Merlin

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Technical Datasheet

The High Speed Photon Counting Detector System.

The Merlin detector system with the photon counting Medipix3 ASIC packs a lot in for its size. With fast frame rates and high pixel density, Medipix3 improves detection results through charge summing to mitigate the effects of charge diffusion. With 2 counters per pixel, Merlin can read new data in while writing the data out from its last capture resulting in zero dead time between frames. The system can also be configured to have up to 8 threshold levels giving colour images and simplifying the interpretation of the results.

Applications

- High Resolution X-Ray Imaging
- Gi-SAXS
- Coherent X-ray Diffraction
- Bunch Synchronised Experiments
- Surface Diffraction
- Phase Contrast Imaging
- Pump and probe experiments
- Powder diffraction
- Multi energy imaging
- High speed real time imaging
- Spectroscopic Imaging

Key Advantages

- Photon Counting eliminates dark noise
- Up to 1200 Hz Frame rates in 1s bursts
- Continuous acquisition up to 100 Hz
- Zero dead time between frames
- High spatial resolution, 55µm pixels
- 24 bit dynamic range with single threshold
- 12 bit dynamic range with two simultaneous thresholds
- Zero read out time with continuous read write mode
- Up to eight thresholds allowing spectroscopic imaging
- Analogue charge summing improving energy resolution
- Robust hardware triggering with < 20 ns jitter
- Compact detector head with remote readout
- No cooling fluid or gas flow required for operation
- Single chip version 14mm by 14mm (256 by 256 pixels)
- Quad chip version 28mm by 28mm (512 by 512 pixels)

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About

Merlin, developed by Diamond Light Source, is a robust and versatile system built around the Medipix3 ASIC. It is designed with the high performance and reliability standards required by synchrotron beamlines and other industrial and large scale scientific applications.

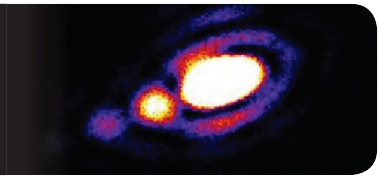
Multiple Configurable Counting Modes

The on board Medipix3 ASIC has a large array of configurable features that allow a number of powerful and novel counting modes:

Zero Readout Dead Time
By alternating the two counters available to each pixel, the system can be continuously sensitive with no readout dead time at all. Whilst one counter is acquiring an image the other is reading out.

"Single slice of a coherent X-ray diffraction pattern at the 111 Bragg peak of a 200nm gold nanocrystal."

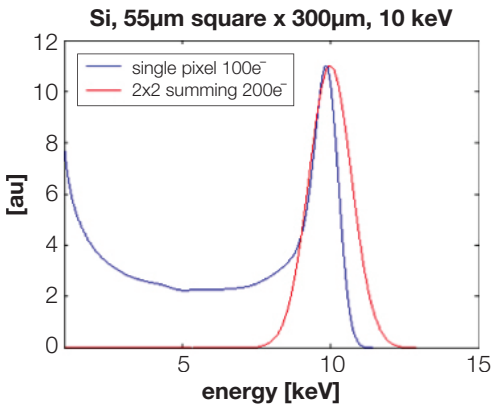
Data were measured at I-16 of the Diamond Light Source by the group of Ian Robinson, University College London.



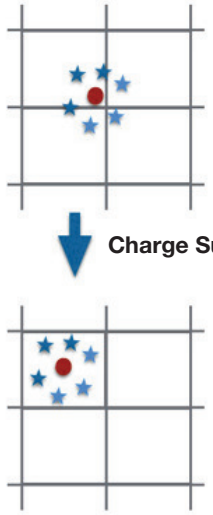
Extremely Deep 24 bit Counter
By connecting the two counters together a single 24 bit deep counter is produced. This, coupled with the small 55µm pixel size produces very high dynamic range imaging. Very faint signals can now be measured immediately adjacent to very intense features.

Two Simultaneous Energy Thresholds
By providing a second threshold for the second counter it is possible to use the system in an energy windowing mode. By recording images of photons that fall between two adjustable energy levels, specific signals can be studied or known sources of noise can be rejected depending on their energy.

Charge Summing Mode
In the circumstances where the charge from an event falls on the boundaries between sensor pixels, the information is shared between the pixels and the event is reconstructed. This significantly increases the accuracy of the spectroscopic information where some below threshold data would normally be lost or lower energies would be recorded.



In blue is the spectrum observed by a 55 µm square silicon pixel detector that is uniformly exposed to 10 keV photons. In red is the spectrum seen by a pixel operating in charge summing mode where the output of 4 pixels are added.



Location of photon strike

Diffused charges within pixel

Charge diffusion drifts to neighbouring pixels

Charge Summing Function

Charges from neighbouring pixels are added to the pixel where the photon event took place giving a more realistic result.

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Colour Mode
Groups of pixels can have their resources pooled together to create a super-pixel. This enables access to 8 independent thresholds allowing multi-spectral colour imaging from a photon-counting device. This high level of configurability and multiplicity of operating modes makes having a robust and easy to operate readout system essential.

Interface/Merlin Readout Electronics

The Merlin readout electronics are based on a National Instruments PXI FPGA system with some additional custom control electronics. This is a robust, extensible and well supported platform with a long product lifetime. It integrates an embedded high performance industrial grade PC and FPGA card with 512GB dedicated RAM. The detector head is connected by a high density cable link that can be up to 10m long allowing a significant degree of flexibility in the mounting of the system.

