

Binocular Holographic Waveguide Visor Display

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Abstract

This paper documents the development of a prototype binocular, see-through, monochrome holographic waveguide helmet mounted display (HWVD). The optical system couples a commercial high resolution 1440 x 1080 pixel (1.5Mpixel) 12mm diagonal LCOS microdisplay with a state of the art holographic waveguide. Utilization of the waveguide gives a wide 40-degree field of view (FOV), while having a large 30x30 mm eyebox. With the advantages obtained by use of the holographic waveguide and the small LCOS microdisplay, the HWVD system enables significant cost, volume, and weight reductions as compared to existing CRT type designs. The design will also address power and efficiency requirements consistent with a pilot HMD system.

Author Keywords

Holographic Waveguide Visor Display; Helmet Mounted Display; Binocular Display; LCOS; Near to Eye Display

1. Introduction

Recent developments in the fabrication of holographic waveguide optics make it possible to replace bulky, expensive, multi-element projection optics systems with light-weight, thin see-through diffractive optics. These advances in holographic optics have demonstrated the potential for the optical image magnification function to be implemented within thin waveguide structures. Figure 1 shows a comparison of conventional HMD optics with an implementation using a waveguide. The potential exists to integrate the projection optics into the structure of the HMD visor itself, ultimately into curved visors. This project is directed at leveraging this technology for the next generation aviation helmet visualization systems. In the paper a prototype binocular holographic waveguide visor display (HWVD) system is described. The HWVD uses BAE Systems second-generation monoblock holographic waveguides¹ and high-resolution LCOS microdisplays^{2, 3} and projector engines to reduce the size, weight, and power of the binocular helmet mounted display system.

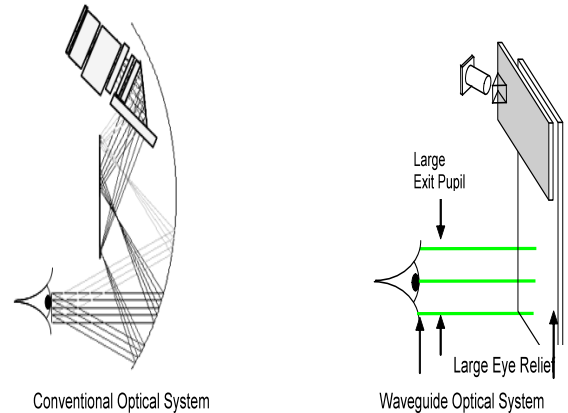


Figure 1. Conventional HMD and Waveguide HMD Constructions (Image courtesy of BAE Systems)

Previously image waveguide technology has been reported for HMD applications by BAE Systems. They have developed and produced the Q-Sight[®] monocular waveguide HMD for aviation applications. This paper is one of the first reported developments of a binocular holographic waveguide aviation HMD.

[®]Q-Sight is a registered trademark of BAE Systems.

The binocular prototype holographic waveguide helmet visor (HWVD) display developed has:

- 40 degrees horizontal field of view
- See through configuration with 80% transmission
- 1460 x 1080 pixel resolution LCOS displays, 6.5 μm pixel pitch, 0.48 inch diagonal
- BAE Systems monoblock Generation 2 holographic waveguides
- 2800 Cd/m^2 brightness monochrome waveguide display with 525nm LEDs
- 500:1 Projection engine sequential contrast ratio
- Lightweight compact design with center mounted binocular modules
- Fiberoptic coupled remote LED sources
- Dual HDMI input to HMD from cockpit supply module

2. Results

The HMD system design is shown in figure 2. The left eye and right eye projector/waveguide modules are integrated into a rigid structure with a center pivot mount to the helmet. The signal, power and fiberoptic illumination delivery cables enter the system over the top of the helmet. The prototype uses similarly configured waveguides for the left and right eyes. The waveguides have the entrance and expanded exit pupil on the same face of the waveguide. There are 3 circuit boards conforming to the opto mechanical design.

