CSE 190: Virtual Reality Technologies

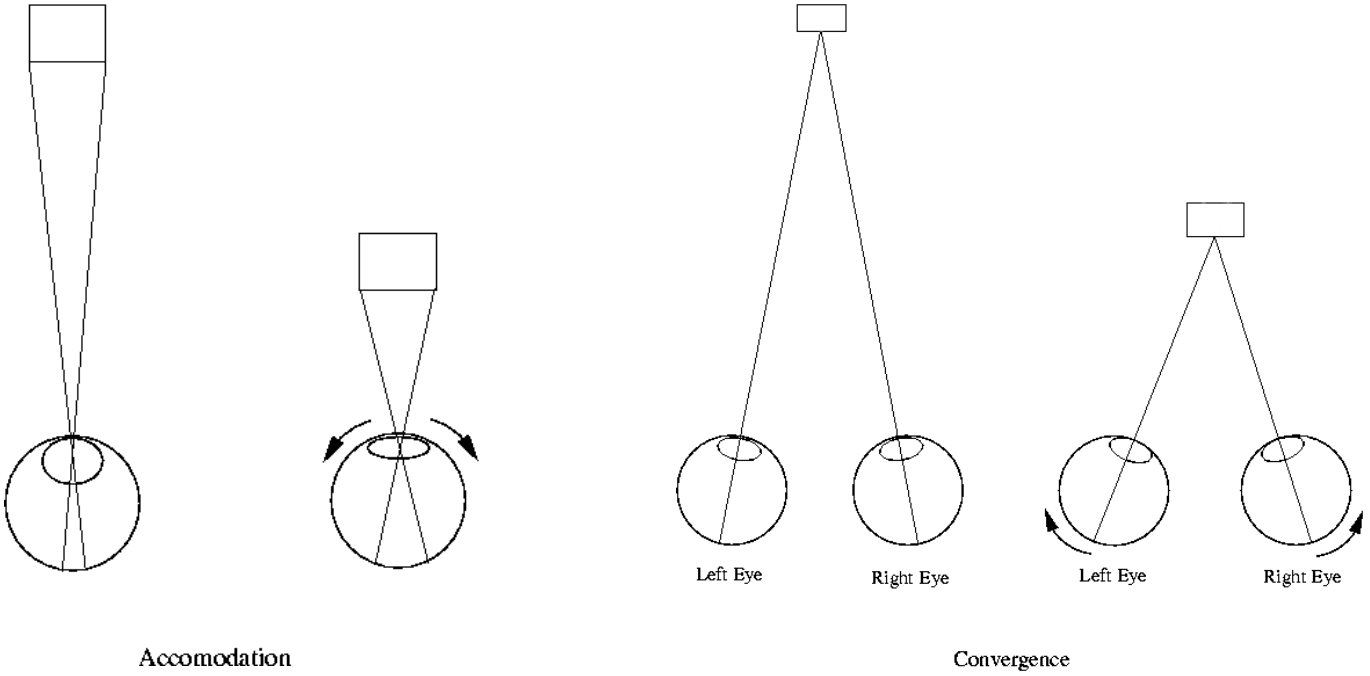
LECTURE #5: STEREO DISPLAY TECHNIQUES

Stereo Vision

Convergence

Rotation of viewer's eyes so images can be fused together at varying distances

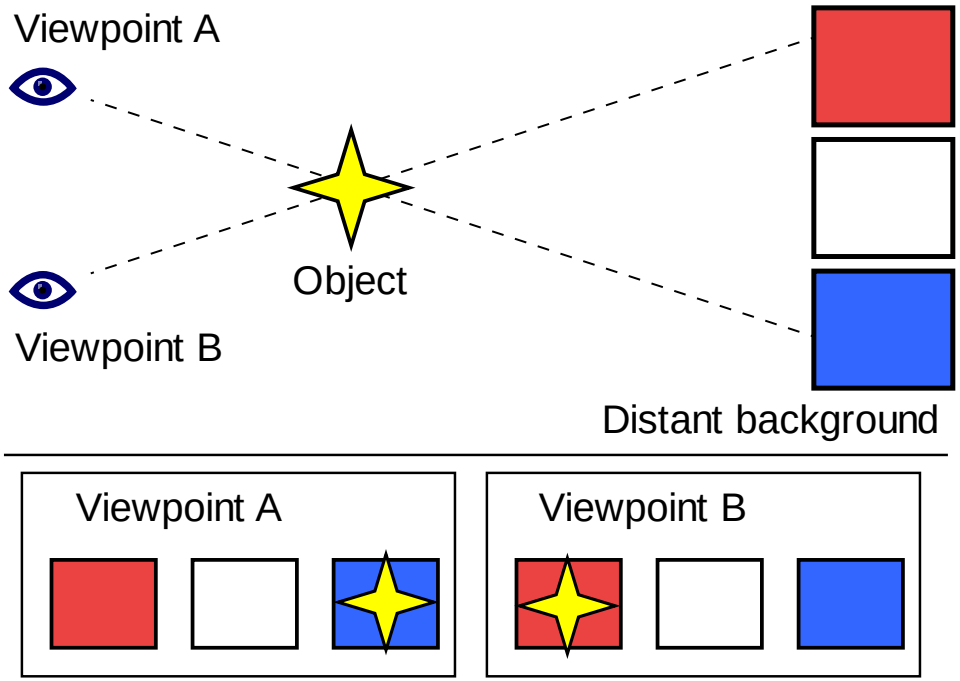
Do not confuse with accommodation!



