HEXITEC

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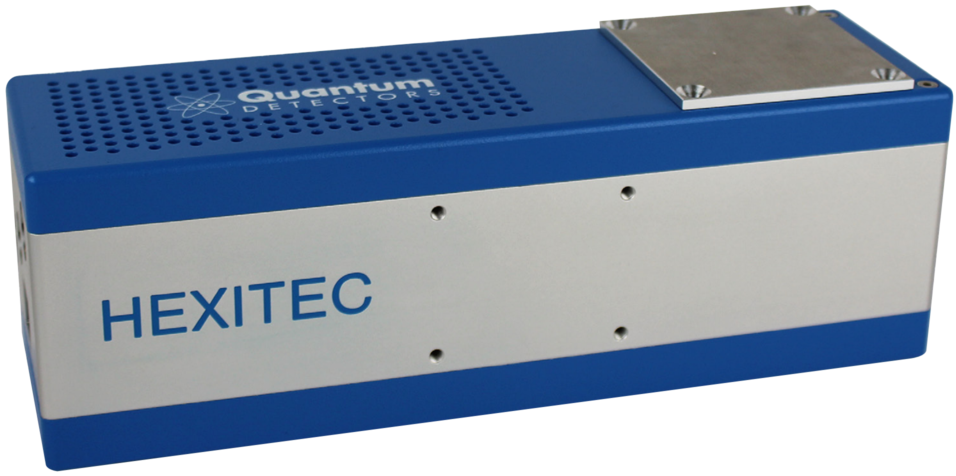
Technical Datasheet



High-energy hyperspectral pixelated area detector

The HEXITEC detector measures the energy and position of every incident photon in the 4-200 keV range. Each one of its 6400 pixels provides a full energy spectrum with an average energy resolution of 1 keV FWHM at 60 keV. This allows for information related to the X-ray emission spectra, and therefore material composition of the image to be obtained for every pixel.

HEXITEC is a self-contained system that requires only a mains power supply and ethernet connection to a PC or laptop. It is supported by our custom built data collection GUI to operate the detector and provide calibrated spectra.

Applications

- **Radio-isotope imaging[1]**
- **High-energy X-ray diffraction[2]**
- **Spectral small-angle x-ray scattering (sSAXS)[3]**
- **Fluorescence imaging[4,5]**
- **Tomography[6,7]**

Key Advantages

- **High resolution, high-energy imaging system**
- **Fully integrated - only a PC required to control and store data collection**
- **Well suited to lab-based X-ray sources**
- **Compact design**

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Technology

The HEXITEC detector is formed around the HEXITEC sensor, a novel energy-resolving pixelated sensor. The 2 x 2 cm sensor has 80 x 80 pixels on a 250 µm pitch and a three-side buttable design allowing it to be tiled into larger arrays. A 1 mm thick CdTe wafer is bump bonded to the HEXITEC ASIC and mounted on an aluminium block. When a photon interacts with the sensor material it generates electron-hole pairs that drift in opposite directions due to the electric field generated by the high-voltage bias applied across the sensor.

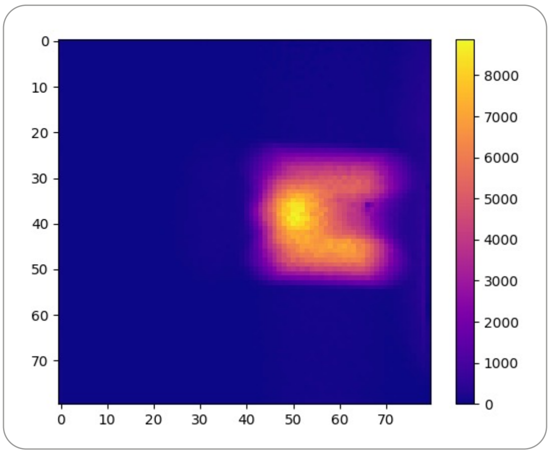

Figure 1: Example of data output by the HEXITEC software.

