CSE 190: Virtual Reality Technologies

LECTURE #6: VR DISPLAYS

Announcements

Homework project 1 due this Sunday, April 19th at 11:59pm

Next Monday: Discussion homework project 2

Update on cloud Macs: deployment delayed

3D Displays

Definition of Display

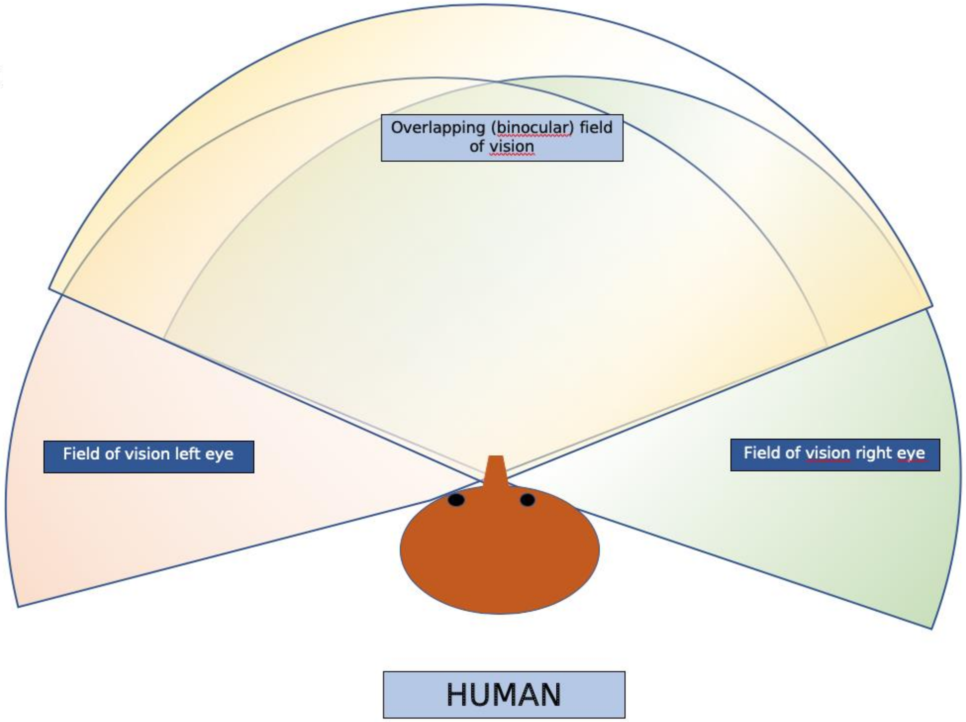
- *Display*: a device which presents **perceptual information**
- In most cases the term “display” is used for “**visual display**”
- Goal for VR: to use display devices which accurately represent **visual perception** in a **simulated world**

Visual Display Characteristics

- Field of View
- Field of Regard
- Spatial Resolution
- Screen Geometry
- Light Transfer Mechanism
- Refresh Rate
- Ergonomics

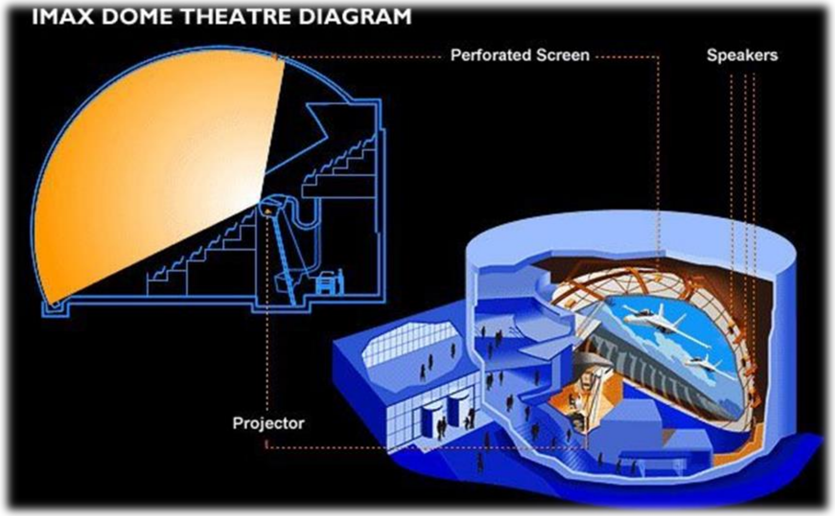
Field of View (FOV)

