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Abstract

Incoherent digital holography for multidimensional motion-picture imaging

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Abstract: Incoherent digital holography (IDH) is a technique to obtain a three-dimensional (3D) image of spatially incoherent light diffracted from an object as an incoherent hologram. Color holographic 3D motion-picture imaging of daily-use light at a frame rate of a color polarization-imaging camera can be achieved by the combination of IDH and single-shot phase-shifting interferometry. We show experimental results for color 3D motion-picture imaging in the presentation.

Keywords: Incoherent digital holography; 3D motion-picture imaging; Color 3D imaging

1. Introduction

Incoherent digital holography (IDH) [1-14] is a three-dimensional (3D) image-sensing technique using interference of light and spatially incoherent light. The interference fringe image that contains 3D information of an object is obtained even for spatially and temporally incoherent light by generating two waves from an object wave and utilizing self-interference. A digital hologram of daily-use light can be obtained using IDH, and applications to fluorescence microscopy [15-20] and 3D imager [21-28] have been actively researched. Full-color holographic 3D imaging using IDH has been demonstrated even for sunlight [5,28].

IDH has the ability for simultaneous imaging of multidimensional information such as a 3D image, multiple wavelengths [18-20,29-31], state of polarization, and variety of light [32]. Holographic quantitative phase imagers can be constructed using a small light emitting diode (LED) [33,34]. High-speed image sensing and robustness against external vibrations are important factors when constructing a multidimensional IDH system. Single-shot IDH [8-14] using single-shot phase-shifting [35-37] has been proposed as an IDH technique to satisfy the factors. In most of this IDH technique, holographic 3D imaging can be carried out using single-shot exposure of a polarization image sensor and a single-path interferometer. We briefly introduce these holography techniques and multidimensional imaging with this IDH technique.

2. Digital holography systems adopting single-shot phase-shifting interferometry for multidimensional motion-picture imaging

Figure 1 illustrates two-types of single-shot single-path digital holography (DH) systems: single-shot full-color IDH system with birefringent materials [27,28] and single-shot DH system for quantitative phase imaging with LED light [34]. A single-path self-interference or self-reference interferometer is adopted to the IDH systems. In these IDH systems, two waves are generated from a wave diffracted from an object. Coherence length should

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be considered to obtain a digital hologram of natural light because of its low temporal coherence. These single-path IDH systems are designed to generate an interference fringe image of temporally incoherent light with high visibility. Optical-path-length difference between the two waves is carefully adjusted using polarimetric optical elements. In. Fig. 1(a), a full-color hologram of natural light is obtained with a single exposure of a color polarization image sensor and single-shot phase shifting. The DH system shown in Fig. 1(b) is based on self-reference interferometer and has improved the depth resolution of DH with an LED light in comparison to self-interference IDH [33,34].

