DECTRIS®

detecting the future

MYTHEN

Microstrip X-ray Detectors

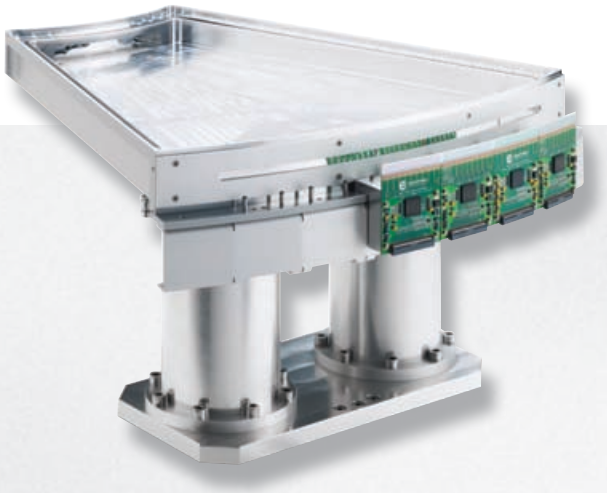
Ultimate data quality in high-throughput single-photon counting

synchrotron | *laboratory and industry* | *specific solutions*

MYTHEN

MYTHEN is a one-dimensional X-ray detector, operating in single-photon-counting mode. As a result of this state-of-the-art technology, it features zero-noise performance. The basic unit is one module containing 1280 silicon microstrips. Each microstrip is only 50 µm wide, enabling ultimate angular resolution. MYTHEN is the detector with the smallest strip size currently available on the market. Supreme temporal resolution is achieved with specially designed readout chips, with a readout time of 300 µs [1]. A complete description of the MYTHEN detector system can be found in Bergamaschi *et al* [2].

Single-photon counting
Fast data acquisition
Maintenance-free operation



Key advantages

– No readout noise and no dark current
– High dynamic range
– Fluorescence suppression
– Excellent point-spread function
– Wide energy range
– Modular design

Applications

MYTHEN X-ray detector systems perfectly accommodate the needs of diverse X-ray experiments. High count rates and radiation-tolerant design make them ideal for synchrotron applications; noise-free single-photon-counting is highly beneficial for weak laboratory sources. Moreover, three available sensor thicknesses and the multi-modular design allow for an optimal performance in a wide range of X-ray energies and an expanded angular coverage.

Techniques & methods

– X-ray diffraction (powder, thin films, texture)
  – Structure determination and refinement
  – Phase analysis
  – Quantification of mixtures
  – Time-resolved measurements
  – Residual stress measurements
  – PDF calculations
– SAXS, WAXS, GISAXS
– Dispersive fluorescence spectroscopy

Module specifications

Strips per module	1'280
Strip width [µm]	50
Sensitive area [mm²]	(1'280 × 50 µm) × 8 = 64 × 8
Readout modes [bit]	4, 8, 16, 24
Dead time [µs]	300 µs (24-bit)
Maximal count rate per strip [phts/s]	$>10^6$
Dynamic range	24 bit (1:16.8 million)
Energy range [keV]	5 – 40
Point-spread function	1 strip
Sensor thickness [µm]	320, 450, 1000
Weight [g]	25
Dimensions without housing (WHD) [mm³]	66 × 88 × 10

[1] Schmitt, B. *et al* (2003). MYTHEN detector system. *Nucl. Inst. Meth. Phys. Res.* A501, 267–272

[2] Bergamaschi, A. *et al* (2008). The MYTHEN detector for X-ray powder diffraction experiments at Swiss Light Source. *Nucl. Inst. Meth. Phys. Res.* A591, 163-166

Features

Noise-free detectors
X-ray photons absorbed by the silicon sensor are directly converted to charge. Photons are individually counted, if their signal exceeds a user-configurable threshold. If this signal is below the threshold, it will not be counted. This makes the detector free of dark current. The digitization of the photons at the earliest possible stage eliminates any readout noise and allows low intensities to be measured accurately.

Fluorescence suppression
The energy threshold is adjustable. When the detector threshold is set higher than the fluorescent energy of the sample, this background is effectively suppressed. Eliminating this source of noise significantly improves data quality. This feature is particular useful for metal containing samples.

