Soft x-ray phase-sensitive imaging with diffractive optical elements

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In the x-ray region, for nearly all elements the real part delta of the complex index of refraction n (n = 1 – delta – i·beta) is larger than the imaginary part beta. It follows that the phase shift of any object is stronger than the absorption. Thus, phase sensitive x-ray imaging techniques like Zernike phase contrast x-ray microscopy [1] were developed to access the phase shifting, real part of the refractive index of the object in order to examine thin and weakly absorbing samples with sufficient contrast. Another alternative approach was the use of segmented detectors in scanning x-ray microscopes [2]. Recently, the differential interference contrast (DIC) method – first introduced by Nomarski [3] for visible light – was demonstrated with so call twin zone plate optics (TZP) at 4 keV photon energy [4]. However, these elements are difficult to fabricate. A possible solution to this problem is the combination of the two zone plates into a single diffractive optical element (DOE). First proof of principle experiments with this kind of optics for DIC-microscopy at 4 keV photon energy were successful [5] and showed the strong potential of DOE x-ray optics.
Obviously, x-ray microscopy in the water window region would also benefit from the DIC contrast mechanism. In this contribution we present the first diffractive optical elements for soft x-ray DIC microscopy. Due to an improved calculation method the nanofabrication accuracy is the same as for a comparable normal zone plate optic with the same outermost zone width. Different DOEs were fabricated with outermost zone width of 100 nm and 50 nm, respectively, different spot separation directions and different phase relations between the two spots. The optics were successfully used in DIC experiments both at the synchrotron radiation based TWINMIC microscope and at the Stockholm compact liquid-nitrogen laser-plasma source based microscope.

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