Photonic Integrated Full-Color Holograms for Visible Light Based on Meta-Waveguides

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Abstract: We experimentally demonstrate photonic integrated visible full-color meta-holograms based on guided wave-driven metasurfaces with complete phase-and-amplitude control capability. Our lightweight and compact meta-holograms can be potentially used for virtual/augmented/mixed reality near-eye displays.

1. Introduction

The hologram is a technique that can record and reconstruct both amplitude and phase information of light field [1,2], which has shown great potentials in cutting-edge areas such as near-eyes display-based virtual/augmented reality, optical trapping, and particle tracking [3-5]. Notably, optical holographic devices applied in these areas are in demand of versatility and integration.

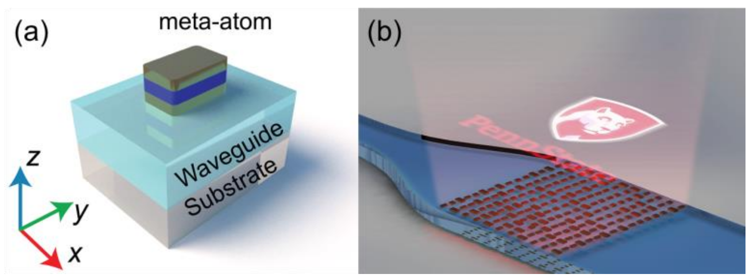

Fig. 1. Schematic view of on-chip color hologram for visible light. (a) A building block of the photonic integrated metasurface. (b) Light propagating inside the waveguide excites the meta-atoms and gets scattered into free space to form a holographic image.

A recently emergent technology of metasurfaces can control both amplitude and phase of the electrical field on a scale of tens of nanometers by artificially mimicking interaction between light with molecules and atoms [6]. Optical meta-waveguides, combining metasurfaces with photonic integrated circuits, enable unprecedented paths in controlling both free-space and guided light and provide emerging opportunities in various applications [7-10]. Among them, waveguide meta-holograms [11,12] are promising in providing an ultrathin, tolerant to alignment error, and compatible with a current nanofabrication technology solution for holographic projection.

In this work, we developed a meta-waveguide that is able to project full-color holographic images from a chip. Furthermore, the proposed platform has the ability to control both phase and amplitude distribution of the light field, enabling high-quality hologram reconstruction, three-dimensional hologram, and optical encryption.

2. Results

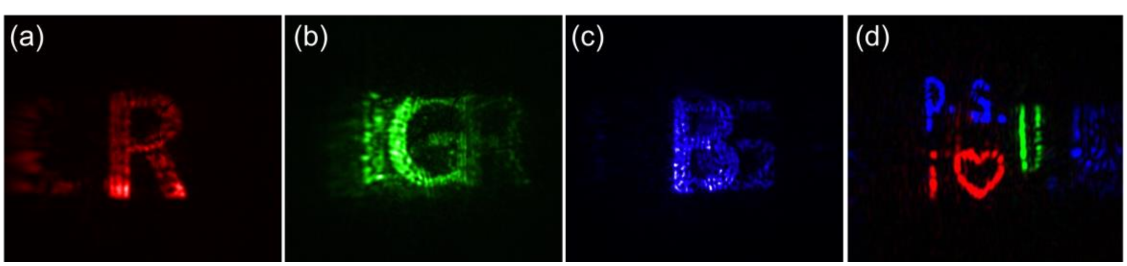

Fig. 2. Generated color holograms with different color laser injection into the waveguide. (a), (b), and (c) Experimentally measured holographic images when the device was injected with red, green, and blue light, respectively. (d) Full-wave simulation results when three lasers are injected into the device simultaneously.

Our metasurface is composed of silver meta-atoms, which support plasmonic resonances, on top of a photonic integrated waveguide, as shown in Fig. 1. The scattering properties, including the scattered wave's phase and amplitude, are determined by the geometries and the positions of the meta-atoms combined.

By judiciously designing the resonance of the meta-atoms, our on-chip device is able to generate wavelength-selective holographic images. In our experiment, we injected lasers of three primary colors (blue, green, and red) into the device using edge coupling and observed the reconstructed holographic images at the plane over the metasurface with the designated height as shown in Fig. 2 (a) to (c). Our full-wave simulation results also show the full-color holographic images can be generated when the device is injected with three colors simultaneously, as shown in Fig. 2(d).

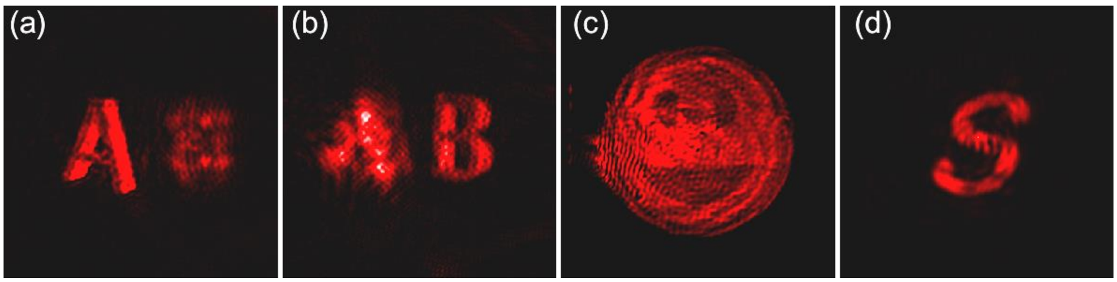

Fig. 3. Full-wave simulated phase-and-amplitude hologram-based 3D hologram projection (a, b) and optical encryption (c, d). (a) and (b) are measured holographic images at different heights above the metasurface. (c) and (d) is the near-field intensity and far-field intensity distribution, respectively.

In addition, our photonic integrated meta-holograms also allow us to control light field amplitude and phase independently. We designed a meta-hologram device for projecting 3D images (Fig. 3 (a)-(b)) as well as an integrated optical encoder that generates different intensity distributions at near-field and far-field (Fig. 3(c)-(d)).

3. References

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