Scene Reconstruction via Two-dimensional Complex Coherency Imaging

Ahmed El-Halawany[1], Andre Beckus[2], H. Esat Kondakci[1], Morgan Monroe[1], Nafiseh Mohammadian[1], George K. Atia[2] and Ayman F. Abouraddy[1]

[1] *CREOL, The College of Optics & Photonics, University of Central Florida, Orlando, FL 32816, USA*
[2] *Department of Electrical and Computer Engineering, University of Central Florida, Orlando, FL 32816, USA*
*ahmedhalawany@knights.ucf.edu

Abstract: The location of 1D objects is determined by numerically back-propagating the experimentally measured spatial coherence function. A partially coherent light and dynamical double slits generated by digital light processor are used in the coherence measurements.

OCIS codes: (030.1640) Coherence; (110.1650) Coherence imaging; (260.3160) Interference

For coherent light, the knowledge of the complex field $E(\mathbf{x})$ at a specific plane is essential in determining the field in any other spatial positions. Such information is crucial in imaging a scene with multiple objects that obscure the field while propagating. Hence, the information carried by the scattered field in the far field regime helps in reconstructing the scene via numerical back-propagation. However, for incoherent light, the particulars of the field are not informative as in the case of the coherent light [1]. Nevertheless, the two-point complex coherence function contains within it essential information for back-propagation. As a result, the scene reconstruction can be achieved [2, 3].

In this work, the investigated scene consists of a partially coherent light source (LED), one or two 1D opaque objects, and a detection plane, which is digital micromirror device (DMD). It is worth to mention that light, after the scene, propagates till there is no shadow or visible intensity variation. The spatial complex coherence function $G(x_1,x_2,\lambda)$ is measured by implementing dynamical double slits by the DMD. Each slits' configuration produces Young's double interference pattern. The measurement setup is demonstrated in Fig. 1. Based on the visibility of the interferogram, the magnitude is obtained, while the phase is determined from the shift of the central fringe with respect to a fixed reference [4]. Subsequently, the measured $G(x_1,x_2,\lambda)$ is numerically back-propagated from the detection plane (DMD) to the LED to disclose the scene and estimate the position of the objects both axially and transversally. To facilitate both the visualization and computation of G, we adapt the rotated coordinate system (y_1,y_2), where $y_1 = (x_1+x_2)/2$ and $y_2 = (x_1-x_2)/2$. In order to guarantee an exact accurate back-propagation, an infinite detector is required. Given that this is physically not feasible, the finite size detector will also reconstruct the scene but associated with imperfections. The imperfections basically stem from the finite resolution that might affect the distinguishability of closely located objects at either transverse or longitudinal positions.

In previous work [5], a single object scene has been investigated. In this study, a two object scene is studied. The scene comprises two identical single objects (two 500 μm diameter metallic wires) located in two different axial planes. The first wire is located 7 cm away from the light source and is displaced 0.375 mm from the optical axis, while the second wire is positioned 22 cm from the LED and is displaced symmetrically opposite -0.375 mm from the optical axis. For this scene, the distance between the LED and DMD is 144 cm. The experimental part involves

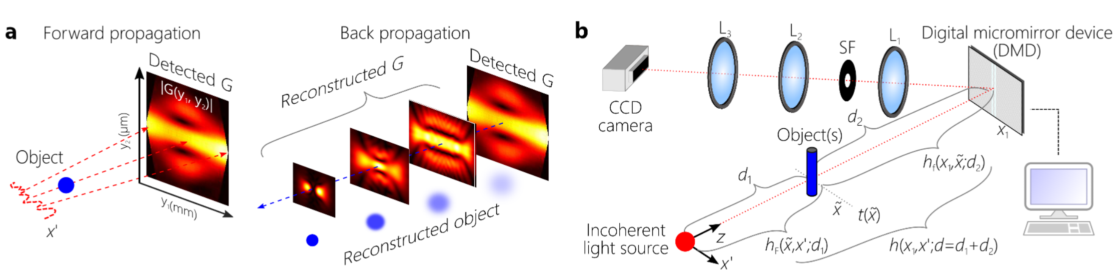

Fig. 1. (a) Concept of lensless coherence imaging. The coherence function $G(x_1,x_2;d)$ after scattering from an object is measured at a plane $z=d$, and then back-propagated computationally to the object. (b) Schematic of the measurement setup where relay lenses (L_1=10 cm and L_2=20 cm) are followed by a third lens in a $2f$ configuration (L_3=20 cm). SF: spatial filter.