Binocular Disparity and Stereopsis

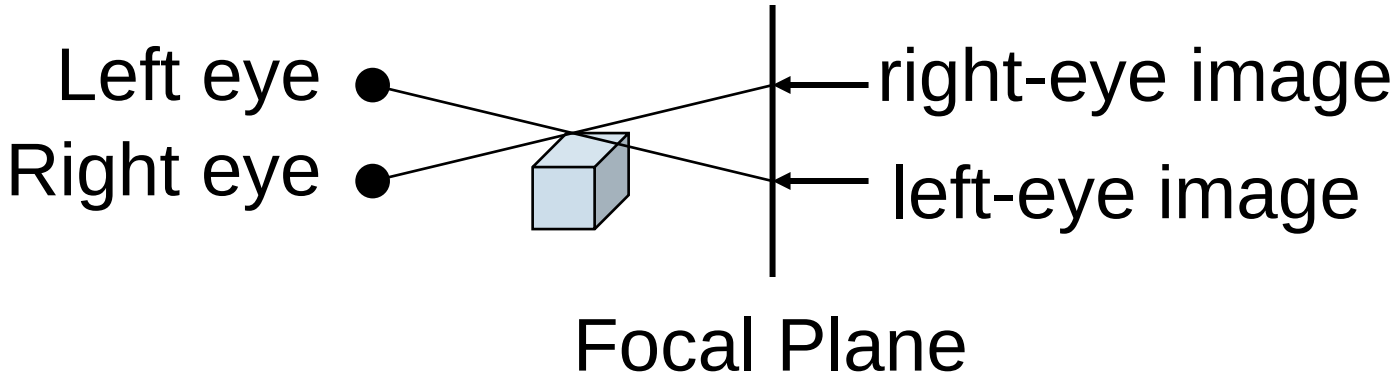
Each eye gets a slightly different image.

Only effective within a few feet from viewer.



Accommodation-Convergence Mismatch

The vast majority of current VR systems confuse the brain with contradicting oculomotor cues.
The accommodation-convergence mismatch comes from the fact that most VR displays have a fixed focal distance, but objects can be rendered to appear at any distance in the space due to their convergence cues.
Example: when you watch a 3D movie in the theater, your eyes' lenses constantly focus on the screen, the lens muscles' contraction doesn't change throughout the entire movie. However, as objects appear to be closer than the screen, your eyeballs converge at the object which appears at a different distance than what your lenses focus on.



Definitions

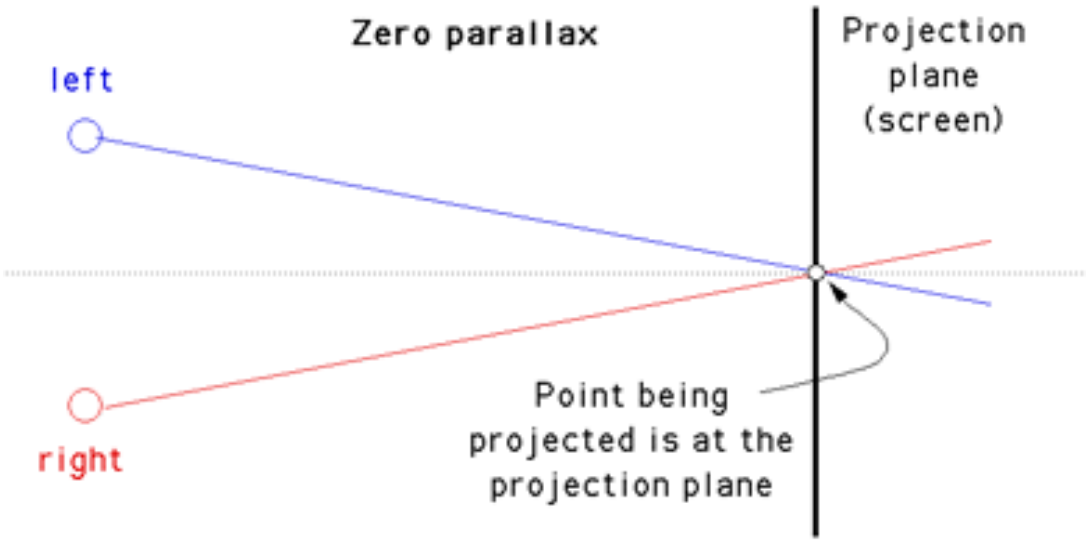
Focal distance: distance from the eye at which objects are "in focus“ - they look sharp rather than blurry.

Focal length: describes the zoom factor of a camera, the field of view (FOV) - it has nothing to do with accommodation or convergence.

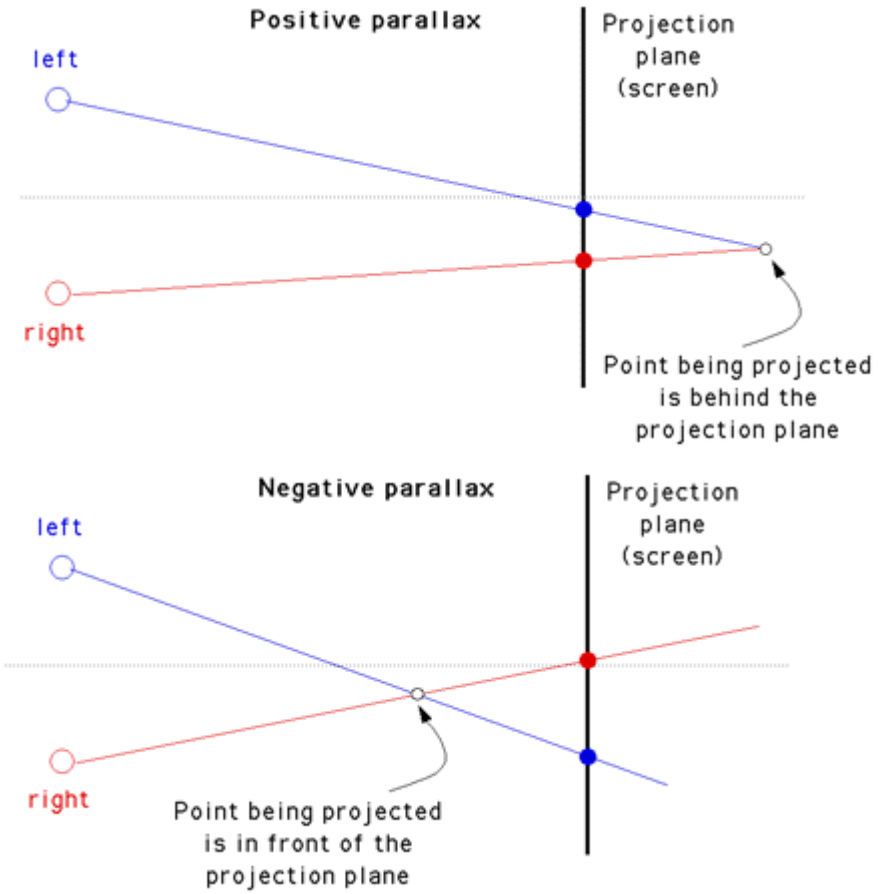
Convergence: the angle at which the eyeballs are pointed towards each other. For objects at infinity, this angle is near-zero. It grows the closer the object the person looks at is to their eyes.

