Phase-Contrast and Dark-Field Imaging and Tomography at OptImaTo laboratory: Implementation and Optimization with Modulation-Based Technique

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Modulation-based imaging is an X-ray phase-contrast technique capable of simultaneously retrieving transmission, differential phase-contrast, and dark-field signals.The method exploits a structured illumination generated by a modulator, avoiding the need for complex optical components.However, achieving stable reconstructions generally requires the acquisition of multiple images of both the modulator alone and the modulator together with the sample, making tomographic applications demanding in terms of acquisition time and radiation dose.

To address these limitations, a systematic experimental campaign was carried out at the OptImaTo Laboratory(Trieste, Italy) [1], where the setup consists of a liquid-metal-jet X-ray source (MetalJet D2+, Excillum) and a photon-counting detector (Lambda350k, X-Spectrum) featuring a cadmium telluride sensor. Planar radiographs were acquired while varying several experimental parameters, including the type of diffuser (sandpaper was compared with a Vogel-spiral membrane*), the propagation distance, and the number of diffuser stepping positions.

Different image-quality metrics and statistical analyses were employed to assess the influence of these parameters on the reconstructed signals and to identify an optimal trade-off between image quality and acquisition time.The resulting optimized configuration enabled the acquisition of the first modulation-based tomographic scans performed at the OptImaTo laboratory. In addition to the well-established UMPA algorithm [2], reconstruction was implemented in the Fourier domain, using a forward model like the one proposed in [3]. The noise spectrum for a photon-counting detector was included in this reconstruction algorithm to further improve the quality of the results.

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References

[1] Vittorio Di Trapani et al., “Speckle-based imaging (SBI) applications with spectral photon counting detectors at the newly established OPTIMATO (OPTimal IMAging and TOmography) laboratory,” Journal of Instrumentation, vol. 19, no. 1, p. C01018, Jan. 2024.
[2] Fabio De Marco et al., “High-speed processing of X-ray wavefront marking data with the Unified Modulated Pattern Analysis (UMPA) model,” Optics Express, vol. 31, pp. 635–650, 2022
[3] Ginevra Lautizi et al. Universal reconstruction method for x-ray scattering tensor tomography based on wavefront modulation. Phys Rev Appl. 2024;22(2):024031.
[4] Clara Magnin et al. On the optimisation of the geometric pattern for structured illumination based X-ray phase contrast and dark field imaging: A simulation study and its experimental validation. arXiv:2504.10665