Digital Fourier transform holography using a beam displacer

Mohit Rathor*, Shivam Kumar Chaubey, Rakesh Kumar Singh

Laboratory of Information Photonics and Optical Metrology, Department of Physics, Indian Institute of Technology (Banaras Hindu University) Varanasi, 221005, Uttar Pradesh, India

Author*: mohitrathor.rs.phy21@itbhu.ac.in

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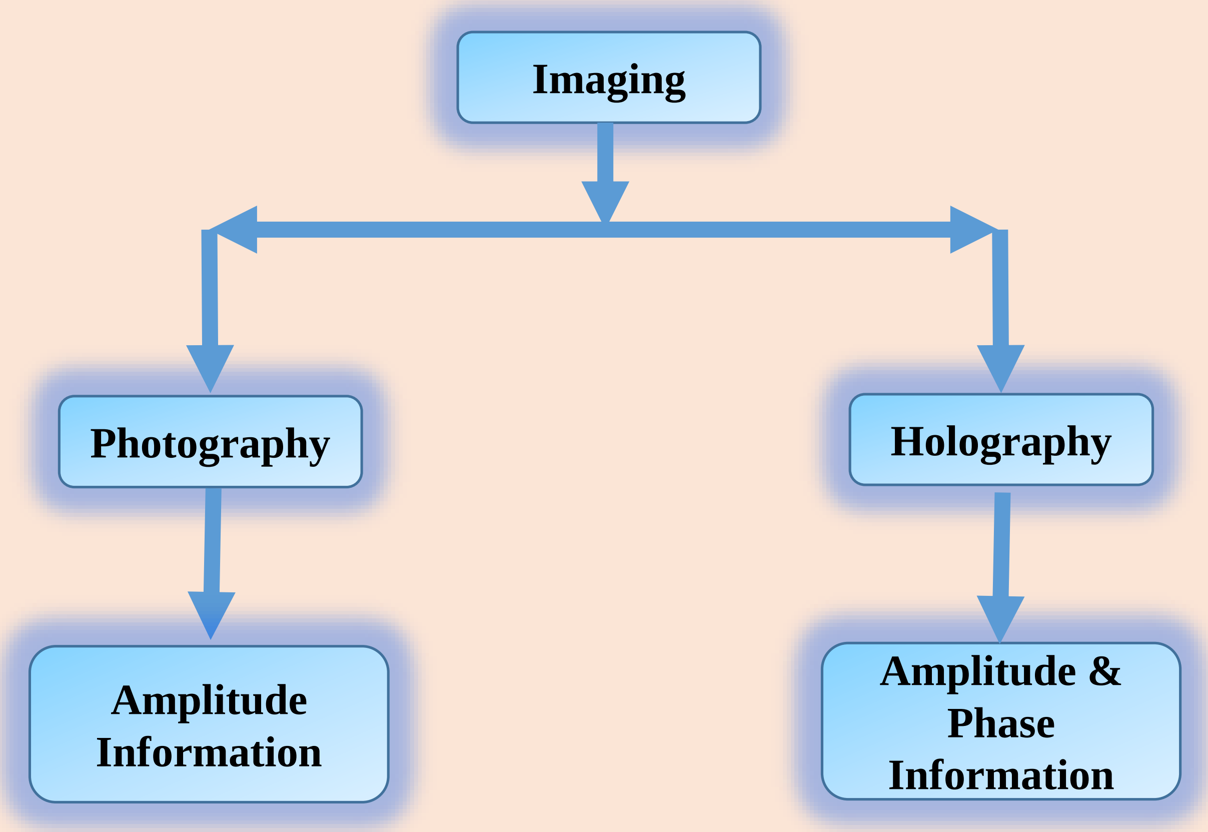
Abstract

Fourier transform holography overcomes the phase recovery challenge by recording complex field information of the object in an interference pattern recorded at the far field, i.e., the Fourier plane. Moreover, this geometry helps to reconstruct the complex field of the object from a single Fourier transform which is an attractive feature for the numerical reconstruction of the digitally recorded hologram. In this paper, we present a nearly common path experimental design for recording of a digital Fourier holographic hologram using a beam displacer and recover the complex-valued objects using the Fourier analysis. The performance of the system is experimentally examined for different objects.

Introduction



Principle

Fourier transform (FT) holography is based on the principle of interference, which encodes complex object in a Fourier geometry. This technique is capable to record and reconstruct complex field from a single FT.