Zero Parallax

Standard case for monoscopic displays



Stereo Parallax



Eye Separation

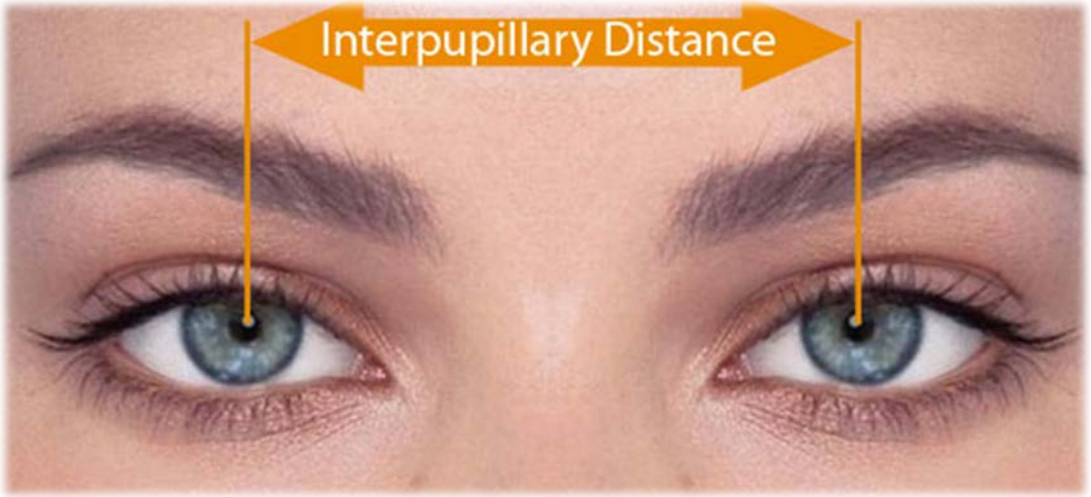
a.k.a. Eye Distance

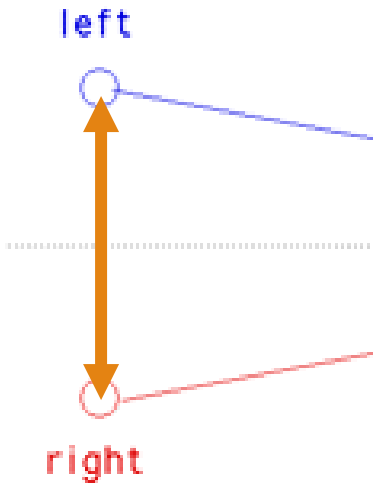
a.k.a. IOD = Interocular Distance

a.k.a. IPD = Interpupillary Distance

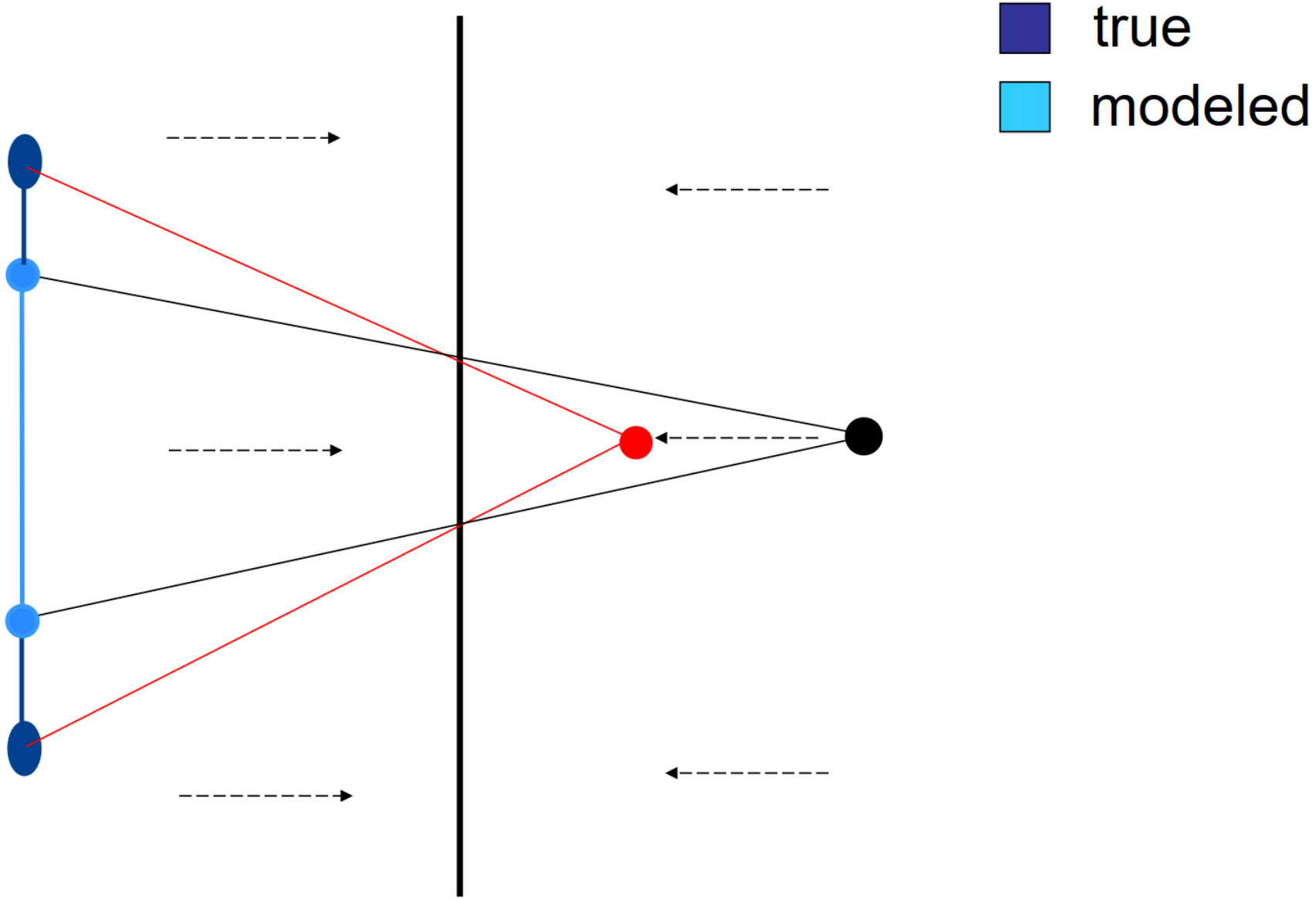
Averages:

