Intro. to Electro-physics

Virtual reality and micro-OLED displays

Jaesang Lee
Dept. of Electrical and Computer Engineering
Seoul National University
(email: jsanglee@snu.ac.kr)

Virtual reality

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What is virtual reality (VR)?

- VR provides the ultimate level of immersion in virtual worlds
- VR creates a sense of physical presence in virtual worlds

How VR works

- VR induces targeted experience by using artificial sensory stimulation
- Users should have little or no awareness of difference

- Targeted experience
  - An experience designed by creator
    e.g.) flying, walking, watching a movie, socializing

- Artificial sensory stimulation
  - One or more senses artificially stimulated by particular gears
  - Ordinary and natural inputs replaced by artificial stimulation

- No awareness
  - A sense of presence in an alternative world
    = Being “fooled” into feeling present in a virtual world

Image courtesy: G2 Learning Hub

Birdly® VR

Image courtesy: Zurich Univ. of Art (Youtube)

2022-1
전자물리의 기초

What can we do with VR?

“We will be able to be anywhere and do anything, with anyone.”

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Game

Image courtesy: Playstation

Travel, Explore

Image courtesy: Atlantis The Palm

Sports, Concert, Movie

Image courtesy: VRFocus

Museum, Shopping

Image courtesy: Intel/VALIS

Education

Image courtesy: InformationAge

Socializing

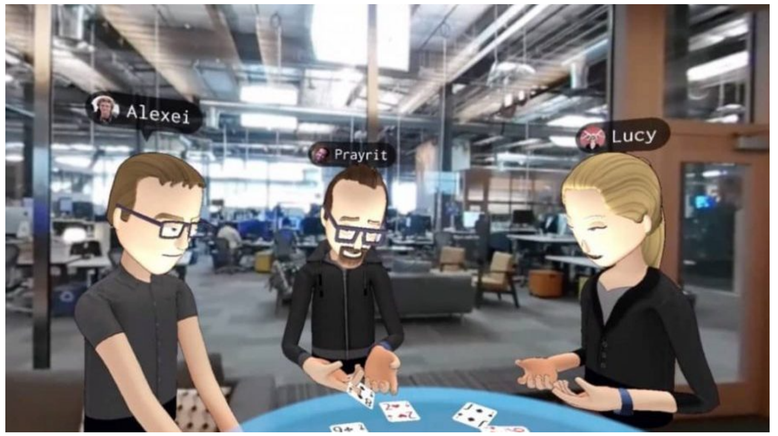

Image courtesy: HolosphereVR

What is required to realize VR glass?

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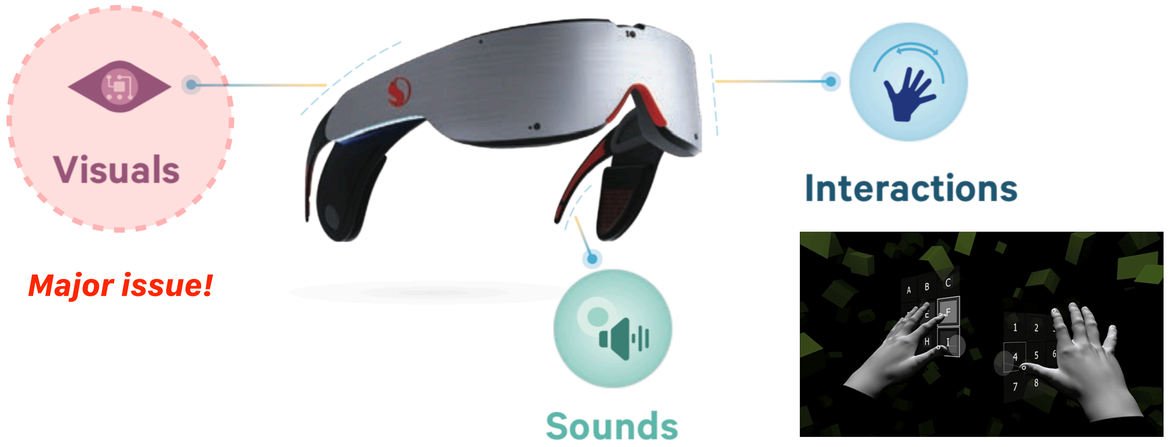
Requirement for full immersion

Vibrant and accurate stimuli with realistic feedback



Major issue!

