Holographic Waveguide Head-Up Display

Pierre-Alexandre Blanche, Ph.D.

College of Optical Sciences, The University of Arizona, Tucson AZ 85721
pablanche@optics.arizona.edu

Head up displays (HUDs) are being deployed in transportation vehicles such as car and aircraft to reduce the amount of time spent looking away from either the road or sky in comparison to a head down display. This advantage helps improve the situational awareness, and reduces the reaction time. There exist many versions of HUDs where the simplest consist of using a smartphone sitting on a dashboard with the image reflected by the windshield into the driver's eyes. Unfortunately, this version does not provide the image at the same focal distance as the road, forcing the eye to accommodate. The current airliner HUD uses a combiner with a dichroic mirror, or a hologram, to reflect a collimated image into the user's eyes. This method effectively overlays an image onto the far field by using a system of lenses to expand and collimate an image from a projector. Unfortunately, the size of the projected image is limited by the size of the projection optics, reason why in both car and aircraft HUD image are still relatively small (figure 1).

Our solution is to use a planar waveguide where the image is injected using a hologram. The light then propagates inside the waveguide and is extracted multiple times by another hologram. The re-circulation of the light several times withing the waveguide expands the pupil so the viewer can see the image from an extended eye-box. By adding a redirection hologram that turns the light inside the waveguide, the pupil is expended in both vertical and horizontal dimension (figure 2).

In addition to expanding the eye-box, our system also magnifies the original image coming out of the projector thanks to the injection hologram which acts as a lens. The advantage over the classical configuration is that the projector is now located near the waveguide and can be extremely compact. Using this technique we were able to increase the field of view of the HUD system up to 24° in the horizontal dimension (figure 3).

A proof of concept of the holographic waveguide HUD has been created to demonstrate the capability of the technology. We optimized the system configuration using the optical simulation software Zemax for the light propagation, and the coupled wave analysis for the hologram dispersion and efficiency. Our prototype has a 2 by 4 inch eye box with a maximum resolution of 12.7 lines/mm. 4 times image magnification and image projection in the far field are both achieved using the hologram's optical power (figure 4).

Full color HUD can be achieved by having holograms recorded with red, green and blue central diffraction wavelengths. These holograms can also be multiplexed inside a single sheet of material.

We also believe that it is be possible to use a curved waveguide, instead of flat, to make the HUD. Int this case, the holograms can be recorded such as they compensate for any residual optical power. The use of a curved waveguide could be interesting for a better integration of the HUD to confine environment such as cars and small aircrafts.

This technology also find application in augmented reality glasses that use the same principle of HUD to display the image in front of the wearer.

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1 Craig Draper et al., "Holographic waveguide head-up display with 2-D pupil expansion and longitudinal image magnification", submitted to Optical Engineering.

2 P.-A. Blanche, at al., "Holography for Automotive Applications: from HUD to LIDAR", Invited paper SPIE proceedings 10757-11, SPIE Optics & Photonics, San Diego, August 2018.

3 C. M. Bigler, P.-A. Blanche, and K. Sarma, "Holographic waveguide heads-up display for longitudinal image magnification and pupil expansion", Applied Optics, 57(9), March 2018.

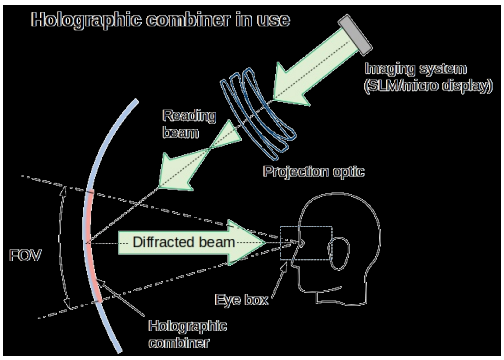

Figure 1: Classical configuration for an HUD where the projection optic occupy a large footprint.

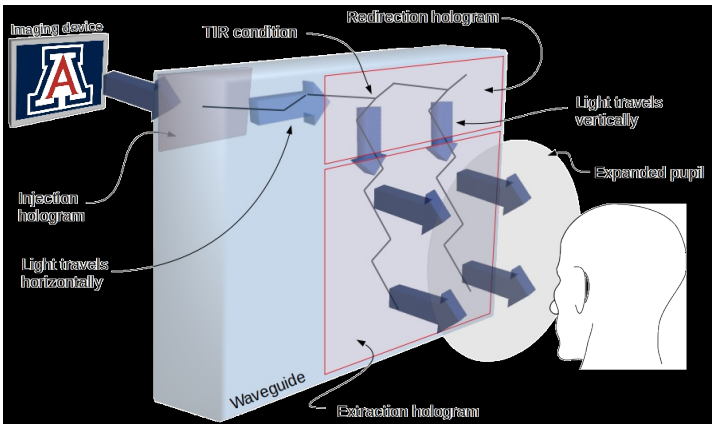

Figure 2: Conceptual design of the holographic waveguide HUD system showing the different hologram sections that couple the image inside the waveguide, redirect it internally, and extract the light with two-dimensional pupil expansion for an increased eye box and field of view.

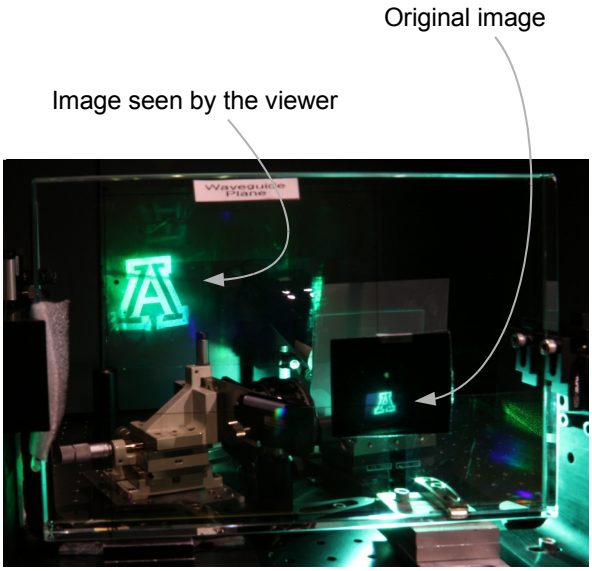

Figure 3: Picture of the prototype HUD system showing the small injection image which is magnified as the out-coupled image.

Figure 4: Picture of the HUD system taken with a SLR camera when focused at infinity. Both the background runway and the symbology projected through the HUD are in focus. This demonstrates that the viewer does not need to accommodate to see the image.