- 62mm (2.44in) for women
- 64mm (2.52in) for men

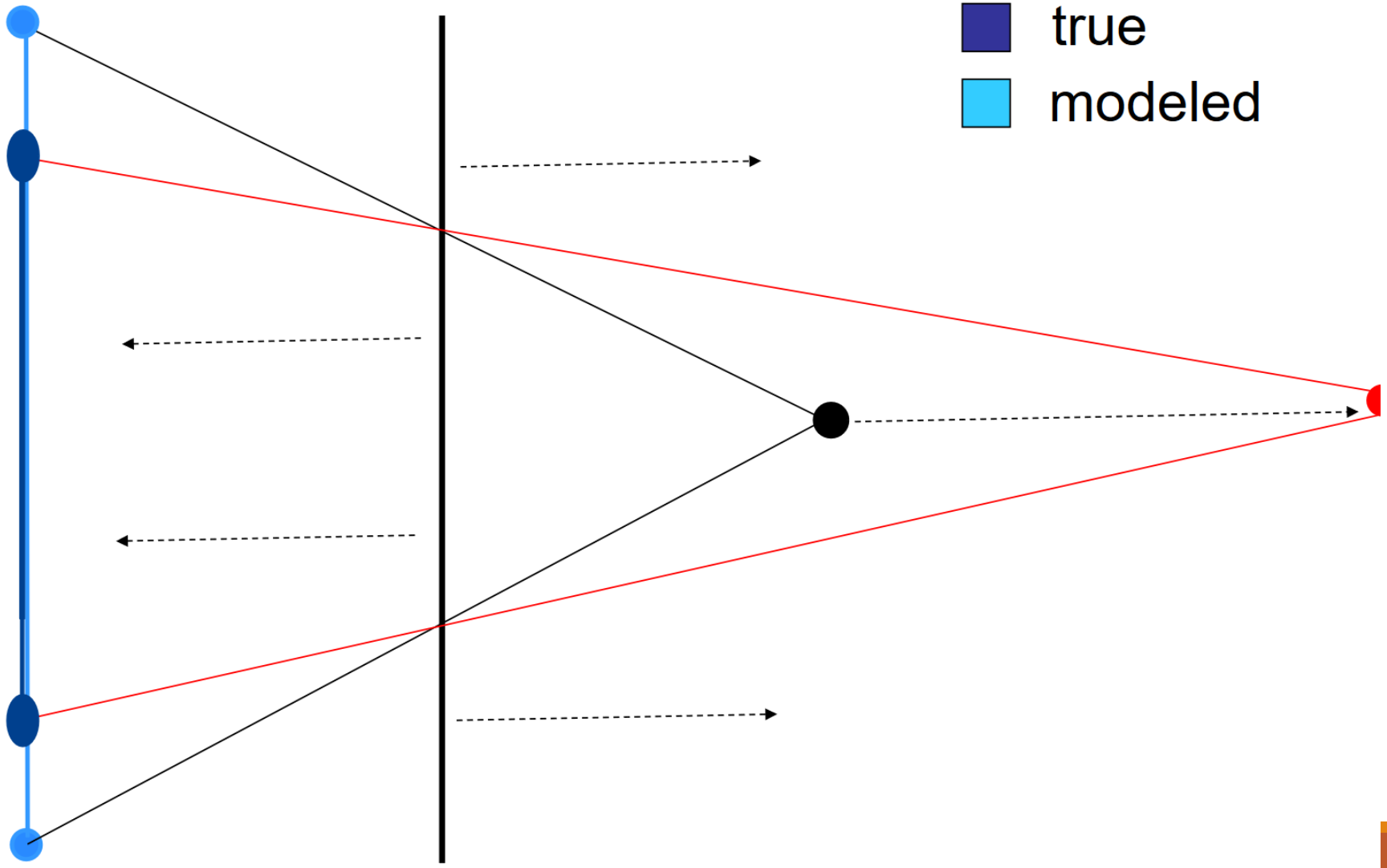




Viewer's IOD greater than average: compression



Viewer's IOD less than average: expansion

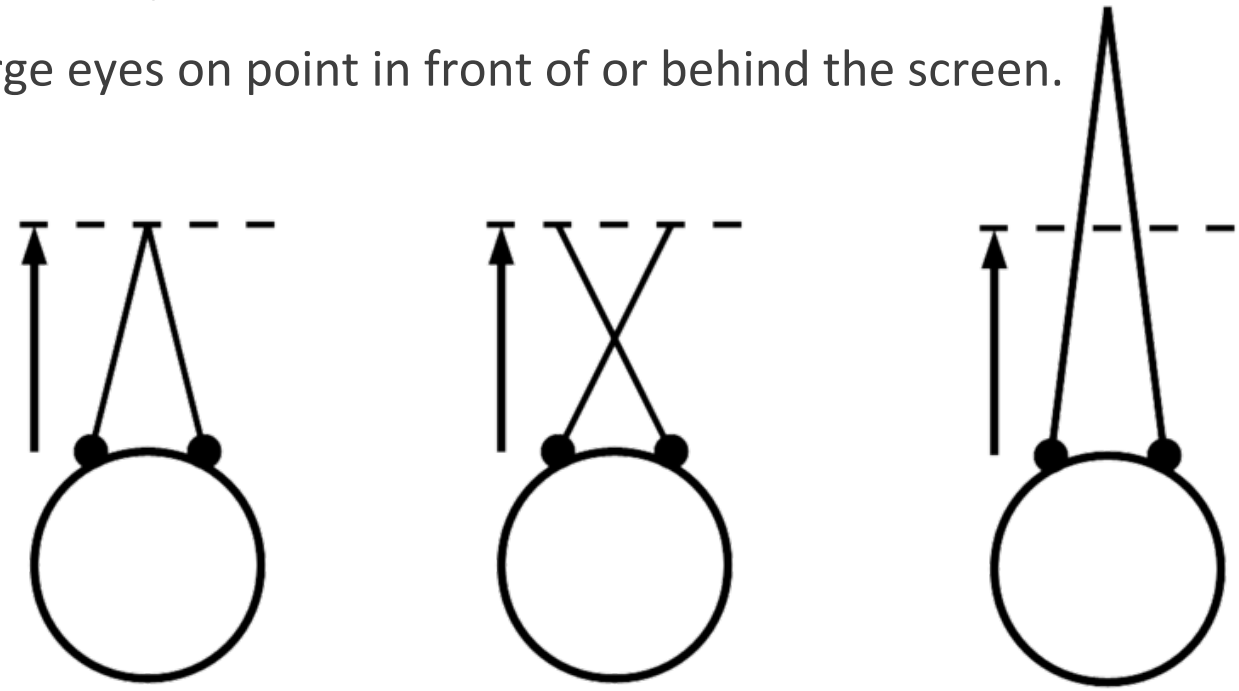


Stereo Imaging

Single Image Stereogram (SIS)

No glasses required

Converge eyes on point in front of or behind the screen.



Aligned vergence and accommodation (normal viewing)

Cross-eyed vergence.
Arrow: accommodation

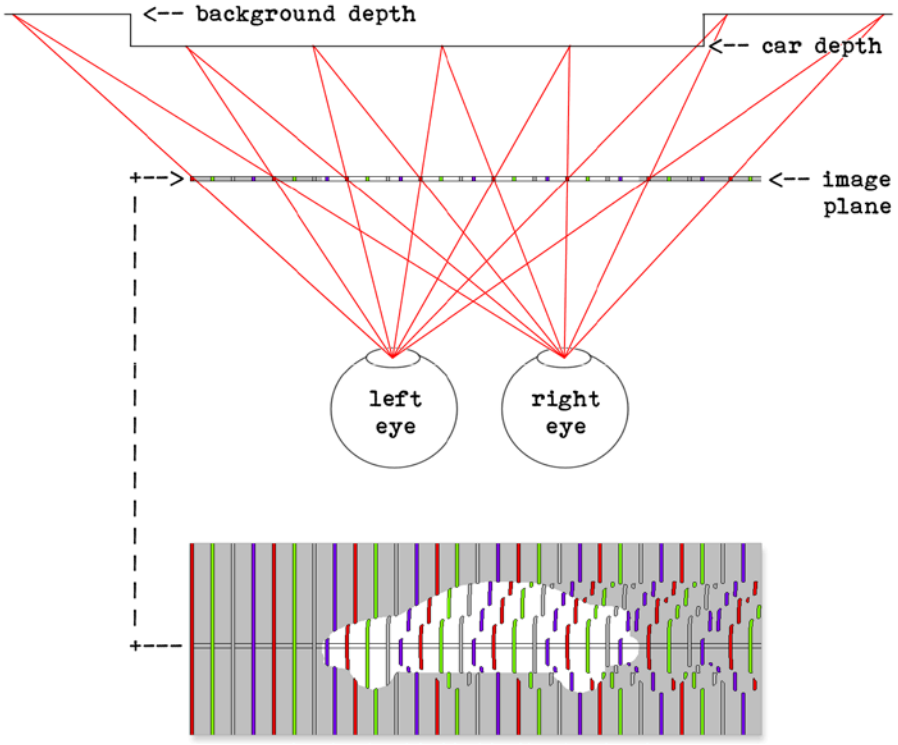
Wall-eyed convergence

SIRDS:
Single Image Random Dot Stereogram

A SIRDS encodes a 3D scene into an image in such a way that both eyes look at slightly distorted copies of the same (noisy) pattern.

