

CSE 190: Virtual Reality Technologies

LECTURE #12: HIGH-END HEAD-MOUNTED DISPLAYS

Upcoming Deadlines

Sunday, May 9: Project 2 late deadline

Monday, May 10: Discussion Project 3

Sunday, May 16: Project 3 due

Monday, May 17: Discussion Project 4

Sunday, May 23: Project 3 late deadline

App Presentations

Anders Johnson

- Engage

Dillon Handal

- Tea For God

Oculus DK1 Kickstarter in 2012

Launch video:



Oculus Rift DK1

Funded through Kickstarter with \$2.4M

Released March 2013

Single LCD display with 1280 x 800 pixels

110 degrees FOV

60 Hz refresh rate

Head orientation tracking only (3 DOF)

- Fast, custom IMU

No tracked controllers available



Inertial Measurement Unit (IMU)

Measures

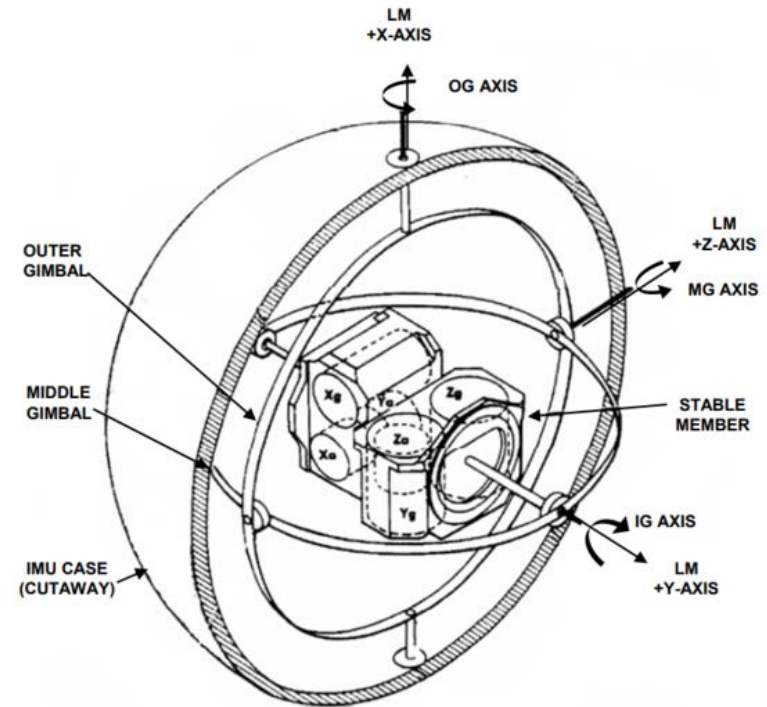
- gravitational force
- angular rate
- magnetic field (optional)

Consists of

- 3 accelerometers
- 3 gyroscopes
- magnetometer

IMUs also used in

- aircraft, spacecraft, satellites
- smart phones
- fitness trackers
- remote controls
- game controllers



Oculus Rift DK2

Released July 2014

Single OLED display (same as Samsung Galaxy Note 3)

1920 x 1080 pixels

Field of view: 95 x 105 degrees

75 Hz refresh rate

Same IMU as DK1

6 DOF tracking with IMU and camera for head location tracking

No tracked controllers available



Sony Playstation VR

Released October 13, 2016

Sold for Play Station 4

Single OLED display

960 x 1080 pixels per eye

100 degrees field of view

90 or 120 Hz refresh rate

Fixed IPD

Headphone jack

Innovative head strap

External camera for tracking

6 DOF tracking with visible light in different colors

Uses Sony Move controllers



HTC Vive

Released April 5, 2016

2 OLED displays

1200 x 1080 pixels per eye

110 x 113 degrees field of view

90 Hz refresh rate

Adjustable eye distance (IPD)

Integrated camera

Headphone jack

Includes two controllers

6 DOF tracking with 2 Lighthouses



Oculus Rift CV1

Released March 28, 2016

2 OLED displays

1200 x 1080 pixels per eye

94 x 93 degrees field of view

90 Hz refresh rate

Adjustable eye distance (IPD)

Integrated headphones

Infrared LEDs on HMD and controllers

6 DOF tracking with infrared cameras (“sensors”)



Initial Oculus Rift kit



Oculus Touch Controllers

Oculus Rift CV1 Teardown



Oculus Rift: Ear Phones



Face Foam



Infrared LEDs



Separate lens/display assemblies



CV1 Lens

Asymmetric

Hybrid Fresnel lens

Focus varies along vertical axis of lens

→ Push lens higher or lower to focus



Lenses: DK2 vs. CV1

Circular vs. Asymmetric



Microsoft Mixed Reality

First devices released October 17, 2017

Virtual Reality HMDs

- No augmented reality, despite the name

Specifications by Microsoft

Dual 6 DOF controllers with infrared LEDs

Inside-out 6 DOF HMD tracking with two cameras

HMDs built by:

