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A 1M charge integrating hybrid pixel detector for electron diffraction

Electrons have emerged as an important complement to X-rays in crystallography, particularly for compounds that present challenges in growing crystals sufficiently large for synchrotron radiation (5–10 µm) or laboratory diffractometers (˜50 µm). Given the nature of electron-matter interactions, electron diffraction (ED) provides a way to experimentally determine the electrostatic potential of compounds, offering insights beyond electron density maps. To fully harness the power of ED, we have integrated a fast, low-noise and radiation-hard 1 megapixel JUNGFRAU detector with a modern JEOL microscope. JUNGFRAU is a charge-integrating hybrid pixel detector, with a dynamic range of 120 MeV/pixel/frame, i.e. 10^4 12 keV photons and a maximum frame rate of 2.2 kHz in continuous mode. It effectively detects up to 1.3 million 200 keV electrons per pixel per second before saturation.

To handle the resulting 5 GB/s raw data stream (fiberoptic; 4 x 10 Gbit/s), our system features an FPGA-based backend, Jungfraujoch, which converts raw ADC values into deposited energy and enables on-the-fly frame summation. Additionally, we developed a software package with an intuitive graphical user interface that integrates detector and microscope control. This solution provides partly automated data acquisition and post-processing, with data stored in compressed HDF5 files with comprehensive metadata.

This work assesses the performance of JUNGFRAU across multiple electron energies by analyzing energy deposition and pixel spread. The complete data pipeline—from detector to user interface—is validated through an ED experiment yielding structural insights, with future improvements also discussed.

Workshop topics

Applications

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