Excellent point-spread function
The contribution of the detector to peak widths is determined by the strip width and the point-spread function. MYTHEN, with its 50 µm wide strips, has a point spread function of only one strip. This contribution to the peak broadening is negligible, compared to the contribution originating from the capillary size or the source.

High local and global count rates
Fast CMOS amplifiers allow each strip to accurately detect more than one million photons per second (local count rates). As each strip counts photons independently, the global count rate is as high as 10^9 photons per second per module.

High dynamic range
The counter depth of 24 bits (1:16.8 million) combined with the excellent point-spread function enables weak reflections to be accurately measured on the same scan and in close proximity to strong peaks.

Short readout times
The standard readout mode in 24-bit corresponds to a readout time of 300 µs. Faster readout can be achieved by reducing the counter depth to 16, 8 or 4 bit. For dynamic studies with ultimate temporal resolution, 4 to 32 data profiles can be stored on the MYTHEN chip and read out afterwards.

Electronic gating
Data acquisition and exposure times are controlled by electronic gating within the detector system, rather than by a mechanical shutter. Consequently, exposure times as short as 100 ns can be set.

Maintenance-free

The detector is maintenance-free.
This means: no gases, no liquids and no cooling. Moreover, the detector is beryllium-free.

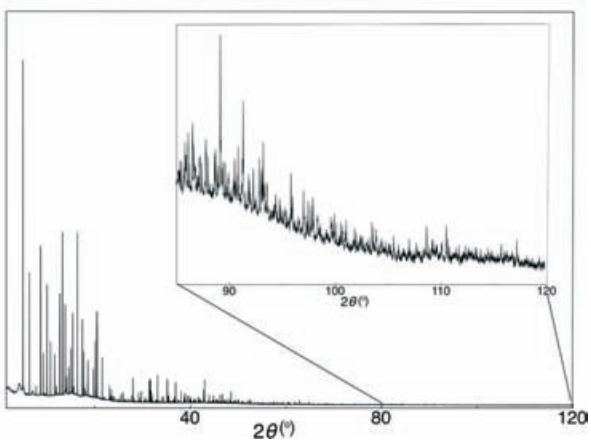
Radiation resistant by design
Silicon sensors used in MYTHEN detectors were initially developed to accommodate the needs of high-energy physics. Such a radiation resistant design makes MYTHEN extremely robust: the systems operated only with indirect beam show virtually endless life cycle.

Calibration and correction
For optimal performance and the simple use of MYTHEN 1K detectors DECTRIS provides calibration and correction files, which are stored on Detector Control Sytem (DCS).

Flexible design for diverse applications

Multi-modular systems

Single modules (up to 24) can be assembled in a multi-modular system, resulting in a wider angular range (up to 120° in 2θ) that can be measured in a single scan. Moreover, as each module measures photons independently, the global count rate increases linearly with the number of modules. The benefits of such multi-modular systems are presented in the figure (right). Using the MYTHEN 24K system, installed at Swiss Light Source (SLS), data covering 120° in 2θ were measured in only 10 s. The high resolution data (d_{min} = 0.58 Å) with excellent statistics can only be obtained due to the highly parallel detection of MYTHEN 24K systems: 24 modules, each with 1280 microstrips sum up to 30720 simultaneously operating detectors with an angular resolution of 0.0037°.



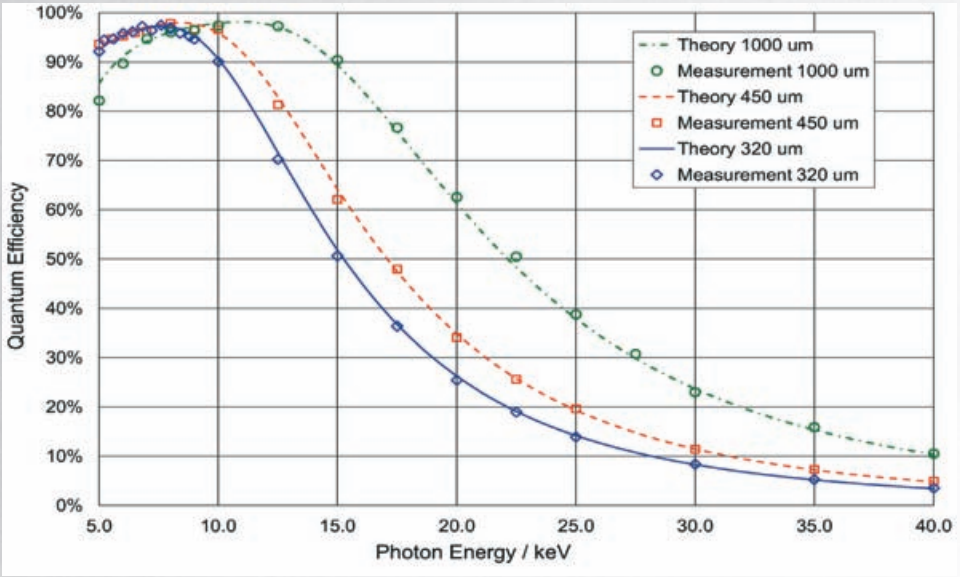
X-ray powder diffraction data measured with MYTHEN 24K in 10 s, at SLS (Paul Scherrer Institute), Switzerland.

