Title

Review of 'Breaking the field-of-view limit in augmented reality with a scanning waveguide display'

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Review of 'Breaking the field-of-view limit in augmented reality with a scanning waveguide display' (March 2022)

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Abstract **—Augmented reality (AR) is a growing field of technology with both entertainment, healthcare, engineering, and many more usages. Currently the major design challenge is to achieve both a wide field of view (FOV) and large eye box for the best viewing experience. The authors propose a novel scanning waveguide display design to overcome the current limits of waveguide displays. The key component is an off-axis reflective lens array, which the authors manufacture with a new chiral liquid crystal polarization holography method. With the new lens, the authors are able to achieve a much wider field of view (100°) compared to the current state of the art HoloLens 2 (52°), while maintaining a large eye box. While the authors' design ran into some resolution limitations, those limitations can be addressed and overall the design shows great promise.**

I. Introduction

THE main idea of AR is a transparent display that the user can see through, which can be used to visually "layer" digital images on top of the real world, thereby augmenting reality.

Key terms: chiral refers to left/right non-symmetry, i.e. the mirror image of something cannot be imposed upon itself. Eye box refers to the physical movement range from once can look at the display and still see a good quality image. Etendue is a property of light that refers to how "spread out" light is in area and angle.

Current AR designs include reflection-type, retinal scanning (figure 1a), and waveguide displays (figure 1c).

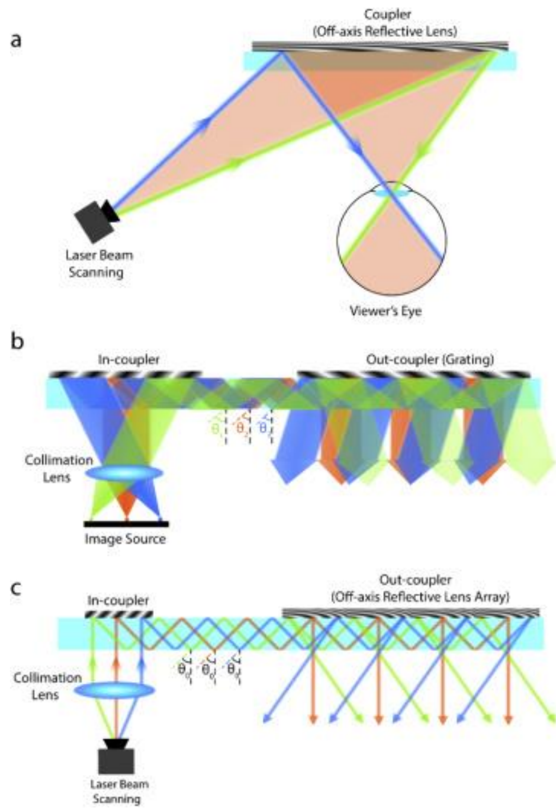

Fig. 1 "Schematic diagram of different see-through display systems: (a) Retinal scanning display with a scanning laser beam and an off-axis combiner lens. (b) Traditional waveguide display. The propagation angle in the waveguide is different for each pixel. (c) The authors' proposed scanning waveguide display. The propagation angle in the waveguide is fixed for all pixels" [1].

All AR displays are constrained by the need to conserve etendue; thus the product of FOV and eye box size are limited. Both retinal scanning and the waveguide designs have been created to work around these limitations. The retinal scanner has unlimited FOV by adjusting the coupler lens, but a very small eye box due to its focal nature. The waveguide design has excellent eye box size and good FOV, but its propagation angle is bound by the need to maintain total TIR on the lower end and maintaining good light uniformity on the upper end. This limits FOV. **Of course, to maximize this, refractive index of the**

transmitting material should be maximized relative to the surrounding material. In addition, the out-coupler is usually an optical grating – which also only functions in a limited range of angles.

To work around these limitations, the authors propose replacing the optical grating with a lens- array component. Then, the burden of varying light angles can be shifted from TIR in the waveguide to the lens-array component. This design, which the authors call a scanning-waveguide display (SWD), combines the wide FOV of retinal scanning and large eye box of waveguide designs.

II. DESIGN

A typical waveguide display has an upper FOV restriction, calculated by

$$FOV = 2\sin^{-1}\left[\frac{1}{2}(n_s \sin\theta_m - 1)\right], \tag{1}$$

Eq. 1. FOV with lower limit bound by TIR angle where “ns is the refractive index of the waveguide substrate and θm is the maximum propagating angle.

