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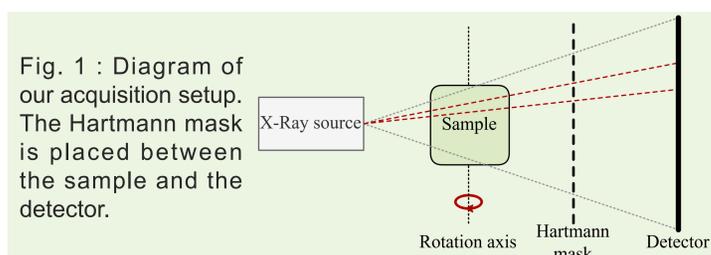
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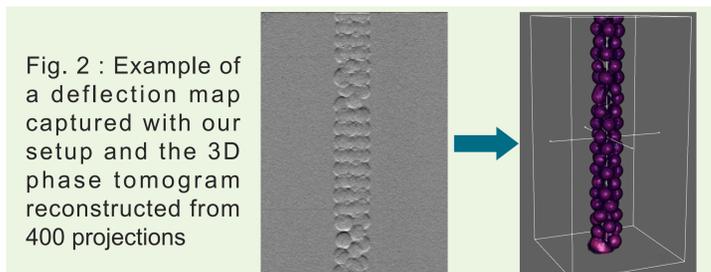
# Simultaneous Wavefront and 3D Tomographic Reconstructions for Phase Imaging Using Hartmann Sensor

## INTRODUCTION

Phase-contrast imaging (PCI) is a promising technique that became practical using high-power micro-focus X-ray sources. The Hartmann method captures the deflections of individual X-ray beamlets to obtain contrast, relying on variations of the imaginary part of the sample complex refractive index  $\delta$ . This is interesting for clinical imagery since  $\delta$  becomes larger than the absorption index  $\beta$  at high energy for soft tissues [1].

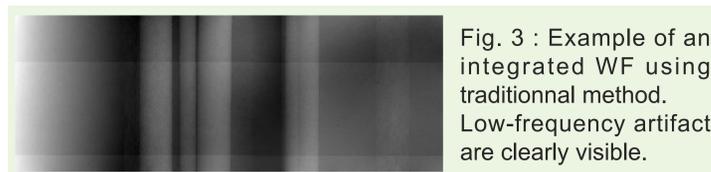


With accurate measurements of the projected phase shifts, a phase tomogram can be reconstructed to obtain localized information on the sample material [2].



Algorithms dedicated to reconstruct wavefronts (WF) acquired using Hartmann sensors have been largely described in the literature. A common one is described in [3] as an iterative reconstruction algorithm (IR-WF).

**Existing algorithms lead to low-frequency artifacts when confronted with noisy images, resulting in incoherent information of each projection.**



## REFERENCES

1. Bravin, A. et al. X-ray phase-contrast imaging: from pre-clinical applications towards clinics., Physics in medicine and biology 58 1, R1–35 (2013)
2. Hagen, C. K., Munro, P. R. T., Endrizzi, M., Diemoz, P. C., and Olivo, A., "Low-dose phase contrast tomography with conventional x-ray sources," Med. Phys. 41, 070701 (July 2014).
3. Southwell, W., "Wave-front estimation from wave-front slope measurements," J. Opt. Soc. Am. 70, 998– 1006 (Aug 1980).

## METHODS

In order to improve the homogeneity between the projections during IR-WF, we developed a 3D-driven algorithm that converges on the reconstructed volume rather than the individual projections. To do so, the IR-WF algorithm is built into the iterative tomographic reconstruction (IR-CT).

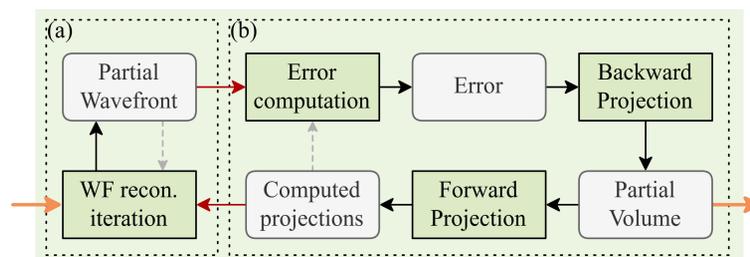


Fig. 4 : Diagram of our simultaneous wavefront and tomographic reconstruction algorithm. (a) represents the IR-WF part and (b) the IR-CT.