FOV = The total area in which VR images can be seen by a viewer **at a particular time instant**.



Field of Regard (FOR)

FOR = The total area in which VR images can be seen by a viewer **when allowed to move their head**.

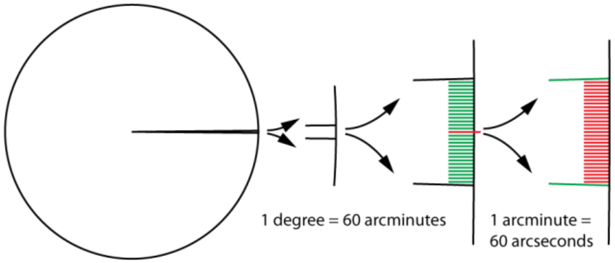


Example: IMAX Dome

The first permanent IMAX Dome installation, the Eugene Heikoff and Marilyn Jacobs Heikoff Dome Theatre at the **Reuben H. Fleet Science Center**, opened in San Diego's Balboa Park in 1973.

It was initially called “Omnimax” and wraps 180° horizontally, 100° above the horizon and 22° below the horizon for a viewer at the center of the dome for a total of 180° x 122° FOR.

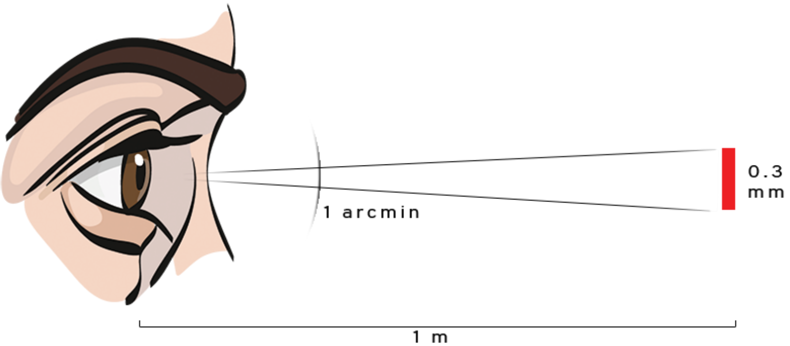
Spatial Resolution

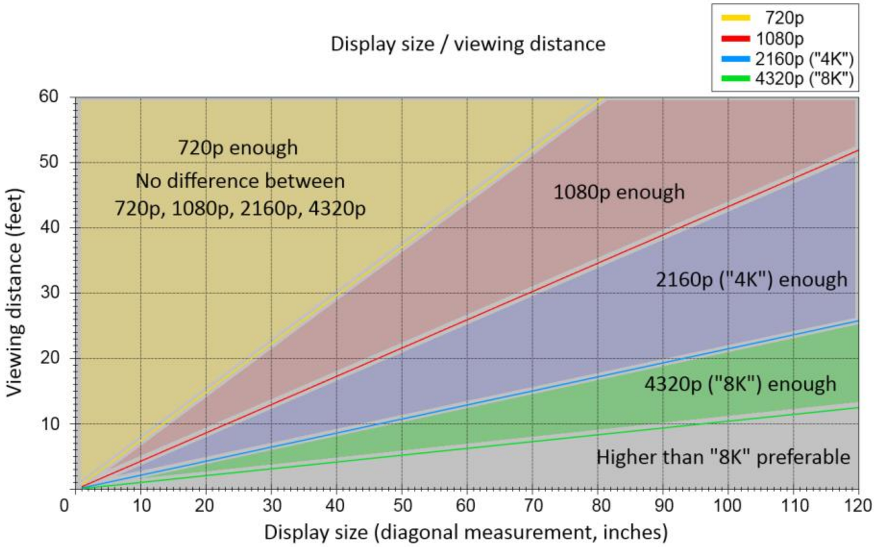


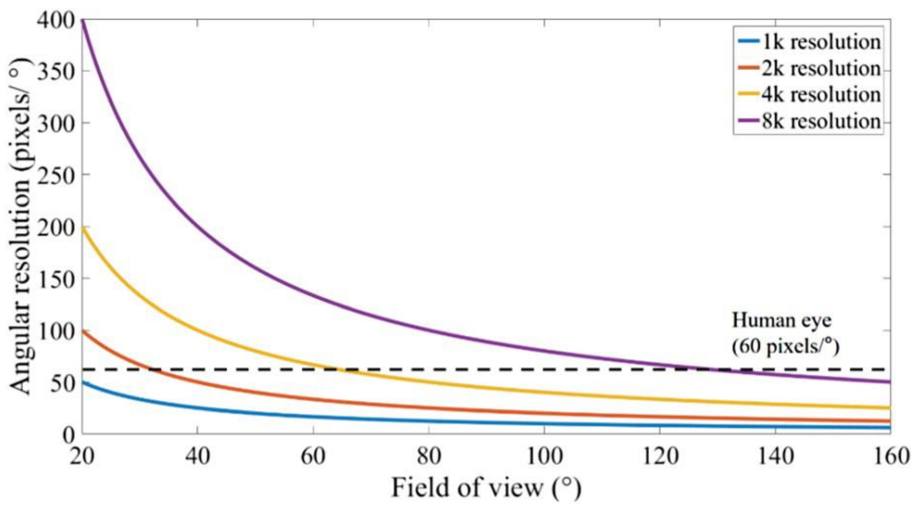
Ratio of pixels per screen area (=pixel density) or pixels per degree of the FOV (=angular resolution).

This is different than screen resolution, which is the absolute number of pixels a screen can display, for example 1920 x 1080 pixels.

Human eye: 150 pixels/degree in center of FOV, diminishes towards edge







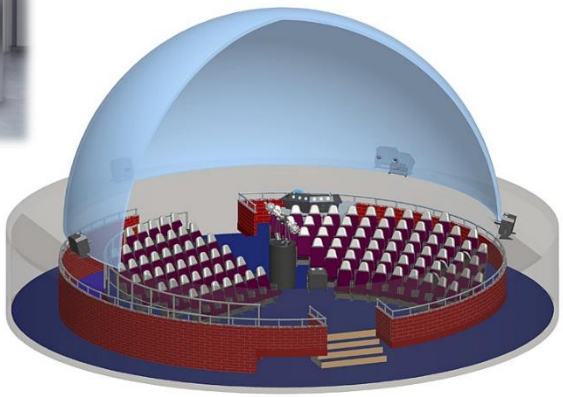
Screen Geometry

The geometric shape of the surface the image is displayed on.

Examples: rectangular, curved, hemispherical

Curved

Rectangular

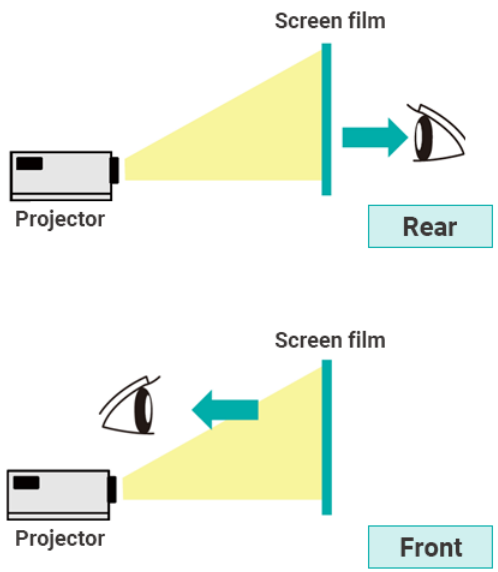


Hemispherical

Light Transfer Mechanism

How is the image generated?

Examples: LCD, front projection, rear projection, laser projection

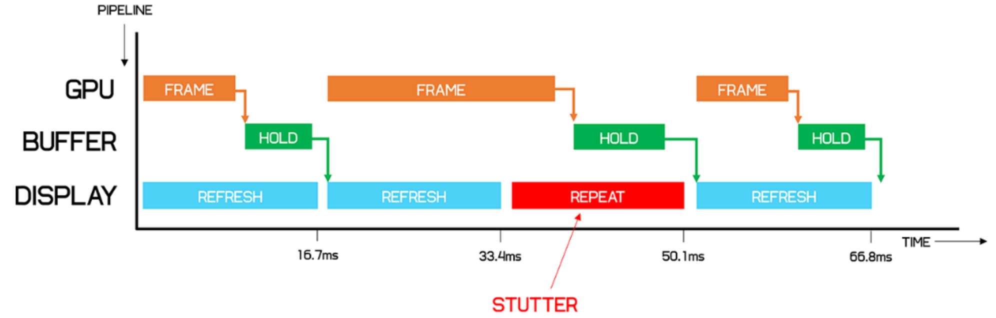


Rear vs. Front Projection

The planetarium at Griffith Observatory (Los Angeles) has one of the first digital laser projection systems

- Two laser projectors are used
- High resolution, brightness, color contrast, saturation
- Reduced image distortion on curved planetarium dome surface
  - with lasers, depth of focus is unlimited
- Low maintenance costs

Refresh Rate



Independent of frame rate

Higher refresh rate is better

Goal: frame rate = refresh rate (e.g., 90 Hz)

At minimum: frame rate = integer fraction of refresh rate (e.g., 45 Hz, 30 Hz)

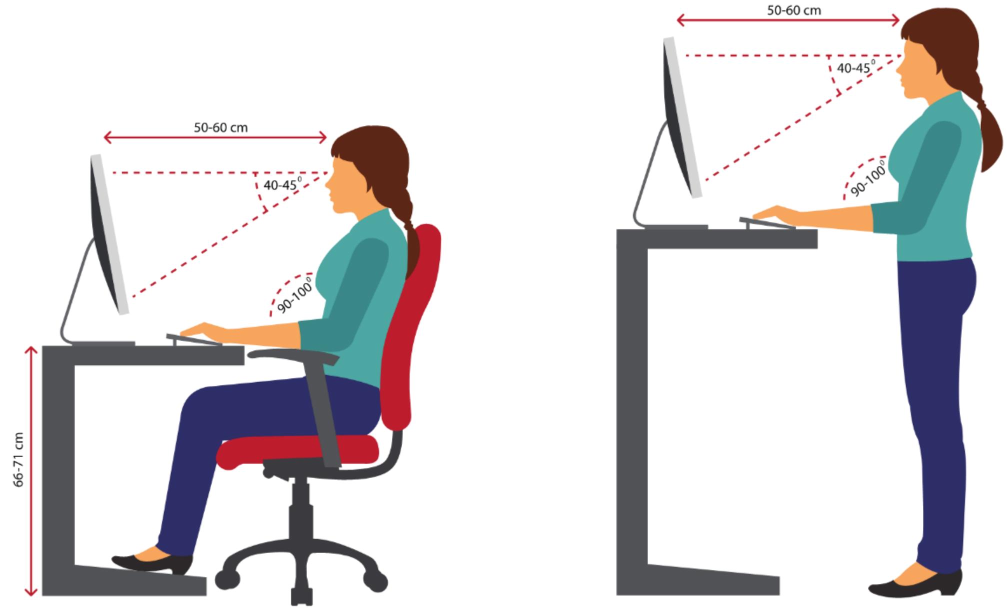
Otherwise: screen tearing

Screen tearing

Ergonomics

How is the system used?

- Seated
- Standing
- Hands on a surface
- Hands in the air



Display Types

3D Monitor

Available for active or passive stereo

“Fishtank VR”

3D Monitor – Advantages

Inexpensive

Crisp image at HD or 4k resolution

Keyboard and mouse work as usual

Can be used with most 3D input devices

3D Monitor – Disadvantages

Not very immersive

User seated, cannot move around

Does not take advantage of peripheral vision

Stereo can be problematic

- Active: user's 3D glasses need to face emitter
- Passive: blank pixel lines can be perceptible

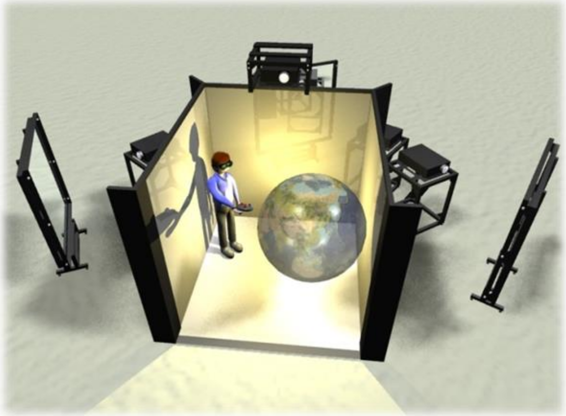
Occlusion from physical objects can be problematic

Surround Screen VE

Puts user in a room for visual immersion

Usually driven by a single or cluster of powerful graphics computers

Requires 3D tracking for head and controller



SunCAVE at UCSD

Built 2017

70 x 55” LCD 4k displays

Passive stereo

36 graphics PCs

71 Nvidia GTX 1080 GPUs

500 Mpixels

40 Gbps network

WAVE at UCSD

35 55” HD monitors with narrow bezels

18 rendering PCs

Passive stereo

70 Mpixels

Other CAVEs

Surround Screen Virtual Environments – Advantages

Provide high resolution and large FOV

Passive stereo: user only needs a pair of light weight glasses for stereo viewing

User has room to move around

Real and virtual objects can be mixed

A group of people can use the space simultaneously

Disadvantages

Expensive (typically >$100k)

Require a large amount of physical space

Projector calibration must be maintained

Normally only one user head tracked

Stereo viewing can be problematic (ghosting, focal plane far away)

Physical objects can get in the way of 3D image

CAVE Interface Design

Do not need to represent physical objects (i.e. hands) as graphical objects

Can take advantage of the user's peripheral vision

Do not want the user to get too close to the screens

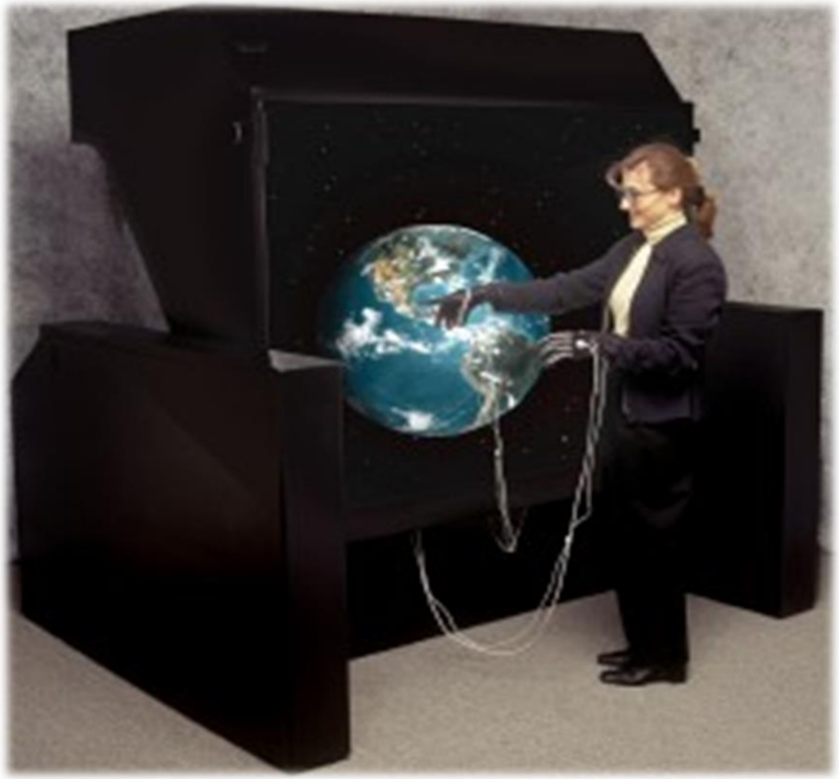
Developer can take advantage of the space for using physical props (i.e. car seat, treadmill)

VR Workbenches

Similar to CAVEs but only one or two displays

Can be a desk or a large single display (e.g., PowerWall)

Traditionally a table top metaphor



VR Workbenches

VR Workbenches

VR table display

Dual-screen VR workbench

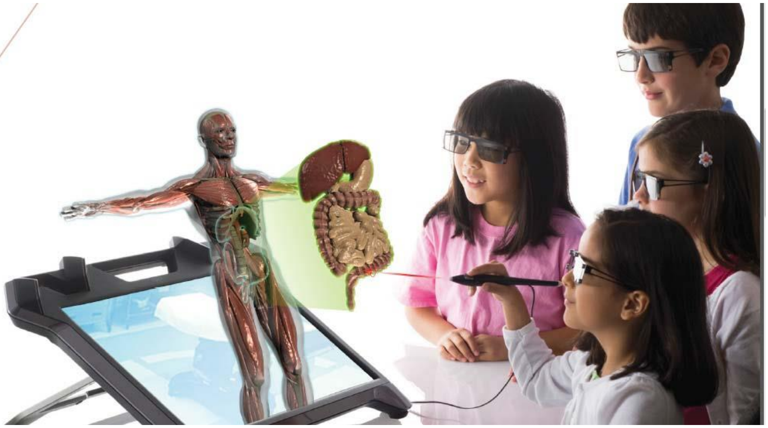
zSpace

3D display with built-in head and stylus tracking

Full screen passive circular polarization

Full HD for each eye

Polarization switching full screen LC layer



Workbenches – Advantages

High resolution

For certain applications, makes for an intuitive display

Can be shared by several users

Workbenches – Disadvantages

Limited movement

Typically only one user head-tracked

No surrounding screens

Physical objects can get in the way of graphical objects

Stereo can be problematic

Workbenches – Interface Design

Ergonomics are important especially when designing interfaces for table displays

User can take advantage of direct pen-based input if display surface permits

No need to create graphical representations of physical objects because users can see them

VR Display Issues: Projectors

Vignetting, caused by hotspot effect
- Brightness falloff
- Viewpoint dependent
- Hotspot at intersection of eye point and projector lens

Polarization falloff
- Viewpoint dependent
- Polarization deteriorates towards more oblique angles

VR Display Issues: Passive LCD

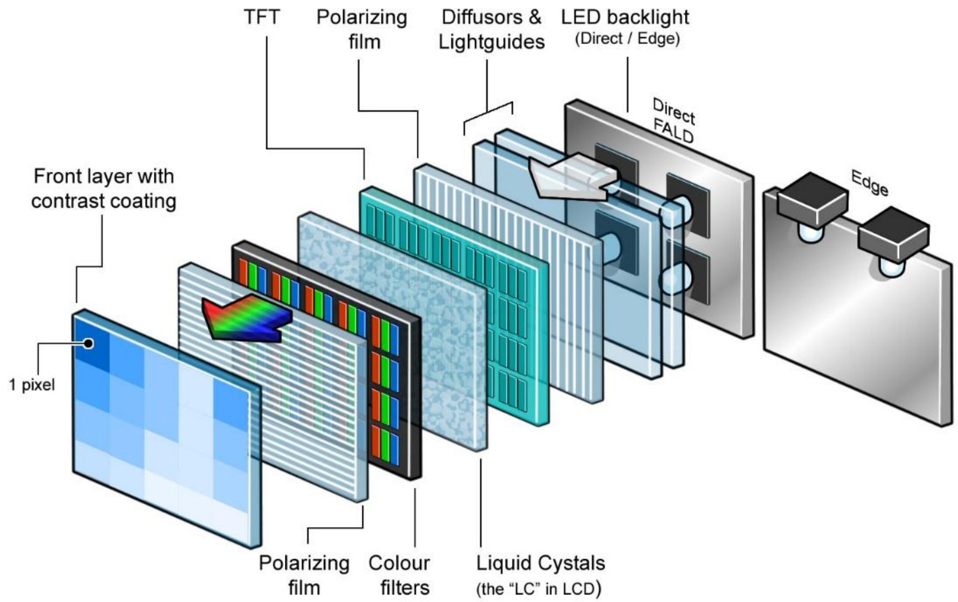
Frame synchronization (simultaneous buffer swaps)

Off-axis viewing along vertical axis causes ghosting

- Caused by distance between pixels and polarization layer (image below does not show polarization layer)

Brightness falloff

Discoloration



VR Display Issues: Passive OLED

Frame synchronization (simultaneous buffer swaps)

Off-axis viewing less bad than with LCDs

- Polarization layer closer to pixels

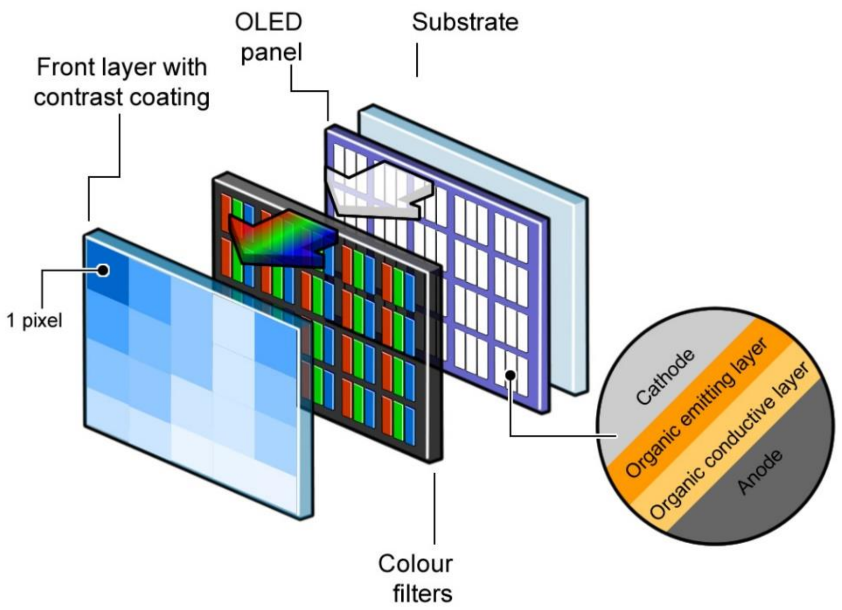
Brightness falloff

Image retention

Burn-in

Automatic Brightness Limiter (ABL)

- Limits overall screen brightness



VR Display Issues: Active Stereo

Synchronization between screens:

- Frame synchronization (simultaneous buffer swaps)
- Image generation ("electron beam"): needs to be in sync between screens and shutter glasses