Modified composite Fresnel zone plates with high numerical apertures
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Traditional Fresnel zone plates (TFZPs) can be used for the focusing and imaging of soft x-rays and EUV radiation. However, the focal spot size of a TFZP is about the order of the width of the outermost half-zone, so its spatial resolution is limited in technology by the smallest structure (20–40 nm) that can be fabricated by lithography. This drawback can be partially overcome by a composite FZP [1] (CFZP) in the paraxial case. Recently, a novel diffractive optical element called a photon sieve [2], which consists of a great number of pinholes, was proposed to overcome the drawback of a TFZP. More recently [3], we proposed the modified Fresnel zone plates that can produce sharp Gaussian focal spots (we call them Gaussian FZPs, GFZPs). Similar to a photon sieve, such a GFZP can also increase the spatial resolution and suppress the sidelobes. When the illuminative light source is brilliant enough, photon sieve and GFZPs are suitable to be used. However, when the illuminative light source is not brilliant enough, photon sieve and GFZPs are not suitable to be used, because they have low efficiency. In contrast, a CFZP has a relatively higher efficiency in the paraxial case. We here show that [4] CFZPs with high numerical aperture (NA) are not suitable for the focusing and imaging of soft x-ray and EUV radiation because of the nonparaxial suppression effect on higher orders. Instead, we [4] suggest a modified composite FZP (MCFZP) that uses the phase match condition at the desired focal point for all the open rings, but allow that the widths of the open rings are an odd integer of that of the local half-zone of the underlying TFZP. We [4] compare a MCFZP with a corresponding CFZP. As shown, the absolute intensity at the desired focal point \((z=0.5 \text{ mm})\) of the MCFZP [shown in (b)] is ten times higher than that of the CFZP [shown in (a)]. This result shows that a MCFZP is superior to a CFZPs in the nonparaxial case, although they are the same in the paraxial case.