PIMEGA 540D AND ITS APPLICATIONS AT SYNCHROTRON BEAMLINES

The PIMEGA 540D is the suitable choice for a synchrotron detector in research that requires large-area, high-resolution, and high-frame per second rate detectors.

The PIMEGA 540D operates without dead-time offering an adjustable energy-discriminating threshold. All PIMEGA detectors make use of CERN Medipix3RX ASIC, with a pixel size of 55 μm which makes direct detection of photons to deliver the highest spatial resolution data (9,4 megapixels) with a 2000 fps data frame rate.

PIMEGA 540D has two options of sensor head assembly: superposed sensors for gapless configuration (medium to far distance sample positioning applications), and coplanar sensors configuration (close distance positioning applications). Additionally, PITEC has several different options of backend systems (optional) according to the user applications.

Cateretê Beamline

Coherent **A**nd **T**im**E** **RE**solved **S**cat**TE**ring

The Cateretê beamline at Sirius, the new Brazilian synchrotron light source, is dedicated to coherent and time-resolved scattering experiments. Experiments such as coherent X-ray diffractive imaging (CXDI) and X-ray photon correlation spectroscopy (XPCS) are at the core of the beamline's activities, as well as time-resolved small-angle X-ray scattering (SAXS), which benefits from the source's high flux. Because of the small-angle geometry, the experimental station is followed by a 28 meters vacuum chamber hosting a silicon PIMEGA 540D detector (Figure 1). The Cateretê beamline can generate images of biological and nanomaterials in the 5 keV to 20 keV range, taking advantage of the coherence properties of Sirius radiation.

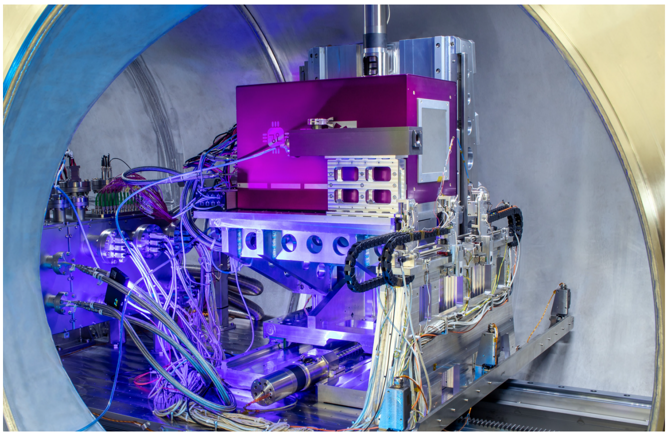

Figure 1: 28 meters vacuum tunnel hosting a silicon PIMEGA 540D detector.

X-Ray Ptychography

The measurement of Siemens Star sample using ptychography is a standard procedure when commissioning a beamline for ptychography experiments. It gives a realistic portrait of a ptychography experiment. Ptychography is a natural extension of the CDI technique where a sample is raster scanned relative to the illuminating beam and multiple diffraction patterns are recorded. Figure 2 shows a schematic diagram of a typical ptychography experiment.

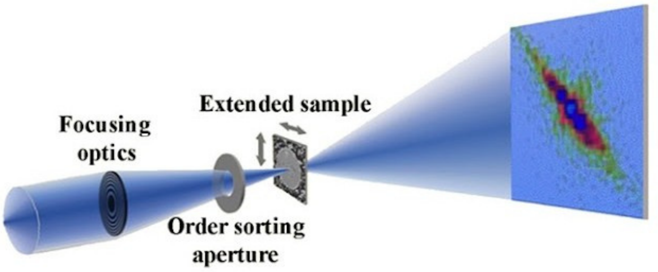

Figure 2: Typical ptychography experiment, where an X-ray beam is focused on the sample. The sample is scanned across the beam with sufficient overlap between consecutive acquisitions. A diffraction pattern is recorded at each scan point [1].

In this experiment, a 3.8 keV pink beam (2% bandwidth) with a ring stored current of 70 mA was used. The detector was placed 14 meters from the sample to optimize the field of view. Figure 3 shows the sample station inside the beamline experimental hutch. The beam reaches the sample after passing through a 5 or 10 µm pinhole. The scattered beam then travels through the vacuum tunnel (10^{-3} mBar) to the detector.

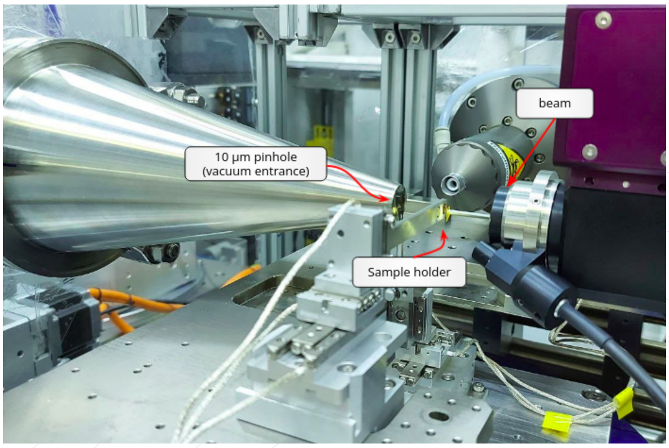

Figure 3: Sample station of the experiment.

The sample was irradiated in multiple overlapping 1.25 µm steps to record a set of diffraction images with the PIMEGA detector at 150 ms exposures and 24 bit counter depth (Figure 4).