The distortion of these copies is specifically crafted to encode the depth of each pixel in a rendered virtual 3D scene.

SIRDS use random dots instead of regular patterns to hide artefacts that could distract the viewer from the illusion.



Stereo Imaging: Concept

General concept: each eye sees a slightly different image

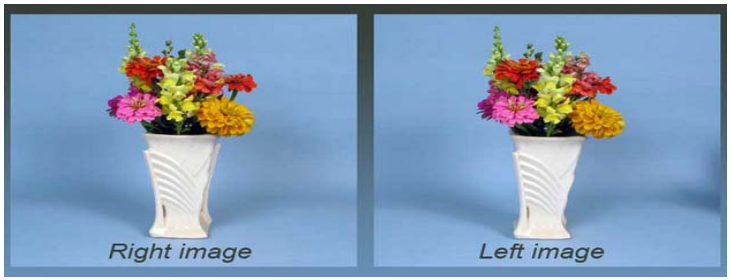
Example: Viewmaster

- Slide reels with 7 image pairs

Stereo Imaging: Side-by-Side

Stereo can be seen by fusing images: converge eyes in front or behind the actual image plane

Eyes converge behind image plane



Eyes converge in front of image plane

Autostereoscopic Displays

Light sent separately to each eye from a monitor

No headgear required

Can be head-tracked (dynamic) or non-tracked (static, head assumed in sweet spot)

Approaches:

