Crossed half-silvered Mirror Array: Fabrication and Evaluation of a See-Through Capable DIY Crossed Mirror Array

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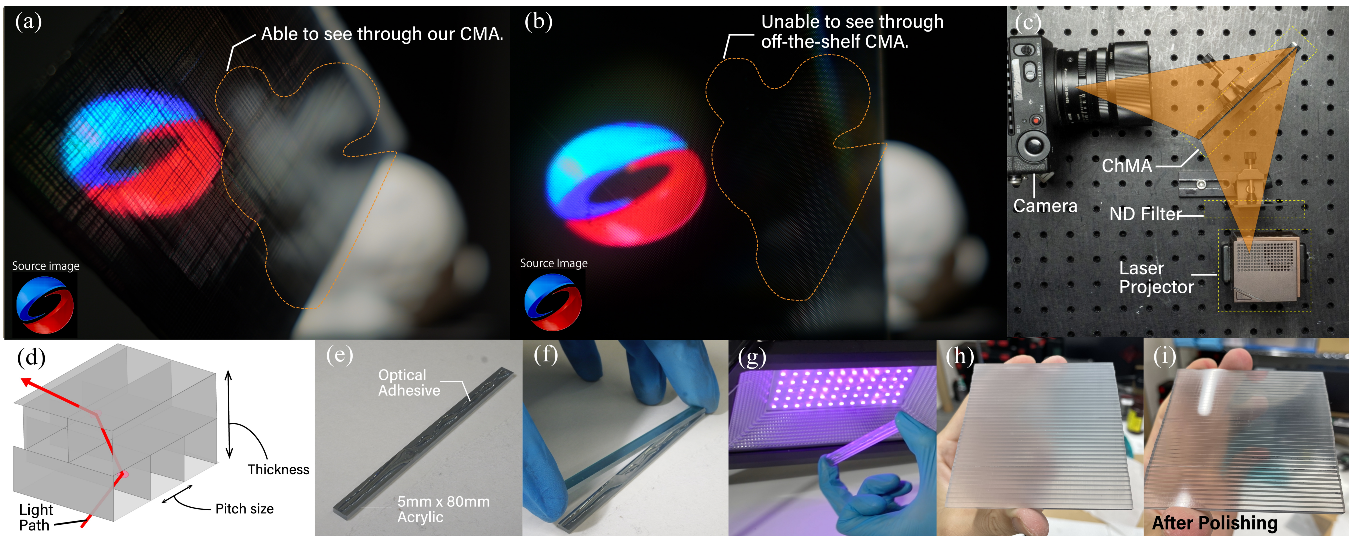

Figure 1: (a) Retinal projection displayed on ChMA, with a physical object behind it. (b) Retinal projection displayed on CMA, with a physical object behind it. (c) Optical setup for retinal projection. (d) Light path in CMA. (e)-(i) ChMA fabrication process.

ABSTRACT

Crossed mirror arrays (CMAs) have recently been employed in simple retinal projection augmented reality (AR) devices owing to their wide field of view and nonfocal nature. However, they remain inadequate for AR devices for everyday use owing to the limited visibility of the physical environment. This study aims to enhance the transmittance of the CMA by fabricating it with half-silvered acrylic mirrors. Further, we evaluated the transmittance and quality of the retinal display. The proposed CMA successfully achieved sufficient retinal projection and higher see-through capability, making it more suitable for use in AR devices than conventional CMAs.

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CCS CONCEPTS

• **Hardware** → *Emerging optical and photonic technologies*; **Displays and imagers**.

KEYWORDS

augmented reality, retinal projection, fabrication process

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1 INTRODUCTION

Augmented reality (AR) devices can potentially replace smartphones as it can offer a rich and immersive experience. However, AR devices have challenges, such as field of view, eye box size, device weight,

