Holography with incoherent light

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Abstract

We present a possible experimental approach for holography with the incoherent light. In case of incoherent light, the complex spatial coherence function is a measurable quantity and the incoherent object holograms are recorded as the coherence function. Thus, to record the complex spatial coherence a square Sagnac radial shearing interferometer is designed with the phase-shifting approach. The five-step phase-shifting method helps to measure the fringe visibility and the corresponding phase, which jointly represents the complex coherence function. The inverse Fourier transform of complex coherence function helps to retrieve the object information.

Introduction

- Digital holography (DH) is a technique of interference of two waves. The recorded interference pattern contains both amplitude and phase information which can be further reconstructed on digitally processing of the recorded hologram.
- A coherent source is utilized to achieve the interference in the DH, but the coherent imaging system suffers from speckle noise and edge effects.
- Whereas, the incoherent imaging systems are free from speckle noise.
- The interference of incoherent light reflected or emitted from an object result in incoherent digital holograms.
- Many known methods of recording incoherent holograms are based on the self-interference principle, and it can generate an interference pattern with light coming from its mirror imaged point.
- These techniques record the incoherent hologram in the form of intensity patterns. The other way to record an incoherent hologram is in the form of two-point spatial complex coherence function .
- In this paper, we present an experimental approach to record an incoherent object hologram as the spatial coherence function.

Principle

The field is Fourier transformed using a lens L having a focal length f and at Fourier plane, a single realization of the field is represented as

$$E(\boldsymbol{r}) = \iint A(\tilde{\boldsymbol{r}};\lambda)\exp\left(-\frac{i2\pi}{\lambda f}(\boldsymbol{r}.\tilde{\boldsymbol{r}})\right)d\tilde{\boldsymbol{r}} \quad (1)$$

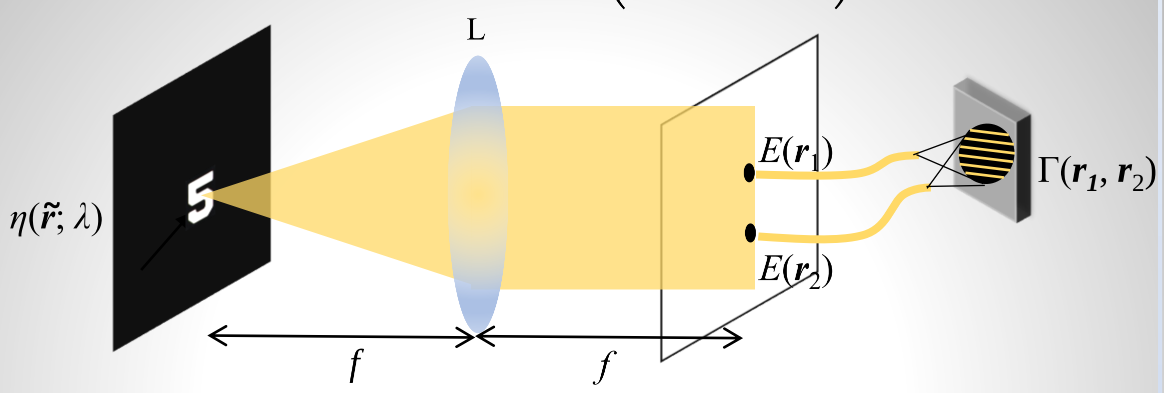

Figure 1. Geometry for recording information of spatial coherence function

The coherence function at the Fourier plane is given by

$$\Gamma(\boldsymbol{r}_1,\boldsymbol{r}_2) = \langle E^*(\boldsymbol{r}_1)\,E(\boldsymbol{r}_2)\rangle \quad (2)$$

From Eq. (1), we can write

$$\Gamma(\boldsymbol{r}_1,\boldsymbol{r}_2) = \frac{\kappa}{\lambda^2 f^2}\left\{\int \eta(\tilde{\boldsymbol{r}};\lambda)\,exp\left[-i\frac{2\pi}{\lambda f}\tilde{\boldsymbol{r}}.(\boldsymbol{r}_2-\boldsymbol{r}_1)\right]d\tilde{\boldsymbol{r}}\right\} \quad (3)$$

The integral inside the curly bracket represents van Cittert-Zernike theorem.

