

Application Note —

HMDs and Microdisplays (Basics)

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1. Introduction

This document offers an introduction to head mounted displays (HMDs). The fundamental parameters that should be considered when designing an HMD system will be considered, as will some standard designs that use reflective LCOS microdisplays. This document is not intended to be an exhaustive discussion of HMDs and their applications, but rather, an introduction to help users define what they require out of their system.

2. Head Mounted Display Fundamentals

The basic parameters that are used to describe the performance of an HMD are the field of view (FOV), resolution/image quality, luminance, eye relief and exit pupil (or eye motion box) size.

2.1 Field of View

Field of view is defined as the angular size of the image as seen by the user. It is usually defined by the angular size of the diagonal of the image. Another method used to describe the size of the image is to state the virtual size of the image at a certain distance. For example, a 30° diagonal FOV is equivalent to a 55cm diagonal image at a distance of 1m.

2.2 Resolution/Image quality

The quality of the image is determined by the quality of the optics and optical design of the HMD, but also more fundamentally the resolution of the display. The relationship between the number of pixels in the display and the size of the FOV will determine how “grainy” the image appears. People with 20/20 vision are able to resolve to 1 minute of arc. The average angle that a pixel subtends can be calculated by dividing the number of pixels by the FOV. So, for an SXGA display with 1280 pixels in the horizontal plane, a horizontal FOV of 21.3° will give 1 pixel per minute of arc. If the FOV is increased beyond this, the pixels will become resolvable, and the image will appear “grainy”. This is however only the case for a system using perfect optics. Most optical systems will introduce aberrations, which will blur the pixels and make them less resolvable, thus reducing the graininess. There will also be an acceptable level of graininess, which will in general mean that larger FOVs can be used. This is in fact essential if the HMD is to be used for an immersive system.

2.3 Luminance

Luminance, or how bright the image appears, is of most importance for a semi-transparent HMD system which is being used to overlay data onto the users view of the outside world. In this case it is important that the data is bright enough to be seen over the light from the ambient scene.

2.4 Eye Relief and Exit Pupil

Eye relief is the distance of the eye from the nearest component of the HMD. The size of the eye relief is often dependent on whether the user is required to keep their eyeglasses on, as this requires extra space between the HMD and the eye. An eye relief of 25mm is usually accepted to be the minimum for use with eyeglasses. If the HMD is focusable such that eyeglasses are not required, the eye relief can be less.

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The exit pupil (or eye motion box) is the area where the eye can be placed in order to see the full display. If the eye is outside the exit pupil then the full display will not be visible. Generally, the greater the eye relief, the smaller the exit pupil will be, as shown in figure 2.1.

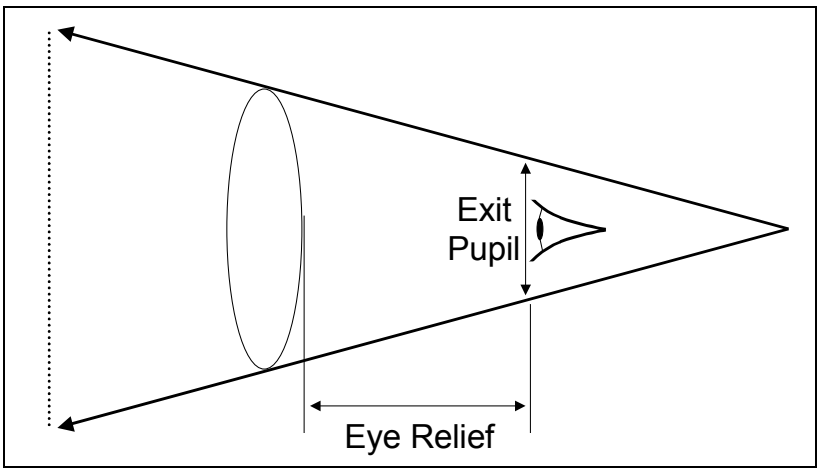


Figure 2.1: Representation of Exit Pupil and Eye Relief

3. System Designs

Some typical designs used for HMD systems are now considered.

3.1 Simple Magnifier

The simplest design for an HMD system is illustrated in figure 3.1. Light from the illuminator (which is commonly an LED array) is directed onto the display using a lens or other form of light management. The illuminating light has to be linearly polarized before it hits the display. This can be done using the polarising beam splitter (PBS), but a pre-polarizer is often also used to improve the contrast ratio. The light reflected from the display is analysed by the PBS. Another linear polarizer can augment the analysis after the PBS if required. The user views the display through a lens or lens combination, which acts as a simple magnifier.

This system is easy to design and construct. However for this type of system, the position and power of the magnifying lens determines the FOV, and the proximity of the lens to the display is limited by the PBS, which limits the FOV. The size of the eye motion box is generally large for this system, which means that the user does not have to position their eye accurately with respect to the system in order to view the full display.

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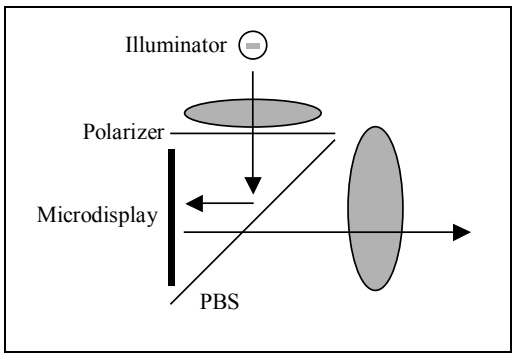


Figure 3.1: Simple Magnifier

3.2 Microscope

The microscope design (figure 3.2) can have the same illumination optics as the simple magnifier design. The viewing optics are based on the principle of the microscope, with lens 1 forming an intermediate image of the display, and lens 2 magnifying this image.