Again, this TIR limit can be derived from **Snell’s Law.**

For the authors’ SWD, each single ray should hit a lenslet. To ensure this,

$$p = 2h\tan\theta_0, \tag{2}$$

Should hold true, “where *p* is the pitch of the lenslet and *h* is the waveguide thickness” [1]. P should be smaller than 2mm, as the human pupil is 2-4mm in size to ensure that no more than 1 spatially consecutive ray misses the eye.

As for the chiral liquid crystal (CLC) lens: chirality is required to even couple light out from the waveguide into a normal direction. I will skip the specifics due to space limitations, but it is quite difficult to manufacture. The authors additionally use a polarization holography technique, which forms **linearly polarized light through interference of left-hand circularly polarized light and right-hand circularly polarized light. This works because light has wave properties.**

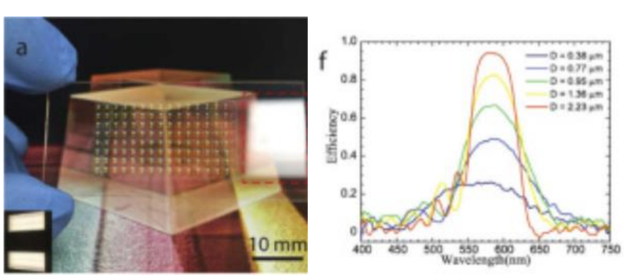

Fig. 2 a) Full picture of 8 by 15 CLC array with 2mm by 2mm lenslets. The bright spots are actually optical images of 2 overhead lights. Notice the excellent optical transparency as required by an AR system. **The material has low optical loss, determined by a imaginary term in the permittivity tensor.**
f) “The chiral lens array also exhibits thickness-dependent efficiency spectrum” “similar to a Bragg grating whose reflection efficiency depends on the thickness” [1]. Noticeably, there is lower absorption around 580nm light, as a material **absorbs a certain wavelength** of light better than others, due to **discrete electron energy levels.** The authors actually chose a lower efficiency thickness to preserve uniformity.

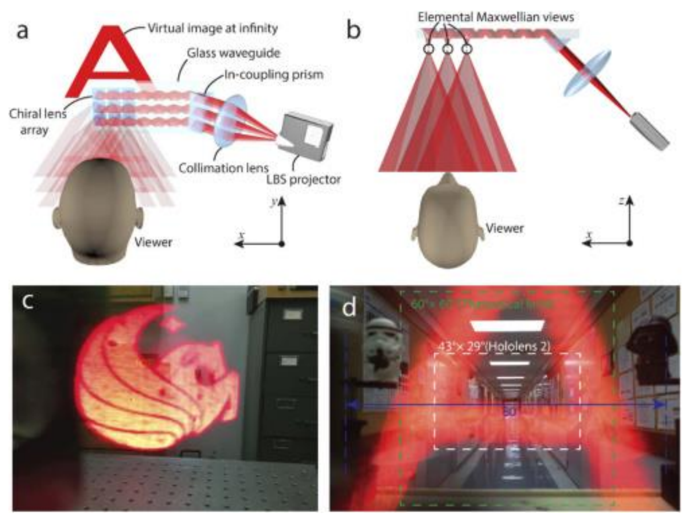

Fig. 3 a), b) Experimental setup and c) successful image. d) comparison of SWD FOV to waveguide theoretical limit and state of the art Microsoft HoloLens 2

III. RESULTS AND CONCLUSION

Overall, the SWD design is successful, achieving a significantly wider FOV while maintaining a large eye box. Note – the authors did not measure the eye box and only gave an empirical statement. However, their SWD exhibits a low resolution, which they attribute to two reasons. One is “digital duplication,” which can be replaced by a fold grating. They do not explain why this duplication is necessary, but I think it may be due to the relatively large (2mm) pitch of the lens array. The second is the beam waist of the Gaussian beam, which they could not decrease further due to limits of the projection device they used.

Overall, the authors proposed and built a SWD that leveraged the large eye box of a waveguide display and wide FOV of a retinal scanning display. The key component was a chiral lens array, which was manufactured using a novel CLC polarization holography method. This SWD system was successful in breaking the bounds of high FOV and high eye box size.

REFERENCES

[1] Xiong, Jianghao, et al. "Breaking the Field-of-View Limit in Augmented Reality with a Scanning Waveguide Display." OSA Continuum, vol. 3, no. 10, 2020, p. 2730., https://doi.org/10.1364/osac.400900.