Now, to reconstruct the object intensity distribution the spatial coherence function is inverse Fourier transformed

$$\tilde{\eta}(\tilde{\boldsymbol{r}};\lambda) = (\alpha-\alpha^{-1})^2\int \Gamma(\alpha^{-1}\boldsymbol{r},\alpha\boldsymbol{r})exp\left[i\frac{2\pi}{\lambda f}(\alpha-\alpha^{-1})\boldsymbol{r}.\tilde{\boldsymbol{r}}\right]d\boldsymbol{r} \quad (4)$$

Experiment and results

In the first part of the set up the object information is recorded as a two-point complex spatial coherence function and in the later part a square Sagnac radial shearing interferometer with five-step phase-shifting technique is designed to obtain the complex coherence function.

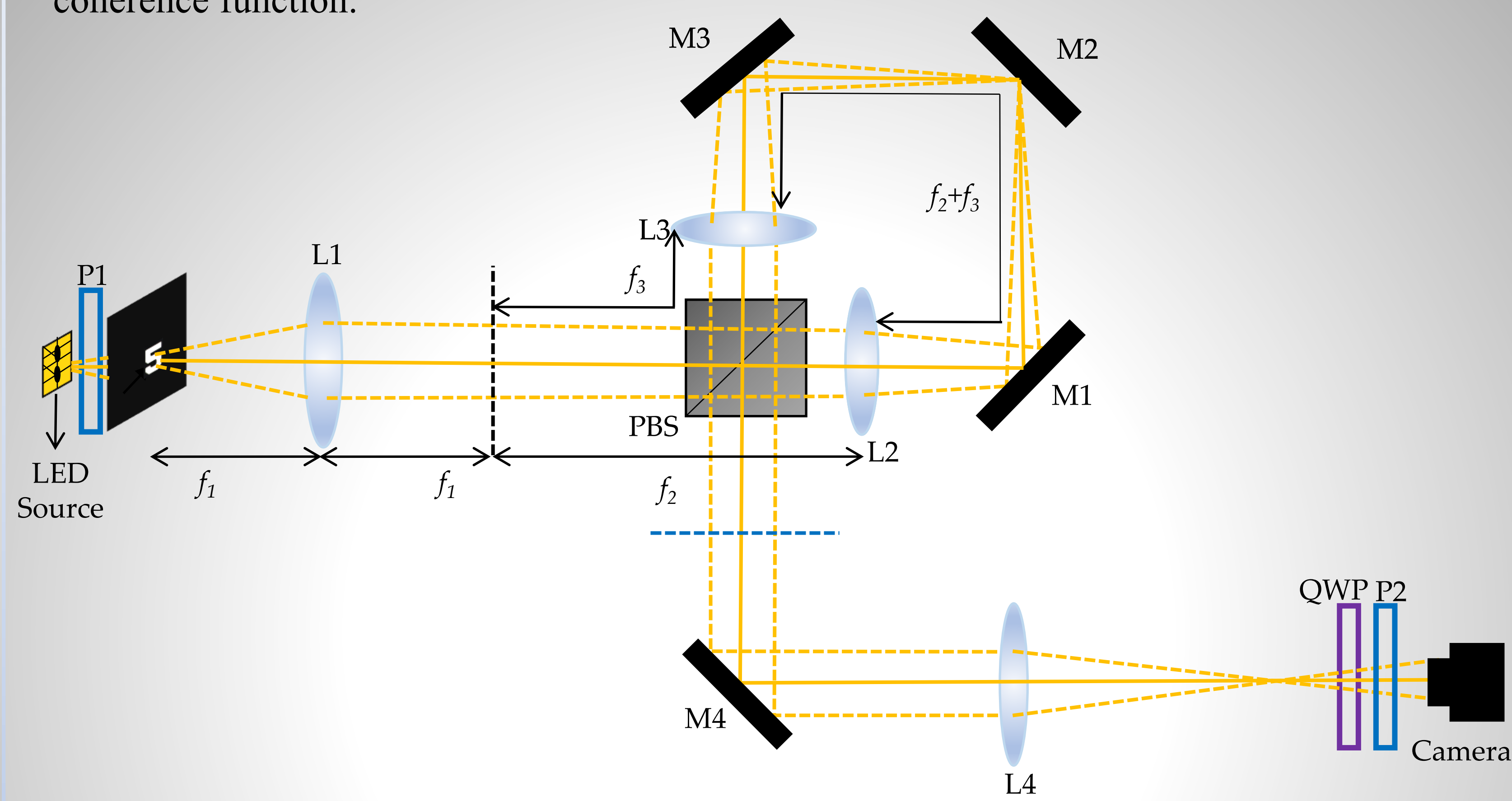

Figure 2. Experimental set up square Sagnac radial shearing interferometer: P: Polarizer, L: Lens, BS: Beam Splitter, M: Mirror, QWP: Quarter Wave Plate