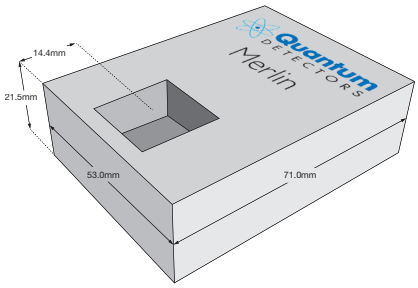
As the Merlin contains an integrated PC, it requires no external input other than mains power to run. In addition to its own intuitive graphical interface, the system also implements a TCP/IP based remote control function that allows easy integration with a users control systems.

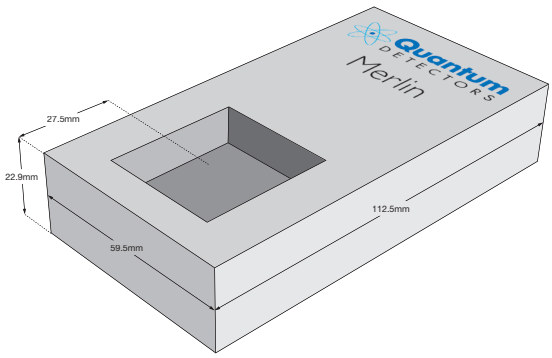
Equalisation and Calibration

Each Merlin detector is calibrated before shipping to achieve good performance immediately upon installation. In some cases, when switching a system to a different application or operating at a very different energy a user may wish to recalibrate their system. For these eventualities a full set of advanced calibration routines are incorporated into the system. These are not required for normal operation and are included to allow advanced users to tune their systems to achieve optimal performance in all situations.

Physical Characteristics

The small size and power consumption of the Merlin detector head, coupled with its room temperature operation allows it to rely on ambient cooling through the detector head housing. It therefore requires no cooling fluids or gas to be supplied. This makes the system very self contained and easy to install and reposition.





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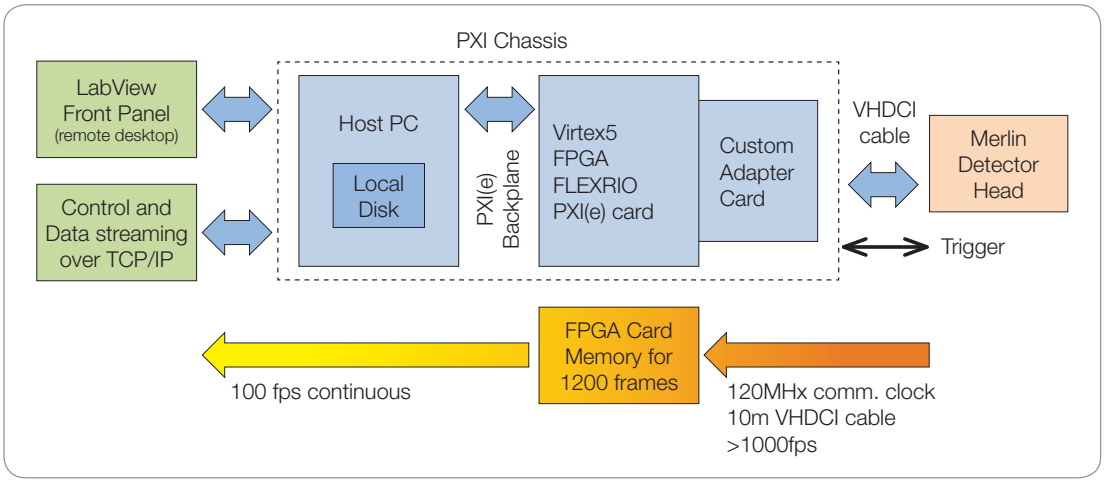
Merlin Block Diagram



Reference

R Plackett et al, “Merlin: a fast readout stystem for Medipix 3” (2013) JINST 8 C01038.

Technical specifications

ASIC	Medipix 3RX
Pixel array	256 by 256 pixels
Pixel size	55µm by 55µm square pixels
Sensor area	14mm by 14mm or 28mm by 28mm
Sensor thickness	500µm
Sensor type	Reverse biased hybrid silicon diode array
Minimum Exposure time	Minimum 1µs, no practical maximum
Dynamic Range	12 bit or 24 bit configurable
Deadtime in continuous mode	Zero
Readout time 12 bit	850µs
Readout time 24 bit	1.8ms
Maximum frame rate (1200 frame burst mode)	1kHz
Maximum frame rate (continuous)	100 Hz
Threshold range	5 keV upwards
Threshold resolution	250 eV
Pixel Threshold Dispersion	2.5keV
Point spread function	1 pixel
Maximum trigger response jitter	20ns
Cooling	air cooled
Operating Temperature	10 – 50 C
Detector head dimensions	7 by 5 by 2 cm
PXI chassis dimensions	25 by 20 by 18 cm
Communication cable type	VHDCI
Communication cable length	1m to 10m

Due to Medipix 3RX licensing restrictions, Merlin may not be sold for the use of material analysis application using X-ray tube based X-Ray Diffraction, X-Ray Fluorescence, Small/Wide Angle X-Ray Scattering and X-Ray Reflectometry techniques. It is not to be sold for X-Ray computed tomography for small animal imaging or human body imaging.