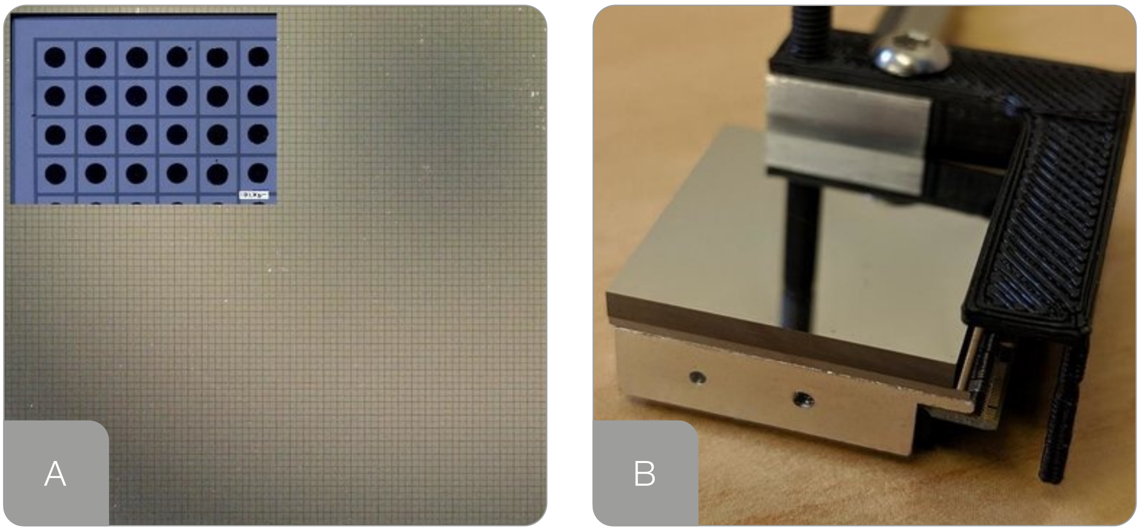

Figure 2: Images of HEXITEC sensor bonded onto its ASIC. In (a) a magnified image shows the edge of the sensor with part of the CdTe material cut away exposing the solder balls and ASIC underneath.

The electrons drift toward a pixel and a charge is induced on that pixel that is directly proportional to the photon energy. The induced charge is converted into an analogue voltage pulse and amplified in the pre-amplifier in the pixel electronics. The voltage pulse is shaped in a two-stage shaper and a peak hold circuit is used to measure the voltage peak height. The height is directly proportional to the charge induced on the pixel and thus the energy of the photon.

The ASIC is continuously read out at kHz frequency, with a 4-band rolling shutter readout scheme. The detector has a dedicated DAQ system that digitises the analogue voltages and buffers the signals into an FPGA. The FPGA conducts individual pixel calibration corrections, and transfers the data to a PC over an ethernet GigE interface.

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Quantum DETECTORS

Data

The data output by HEXITEC includes the energy and position of every event that occurred in each of the 5000 frames per second of data capture. The energy, spatial and temporal information is recorded and output, frame by frame.

The aggregate data is integrated across the capture period to give a single energy histogram for each individual pixel. This format requires less data and so is quicker to analyse, making it useful for monitoring or for experiments that do not require event level statistics.

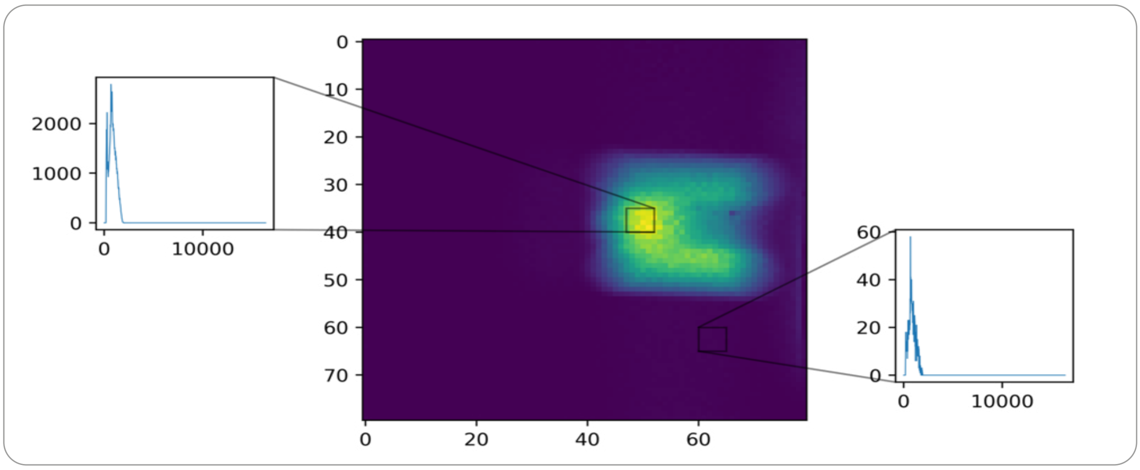

Figure 3: Example of data output, including the selection of individual pixel energy spectra for multiple parts of the image.

Software

Quantum Detectors have developed a dedicated software platform to leverage as much of the data from the sensor as possible. A custom GUI is used to collect data which can then be processed using the user's preferred package, offering ultimate flexibility. The platform also allows previously captured data to be played back for viewing of spectral information throughout the scan. Python scripts are supplied as examples of how to access and further process the data.