Sensors for a wide energy range

Three available sensor thicknesses allow for optimal operation in the energy range from 5 to 40 keV. This wide energy span makes MYTHEN suitable for different applications. MYTHEN's 320 µm sensor is a perfect choice for residual stress measurements. Its high quantum efficiency at low energies enables fast measurements using Cr radiation. On the other hand, the 1000 µm sensor allows excellent PDF data to be collected with laboratory Ag sources [3].

Sensor thicknesses and recommended energy ranges

Sensor [µm]	320	450	1000
Energy [keV]	5 – 12.5	7.4 – 17.5	7.4 – 40



Efficiency of 320, 450 and 1000 µm sensors, measured at PTB, BESSY II, using similar detector (PILATUS).

[3] Fink, L. *et al* (2013). Recent results in PDF calculations using STOE Stadi P with Ag $K\alpha_1$-radiaton and DECTRIS' MYTHEN 1K detector. *Acta Cryst.* A69, s57

Software

There are three types of interfaces for convenient and easy control of the detector:

- MYTHEN Web Client (Linux, Windows, OS X): Web Client is a graphical interface for controlling the detector (figure right). It is used to define measurement parameters (dynamic range, exposure time) and data corrections.
- Socket connection *via* TCP/UDP. The detector is controlled through command lines. TCP is more reliable, UDP is faster and allows for higher frame rates.
- SPEC interface: Certified Scientific Software, available from: http://www.certif.com/

MYTHEN Web Client: Graphical User Interface

Success stories

Accurate intensities of XRPD patterns are important not only for *ab initio* structure determination, but also for the level of sophistication of the structure analysis. Short acquisition times, noise-free performance, and high dynamic range of MYTHEN detectors provide data of highest accuracy.

(1) D-mannose, an organic sample whose structure was originally solved from single crystal data, was measured using MYTHEN detectors with synchrotron radiation as well as a laboratory source. In only 60 s, the MYTHEN 24K at the SLS provided high resolution data, whose quality allowed restraint-free Rietveld refinement. Results of this refinement were compared with the single crystal results (Figure 1). Perfect correlation between the two sets of atomic coordinates proved that MYTHEN data can be comparable to single crystal data. Similar results were obtained with the data collected in 14 hours, using a STOE Stadi diffractometer, equipped with a Cu source and a MYTHEN 1K detector.

(2) D-ribose presented a puzzle since 1956: its exact molecular structure was not known (pyranose-furanose dilemma), and the determination of the crystal structure was hindered by the poor quality of crystals. Almost 50 years later, the MYTHEN 24K at SLS was exploited for structure determination based on XRPD data. Due to its short readout time and parallel detection, 10 patterns could be consecutively measured in a matter of minutes. This allowed radiation-induced crystal decay to be controlled. Moreover, averaging the ten patterns produced high statistics data. In combination with high dynamic range, this resulted in accurate determination of low intensity reflections. This is particularly important for reflections at high 2θ angles, as they hold information about structural details. In the case of D-ribose, high accuracy data enabled complete solid-state characterization. Two pyranose molecules, of which one is disordered, were found in the asymmetric unit (Figure 2).