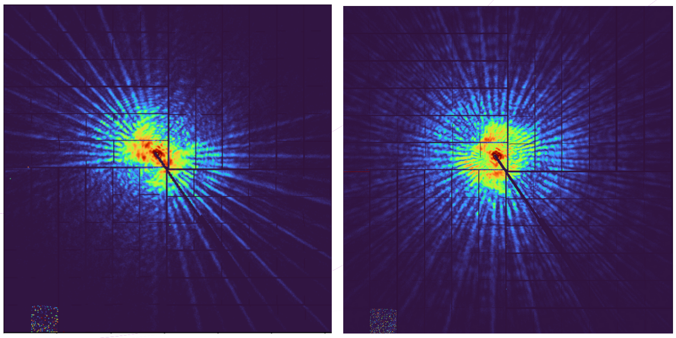

Figure 4: Scattering patterns at PIMEGA detector in a single frame.

An iterative engine algorithm was used to reconstruct the diffraction images for retrieving the object (Figures 5 and 6).

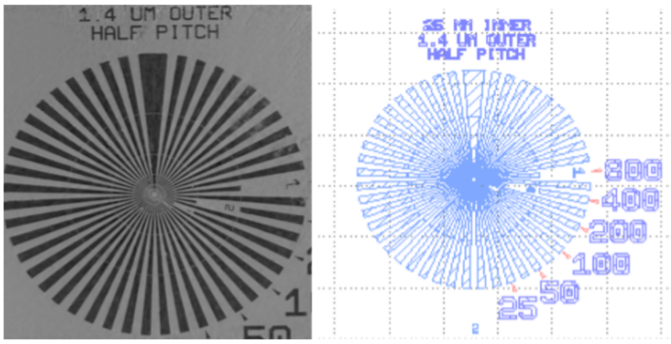

Figure 5: *(Left)* Reconstruction of the siemens star structures test pattern with multiple spoke distances in nanometers. Acquired at E = 3.8 keV; sample to detector distance = 28 meters; pinhole = 10 µm; Step scans = 2 µm; field of view indicated on the reconstructions; Reconstruction pixel size = 50 nm. *(Right)* Reference model of the sample pattern.

Figure 6: A sImilar experiment resulting in a smaller reconstruction pixel size. In this example, it is possible to distinguish the 25 nm features in the center of the siemens star.

The visualization of complex morphologies requires the use of advanced 3D imaging methods. In this context, ptychography images of polymers such as polyethersulfone (PES) were obtained with the PIMEGA detector. As a result, images of polymer composites with nanometric resolution were obtained.

PES

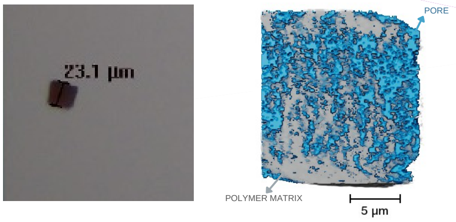

Figure 7: Microscopic image of the polyethersulfone (PES) *(Left)* and final reconstructed structure after the experiment *(Right)*.

The experiment was performed at 3.8 keV (pink beam), 13 m distance of the sample from the detector, and pinhole size of 5 µm. Figures 7 and 8 show the reconstructed images after the iterative engine algorithm.

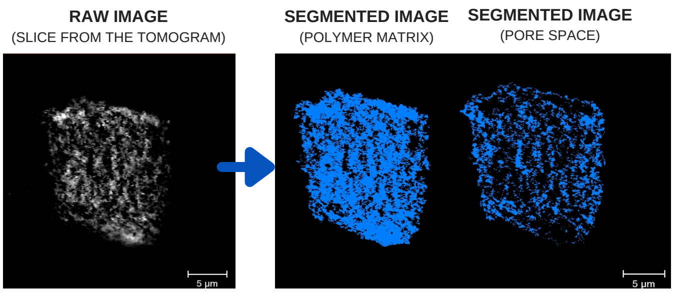

Figure 8: Slice from the tomogram, separating the polymer matrix and its pore space.

For this case, the pixel size attained was of 27 nm, and the resolution of the 3D reconstruction was of 33 nm. While separating connected porosity from isolated pore space, the network analysis gives us the volume fraction of constituent phases. Figure 9 shows the results in 3D.

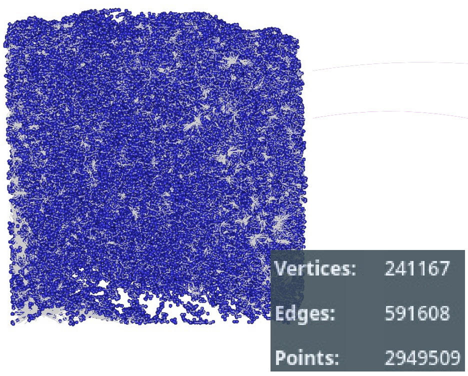

Figure 9: Network analysis (skeleton) showing the number of connections (vertices) and the number of pores (points).

Conclusion

The researchers from the Cateretê beamline have succeeded in the first measurements using the PIMEGA 540D detector. Beamlines for ptychography experiments with a state-of-the-art detector are an excellent instrument for studying small and complex structures.

PITEC acknowledges the support from the Cateretê scientists for providing the images. Unless stated otherwise, the x-ray experiments and ptychographic reconstructions were performed by Florian Meneau[1], Carla Polo[1], Aline R Passos[1], Tiago A Kalile[1], Paulo R A F Garcia[1], Paola C. Ferraz[1], Eduardo X.S. Miqueles[1], Suzana P Nunes[2], Valentina E Musteata[2], and Radoslaw P. Gorecki[2].

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References

[1] Miao, Jianwei, Tadaaki Ishikawa, Ian K. Robinson and Margaret M. Murnane. “Beyond crystallography: Diffractive imaging using coherent x-ray light sources.” Science 348 (2015): 530 - 535.

[2] Polo, C.C., Pereira, L., Mazzafera, P. et al. Correlations between lignin content and structural robustness in plants revealed by X-ray ptychography. Sci Rep 10, 6023 (2020).

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