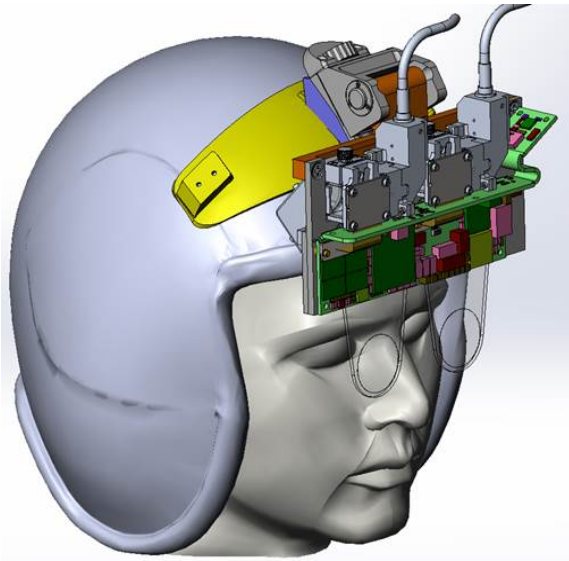


Figure 2. HWVD Binocular Design

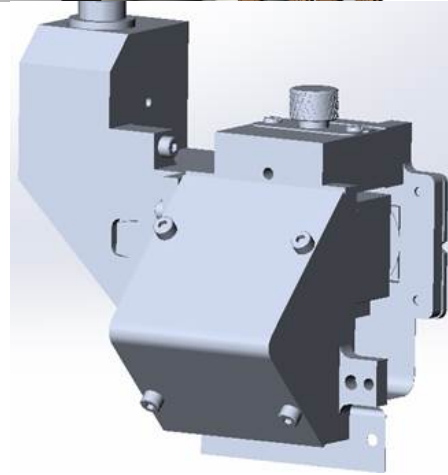
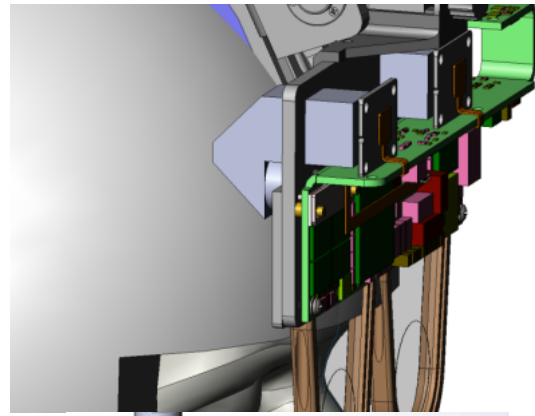


Figure 4. Optical Module showing LCOS Panel and Folded Optical Projection Lens

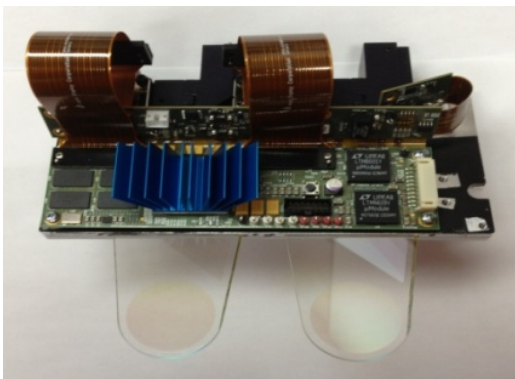
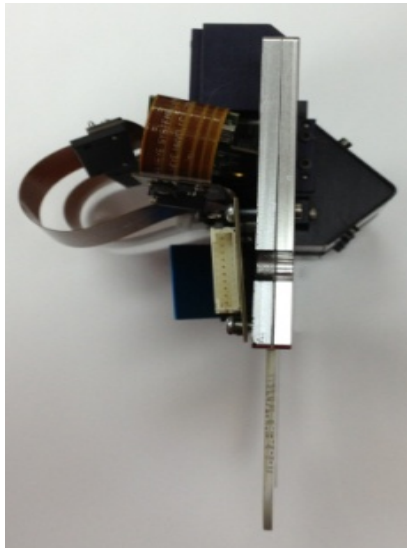


Figure 3. Prototype Binocular HWVD Design and Implementation

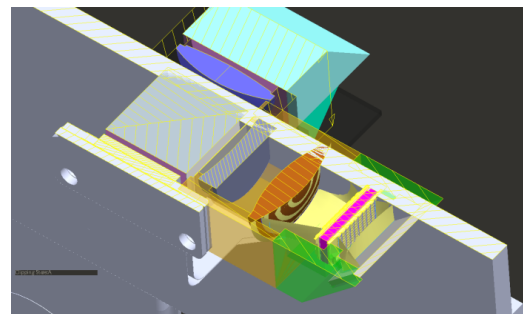
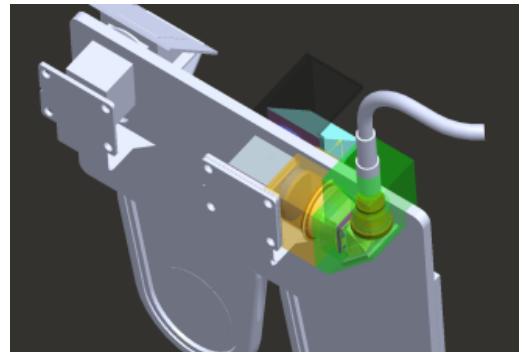


Figure 5. Fiberoptic coupled remote LED Illumination System Design for One Eye Module

The key individual components are:

- Microdisplay: Jasper Display Corp. SP 55 LCOS microdisplays
 - 1920 x 1080 pixel resolution, letterbox to 1440 x 1080 in HWVD
 - 0.55 inch diagonal, 0.48 inch diagonal in HWVD
 - VAN mode LC alignment
- Circuitry in HWVD
 - 3 conformal boards connected by flex connectors
 - Xilinx Kintex 7 based FPGA circuit driving both left and right eye modules
 - HDMI signal to the HWVD from cockpit module
- Optical projection modules
 - LCOS panels mounted vertically in front of waveguides with polarizing beam splitter. Projection lens folds over top to input pupil on back face of waveguide for minimal size and weight forward from the helmet
 - Illumination system: fiberoptically coupled Luminus PT54 525 nm LED sources with Imagine Optix PG-PCS microlens array/polarization converter
- Holographic Waveguides
 - BAE Systems monoblock configuration
 - Monochrome green
- Both waveguides are left eye configured

