Contribution ID: **72** Type: **Poster**

Computational microscopy with the PERCIVAL detector system at TwinMic

Monday 1 July 2024 18:12 (1 minute)

PERCIVAL (Pixelated Energy Resolved CMOS Imager, Versatile And Large) [1] is a new soft-X-ray detector system also designed for modern computational synchrotron radiation microscopy. Developed collaboratively by seven research institutes (DESY, RAL/STFC, Elettra Sincrotrone Trieste, PAL, SOLEIL and Pohang Light Source), this detector is now at an advanced stage, featuring a Back-Side-Illuminated (BSI) sensor, fast acquisition/conversion electronics, and specialized control software. It represents a novel and advanced detection system that should improve existing computational microscopy techniques and potentially inspire new ones.
In December 2023, we conducted an exploratory computational microscopy experiment at the TwinMic synchrotron radiation beamline in Elettra Sincrotrone Trieste [2] (Trieste, Italy), exploiting the latest version of the PERCIVAL detector system: the updates consists of a new sensor die (with P+implant below Si02window to avoid electron trapping) and a new electronics, allowing for greater versatility and improved acquisition performances. The detector has been integrated in the existing TANGO-based beamline control system.
TwinMic operates in the 400 - 2200eV energy range and supports both Scanning Transmission Mode (STXM) and full-field imaging mode. The STXM capabilities can be extended to include phase-diverse Coherent Diffraction Imaging (CDI - Ptychography) [3], a lensless high-resolution and phase-sensitive computational microscopy technique (as in [4][5]), by using innovative algorithms [6].
In this work, we explain the (intricate) process by which we transformed RAW data from the detector into meticulously calibrated frames. Furthermore, we unveil the pioneering soft X-ray reconstructions, including absorption, differential phase contrast, integral phase, dark contrast, and phase, obtained at Elettra. These reconstructions encompass diverse subjects, ranging from test pattern objects to real samples like plant tissue and foraminifera. By leveraging the system's high-speed, the high-dynamic-range of the sensor and the new reconstruction algorithms, we achieved the highest resolution ptychography reconstructions with PERCIVAL detector to date (compared with the previous state-of-the-art [7]).
[Figure 1 in the attachment]
Fig. 1: Ptychography reconstruction of a coccolith, shown in magnitude and phase (transmission function, panel a and b), obtained from a series of far-field diffraction patterns (a representative RAW data frame in panel c). The algorithm reconstructs also the illumination (magnitude and phase in HSV color-space, panel d). The resolution of the object reconstruction is estimated with the Fourier Ring Correlation [8] (intercept with the 1/7 bit curve), showing a resolution of 40 nm (panel e). All the scale bars in panel a, b and e are 2 μm long.

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Session Classification: Poster Session