Dose-efficient propagation-based X-ray phase contrast imaging at high and low resolution by Bragg crystal optics

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X-ray phase contrast imaging techniques can visualize weakly attenuating samples by exploiting the phase shift that the sample imprints on the incident wavefield. Propagation-based phase contrast imaging (PB-PCI) uses the self-interference of the diffracted wavefield behind the sample, which gradually evolves into intensity contrast as the propagation distance between the sample and the detector increases. However, conventional scintillator-based detectors for micrometer resolution suffer from low detection efficiency. In addition, imaging large samples at moderate resolution requires a propagation distance of tens to hundreds of meters to generate sufficient image contrast.

Both above-mentioned limitations can be overcome by employing Bragg crystal optics. For high resolution, a Bragg magnifier allows directly magnifying the X-ray wavefield and using a highly efficient single-photon-counting detector while maintaining micrometer resolution. This results in a superior imaging performance compared to conventional detector systems and yields a substantial increase in dose efficiency for high spatial frequencies that comprise the relevant high-resolution components of the image [1].

For imaging centimeter-sized samples at moderate resolution, the Bragg demagnifier yields strong image contrast within a meter-scale setup, thereby eliminating the need for very long propagation distances [2]. Simultaneously, image blur caused by the finite X-ray source size is reduced. The strong increase in image contrast is demonstrated experimentally [2]. This approach paves the way for low-dose studies of large radiation-sensitive samples, with potential applications ranging from biomedical soft tissue and small animal in vivo imaging up to medical diagnostics.

Progress and ongoing developments regarding the setup stability are also discussed.

References

[1] R. Spiecker et al., ”Dose-efficient in vivo X-ray phase contrast imaging at micrometer resolution by Bragg magnifiers”, Optica 10 (2023)

[2] R. Spiecker et al., ” X-ray phase contrast imaging with kilometer propagation distance within a meter ”, Phys. Rev. Res. 7 (2025)