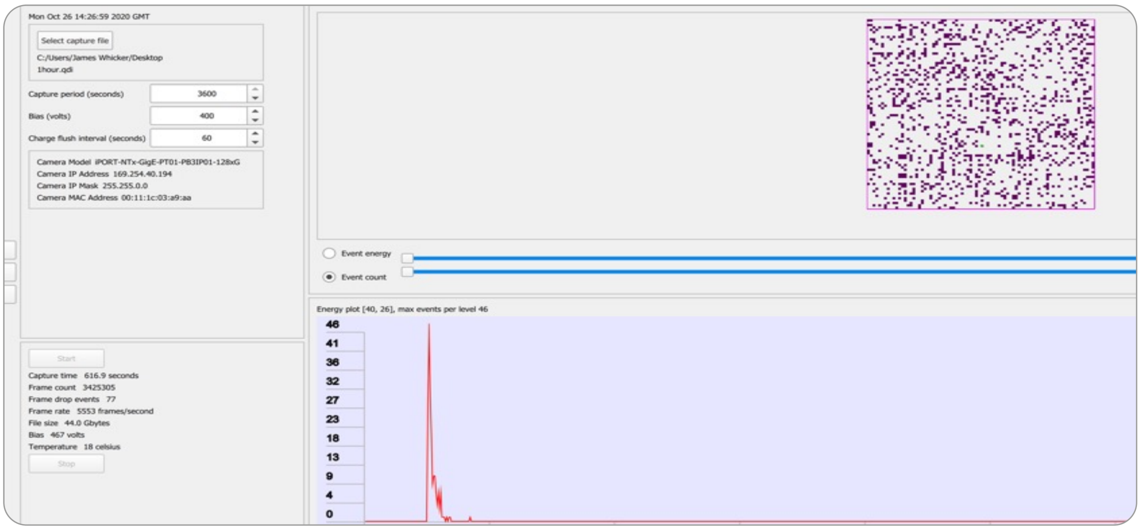

Figure 4: Example of data playback and energy spectra viewing within Quantum Detector's Helvellyn software. The user is able to select individual pixels and view the cumulative energy spectra at any point throughout the image acquisition.

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Specifications

Energy range	4 - 200 keV
Energy resolution per pixel	1 keV @ 60 keV
Frame rate	5 kHz
Count rate (entire sensor, 10% occupancy)	3.2 x 10^6 photons/second
Detector material	1 mm CdTe
Dimensions (L, W, H)	242 x 72 x 85 mm
Weight	1.5 kg
Interface	GigE ethernet
Pixel size	250 x 250 µm
Number of pixels	80 x 80 (6400 total)

HEXITEC requires a control PC with the following minimum specifications. Quantum Detectors do not supply this as standard, but can on request at additional cost.

Processor	Intel 64-bit i5, i7, i9, or later. AMD 64-bit currently untested.
RAM	8 GB
Storage	SSD unit with >250 MB/sec data rate
Display	2048 x 1024 resolution
Ethernet	High performance dedicated Gigabit Ethernet
Operating system	MS Windows 10

References

The unique high-energy dispersive X-ray imaging capability of the HEXITEC detector has been demonstrated in a number of applications.

Radio-isotope imaging

1. J.W. Scuffham et al. Imaging of Ra-223 with a small-pixel CdTe detector, 2015 JINST 10 C01029. doi: 10.1088/1748-0221/10/01/C01029

High-energy X-ray diffraction

2. Rakowski, R., Golovin, G., O'Neal, J. et al. Single-shot structural analysis by high-energy X-ray diffraction using an ultrashort all-optical source. Sci Rep 7, 16603 (2017). doi: 10.1038/s41598-017-16477-0

Spectral small-angle X-ray scattering (sSAXS)

3. Dahal, E., Ghammraoui, B., Ye, M. et al. Label-free X-ray estimation of brain amyloid burden. Sci Rep 10, 20505 (2020). doi: 10.1038/s41598-020-77554-5

Fluorescence imaging

4. Liotti, E., Lui, A., Connolley, T. et al. Mapping of multi-elements during melting and solidification using synchrotron X-rays and pixel-based spectroscopy. Sci Rep 5, 15988 (2015). doi: 10.1038/srep15988
5. S. Jayarathna, M. F. Ahmed, L. O'ryan, H. Moktan, Y. Cui and S. H. Cho, "Characterization of a Pixelated Cadmium Telluride Detector System Using a Polychromatic X-Ray Source and Gold Nanoparticle-Loaded Phantoms for Benchtop X-Ray Fluorescence Imaging," in IEEE Access, vol. 9, pp. 49912-49919, 2021. doi: 10.1109/ACCESS.2021.3069368

Tomography

6. Egan, C., Jacques, S., Wilson, M. et al. 3D chemical imaging in the laboratory by hyperspectral X-ray computed tomography. Sci Rep 5, 15979 (2015). doi.org/10.1038/srep15979
7. Connolley T, Magdysyuk OV, Michalik S, Allan PK, Klaus M, Kamm PH, Garcia-Moreno F, Nelson JA, Veale MC, Wilson MD. An operando spatially resolved study of alkaline battery discharge using a novel hyperspectral detector and X-ray tomography. J Appl Crystallogr. 2020 Oct 13;53(Pt 6):1434-1443. doi: 10.1107/S1600576720012078

More information on the HEXITEC technology can be found in the following papers.

8. Lawrence Jones, Paul Seller, Matthew Wilson, Alec Hardie, HEXITEC ASIC—a pixellated readout chip for CZT detectors, Nuclear Instruments and Methods in Physics Research Section A, Volume 604, Issues 1–2, 2009, Pages 34-37, doi: 10.1016/j.nimsa.2009.01.046
9. J W Scuffham et al, A CdTe detector for hyperspectral SPECT imaging, 2012 JINST 7 P08027. doi: 10.1088/1748-0221/7/08/P08027