Merlin
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)
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.

Si, 55µm square x 300µm, 10 keV

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.

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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.
Merlin Block Diagram

The following is an example of one of the calibration plots that is sent with each unit. The chart shows both the linearity (in blue) and the deviation from linearity (in red).

LabView Front Panel (remote desktop)
Control and Data streaming over TCP/IP

Host PC
Virtual PXI(e) Backplane
Custom Adapter Card

100 fps continuous
120M/Hx comm. clock
10m VHDCI cable
>1000fps

Reference

Technical specifications

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

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.