- Samsung, Dell, HP, Lenovo, Acer, Asus



HTC Vive Pro

Released April 5, 2018

Built-in stereo cameras for AR

1440 x 1600 pixels per eye

90Hz refresh rate

110 degrees FOV

Integrated headphones

New design with sizing dial

2 cameras

Tracking space up to 10 x 10 meters with new Lighthouses 2.0 (released April 23, 2018)



Oculus Rift S

Release date: May 21, 2019

LCD display

1280 x 1440 pixels per eye

80 Hz refresh rate

Internal speakers + headphone jack



Valve Index

Release date: July 1, 2019

1440 x 1600 pixels per eye

LCD display

120 Hz refresh rate (144 Hz experimental mode)

Integrated speakers

Lighthouse base stations 2.0

New Index (“Knuckle”) controllers: sense finger positions, allow open hands



Vive Cosmos

Released October 2019

Inside-out tracking with 6 cameras

Price: \$700

1440 x 1700 pixels per eye

90Hz refresh rate

110 degrees FOV

Built-in stereo headphones

Adjustable IPD

Includes controllers



HP Reverb G2

Released November 2020

Windows Mixed Reality headset

2160 x 2160 pixels per eye

114 degrees field of view

90 Hz refresh rate

6 DOF inside out tracking

Same controllers as other Mixed Reality systems



Oculus Quest 2

Release date: Oct 13, 2020

Standalone VR HMD

- Inside-out 6 DOF tracking

LCD display

1832 x 1920 pixels per eye

90 Hz refresh rate

90 degrees FOV

Adjustable IPD (3 settings)

Qualcomm Snapdragon XR2

Built-in headphones

Includes 2 controllers



Issues with VR HMDs

High-End (PC-Based) VR:

- Most drivers for Windows only, Mac and Linux lacking support
- User can get tangled up in cables (except for wireless HMDs)
- Cumbersome camera calibration (even with inside-out systems)

Low-End (Smart Phone-Based) VR:

- Most apps only have orientation tracking
 - Position tracking possible with Apple's ARKit and Google's ARCore, but rarely used for VR
- Hand-held controllers not standardized and usually not supported

Both:

- More powerful GPUs needed for more visual realism
- Most VR HMDs don't allow view of environment
- Wearing an HMD is socially awkward (looks weird, can't see other people)
- AR is coming, but technology lagging behind VR

DEVICE	FOV	REFRESH RATE	TRACKING TECHNOLOGY	PLATFORM SUPPORT	PRICE (USD)	WIRELESS CAPABLE	DISPLAY DETAILS	RESOLUTION PER EYE
Google Cardboard	~90	(as low as) 60Hz (as high as) 144Hz	X	G	HEADSET \$15 FULL KIT X	✓	VARIES	(as low as) 540x480 (as high as) 2160x2160
Switch LABO	~90	60Hz	X	Nintendo	CONSOLE \$299 LABO KIT \$39	✓	LCD RGB	640x480
Playstation VR	100	120Hz (REPROJECTION)	T	PS	HEADSET X FULL KIT \$349	X	OLED RGB	960x1080
Oculus Rift S	90	80Hz		O	HEADSET X FULL KIT \$399	X	LCD RGB	1280x1440
Asus HC102	95	90Hz			HEADSET X FULL KIT \$400	X	OLED PENTILE	1440x1440
Lenovo Explorer	110	90Hz			HEADSET \$349 FULL KIT \$450	X	LCD	1440x1440
Dell Visor	110	90Hz			HEADSET \$350 FULL KIT \$450	X	LED RGB	1440x1440
Oculus Quest 2	89	120Hz (EXPERIMENTAL)		O	64GB \$299 256GB \$399	✓	LCD RGB	1832x1920
Oculus Quest	94	72Hz		O	64GB \$399 128GB \$499	✓	OLED PENTILE	1600x1440
Odyssey+	110	90Hz			HEADSET X FULL KIT \$499	X	AMOLED PENTILE	1440x1600
HP Reverb G1	114	90Hz			HEADSET X FULL KIT \$599	X	LCD RGB	2160x2160
HP Reverb G2	115	90Hz			HEADSET X FULL KIT \$599	X	LCD RGB INDEX LENSES	2160x2160