Table 1. Prototype Performance Parameters

Parameter	
Projection engine lumen output	30 Lumens
Projection engine contrast ratio	600:1
Projection Engine resolution	1440 x 1080
Full field brightness of waveguide	2800 Cd/ m ²

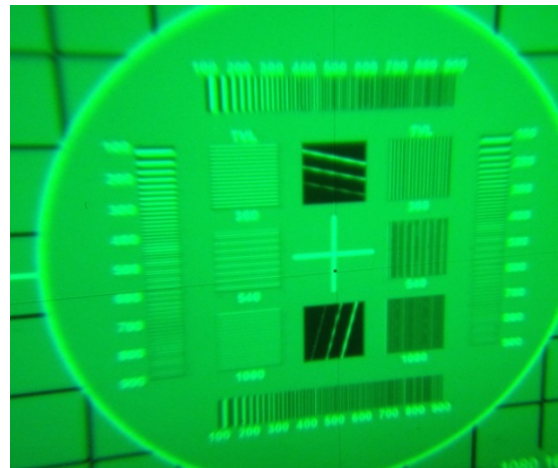


Figure 7. Projection Engine Test

1. Horizontal waveguide expands the pupil horizontally.
2. Vertical waveguide expands the pupil vertically.

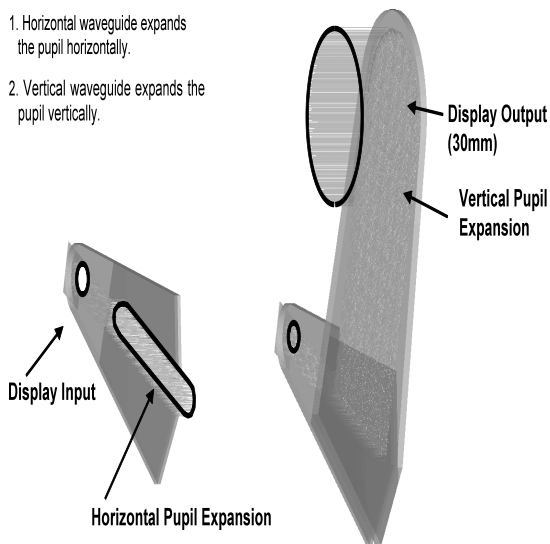


Figure 6. Schematic Diagram of Holographic Optical Waveguide Element

In figure 8, the operation of the prototype is shown.



Figure 8. HWVD Prototype

3. Summary

The significance of this work is the design, development and prototyping of a rugged, compact binocular HMD based on state of the art wide FOV planar holographic waveguide technology and a high resolution LCOS image

input. The design provides a rugged central mount of the binocular modules for ease of use and pilot comfort. The fiber optical coupling of the remote LED sources reduces weight and power in the HMD. The large 30mm eye boxes of the waveguide allow a fixed configuration of the waveguides. This provides a stable registration of the 2 exit pupils in aviation applications. The high resolution LCOS panels provides multi pixel digital convergence of the 2 images to avoid stereopsis. Future development is directed to further reduction of the weight and power of the HWVD and increase of the resolution to a threshold of 5Mpixel/40° FOV to an objective of 8Mpixel. HOLOEYE is presently developing a 0.7 inch 4096 x 2400 pixel LCOS microdisplay for these applications. The concept design is shown in figure 9.

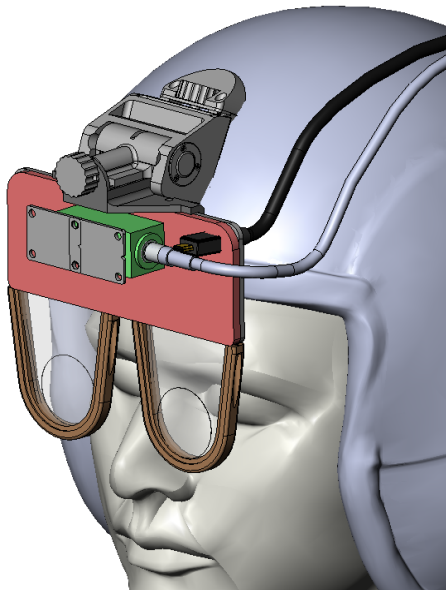


Figure 9. Concept for Next Development of HWVD

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- BAE Systems internal R&D funding
- HOLOEYE Systems internal R&D funding

5. References

1. A. Cameron, "Optical Waveguide Technology & Its Application in Head Mounted Displays, Proceedings of SPIE, Vol 8330E, 2012.
2. W. Bleha, L. Lei, "Advances in Liquid Crystal on Silicon (LCOS) Spatial Light Modulator Technology", Proceedings of SPIE Vol 8736, 2013.
3. G. Lazarev, A. Hermersmidt, S. Kruger, and S. Osten, "LCOS Spatial Light Modulators: Trends and Applications", Optical Imaging and Metrology: Advanced Technologies, Wiley-VCH Verlag, 2012.