This system can have a larger FOV than the simple magnifier system as the second lens can be very close to the intermediate image. The extended path length between lenses 1 and 2 can also be used to fold the system, which is often helpful in managing the weight distribution about the head. This system suffers from having a fairly small exit pupil, which means that the positioning of the eye is more critical than for the simple magnifier system.

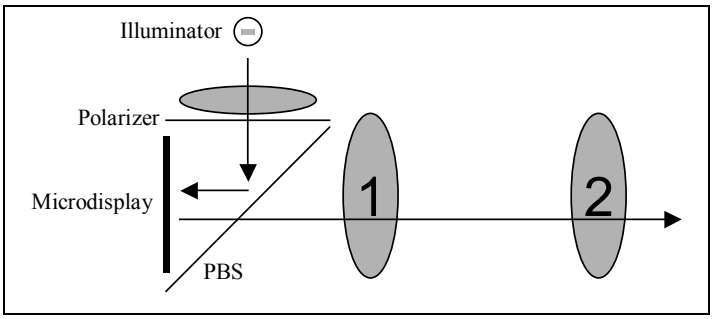


Figure 3.2: Microscope design

3.3 Birdbath

The birdbath mirror design (so called because the spherical mirror is known as a birdbath mirror) uses a mirror to do the magnification of the image (figure 3.3). In this system, light from the illuminator is polarized by a linear polarizer before passing through a non-polarizing beamsplitter and onto the display. The light reflected off the display reflects off the beamsplitter and onto the birdbath mirror, which forms a virtual image. The light is analysed by a linear polarizer after the last pass through the beamsplitter.

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Using a mirror allows a larger FOV than the simple magnifier system and also avoids any chromatic aberration problems. The main problem with this design is that 50% of the light is lost on each pass or reflection by the beamsplitter, but using a more powerful illumination source can compensate for this. It is important that the linear polarizers used should have a very good extinction ratio, as the first reflection off the beamsplitter directs the light towards the eye.

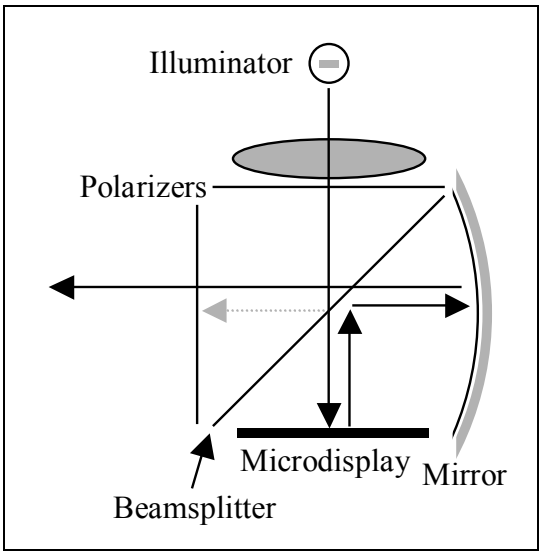


Figure 3.3: Birdbath mirror design

3.4 Projection

The projection system design of HMD (figure 3.4) is similar to the microscope design (figure 3.2) but in this design a real image is formed on a screen between the two lenses.

This system has the same advantages and disadvantages of the microscope design, although using a screen does allow a larger exit pupil to be created. Another possible problem with this design is that the screen has to have a very fine structure otherwise it will be highly visible to the user.

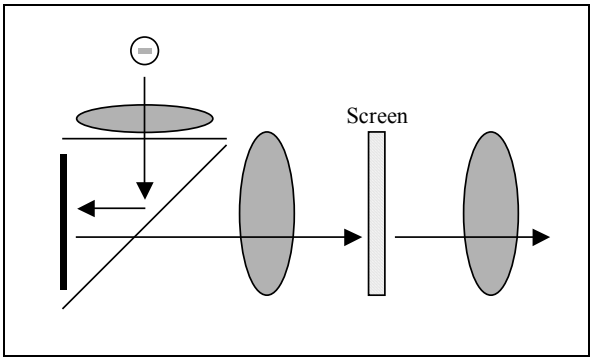


Figure 3.4: Projection design

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3.5 Holographic

Holographic elements can be used in HMD systems to replace traditional lenses. This can allow more compact designs and different optical paths.

3.6 Semi-transparent

HMD systems are sometimes required to be semi-transparent so that the outside world can be seen. This type of system might be used as a data overlay system. One possible system design would be to make the birdbath mirror semi-transparent (figure 3.3). As noted in section 2.3, the illumination of the display can be critical in this type of system so that the image on the display is visible over the ambient light.

4. Number of Oculars

An HMD can be for one or two eyes. A one eye system is known as a monocular system, while a two eye system can be biocular or binocular.

4.1 Monocular systems

A monocular system uses one display for one eye. This is the simplest type of system to build, as there is no requirement to match what each eye sees. This type of system should generally have a limited FOV, as it will not be comfortable for one eye to be scanning over a wide FOV while the other eye is not. This type of system will require one display and one set of electronics.

4.2 Biocular systems

A biocular system is one in which both eyes see the same image. This can be achieved by using two displays with one set of electronics to show the same image on both displays, or by using one display with one set of electronics and complicated optics to allow each eye to view the same display.

4.3 Binocular systems

A binocular system is one in which each eye sees a different image. For this system, two displays and two sets of electronics will be required. A binocular system is required for stereoscopic viewing.

Both biocular and binocular systems are more complicated than monocular systems, as they require the displays to be separated by a specific distance known as the interpupillary distance (IPD) (the distance between the eyes). How critically the display positions are matched to the IPD will depend on the size of the exit pupil.

Binocular systems also require the images to be overlapped in order to produce a stereoscopic view.

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