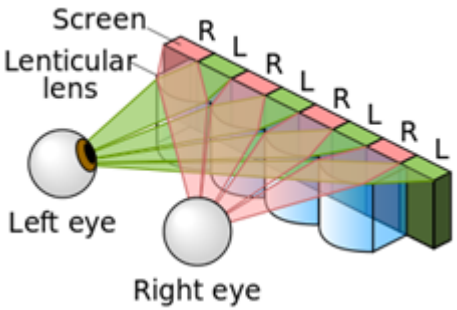
- lenticular screen
- barrier screen

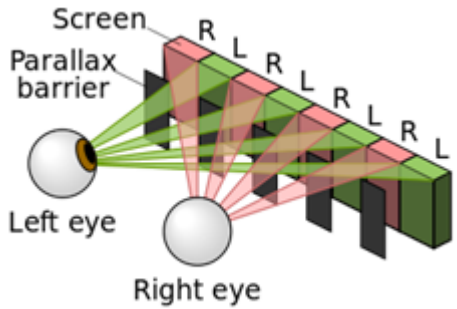
SeeReal display

Nintendo 3DS

Autostereo

Lenticular screen





Parallax barrier

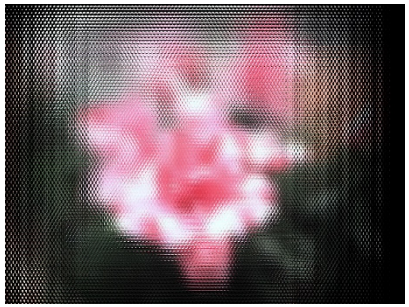
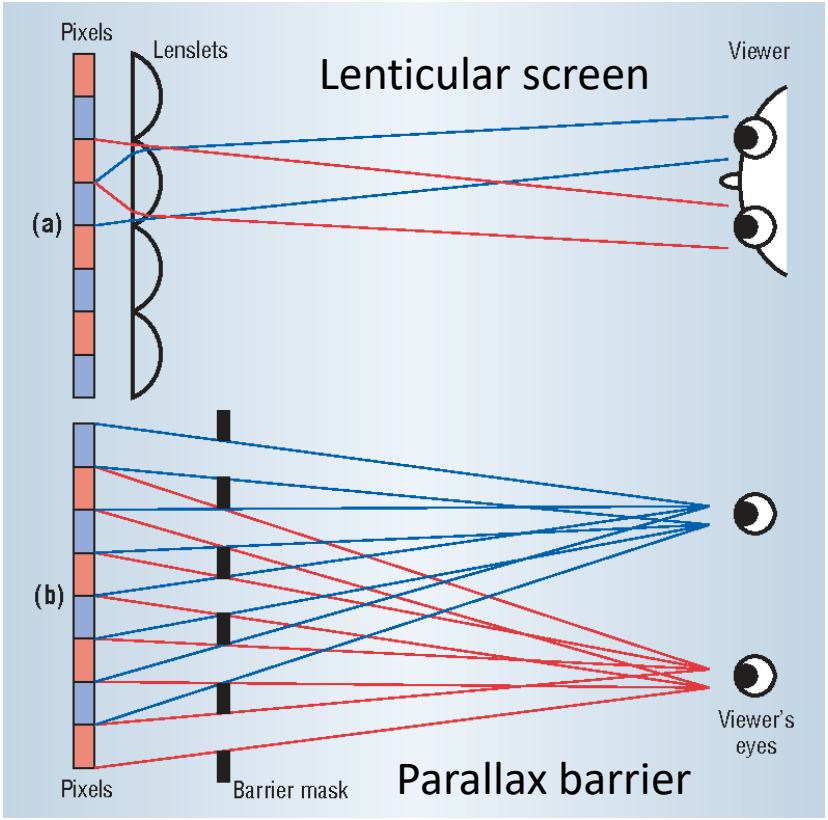


Image without autostereo filter



Stereo with 3D Glasses

Two options:

- Passive stereo: unpowered glasses with optical filters
- Active stereo: powered glasses with LCD shutters

Polarized sunglasses

Active LCD 3D Shutterglasses

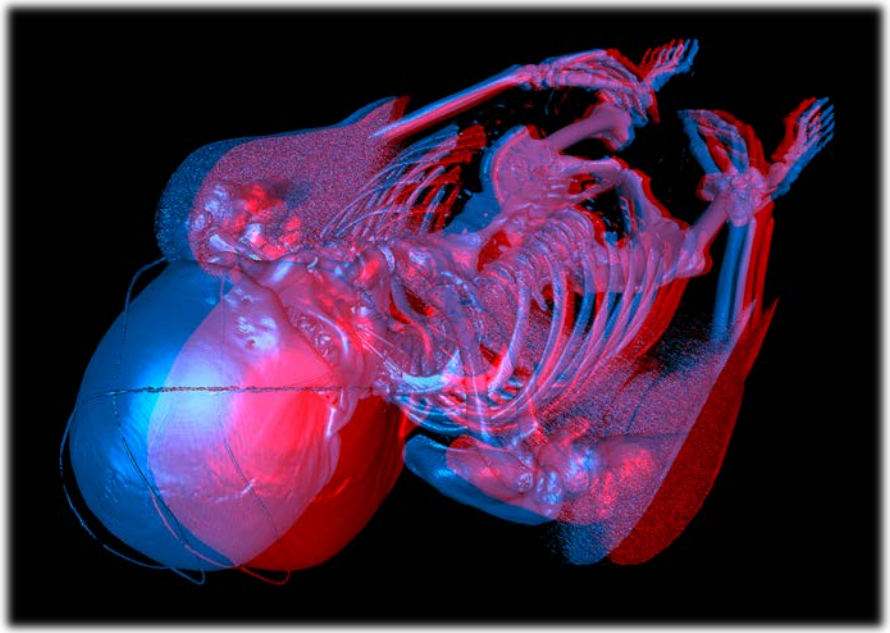
Passive Stereo in Anaglyph 3D

Requires anaglyph red/blue or red/green glasses

- Available in cardboard (~$0.50) or plastic (~$5)

Color is diminished (but not entirely lost)

Example below: view with which of the glasses on right?



Passive Stereo with Polarized Light

Two options:

- Linear polarization
- Circular polarization: creates circularly polarized light by adding a quarter-wave plate after a linear polarizer

Polarizing glasses are inexpensive (~$2-10)

