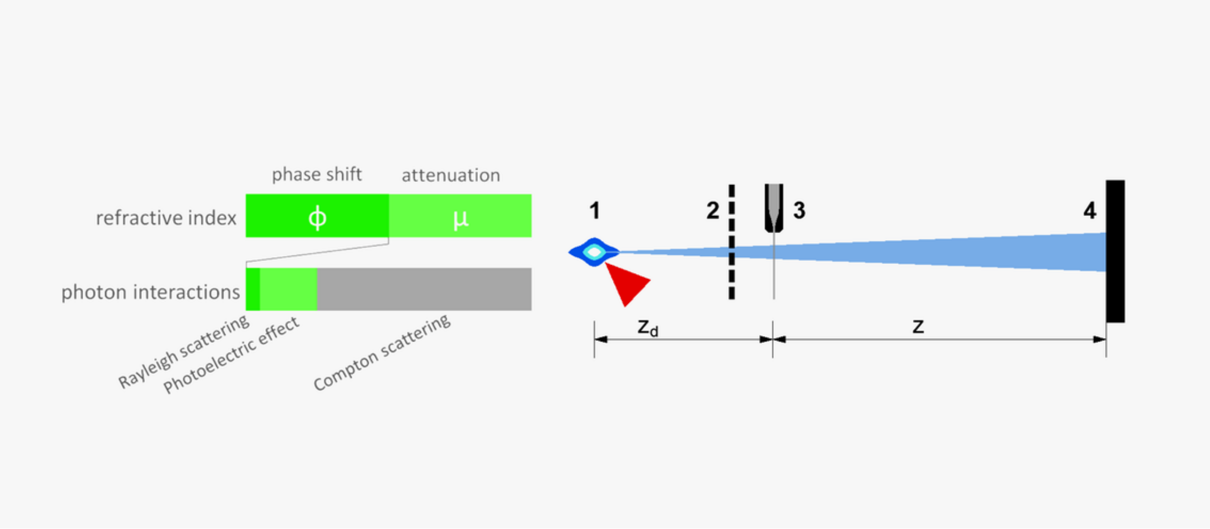
X-ray Phase – Contrast Imaging (XPCI)



Phase – contrast imaging techniques capture the X-ray wafefront deformation and loss of coherence coused by the object. The phase contrast and darkfield images that are obtained substantially expand on the information about the object and reveal features of it that are invisible to classical absorption-based radiography.

The majority of the X-ray imaging techniques depend on the phenomenon of radiation being attenuated by an object. The phase contrast imaging (PCI) and spatial harmonic imaging (SHI) techniques can reveal other essential mesoscopic and microscopic properties of the object by sensing the X-ray wavefront deformation and coherence loss. The sensitivity of PCI can also be several orders of magnitude higher than the attenuation-based one due to the large ratio of phase-shift and attenuation terms of the object's refractive index.

Ultrafast (sub-ps) X-ray pulses can be used in time-resolved phase-contrast imaging [PCI1] for femtosecond phase-contrast stroboscopy applications. A special emphasis is placed on the development and application of the Talbot-Lau-type grating-based PCI technique as shown in the inset. The sub-ps X-ray burst from a point-like source (PXS or betatron, 1) is projected through dense, µm-pitch mesh (2) and sample (3) onto a two-dimensional integrating detector (4). The phase variations in the sample are encoded into the projected pattern in the form of mesh deformations and loss of contrast. Finally, the recorded pattern is analyzed in Fourier space, yielding two pairs of phase-contrast and scatter images [PCI2,3].

Both the laser-driven plasma X-ray source (PXS, E1) and the betatron X-ray source (E2) are excellent candidates for PCI. Bright, micrometer-sized sources (30 µm PXS, ~2 µm betatron) satisfy the spatial coherence requirements of PCI, while the pulsed regime of the sources permit time-resolved studies of topological or conformational changes of the materials in situ. Since most mesoscopic changes that are detectable through PCI occur on picosecond time-scales and longer, the PXS source can take advantage of L1.2 uncompressed beams (a few ps) in order to cause the peak photon flux to increase substantially. The compactness of the PXS source allows it to be transported to other ELI halls where it can be used, for example, as a backlighter to study hot dense plasma dynamics.

Ultrafast PCI can be used as high spatial resolution time-resolved radiography for high energy density experiments of medium/high-Z samples, to study shock waves and radiative fronts propagating in an opaque matter or as a backlighter to follow hot dense expanding plasma and plasma jet imploding targets [PCI1,4,5,6]. The ultra-short pulse duration can be exploited in time-of-flight-based electronic scatter rejection. This technique allows for distinguishing between primary X-ray photons and the scattered photons because of the delay between their respective times of arrival at the detector [PCI1]. In addition, X-ray full-field phase-contrast imaging allows for the capture of near-nozzle jet morphology and the instantaneous velocity and internal structure of optically dense sprays with a potential for the study of transient phenomenon dynamics [PCI7,8,9].

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