Beam-shaping Refractive Optics for High-energy X-rays

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The most advanced X-ray sources, such as third-generation synchrotrons and free electron lasers (XFEL), are capable to generate high brightness coherent radiation, especially in the hard X-ray region. The availability of such beams facilitates the development of a new generation of X-ray optics, whose optical properties enable to go far beyond simple collimation and focusing functions. This so called beam-shaping optics allows generating the amplitude and phase of the wave front with almost complete freedom.

One of the most vibrant demonstrations of the beam-shaping optics is a special class of refractive optical elements that have axial symmetry and are capable to convert a point-like source to a narrow axial straight line segment. These optical elements are called axicons. Recently, we demonstrated an X-ray parabolic refractive axicon lens as a novel type of X-ray beam-shaping element [1]. Under coherent X-rays, the parabolic axicon generates Bessel-like beam propagated along the optical axis in the near field, and ring-shaped beam in the far field. The optical transformations produced by axicon can be used in areas requiring special illumination, as well as extended focused beams. Such beam-shaping capabilities can significantly simplify some existing experimental layouts or lead to completely new optical schemes for X-ray techniques. Most recently, we proposed a phase-contrast microscopy technique based on the axicon optics [2]. Due to unique optical properties of the parabolic refractive axicon lens, the new approach turned out to be more efficient for visualization of weakly absorbing samples as compared with the traditional microscopy technique.

In addition to axicon beam-shaping elements, it is also worthwhile to consider interferometers, whose optical functions are well known and successfully used. These devices allow to realize the paraxial optical schemes of interferometry based on the coherent properties of modern X-ray sources. Recently, we demonstrated bilens and multilens interferometers based on refractive optics, which under coherent illumination generate array of mutually coherent beams focused at some distance [3-4]. The size of the focal spots is diffraction limited and can be less than tens of nanometers. When the beams overlap they produce a steady interference fringe pattern in the far field. The field of applications of their optical functions is not limited only to the interferometry techniques, and can be extended in the area of beam diagnostics and beam conditioning. Moreover, such lens systems open up new opportunities for the development of phase-contrast imaging technique, which we recently demonstrated [5].

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