SHAPING X-RAYS BY DIFFRACTIVE CODED NANO-OPTICS

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Abstract

The current intense interest in extreme ultraviolet and x-ray microscopy is mainly due to the availability of a nearly ideal optical source for nano-optics based on diffraction, that is, a source with low divergence whose wavelength can be tuned over a range of several keV and whose spectrum can be monochromatised with a band pass $\Delta\lambda/\lambda$ of less than 10^{-4}. Synchrotrons of the latest generation and free electron lasers (in the near future) are devices that produce x-rays with these characteristics. When a source of electromagnetic radiation is bright enough, that is, point-like and monochromatic, a new world opens for the designer of optical instruments and for a wider community of experimenters and theorists. This happened with the invention of the optical microscope and is still happening with x-ray microscopes of the latest generation. Although available x-ray sources have coherence characteristics very close to those of lasers at visible wavelengths, up to now the design of new optical devices has not proceeded much beyond simple focusing optical elements. In fact the zone plate, that can be now considered a well established focusing element for x-rays, was invented more than hundred years ago but due to technological difficulties, they have been implemented only in the last two decades.
In this article we show that it is possible to design, fabricate and easily use new optical elements that, beyond focusing, can perform new optical functions. In particular, the intensity (and polarization for extreme ultraviolet wavelength) of light in the space beyond the optical elements can be redistributed with almost complete freedom. In other words, already available extreme ultraviolet and x-ray sources are suitable as ideal sources for diffractive optical elements designed to perform new optical functions that can conveniently be summarized under the expression of "beam shaping".
To our knowledge this is the first example of design, fabrication and application of novel x-ray optical elements that can perform multi-focusing in a single or multiple focal plane, beam shaping of a generic monochromatic beam into a well defined geometrical and "artistic" shape. These new optical functions, can be used for many applications ranging from microscopy, such as differential interference contrast microscopy, bio-imaging, maskless lithography and chemical vapour deposition induced by extreme ultraviolet and x-ray radiation.