Direct laser writing of color transmission holograms

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Color transmission holography has recently been demonstrated with plasmonic metasurface holograms[1,2] comprising subwavelength phase-shifting structures fabricated by electron-beam lithography. However, this meta-hologram approach requires circularly polarized light and has low transmission efficiencies of 10% and below. Furthermore, off-axis illumination is required and holographic projections are presently limited to a microscopic field of view.

We propose and demonstrate a simple method for obtaining color holographic projections in the Fraunhofer limit from transmission phase holograms. Direct laser writing of computer-generated wavelength multiplexed holograms is achieved by two-photon polymerization of photoresist on a glass substrate to create an array of “hologram pixels”, namely dielectric tiles whose thickness variations control the local phase shift of transmitted light. To reduce unwanted crosstalk between the multiplexed color channels, an integrated color filtering scheme[3] is introduced wherein pillar gratings[4] are printed in situ directly atop the hologram pixels (Figure 1). The hologram design and optimization of the fabrication process will be discussed in this presentation.

Due to the wavelength multiplexing scheme employed, the same hologram can encode different grayscale images, which can be selected with the appropriate wavelength of laser illumination (Figure 2). The resulting holographic projections can be shown using a handheld laser pointer and viewed by eye without the need for specialized setups or fine optical alignment. If multi-color on-axis laser illumination is used, a full-color projection can be obtained by combining red, green, and blue color channels into a single image.

Notably, the entire fabrication process is accomplished in a single exposure and development step without any lift-off. The simplicity of the pillar-on-tile surface topography suggests that these color holograms are amenable to replication by imprinting-based techniques and have good potential for mass production.

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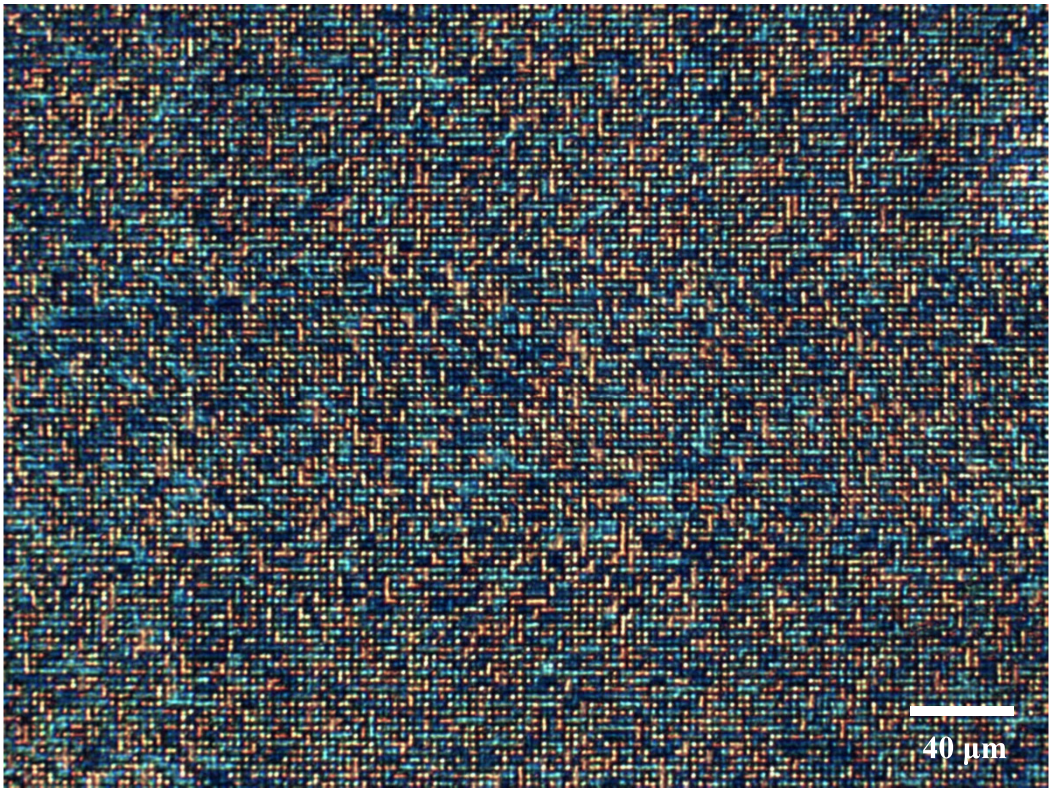

Figure 1: Transmission optical micrograph of a part of a 3 mm by 3 mm color hologram: The pixels are square blocks with side length 3 µm and thickness varying between 0 and 1.2 µm in 16 steps. The color of the hologram pixels is imparted by pillar gratings which serve to improve the wavelength selectivity of the wavelength multiplexed hologram.

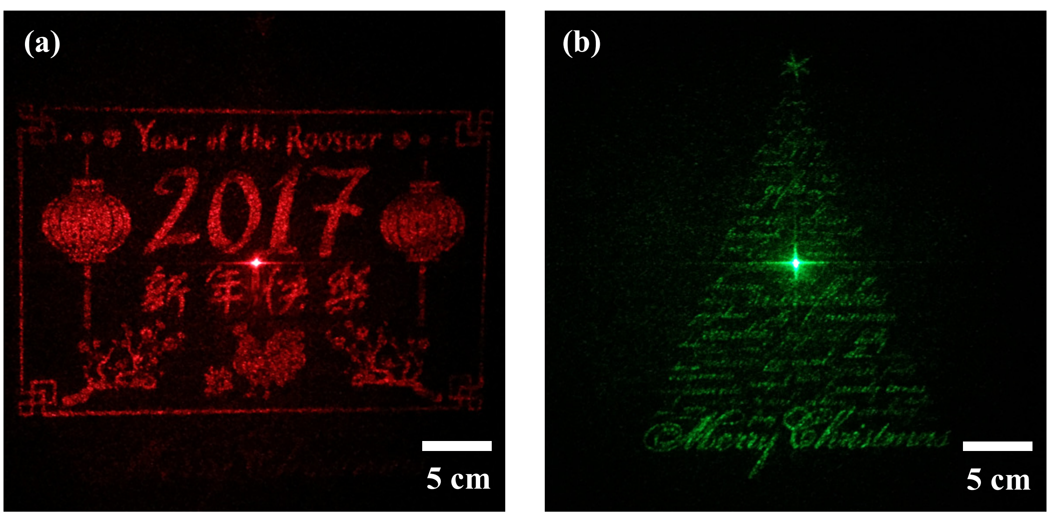

Figure 2: Projected images from the same color hologram under different illumination: With (a) red laser, wavelength 650 nm; and (b) green laser, wavelength 520 nm. Fine features of the text are evident. Photographs were taken in a darkened room with shutter speed 1/17 s, aperture f/2.2, and exposure compensation of −1 stop. Image brightness and contrast were increased by 20%.