DEVICE	FOV	REFRESH RATE	TRACKING TECHNOLOGY	PLATFORM SUPPORT	PRICE (USD)	WIRELESS CAPABLE	DISPLAY DETAILS	RESOLUTION PER EYE
Vive Cosmos	110	90Hz			HEADSET X FULL KIT \$699	✓	LCD RGB	1440x1700
HTC Vive Focus	110	75Hz			HEADSET X FULL KIT \$799	✓	AMOLED PENTILE	1440x1600
Cosmos Elite	110	90Hz			HEADSET \$549 FULL KIT \$899	✓	LCD RGB	1440x1700
PiMAX 8K	170	80Hz			HEADSET \$499 FULL KIT \$999	X	LCD RGB	3840x2160
Valve Index	130	144Hz			HEADSET \$499 FULL KIT \$999	X	LCD RGB	1440x1600
HTC Vive Pro	110	90Hz			HEADSET \$799 FULL KIT \$1199	✓	AMOLED PENTILE	1440x1600
PiMAX 8K	170	80Hz			HEADSET \$1299 FULL KIT X	X	LCD RGB	3840x2160
PiMAX 5K PLUS	170	144Hz			HEADSET \$899 FULL KIT \$1399	X	OLED PENTILE	2560x1440
StarVR ONE	210	90Hz			HEADSET \$3200 FULL KIT X	X	AMOLED RGB TOBII EYE	1830x1464
HTC Vive	110	90Hz			HEADSET DISCONTINUED FULL KIT DISCONTINUED	✓	AMOLED PENTILE	1080x1200
Oculus CV1	94	90Hz		O	HEADSET DISCONTINUED FULL KIT DISCONTINUED	✓	OLED PENTILE	1080x1200
Virtual Boy	~30	50Hz	X	Nintendo	HEADSET DISCONTINUED FULL KIT DISCONTINUED	X	LED	384x224 (1x224 scanned)

Discalimers:

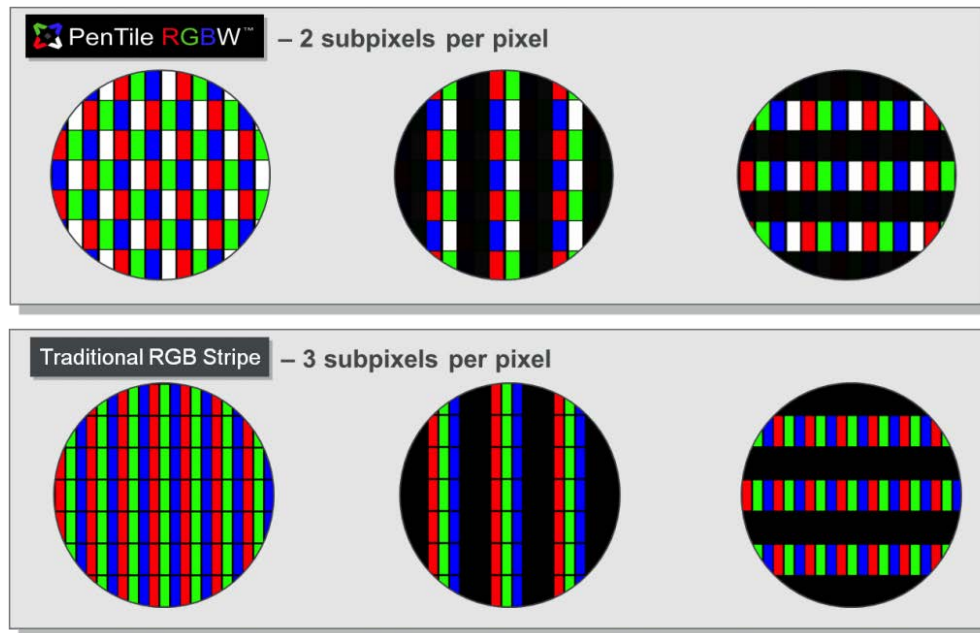
Field of view depends highly on the screen size and eye relief (eye to lens distance).

All FOVs listed are the horizontal specifications.

