Realistic Luminance in VR

Supplementary Material, SIGGRAPH Asia 2022

A DISPLAY RESOLUTION

Our prototype's monochrome liquid crystal display, the layer set to be in focus for the user, is 51μm on each side. With the Thorlabs 50mm focal length eyepiece, this produces at most 17.1 pixels-per-degree of angular resolution for the viewer, assuming perfect geometric optics. Using the manufacturer-provided CodeV model of this lens, we can simulate the tangential MTF at the Nyquist-limited spatial frequency of the display, which is shown as the dotted line in Figure 1. By sweeping a single-pixel column across the display and capturing a series of through-the-lens-images, we measure an estimate of the tangential MTF at the maximum displayable frequency in the built system, shown in Figure 1 as the solid line. Due to scattering in the headset this measurement has significantly lower contrast than the idealized simulation, but remains flat over the measurement range as the display's resolution is pixel limited.

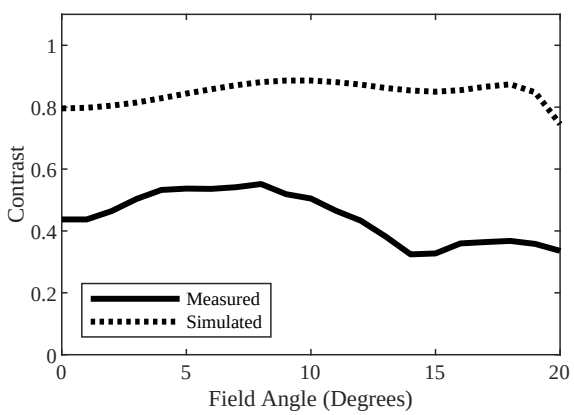
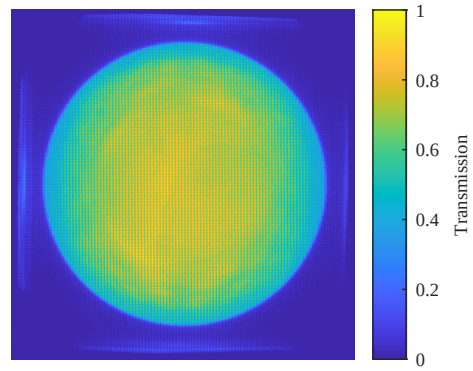


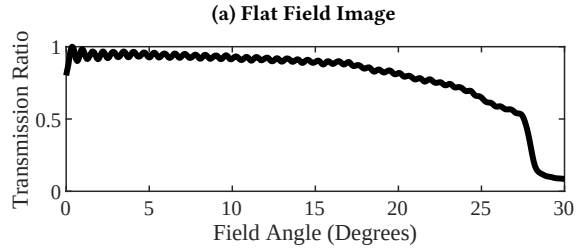
Figure 1: Simulated (dashed line) and measured (solid line) contrast as a function of field angle for an angular frequency of 8.55 cycles per degree, the pixel Nyquist limited angular resolution of the display.

B DISPLAY UNIFORMITY

The backlight design for this headset aims to critically fill the display image plane with simple illumination optics. This serves the purpose of maximizing the display intensity and minimizing stray light, but does not seek to improve uniformity, resulting in nonuniformities in the chip-on-board LED's emission being retained. Furthermore, the pixel grids of both liquid crystal displays contribute to high frequency artifacts in the image. The joint effect of these uncorrected artifacts can be observed in the through-the-lens flat field image in Figure 2a and in the radial transmission profile shown in Figure 2b.



(a) Flat Field Image



(b) Transmission by Field Angle

Figure 2: (a) A normalized image of a flat white field captured through the experimental prototype. (b) The transmission ratio as a function of field angle calculated from the flat white field image. Backlight intensity falloff and high frequency effects due to the dual display pixel grids are both visible.

C DISPLAY LATENCY

The latency of the inside-out tracking module, a Stereolabs ZED Mini, was reported by the manufacturer as 20-30ms. Due to the 50Hz refresh rate of the monochrome display, the presented frame will appear to the user as much as 20ms after the tracker reports a change in position, for a total latency of 50ms or less. Furthermore, the best available transmissive color and mono displays of this size had differing refresh rates (60Hz and 50Hz, respectively), so the two displays are not synchronized. We subjectively evaluated these temporal effects and found that they did not cause distracting breakup of the content in our study, nor did they appear to vary as a function of luminance. We felt this was a reasonable trade-off, introducing negligible confounding effects, to achieve the high contrast and high luminance enabled by the color-mono pair.