Progressive on-the-fly Fourier ptychography reconstruction

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Abstract: Fourier ptychography consists in reconstructing high-resolution images by accumulating hundreds of illumination images in the Fourier domain. Capturing many images and reconstructing at full resolution are heavy processes that delay availability of results. We show that the result image can be progressively reconstructed on the fly while capturing illumination images, by modifying the order of iterations at the cost of a minor degradation in the final result image.

INTRODUCTION
Fourier ptychographic microscopy (FPM) has been introduced to produce large field of view images with high resolution using a low magnification microscope. LEDs in a programmable array successively illuminate the observed slice is with plane waves at known angles. Information is then accumulated in the Fourier domain to reconstruct intensity and phase images [1].
Although, capturing hundreds of illumination images may take minutes and reconstructing large images is a computationally intensive process (*e.g.*, around 30 mn on a high end PC using the Matlab code in [2] for a 120 Mpixels image). In pathology applications, images at an intermediate resolution (partially reconstructed) are useful for detecting regions of interest, while high resolution (full reconstruction) is only needed inside ROIs to characterize objects. Image tiling allows limiting computation to those tiles that support ROIs.
We propose and discuss a modification of the algorithm that allows reconstructing while capturing.

EXPERIMENTS
Classical FPM reconstruction accumulates information by iterating on all the LED illuminations [1] (fig. 1, left). This requires that all the illumination images have been captured before reconstruction starts.
Instead, iterating LED by LED (fig. 1, right) allows progressive reconstruction from a subset of available LED illumination images while they are being captured.

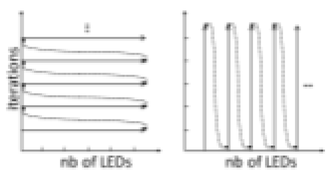

Fig. 1:
Left: classical FPM reconstruction order.
Right: progressive reconstruction order.

We have compared the reconstruction errors on simulated acquisitions synthesized (with 80 % spectrum redundancy [1]) from given reference intensity and phase images.

RESULTS AND DISCUSSION
Figure 2 and 3 show the images resulting from progressive and classical reconstructions, respectively.

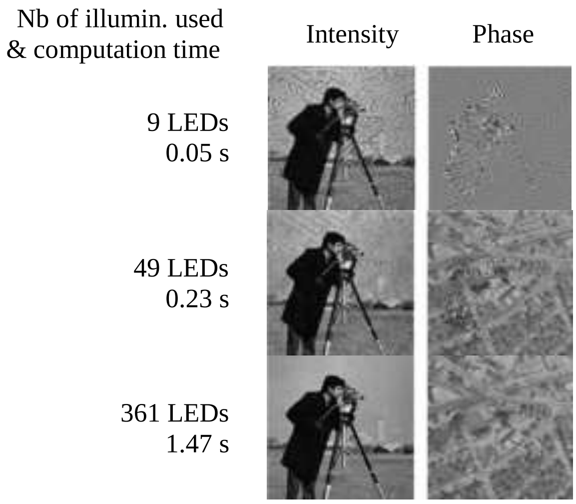

Fig. 2: Progressive reconstruction.

Fig. 3: Classical reconstruction.

Table 1: Root mean square reconstruction errors

Method	Intensity	Phase
Classical reconstruction	$0.002 \cdot 10^{-3}$	$1.7 \cdot 10^{-3}$
Progressive reconstruction	$0.24 \cdot 10^{-3}$	$1.3 \cdot 10^{-3}$

Table 1 compares the respective errors at full reconstruction (361 LEDs). Progressive reconstruction has higher errors but they remain hardly visible (around 1/1000 of images dynamic range).

CONCLUSION
Progressive reconstruction opens the path for optimized integrated FPM systems capable to interrupt the acquisition of a field after few illuminations if it does not hold any ROI, so saving both capture and computation time.

REFERENCES
[1] G. Zheng, R. Horstmeyer and C. Yang, *Nature Photonics* 7:739–745, 2013.
[2] L. Tian and L. Waller, “LED array Fourier Ptychography dataset” and “Fourier ptychography reconstruction algorithm…”, online at www.laurawaller.com/opensource [acc. in 3/2017].