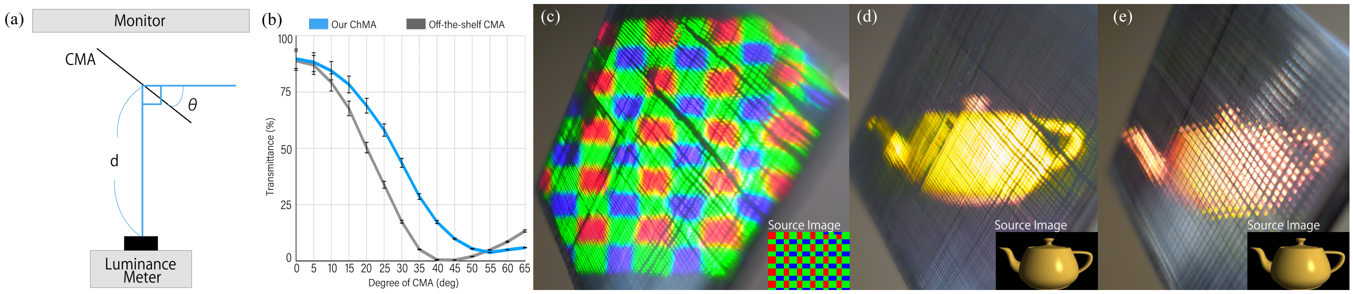

Figure 2: (a) Transmittance experiment device setup. (b) The average luminance of transmittance experiment. (c) Retinal projection result (1 mm pitch). (d, e) Retinal projection comparison between 1 mm pitch ChMA (d) and 2 mm pitch ChMA (e)

display quality, and visibility of the physical environment. To address these challenges, studies have explored various approaches including crossed mirror array (CMA). The CMA consists of micro-mirror array (MMA) grids [Yamane et al. 2015], which transfer the projected image to a plane-symmetrical position as a distortion-free real image (Fig. 1(d)). In 2018, Ochiai et al. utilized this property for retinal projection, which outperformed conventional AR devices [Ochiai et al. 2018]. However, CMA had insufficient visibility of the physical environment owing to its low transmittance of the MMAs (Fig. 1(b)).

This study aims to improve the visibility of the physical environment of a CMA by fabricating a crossed half-silvered mirror array (ChMA) using half-silvered mirrors and optical adhesives. The evaluation included a comparison of ChMA's transmittance with an off-the-shelf CMA and the assessment of the retinal display quality using two ChMAs with different pitch sizes. The results showed that the ChMA achieved higher transmittance and retinal projection capabilities, improving the CMA's drawbacks for AR devices (Fig. 1(a)).

2 CROSSED HALF-SILVERED MIRROR ARRAY

2.1 Fabrication Process

Factors such as the mirror-coating ratio, pitch size, and plate thickness were considered during the ChMA design, along with processing capabilities and availability of adhesives with identical refractive indices (RI) to pass light through the ChMA without refraction. For this fabrication, half-silver mirrored acrylic plates (RI=1.49) and Norland's NOA78 UV-curable optical adhesive (RI=1.50) were used (Fig. 1(e)). The acrylic was 5 mm × 80 mm (W × L) in size and 2 mm thick and one side was half-silver coated. By stacking the plates together (Fig. 1(f)) and curing them using a 60 W UV lamp (Fig. 1(g)), we fabricated an MMA (Fig. 1(h)). After two MMAs were fabricated, the surfaces were polished (Fig. 1(i)) and positioned orthogonal to each other to form one ChMA. The final ChMA was 9 mm thick with a 2 mm pitch (Fig. 1(d)). The ChMA thickness was set to match an off-the-shelf CMA (ASKA 3D plate; Asukanet Co., Ltd.), which was 2 mm thick, with a 0.5 mm pitch and 100% silver mirrored glass.

2.2 Transmittance Evaluation

We compared its transmittance with that of an off-the-shelf CMA. The experimental setup is shown in Fig. 2(a), with d being set such that the measuring range did not exceed the CMA at every θ, and the aperture of the luminance meter (SR-LEDW; TOPCON TECHNOHOUSE CORPORATION) was 2.0°. We then changed the angle θ from 0–65° and measured the luminance at every 5° change. The experiment was repeated three times, and the average and the standard deviation of the results is presented in Fig. 2(b). The difference between the proposed CMA and the conventional CMA is particularly evident between 30° and 45°. The proposed ChMA remains transmissive, whereas the CMA has an almost negligible transmittance. This is relevant as the CMA is typically set in the range of 30–50° for effective retinal projection (Fig. 1(c)).

2.3 Display Results

In addition, we examined the retinal projection capability of the fabricated ChMA. Because the retinal projection display quality depends on the pitch size of the CMA, we fabricated another ChMA, which was 5 mm thick, with a 1 mm pitch using acrylic half-silvered mirrors. This ChMA performed better display quality than that of the 2 mm pitch ChMA (Fig. 2(d), (e)), thereby indicating that the fabricated ChMA with an acrylic mirror performs adequately as a CMA.

3 DISCUSSION AND CONCLUSION

This study aimed to enhance the visibility of CMAs by fabricating them using half-silvered mirrors as the MMA. The display quality of the ChMA was limited due to processing difficulties, resulting in black lines from air bubbles (Fig. 2(c)), indicating a need for improvement in future research. Despite this, the ChMA demonstrated higher transmittance and retinal projection capability, making it more suitable for AR devices. This study provides a solution to the challenges faced in developing wearable AR devices and opens up possibilities for everyday use.

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