Advancing Synchrotron Imaging using Next-Generation Hybrid Photon Counting Detectors

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The evolution of synchrotron light sources toward diffraction-limited storage rings fundamentally expands the scope of X-ray imaging. Beyond the traditional absorption-based techniques, it opens multidimensional and coherent methods allowing for the characterization of materials with unprecedented spatial and temporal resolution. This progress is going hand in hand with the development of Hybrid Photon Counting (HPC) detectors capable of handling extreme fluxes while maintaining high frame rates and a wide dynamic range.

This work explores four key frontiers in synchrotron imaging enabled by recent detector advancements. First, we discuss high-speed coherent imaging, where new ASIC architectures enable frame rates up to 120 kfps, facilitating ptychographic measurements that resolve the high-intensity gradient between the central beam and diffuse scatter [1,2]. Second, we present a demonstration of soft X-ray ptychography, utilizing LGAD-based sensors as an ongoing development to extend photon-counting capabilities below 1 keV for the study of light elements and magnetic systems [3].

Furthermore, we highlight the rise of scanning-based multidimensional tomography, such as XRD-CT and SAXS tensor CT. By utilizing high-Z sensor materials (CdTe) and high-speed readouts, it is now possible to map chemical phases and nanoscale orientations in 3D during operando processes, such as battery cycling [4,5]. Finally, we demonstrate the clinical potential of propagation-based phase-contrast imaging, showing enhanced soft-tissue visualization in lung phantoms [6]. Together, these applications illustrate how modern detection technology acts as the primary bridge between the increased brilliance of 4th-generation sources and new scientific insights in materials and life sciences.

References

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