All specifications listed are from the "Comparison of virtual reality headsets" Wiki Article

PenTile Displays

A display technology from Samsung that uses clusters of **five** (penta) **subpixels**. Originally developed by Clairvoyante, PenTile uses fewer subpixels, and subsequently less power, for the total number of pixels on screen than the conventional RGB subpixel method. [Wikipedia]



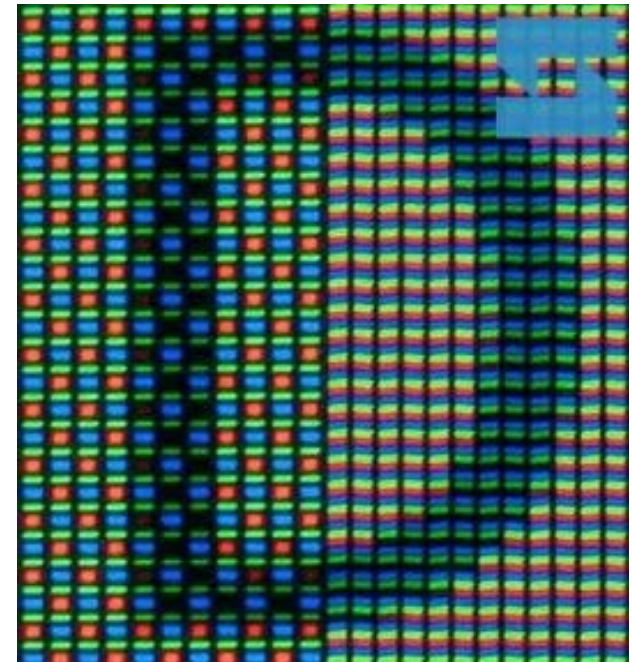
AMOLED Displays

AMOLED = Active-Matrix Organic Light-Emitting Diode

AMOLED screens don't need a backlight, as each pixel is able to produce **its own light** when it needs to. This makes **blacks look amazing** when viewing a picture or video, because the pixels do not have to provide light at all, rather than LCD displays where the backlight bleeds through and you get a dark grey color where there should be black.

AMOLED drawbacks:

- more expensive to produce
- not as sharp as LCD displays when looking up close
 - AMOLED uses a different subpixel arrangement than LCD displays, which makes individual pixels more noticeable (see picture)



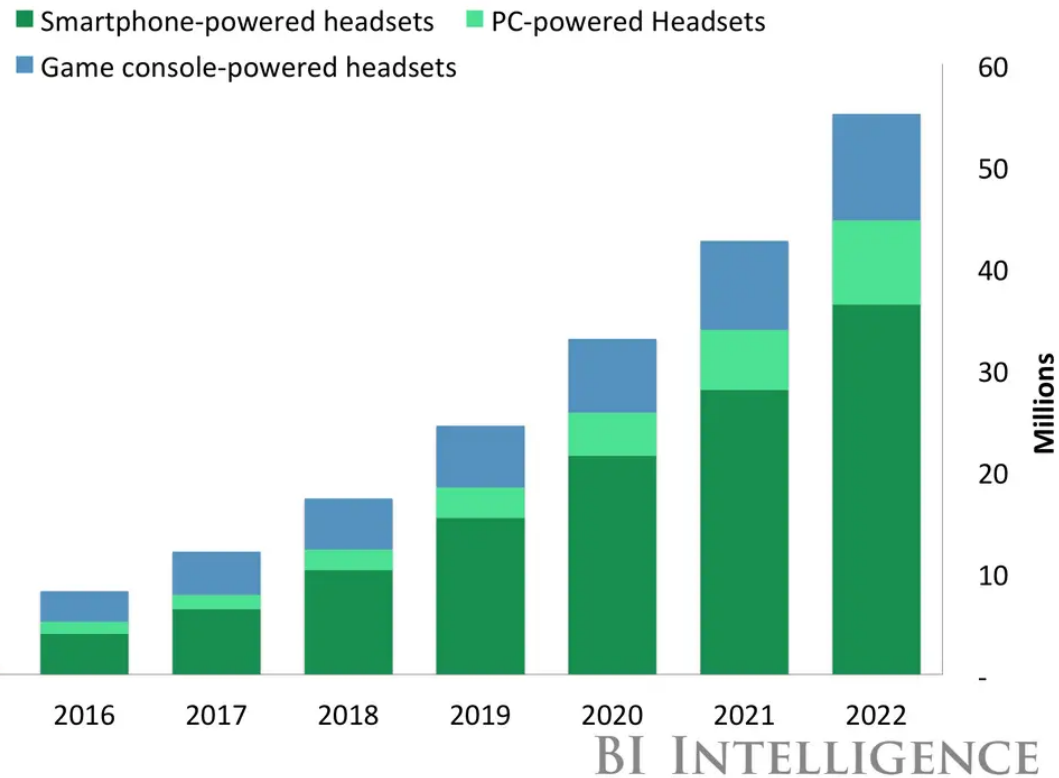
AMOLED

LCD

HMD Sales Forecast

FORECAST: Global VR Headset Shipments

By Category



Source: BI Intelligence Estimates