Fourier array illuminators optimized from lenslet arrays

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Fourier array illuminators (FAIs) can be iteratively designed with the Gerchberg-Saxton (G-S) algorithm. Design iterations usually start with a random phase distribution, either in the FAI's plane or in the reconstruction field. Although the G-S algorithm is relatively fast, optimization of a FAI with large space-bandwidth product (SBP), starting with an initial random filter, may require too much computing effort and frequently the result is a highly chaotic optimized phase profile, with a large number of jumps.

To reduce the optimization time, and to design FAIs with low entropy, we investigated the use of parabolic phase profiles, with adequate focusing power, as inputs for the G-S algorithm. The initial parabolic profile of the FAI's basic cell is designed to provide a diffraction pattern formed by an array of NxM diffraction orders. This array should cover the desired spot array, in the reconstruction. If the FAI's period is d (in both directions), the two-dimensional (2-D) parabolic phase profile of the basic cell is

\[ t(x, y) = \exp\left[-i\pi \frac{Nx^2 + My^2}{d^2}\right] \]  

(1)

We derive this phase distribution with para-geometrical arguments. The result is in agreement with analysis in Ref. [1], that proposed a lenslet array as a Fourier array generator. The phase function in Eq. 1 should be sampled out, to define the basic cell's phase distribution, depending on the spatial quantization of the FAI. As an illustrative example, we consider the design of a 5x5 spot FAI with 128x128 pixels in the basic cell. Fig. 1 (left) shows the density plot of the initial parabolic basic cell's phase distribution. After optimization with the G-S algorithm, the final phase distribution is the one shown in Fig. 1(b), for which a phase quantization with 8 phase levels is imposed.

![Initial parabolic basic cell](image1)

![Optimized basic cell](image2)

Fig. 1. Initial parabolic (left) and optimized (right) basic cells for a 5x5 spot FAI:

For this example, it is noted that both, the parabolic and the optimized basic cells have basically the same number of 2pi-jumps. The main difference is a topological deformation of iso-phase curves. The highly symmetric result in Fig. 1b depends on the high symmetry of the square 5x5 spot array.

We employed our approach also for the design of highly complex, symmetric and non-symmetric FAIs. In general, computing effort and complexity of final designs are highly reduced with our approach. We note also that FAIs optimized from parabolic profiles, exhibit higher efficiencies and smaller reconstruction errors than FAIs optimized from random phase distributions. Additional advantages of our approach are being investigated.

Reference: