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Towards an Unified System Integrating X-ray Spectral and Phase Contrast Imaging

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The combination of X-ray spectral and phase contrast imaging offers complementary advantages for comprehensive imaging and analysis of complex samples. Such combined approach (XSPI) enables simultaneous visualization of structural features and elemental composition, facilitating quantitative multi-modal characterization of materials with diverse compositions and properties [1]. This integration yields both high visibility of soft tissues and effective separation of high-Z materials augmenting the performance of X-ray imaging systems, particularly in applications such as medical imaging, material science and cultural heritage. In the frame of the INFN project Sphere-X (Spectral Phase Retrieval X-ray imaging), we are developing a unique synchrotron radiation based XSPI system (Figure 1), which is under test at the SYRMEP bending magnet beamline at Elettra. This novel X-ray imaging system yields spectral information and retrieves the phase simultaneously in a single acquisition procedure. Spectral information is obtained by a cylindrically bent Si Laue crystal which disperses the polychromatic synchrotron radiation in the vertical diffraction direction onto a 2D detector, which is located downstream the horizontal focal line where the sample is placed. The diffraction orientation, asymmetry angle and bending radius of the crystal is chosen such that the geometrical and polychromatic foci are congruent [2]. Multidimensional CT images are obtained by rotation and translation of the sample through the vertically narrow focused line beam. The energy resolution and energy range can be tuned by adjusting the bending radius and the crystal-to-detector distance. This allows to fit either simultaneously several absorption edges or a single absorption edge with high energy resolution into the vertical field of view of the detector. As a result the X-ray spectral imaging part allows either multi material decomposition on the mg/ml level or single shot spatially resolved EXAFS/XANES imaging. The beam tracking edge-illumination technique [3] is applied to obtain the phase contrast information. Utilizing beamlets generated by an absorption mask upstream the bent crystal in combination with a dithering process yields high resolution parametric images describing absorption, differential phase/refraction and scattering. Inserting the phase image into the material decomposition algorithm allows retrieving an additional material while keeping high contrast and spatial resolution of X-ray phase contrast in low density objects. In this presentation we provide an overview of our XSPI system, highlighting its principles, advantages, and applications. We discuss recent advancements in instrumentation, simulation, data processing algorithms, and preliminary imaging results.

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Figure 1: Schematic layout of the XSPI system (adapted from [2]).

[1] Brombal L. et al., Phys. Med. Biol. 69, 075027 (2024)
[2] Zhu Y. et al., Phys. Med. Biol. 59, 2485–2503 (2014)
[3] Vittoria F.A. et al. Appl. Phys. Lett. 106, 224102 (2015)

I plan to submit also conference proceedings

Yes

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