Image synthesis for off axis low coherence digital holography

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Abstract A simple method for image synthesis of the reconstructed images from low coherence digital holograms is presented. High quality full-field holographic images can be obtained by this method.

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Digital holographic adaptive optics (DHAO) is a promising technique to obtain images of diffraction limited resolution in ophthalmology and microscopy with optical aberrations [1]. Usually, laser is used as the light source to measure the aberration and perform full-field imaging. If the sample is highly diffuse, the coherent noise such as speckle may be an issue for full-fielding imaging. To address this issue, we are working on the low coherence digital holography that has proved effective in alleviating coherent noises [2, 3]. Due to the short coherence length, only a fraction of hologram shows high contrast fringe, resulting in good reconstruction in this region. To obtain a full-field image, we need synthesize reconstructions from many holograms into a whole image.

The schematic diagram of the apparatus of low coherence digital holographic imaging system is shown in Fig. 1. The light from LED is focused by combination of lens L1 and L2 at pinhole which is 100 μm in diameter to improve the spatial coherence and collimated by L3. L4 and L5 are lens of focal length 25mm. Focal length of L6 is 200mm. The CCD is put at the image plane of the object plane. The object and reference beams will interfere at CCD plane and form an off axis hologram.

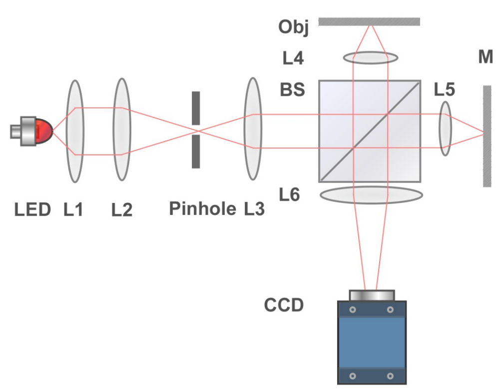

Fig. 1 The schematic diagram of the off axis low coherent digital holography system. L1-L6: Lens. BS: beamsplitters.

The reconstruction from one such off axis hologram is shown in Fig. 2. (a) shows the hologram. The contrast of the fringes reduces from center to two sides diagonally, which indicates the zero-path-difference point is in middle of the sensor. The angular spectrum of the hologram is shown in (b), where three orders are overlapped. Because of the natural vibration of the optical setup, the reference and object beam will have some phase shifts if we take a second hologram. Thus the second hologram will contain same zero order but different twin and image orders at high chance. If we subtract the second hologram from the first one, the zero-order can be removed as shown in (c). (d) is the extracted upper right order of (c). The reconstructed amplitude is shown in (e) and phase in (f). The phase profile is well reconstructed while the amplitude is limited a slice of the whole picture.

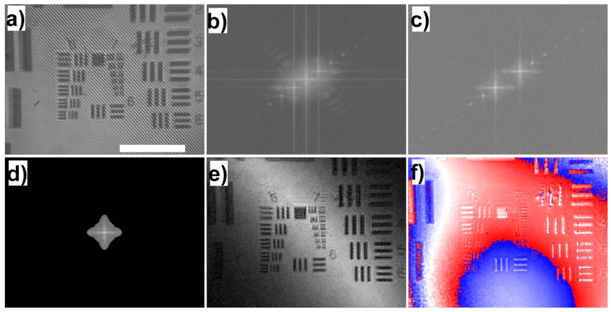

Fig.2 Reconstruction from single hologram. (a) hologram; (b) angular spectrum of (a); (c) angular spectrum with zero order removed; (d) upper right order in (c); (e) reconstructed amplitude; (f) reconstructed phase. Scale bar: 100μm.Same for following images.

To solve this problem, we can move the center of the fringes diagonally and collect holograms with different zero-path-difference points. Figure 3(a)-(c) show three such holograms. Regions of high contrast fringes are different. Fig. 3(d)-(f) show the corresponding reconstructions. For each reconstruction, only a fraction of the whole image is obtained. The full-field image can be obtained by adding multiple such single reconstructions on the intensity basis. The synthesized image is shown Fig. 4. Figure 4(a) shows direct image of the object with reference beam blocked as a baseline. The synthesized image is shown in Fig. 4(b) that is comparable to the direct image (a).

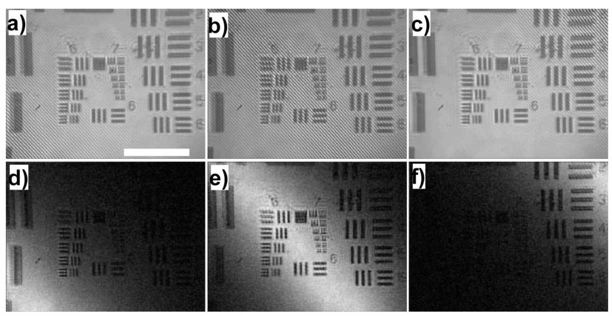

Fig.3 Reconstructions from holograms with different zero-path-difference positions. (a) -(c): holograms. (d)-(f) are reconstructed amplitudes.

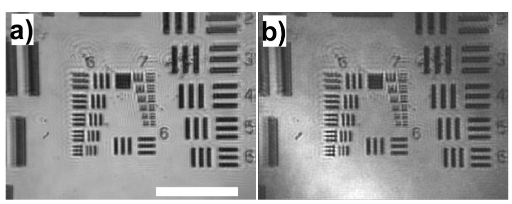

Fig.4 Synthesized image. (a) direct image with reference beam blocked; (b) synthesized image.

In conclusion, we have demonstrated a simple method for image synthesis for low coherence digital holography. This method may be incorporated into DHAO system to address the coherent noise and improve the corrected image quality. We acknowledge the support of NIH under grant No. R21EY021876.

References

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