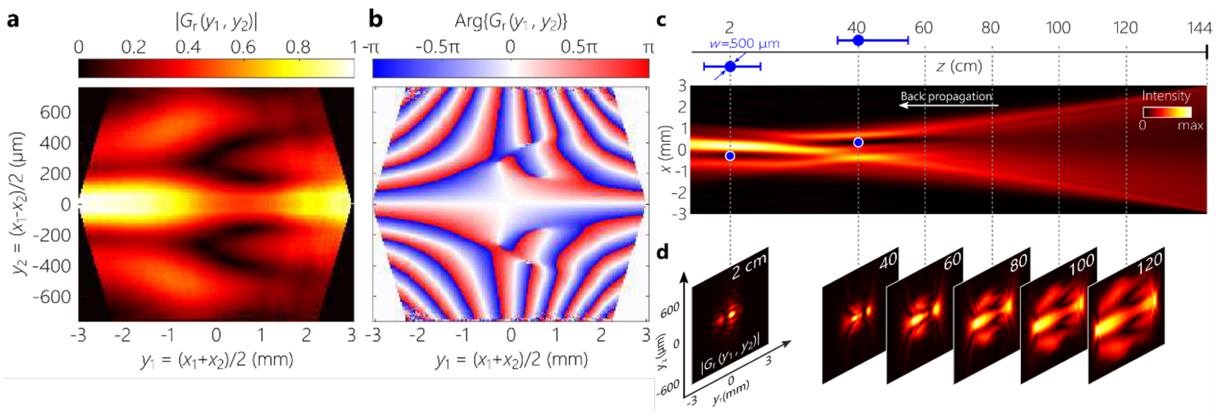

Fig. 2. Back-propagation of the measured complex coherence function for two objects scene. (a) The experimental amplitude of $G(y_1, y_2; d)$. (b) The experimental phase Arg$G(y_1, y_2; d)$. (c) Back-propagation of the intensity along the z-axis. (d) Selected profiles of the coherence function at various z-planes showing the evolution of from the DMD to the LED.

the acquisition of the complex coherence function of the light propagating through the scene. Afterwards, we back-propagate them, numerically, towards the LED (see Fig. 2). As shown in Fig. 2(c), the complex coherence function is plotted at different positions. The determination of the object's position is inferred from the shadow created by the object in the intensity profile. The object's position would be at the location of the lowest point in the intensity profile. The lensless coherence imaging finds the following: two 1D objects with estimated widths of 400 μm. The location object near the source is determined with -3.6 % error and the further object is estimated with 14.6% error.

In conclusion, the proposed lensless coherence imaging has been applied to two objects scene. In each case, the measured spatial coherence function is numerically back-propagated to discover the scene. In both cases, the objects in the scenes have been identified.

References

1. N. George, "Lensless electronic imaging," Opt. Commun. **133**, 22-26 (1997).
2. A. F. Abouraddy, K. H. Kagalwala, and B. E. A. Saleh, "Two-point optical coherency matrix tomography," Opt. Lett. **39**, 2411 (2014).
3. K. H. Kagalwala, H. E. Kondakci, A. F. Abouraddy, and B. E. A. Saleh, "Optical coherency matrix tomography," Sci. Rep. **5**, 15333 (2015).
4. H. E. Kondakci, A. Beckus, A. El-Halawany, N. Mohammadian, G. K. Atia, and A. F. Abouraddy, "Coherence measurements of scattered incoherent light for lensless identification of an object's location and size," arXiv:1703.10980 [physics.optics].
5. A. El-Halawany, A. Beckus, H. E. Kondakci, M. Monroe, N. Mohammadian, G, K. Atia, A. F. Abouraddy, "Incoherent lensless imaging via coherency back-propagation," arXiv:1705.03993 [physics.optics]