- Beam displacer splits a diagonally polarized coherent beam into two orthogonal linear polarization states
  $\{E_x = (1 \quad 0)^T \ \& \ E_y = (0 \quad 1)^T\}$
- One orthogonal beam passes through the object and is referred to as an object beam (O_x). Other orthogonal beam passes through a pin hole is referred to as a reference beam (R_y)
  $$O_x = O * \begin{pmatrix} 1 \\ 0 \end{pmatrix} ; R_y = \begin{pmatrix} 0 \\ 1 \end{pmatrix} ;$$
- These beams are Fourier transformed by the lens L2 and hologram recorded at the back focal plane of the lens L2 by a camera
- Output field at the camera plane will be due to polarizer at 45 degree is
  $$E_{out} = P(45°) \times (O'_x + R'_y) = O + R \ ; \text{ Where } P(45°) = \frac{1}{2}\begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}.$$
- Recorded intensity of the Fourier transform hologram will be
  $$I = |(O + R)|^2 = OO^* + RO^* + OR^* + RR^*$$
- Numerical reconstruction of the hologram.
- Experimentally recorded Fourier transform hologram is shown in fig 1

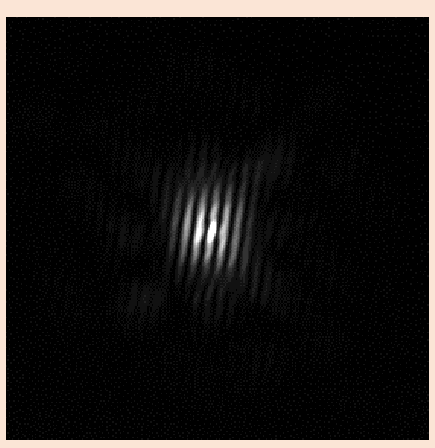


Fig.1: Digitally recorded Fourier Transform hologram

Experimental Setup

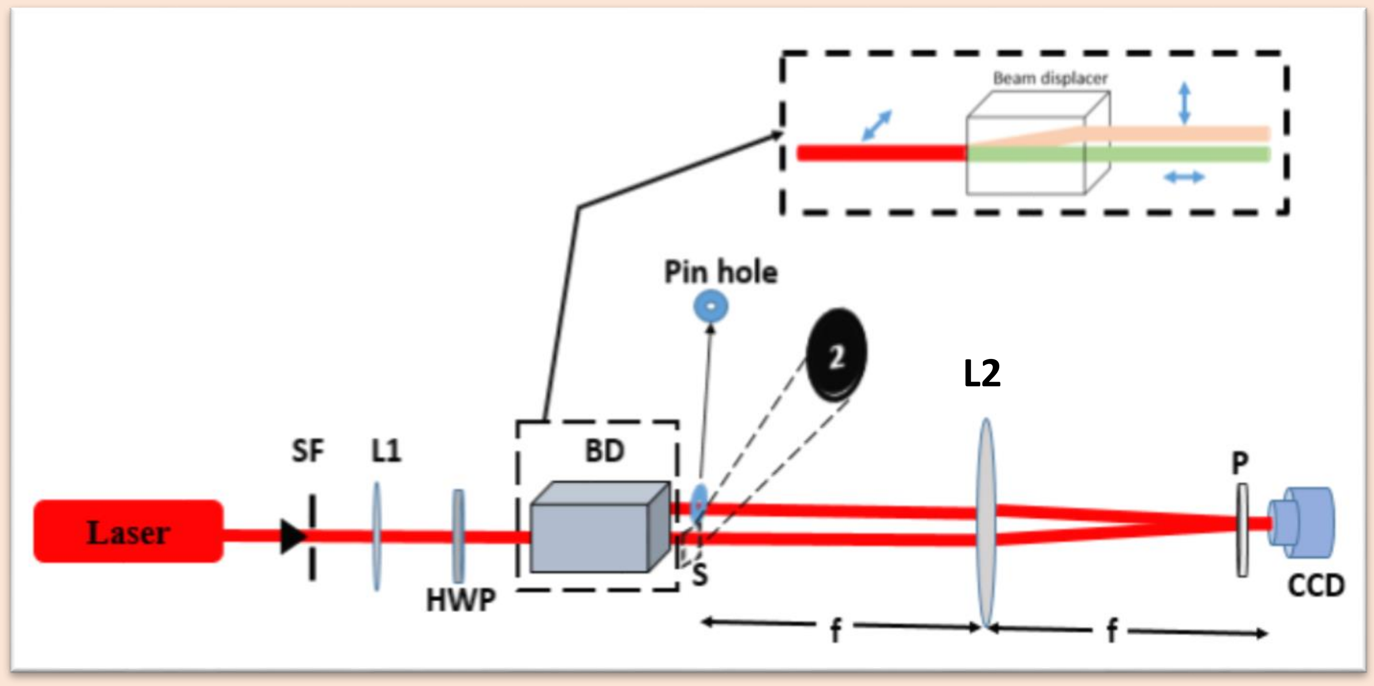


Fig.2: A compact experimental setup design for recording the digital Fourier transform hologram with the help of a beam displacer. HWP is a half wave-plate, SF is a spatial filter, L1 &L2 are lenses, BD is the beam displacer, S is the sample, P is a polarizer and CMOS is the complementary metal oxide semiconductor camera..