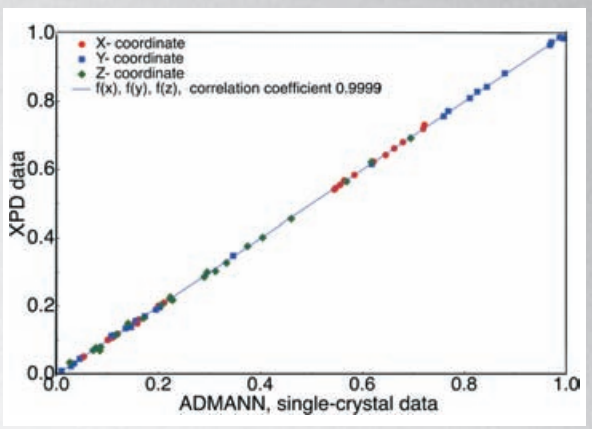


Figure 1: Comparison of D-mannose atomic coordinates (x, y, z) obtained from single-crystal data (ADMANN) and powder diffraction data measured with MYTHEN 24K at SLS.

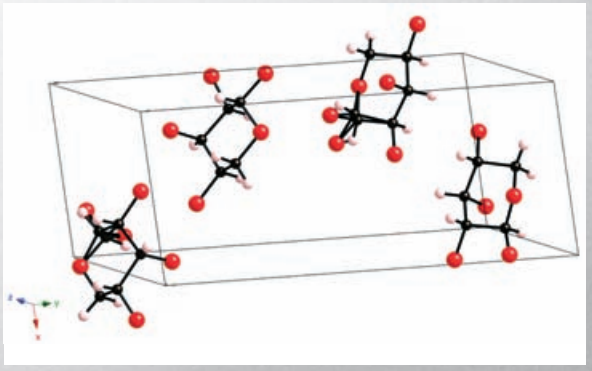
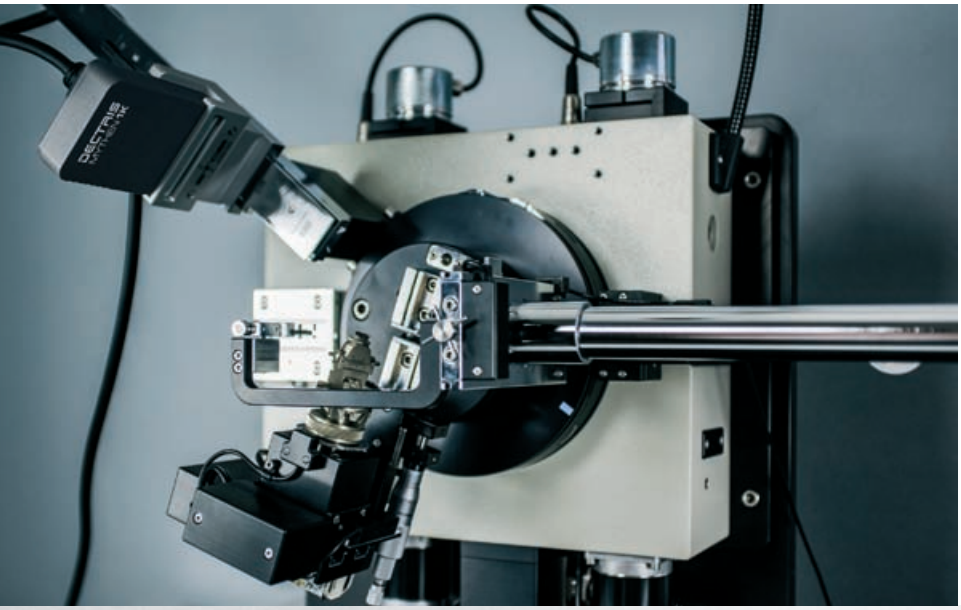


Figure 2: Crystal structure of D-ribose, derived from XPD data.

[4] Šišak, D. *et al* (2010). D-ribose - at last! *Angew. Chem. Int. Ed.* 43(26), 4503 – 4505



STOE Stadi diffractometer with MYTHEN 1K

MYTHEN family

MYTHEN 1K detector systems consist of one detector module with 1280 strips, and a Detector Control System (DCS).

Several MYTHEN modules can be assembled into large multi-modular systems. The MYTHEN 6K system is built by connecting two to six detector modules to a DCS6 unit. MYTHEN 24K system consists of seven to 24 modules and a DCS24 controller.

The standard MYTHEN 1K module is delivered in a compact and robust housing. Bare modules for multi-modular systems or upgrades of existing systems are also available. For 6K and 24K systems, DECTRIS, in collaboration with Huber Diffraction Equipment, offers curved housings with a radius of 760 mm. This setup results in high angular resolution of 0.0037°.

