absence of detector noise ensures unprecedented contrast and dynamic range; another PILATUS3 hallmark leading to excellent image and data quality (fig. 4). Extremely strong and weak signals can be accurately detected on a single image.

Figure 3: Absence of readout noise and dark current in PILATUS Hybrid Photon Counting detectors.
Images of a single PILATUS module without exposure to an X-ray source with 100 ms or 1 hour of acquisition time. After 100 ms, all pixels have zero counts because no noise is added during readout of the image. After 1 hour, most pixels still have zero counts, since no dark current accumulates during long exposure and no noise is added during readout. All counts in the exposure arise from general background radiation, which accounts for 0.2 cts/h/pixel.

Fast readout and shutterless operation

PILATUS3 S and X systems feature short readout times and high frame rates, which substantially reduce measurement time and maximize efficiency and throughput. Most importantly, this allows shutterless, continuous acquisition of full images.

High local and global count rates

PILATUS3 detectors feature DECTRIS instant retrigger technology, which enables each pixel to accurately detect up to ten million photons per second. Furthermore, global count rates of more than 2 x 10^8 photons per second and mm^2 can be achieved. Both local and global count rates of PILATUS detectors are far superior to those of counting detectors based on gas discharge or similar technologies.

Ease of maintenance and operation

PILATUS3 detectors have low power and cooling requirements. All detector components are operated at room temperature, which vastly simplifies cooling. The PILATUS3 X 200K-A detector is fully air-cooled and maintenance-free, while the PILATUS3 X 100K-A is entirely media-free. Other models of the PILATUS3 S and X series use low-maintenance, closed-circuit water cooling for temperature stabilization at 23° C.

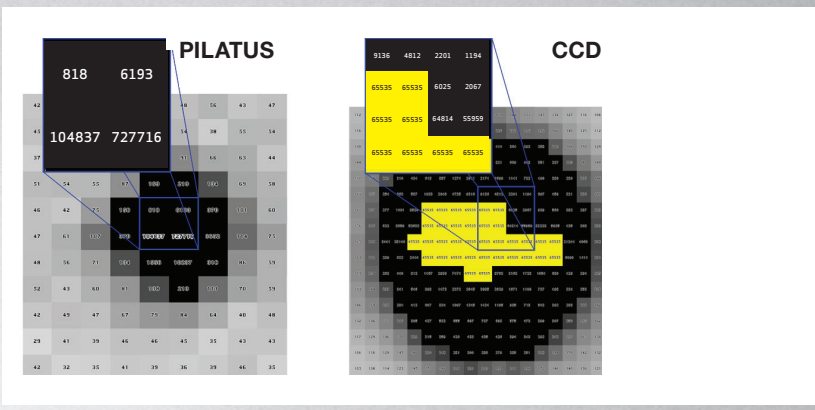


Figure 4: Superior dynamic range and point-spread function of PILATUS Hybrid Photon Counting detectors.
Details of diffraction images showing the same reflection of an insulin crystal. The images were acquired at a synchrotron beamline with identical parameters except for the detector distance that was adjusted to achieve the same resolution at the detector edge, depending on the detector size. PILATUS: The 20 bit counter depth of the hybrid pixel detector provides sufficient dynamic range to record 727,716 counts in the highest pixel intensity. With the excellent point-spread function, the spot is well confined to a small area. Furthermore, the sharp reflection profile of the low mosaicity crystal is accurately represented with a more than one-thousand-fold difference in intensity between neighboring pixels. CCD: The same reflection recorded with a CCD contains many overloaded pixels. The reflection intensity is smeared out over a large area.

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