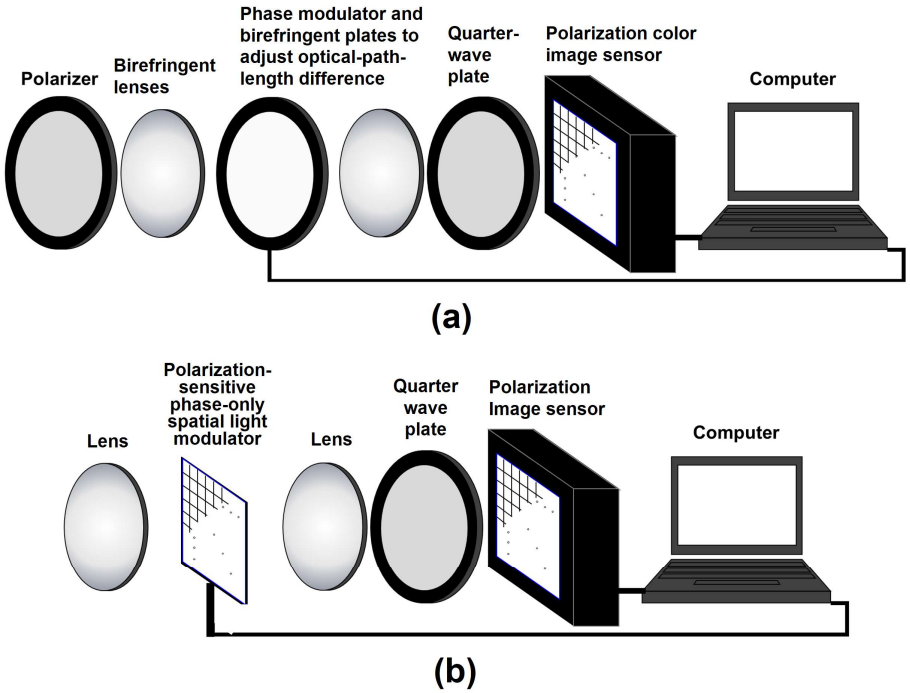

Figure 1. Single-shot single-path DH systems. (a) Single-shot full-color IDH system with birefringent materials [27,28]. (b) Self-reference DH system with a commonly used light source [34].

Figure 2 shows photograph of the constructed single-shot full-color IDH system and an example of experimental results obtained with the constructed IDH system. This IDH system can be used on a wood table to record a full-color hologram of objects illuminated by sunlight [27]. A full-color holographic image has been obtained from a single-recorded hologram using the constructed IDH system and an RGB-LED as shown in Figs. 2(b) and 2(c). Video-rate full-color holographic 3D motion-picture imaging has also been experimentally demonstrated with the setup [28].

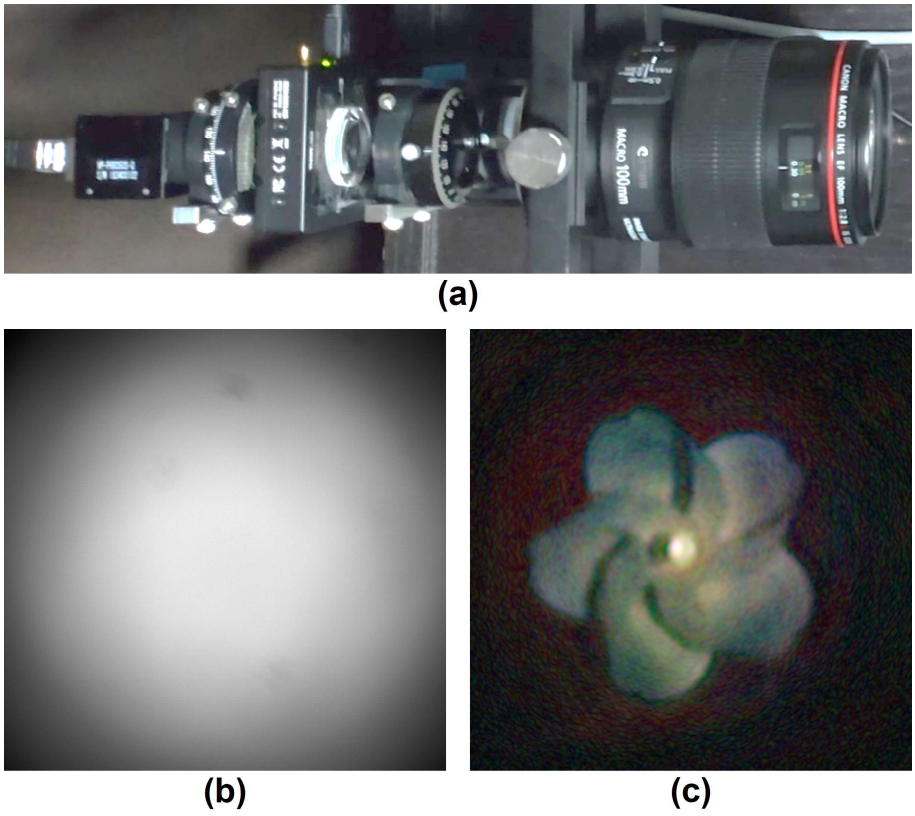

Figure 2. An optical implementation and an example of experimental results. (a) Constructed single-shot full-color IDH system with birefringent materials with a camera lens, termed "Holocamera." (b) A recorded hologram with a holocamera and (c) the image reconstructed from (a).

3. Conclusion

We have briefly introduced single-shot single-path IDH for multidimensional imaging. As another remarks, the limitation of the measurement accuracy in interferometry and holography can be quantitatively evaluated based on the theory of quantum optics [38]. Algorithms and architectures for high-speed image reconstruction are also highly required for real-time measurement [39-41]. We will show experimental results for multidimensional holographic imaging of incoherent light such as sunlight and LED light in the presentation.

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