**By doing both reconstructions at the same time all wavefronts are constrained to converge to the same result. This attenuates the artifacts caused by the IR-WF.**

To validate our algorithm we used datasets obtained with three samples : (A) a set of quartz, alumina and crystalline silicon rods, (B) a juvenile oyster shell (from Institut Fresnel, Marseille), and (C) a polycarbonate tube filled with silica micro-spheres.

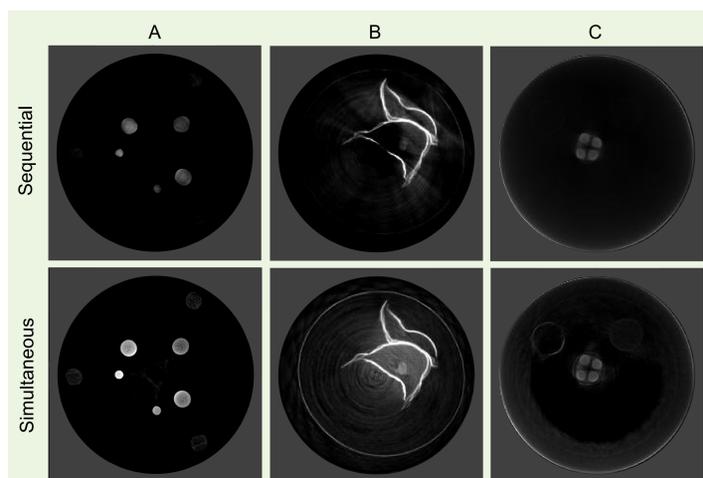


Fig. 6 : Slices from the reconstructed objects using the sequential (top) and simultaneous (bottom) methods. The simultaneous method offers a more homogeneous result and is able to resolve some details that are not visible with the sequential method.

## RESULTS

We measured the SNR, PSNR and CNR on the three different dataset using both methods to assert the quality of the 3D reconstruction. The values of these metrics are reported in Fig. 7, as well as the evolution of the SNR vs iteration # on dataset (A) in Fig. 8.

Dataset	SNR		PSNR		CNR	
	Seq.	Sim.	Seq.	Sim.	Seq.	Sim.
A	2.3	7.6	6.5	11.0	4.2	9.5
B	5.2	7.16	26.2	20.1	4.6	6.1
C	1.2	1.4	5.3	5.5	0.38	0.67

Fig. 7 : SNR, PSNR and CNR extracted from layers illustrated in Fig. 6. The simultaneous method shows a better result than the sequential method in almost all cases.

We can see that unlike the sequential method, our simultaneous method is able to converge further and can support more iterations without introducing a quality loss.

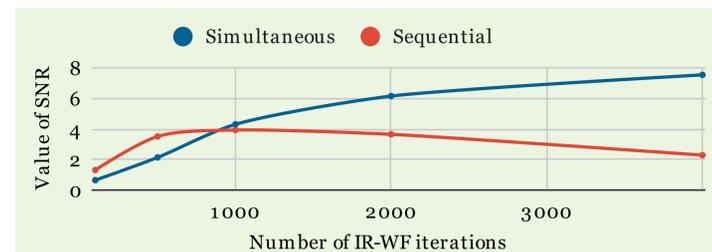


Fig. 8 : Evolution of the SNR of the reconstruction of dataset (A) as a function of IR-WF iterations number.

## CONCLUSIONS

Our simultaneous IR-WF and IR-CT algorithm provides superior results compared to the existing algorithm when provided with a Hartmann PCI tomographic dataset by using the information of all projections in the iterative process. Although the computational complexity are equal, our method tends to converge more slowly due to the 3D homogeneity constraint.

**This method allows to obtain a more homogeneous result with better SNR and CNR than the consecutive application of IR-WF and IR-CT.**

## ACKNOWLEDGMENT

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