All MYTHEN systems come with power supply and data cables. Calibration and correction files as well as firmware are stored on the DCS. This makes the integration into synchrotron and laboratory instruments fast and easy.

MYTHEN 1K systems are integrated in ready-to-use laboratory diffractometers and cameras, produced by DECTRIS' OEM partners (Anton Paar, GE-IT, PROTO, Shimadzu, STOE).

	MYTHEN 1K	MYTHEN 6K	MYTHEN 24K
Number of detector modules	1	2–6	7–24
Number of strips	1280	2560–7680	8960–30720
Sensitive area [mm²]	(1) × 64 × 8	(2–6) × 64 × 8	(7–24) × 64 × 8
Gap between the modules [mm]	–	2	2
Housing dimensions (WHD) [mm³]	72 × 100 × 24	–	–
Housing radius (sensitive area) [mm]	–	760	760
Coverage* (°)	–	10–30	35–120
Angular resolution* (°)	–	0.004	0.004

* Coverage and angular resolution depend on the sample-detector distance. For 24K and 6K systems, values correspond to the case where the sample is at the origin of the detector curvature

	DCS1	DCS6	DCS24
Number of detector modules	1	2–6	7–24
Maximal frame rate*	700	450	100
Dimensions (WHD) [mm³]	176x50x200	296x65x300	397x298x82
Weight [kg]	1.7	4.3	6.5

* Maximal frame rate depends on number of modules, dynamic range (4-, 8-, 16- or 24-bit) protocol (TCP, UDP) and data correction used. The values in this table are measured for maximum number of modules (1,6, 24) and 4-bit dynamic range. Maximal frame rate corresponds to raw data transfer.

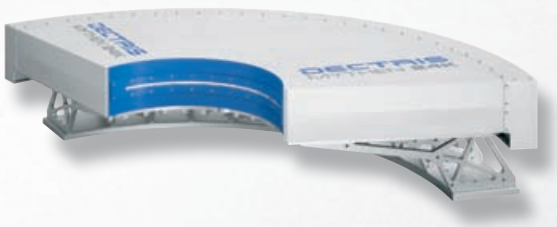
MYTHEN 1K detector system

MYTHEN 1K systems bring out the best in laboratory data collection: superb data quality suitable for Rietveld refinement can be collected in the matter of hours. These systems are ready to be implement as an upgrade of existing diffractometers or available from our OEM partners as turn-key diffractometers and cameras (Anton Paar, GE-IT, PROTO, Shimadzu, STOE). MYTHEN 1K detectors are also frequently used with synchrotron sources, covering a variety of applications, for example *in situ* stress measurements [5]. MYTHEN 1K detectors are CE certified.

MYTHEN 6K detector system

MYTHEN 6K detector systems are used in X-ray analysis at synchrotron facilities. As the number of modules is proportional to angular coverage, this system is ideally used for *in situ* measurements, such as phase transitions, where patterns of large angular range need to be collected with ultimate temporal resolution.
The MYTHEN 6K system housing is produced by Huber diffraction equipment.

MYTHEN 24K detector system



MYTHEN 24K detector systems are used exclusively with synchrotron sources, especially at high-resolution powder diffraction beamlines. These outstanding detector systems allow patterns of 120° in 2θ to be measured in a matter of seconds. This enables highly accurate structure determination of both radiation sensitive compounds and intermediates in time-resolved experiments. Moreover, the extremely large angular range can be used to simultaneously obtain two powder patterns of different orientations, enabling ultra-fast texture analysis [6] and *in situ* stress measurements [7]. The MYTHEN 24K system housing is produced by Huber diffraction equipment.

[5] Kostov, V. *et al* (2012). Fast in-situ phase and stress analysis during laser surface treatment *Rev. Sci. Instrum.* 83, 115101
[6] Grässlin, J. *et al* (2013). Advances in exploiting preferred orientation in the structure analysis of polychrystalline materials. *J. Appl. Cryst.* 46, 173-180
[7] Budrovic, Z. *et al* (2004). Plastic deformation with reversible peak broadening in nanocrystalline nickel. *Science* 304, 273-276

DECTRIS Ltd.
Neuenhoferstrasse 107
5400 Baden
Switzerland

Phone +41 56 500 21 00
Fax +41 56 500 21 01
E-Mail sales@dectris.com
www.dectris.com

DECTRIS®