Single-shot multidimensional phase imaging with a coded aperture

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1. Introduction

Phase imaging has been utilized in the field of biomedicine because biomedical cells have low light absorptions. A famous approach for phase imaging is digital holography (DH) [1]. It uses reference light for quantitative phase detection. But introduction of the reference light increases the size of the optical setup. Another phase imaging approach is coherent diffractive imaging (CDI) [2]. CDI does not use reference light and can significantly simply the optical setup for single-shot phase imaging. But its field-of-view (FOV) is severely limited by a phase retrieval process [3].

2. SPICA

We have proposed a single-shot phase imaging with a coded aperture (SPICA) [4]. SPICA connects a synthetic aperture holography method, which is called compressive Fresnel holography (CFH), and CDI with a coded aperture. CFH can observe a large complex field of an object with sparsely and randomly distributed detectors by using a compressive sensing algorithm [5]. In SPICA, random pinholes on the coded aperture correspond to the detectors in CFH.

We have recently extended SPICA to multidimensional complex object acquisition [6]. The schematic diagram of multidimensional SPICA is shown in Fig. 1. The object is illuminated with coherent light and the object field propagates onto the coded aperture. The complex field sieved by the coded aperture is modulated by a coding optics. Finally the image sensor observes a single intensity image of the modulated complex field. The coding optics is changed for applications, e.g., diffractive gratings for multispectral imaging and birefringence elements for polarimetric imaging.

3. Simulation

Multidimensional SPICA was verified numerically as shown in Fig. 2. The lateral pixel count of the object was 512×512. The object is composed of two depth channels (z1 and z2) and three spectral channels (red, green, and blue) as shown in Fig. 2(a). Free space propagation was chosen as the coding optics because Fresnel kernel is dependent on depth and spectrum. A magnified image of the coded aperture is shown in Fig. 2(b). The captured intensity image is shown in Fig. 2(c). A white Gaussian noise at 30 dB was added to the captured image. The object is reconstructed well as shown in Fig. 2(d), where the peak signal-to-noise ratio was 29.5 dB.

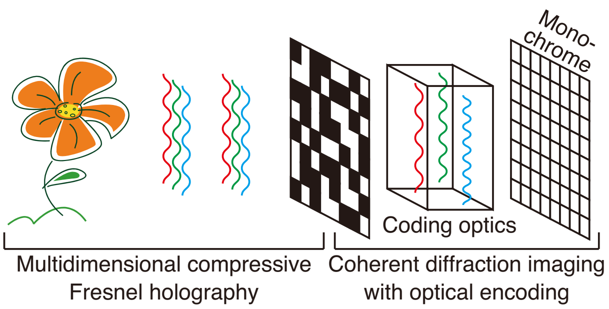

Fig. 1. Multidimensional SPICA.

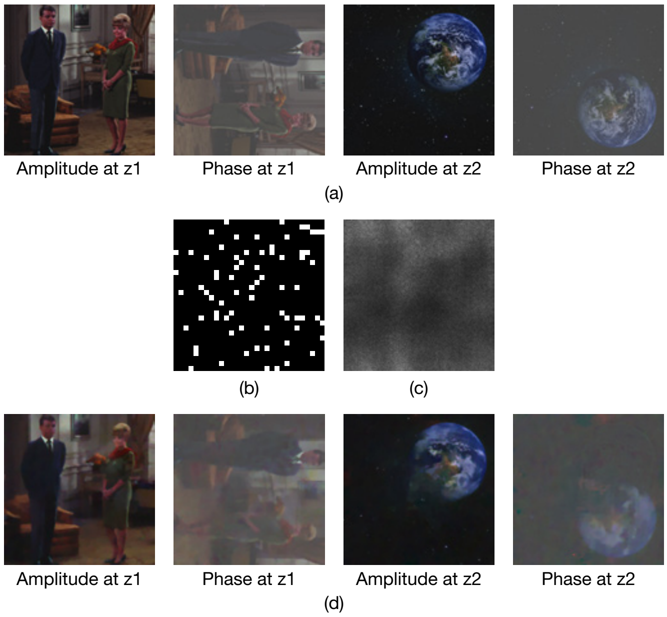

Fig. 2. Simulation results. (a) Object, (b) magnified image of the coded aperture, (c) captured image, (d) reconstruction.

4. Conclusion

We have proposed and numerically demonstrated a generalized framework for single-shot acquisition of multidimensional complex fields based on SPICA. It can significantly simplify and extend the FOV compared with previous single-shot phase imaging methods.

References

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