Stereo projectors

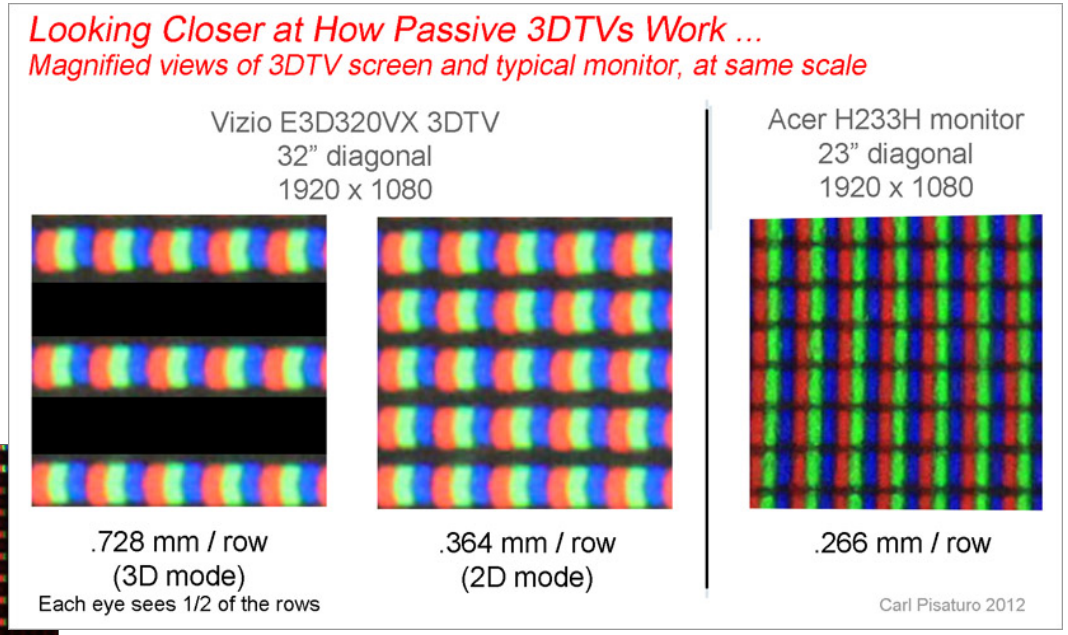
Polarizing glasses

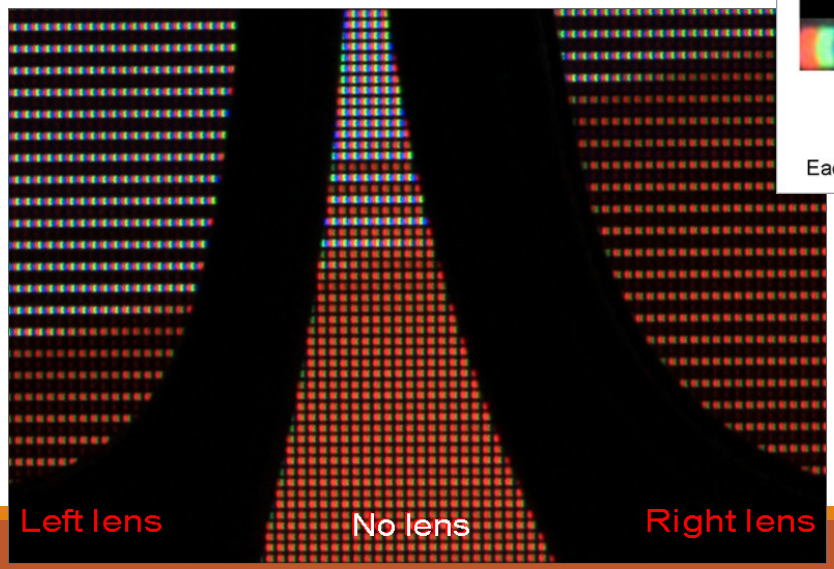
Passive Stereo Monitors

Filter on monitor polarizes alternating pixel rows clockwise/counter-clockwise

Best view point is on-axis

Off-axis viewers see ghosting



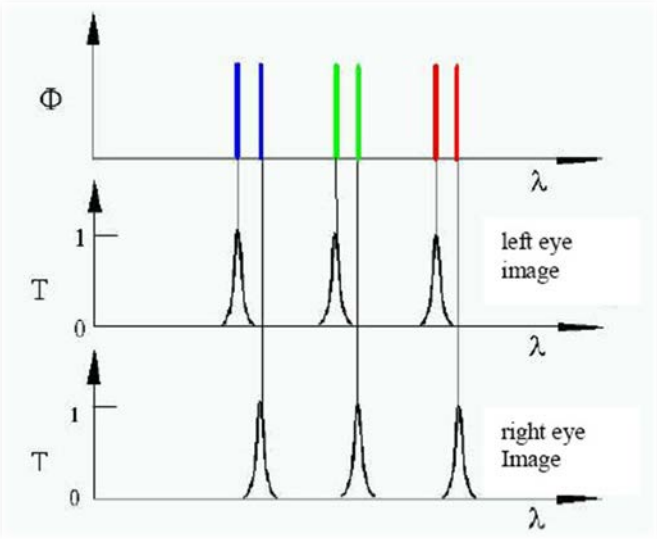


Interference Filters

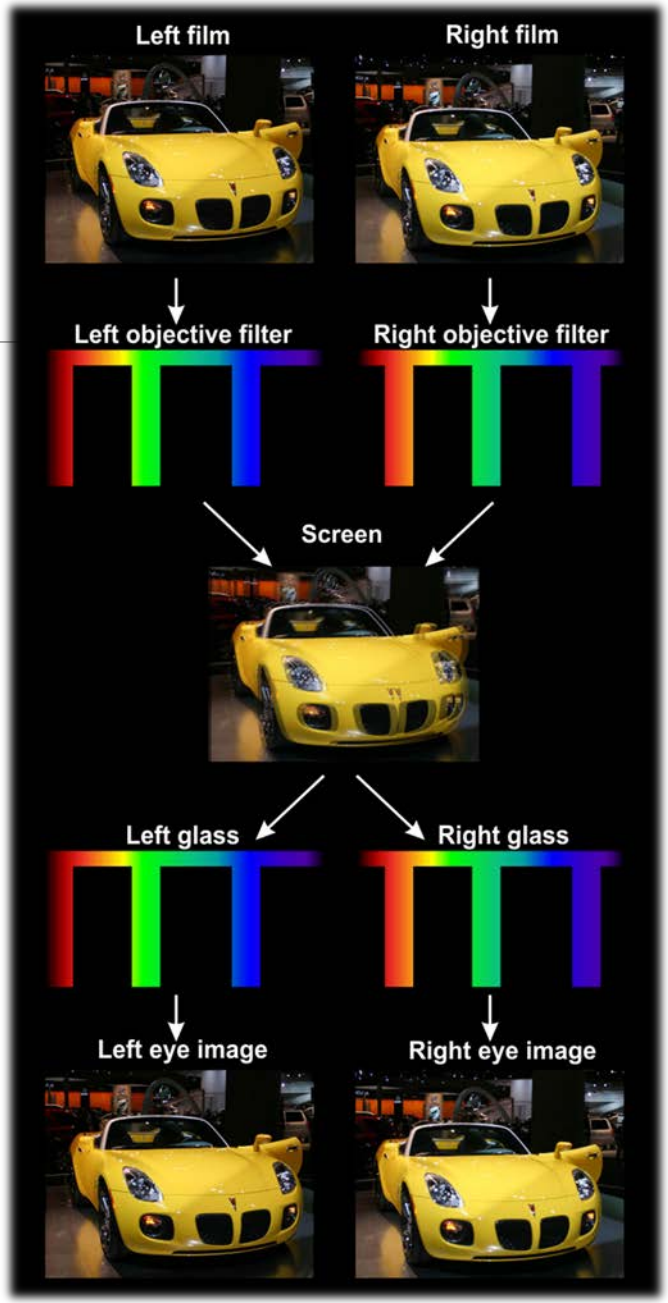
Uses specific wavelengths of red, green and blue for the right eye, and different wavelengths of red, green and blue for the left eye. Example: Dolby 3D