The digital inverse Fourier transform of complex coherence function helps to retrieve the object information.

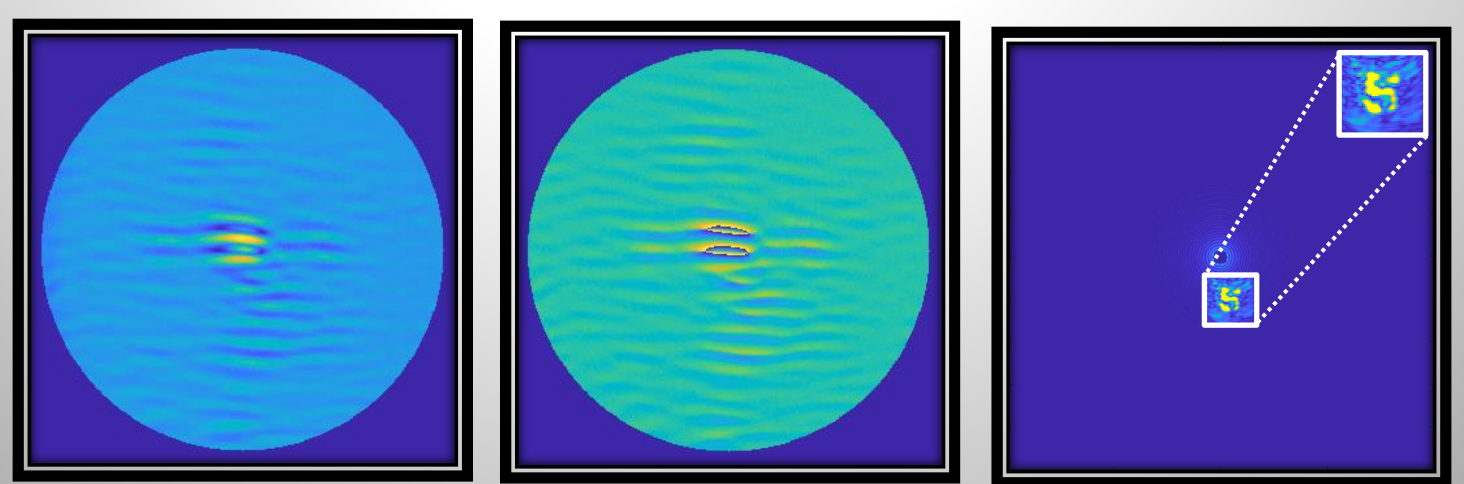

Figure 3. Digitally constructed coherence function (a)fringe visibility (b) corresponding phase and (c) reconstructed object intensity distribution

Conclusion

We have presented an experimental method using shearing for holography with the incoherent source. The object information is recorded in the form of complex spatial coherence function based on the principle of van Cittert-Zernike theorem and later it is analysed using a Sagnac radial shearing interferometer with the five-phase shifting algorithm. The object information is computationally acquired on inverse Fourier transform.

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