Make your own Retinal Projector: Retinal Near-Eye Displays via Metamaterials

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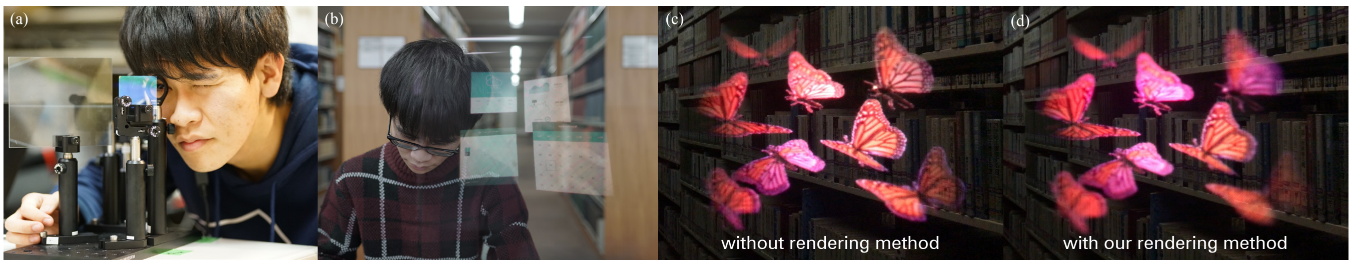

Figure 1: (a) Prototype display based on our optical schematics. (b) The obtained image from see-through prototype. (c), (d) The result of applying simulated retinal blur. Note that there is a difference between the image acquired by the camera and the image actually seen through the human eye.

CCS CONCEPTS

• **Hardware → Displays and imagers**;

KEYWORDS

augmented reality, near-eye displays, transmissive mirror device, retinal projection

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1 INTRODUCTION

Retinal projection is required for xR applications that can deliver immersive visual experience throughout the day. If general-purpose retinal projection methods can be realized at a low cost, not only could the image be displayed on the retina using less energy, but there is also a possibility of cutting off the weight of projection unit itself from the AR goggles. Several retinal projection methods have been previously proposed. Maxwellian optics based retinal projection was proposed in 1990s [Kollin 1993]. Laser scanning [Liao and Tsai 2009], laser projection using spatial light modulator (SLM) or holographic optical elements were also explored [Jang et al. 2017]. In the commercial field, QD Laser[1] with a viewing angle of 26 degrees is available. However, as the lenses and iris of an eyeball are in front of the retina, which is a limitation of a human eyeball, the proposal of retinal projection is generally fraught with narrow viewing angles and small eyebox problems. Due to these problems, retinal projection displays are still a rare commodity because of their difficulty in optical schematics design.

To solve this problem, we introduce novel methods and samples of an optical system for solving the common problems of retinal projection by using the metamaterial mirror (plane symmetric transfer optical system). Using this projection method, the designing of retinal projection becomes easy, and if appropriate optics are available, it would be possible to construct an optical system that allows quick follow-up of retinal projection hardware [Ochiai 2018].

2 DESIGN

A Transmissive Mirror Device (TMD) consists of micro-mirrors that can render real images in the air by retro-reflection [Yamane et al. 2015]. There are several studies on usage of TMDs for near-eye displays [Otao et al. 2018]. They aimed to increase the viewing angle by shortening the optical path length of the generated virtual lens. In contrast to previous work, we use TMD as focusing optics

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[1] http://www.qdlaser.com/ (last accessed May 16th, 2018)

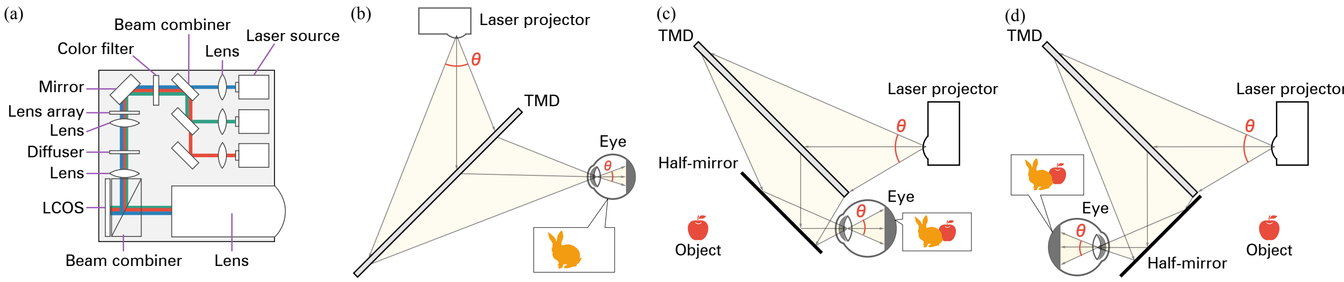

Figure 2: (a) The configuration of laser projector. The point light source passes through the optics such as beam combiner and the image is determined by the LCOS. These techniques realize a wide viewing angle, a high frame rate, and a high resolution compared to the scanning type. (b) Our proposed configuration with TMD. (c), (d) Our proposed see-through configuration with TMD and half-mirror.

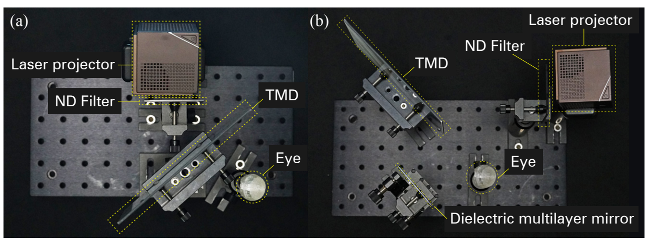

Figure 3: Hardware implementation. (a) Non-see-through prototype with single TMD and laser projector. (b) See-through prototype with dielectric multilayer mirror as beamsplitter.

for the laser projection and render the image on retina directly. By focusing rays with micro-mirrors, it enables distortion-less projection of the wavefront with always in focus with low energy power. To design the optical schematics easily and avoid the optical distortion of our eyeball lens, we employed the laser projection system, shown in Figure 1 (a) and Figure 2. An SLM-type laser projector was adapted as a point light source. Red, green and blue laser light sources were modulated through the SLM and collimated using collimating optics. This type of projector is compact and does not require focusing on the projection surface. Then, we set TMD as focusing optics and the focal point is center of pupils. The key feature of our proposed schematic is that it concentrates the divergent light from the projector using the TMD. This device transfers point light sources to plane symmetric positions using retro-reflection. Since the TMD is composed of micro-mirrors, chromatic aberration and distortion do not occur, and the wavefront is kept coherent.

For implementation, the projection system consisted of a laser driven LCOS and a class 1 laser source. The resolution was 1280×720 pixels, the brightness was 100 lumens. The horizontal viewing angle of the projector was 38 degrees and the vertical viewing angle was 22 degrees. Note that if all the optical components meet the necessary specifications, the viewing angle of our retina display coincides with the viewing angle of the laser light source. The implemented optical circuit is shown in Figure 3. The obtained image from see-through type is shown in Figure 1 (b).

Light field and CGH defines the higher dimensional parameter space to describe the optics and environment. By employing TMD optics and infinite focus projection, we can define the retinal projection matrix that coupled with retinal receptors and transform the optical information in rendering as 2D matrix of homography transformation. The rendering procedure in this framework is divided into two parts. One is the computational calculation in the virtual space that corresponds to the retinal map and focal map of our eyes. The other is the transformation towards 2D projection which is computationally less expensive than computer generated hologram and light field renderings. The result of applying the rendering method is shown in Figure 1 (c) and (d).

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