Dolby 3D glasses

Stereo projectors with filters



Stereo projectors with filters

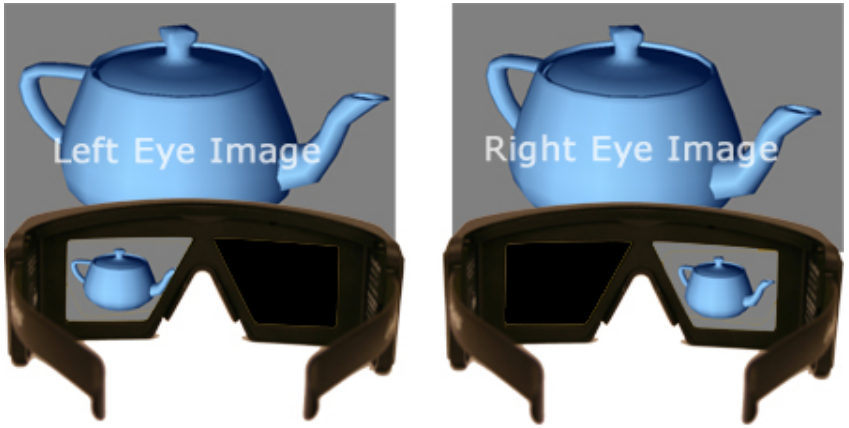


Active Stereo with Shutter Glasses

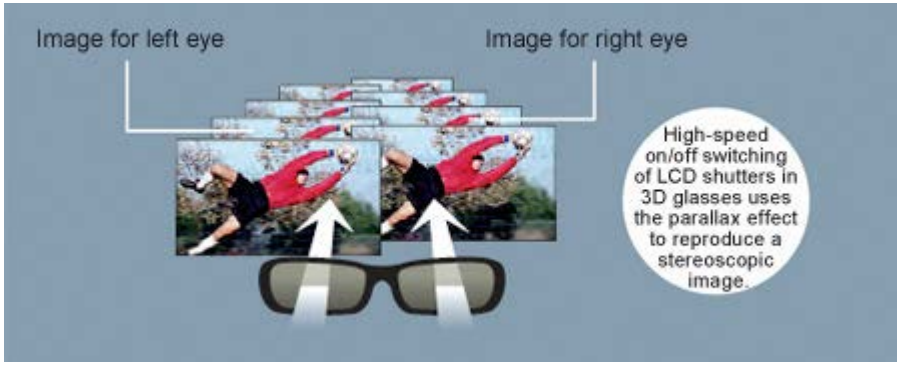
Display alternates between images for left and right eyes at 120+ Hz

Shutter glasses:

- synchronized to display refresh rate
- more expensive than passive glasses (~$30+)
- require batteries



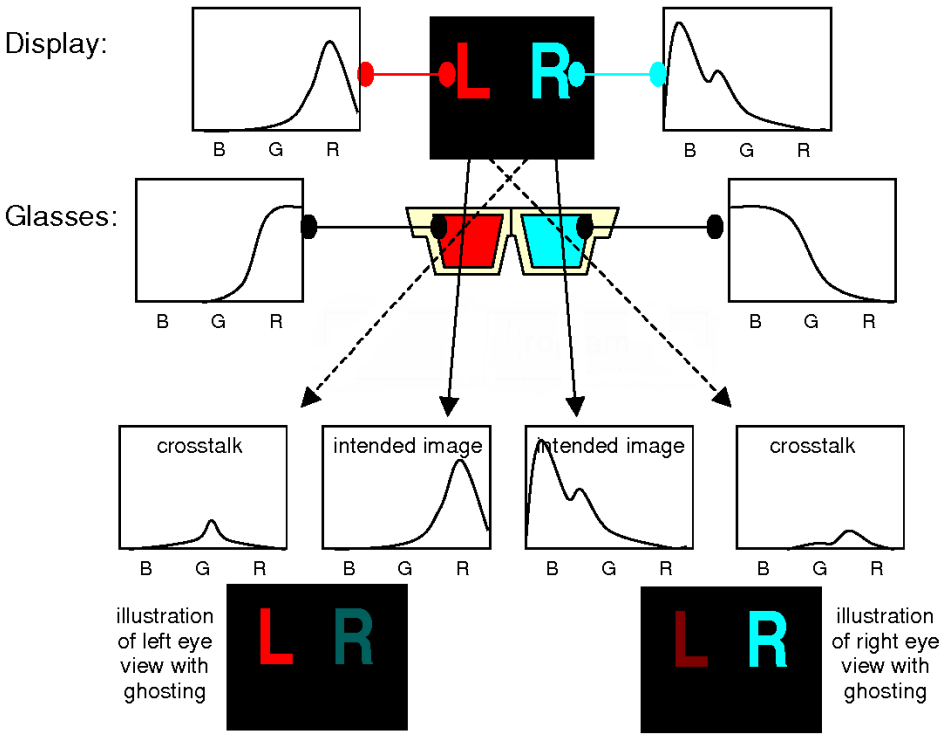
3D shutter glasses



3D Crosstalk – Ghosting

Ghosting is when a **secondary** "ghost" image can be seen along with the primary image.

On stereo displays, the ghost image is the image displayed for the other eye, visible because of **insufficient filtering** by the stereo glasses.



Example: ghosting with anaglyph 3D

Ghosting

Which 3D stereo techniques are prone to ghosting?

All filter-based techniques:

- Autostereo displays
- Anaglyph 3D
- Passive stereo
- Interference filters
- Active stereo

Separate Displays for Each Eye

Stereo created by showing physically separated displays to each eye.

Requires head-worn 3D display

No ghosting

Examples:

- Viewmaster
- VR headsets
- AR headsets

3D headsets with physically separated displays