Experimental Results

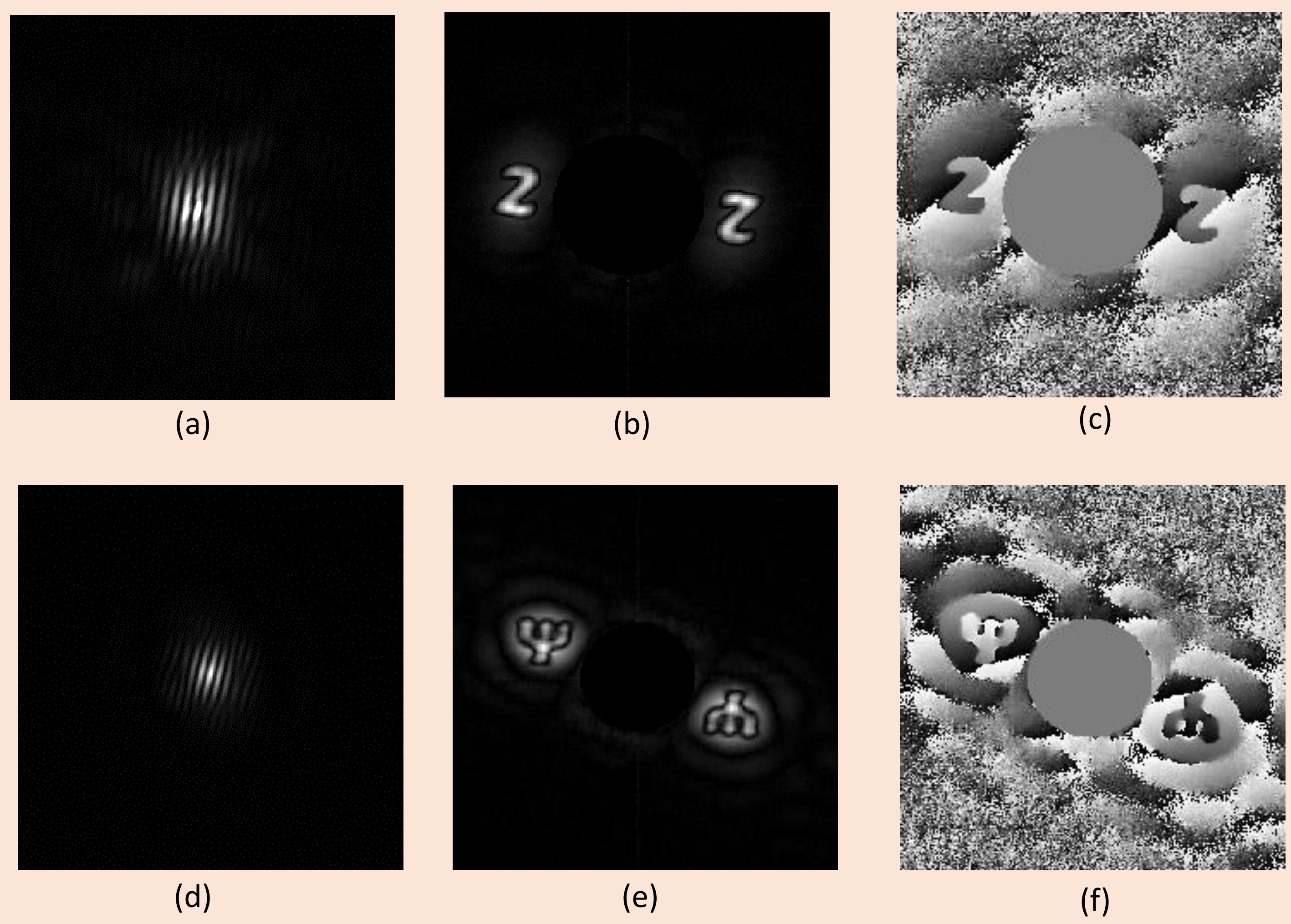


Fig. 3: a, d are digitally recorded Fourier transform hologram,(b, e) are recovered amplitudes and (c,f) are recovered phase for the object " ψ" *and "2" respectively*

Conclusion

In this paper, we present a nearly common path experimental configuration using a beam displacer for the recording of a digital Fourier transform hologram and reconstruct the complex-valued objects information using a fast Fourier transform.

Acknowledgement

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References

1. Goodman J.W. Introduction of Fourier optics, 2nd ed.; McGraw-Hill:, New York; pp. 295–363.
2. N. Lecture, "Gabor-Lecture-Holography," *Science (80).*, vol. 177, p. 299, 1972.
3. Apostol D. et al.,Fourier transform digital holography, Proc. of SPIE, 2007;678522-6