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Low-data DOE simulation based on the zones geometry

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1 Introduction

Diffractive Optical Elements (DOEs) used in beam shaping or in focusing are usually either elements based on a geometric mapping between input plane and output plane, or elements composed of a superposition of gratings whose diffraction orders overlap in the output plane, sometimes referred as Computer Generated Holograms (CGH).

The first type of element, e.g. Phase Zone Plates (PZPs) or Aperture Modulated Diffusers (AMDs)[1], present a local structure while the grating superposition type may not exhibit any local structure.

DOE analysis is usually done either through a bitmap description, using discrete Fourier Transform capabilities of computers, or through analytical formulas (e.g. use of Bessel functions) which are strongly restricted to elements presenting symmetries (rotation, translation). While a bitmap description is well suited to describe a grating superposition designed by iterative techniques, it does not accurately describe the zones geometry of a PZP. Moreover, two-dimensional bitmaps produce a high amount of data that can exceed the capabilities of computers

We present here an hybrid technique based on a geometrical description of the zones, requiring thus a small amount of data, while being better suited to describe zone plates.

2 Structures in a Fresnel Zone Plate

Phase Zone Plates are composed of zones, presenting in most cases a geometrical structure, as shown in Fig. 1(a). They may exhibit strong symmetry, as rings in the central part of the lens, but also may not have this property, as the corners of the lens in Fig 1(b).

Figure 1: (a) Example of a PZP and (b) close up on a non symmetric area.

Using a geometrical description of the zones, we can lower the data needed for the whole element, while being able of representing any kind of shapes, under any rotation with a better accuracy than the bitmap based description, as shown in Fig. 2(a). The bitmap representation (circular markers) uses a two-dimensional grid, while a one-dimensional representation (triangular markers), with the same resolution, can achieve a much improved precision. Moreover, as illustrated in Fig. 2(b) and 2(c), the amount of data required for the description is smaller, and while an increase in resolution will result in a linear increase of the data for our description, it usually results in a quadratic increase for a bitmap description.

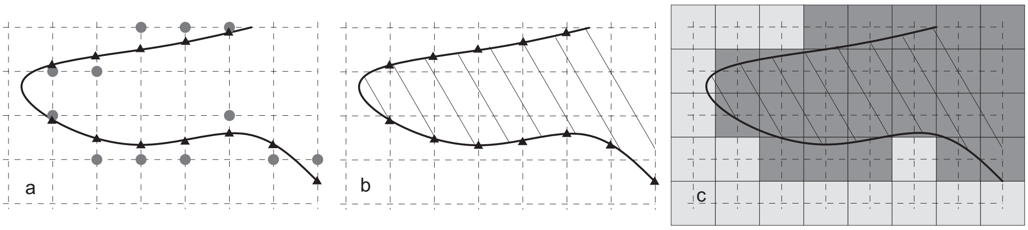

Figure 2: Two-dimensional (discs or square pixels) and one-dimensional samplings (triangles) of a zone contour (plain line). Accuracy is better (a), and amount of data is smaller (b),(c).

3 Propagation

Far field simulation, achieved through Fourier Transform of the DOE phase, is usually computed through two successive one-dimensional Fourier Transforms, one in each direction of the bitmap grid. Thanks to the zones description of the element, we can compute analytically the first of these operations. For multi-level elements, data needed is only the contour of each zones sampled in one direction. This is essentially an extension of the Central Slice Theorem[2], used in tomography, to non central slices. The second step is then performed through a classical DFT. Aliasing effect may only arise in this computation.

In Fig. 3 a comparison between the simulated and the measured far field intensity distribution for a beam shaper under incoherent illumination is shown. Not only the simulation is qualitatively similar to the measurement, but the numerical values (e.g. FWHM) present a high accuracy, better than the measurements precision.

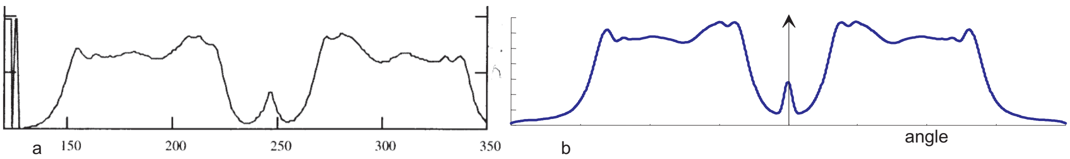

Figure 3: (a) measured and (b) simulated far field intensity distribution.

4 Extensions

While we have discussed the Fourier propagation of a phase generated by a perfect multi-level element, this description may also be used for other profile types, and propagators. Fresnel diffraction can also be simulated, and possibly other kernels, as step-discontinuity method[3] may be implemented.

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