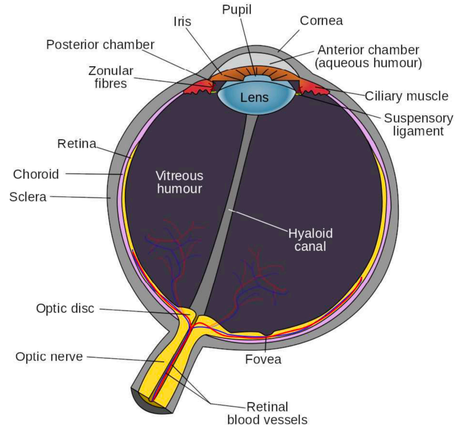
Engineering

software &
hardware design

Perception engineering

Human physiology
→ How sense organ &
perceptual systems work

Perception engineering



Understanding how our body works

(Especially, our eyes)

Design and deliver

"natural" perceptual illusions to users

Primary specs for VR glasses

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Specs	Item	Specificiation
Ergonomically friendly	Easy to wear	• Small volume & weight (< 500 g)
	Wireless	• Battery-run / wifi enabled
High-quality visual experience	High brightness	• 150 (cd/m^2) in headset • 20,000 (cd/m^2) from pixel
	High dynamic range	• >100,000 : 1
	High resolution	• >2,500 (ppi)
	Fast response time	• >200 (Hz)
	Large Field of View (FoV)	• 150º ✕ 135º (per eye)
	Large color gamut	• sRGB (X), DCI-P3 (○), BT.2020(◎)
	No visual artifacts	• Panel-oriented - Burn-in - Electrical crosstalk - Optical crosstalk (in white OLED + CF) • Lens-oriented - Chromatic aberration

Risk level

- Low
- Moderate
- Dangerous
- Show-stopper

Recent VR glasses

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Product	Sony PlayStation VR (Oct 13, 2016)	HTC Vive Focus 3 (May 11, 2021)	Oculus Quest 2 (Oct 13, 2020)	…	Goovis
Display & size	OLED (5.7″)	LCD (2.88″)	LCD (-)		OLEDoS (0.7″)
Size / resolution*	1,080 × 960 (189 ppi)	2,448 × 2,448 (800 ppi)	1,832 × 1,920 (-)		1,920 × 1,080 (3,147 ppi)
Refresh rate	120 (Hz)	90 (Hz)	90 (Hz)		60 (Hz)
Field of View (FoV)	100º	120º	-		53º

** per single eye*

Screen door effect (SDE)

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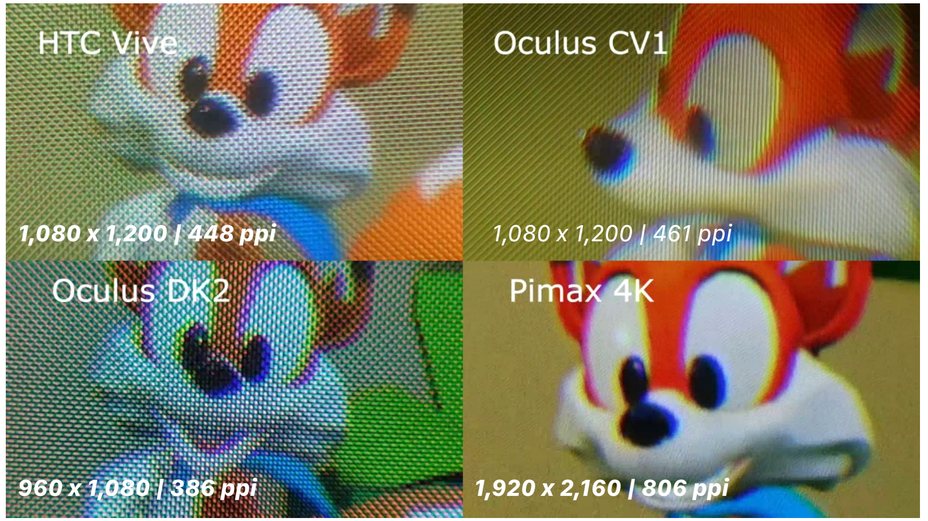
Anti-insect "screen door"

thd_fon/Shutterstock.com

SDE comparison in various VR headsets



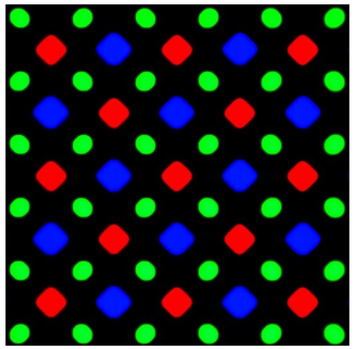
Screen Door Effect (SDE) comparsion with ZOOM 8x [youtube.com]

Screen-door effect (SDE)

- Black grid seen on the screen
- Look as if you view the scene through a grid mesh (e.g., "screen door")

Why?

- Physical gap between sub-pixels (∵ pixel fill-factor ~ 30%)
- Viewing distance for VR much shorter (~1") than other display applications (>10")



Img source: DisplayMate

pentile RGB configuration
(iPhone X, 458 ppi)

Visual acuity

Visual acuity

- A measure of sharpness or clarity of vision
- How well eyes recognize tiny features or discern letters at a given distance

Snellen eye chart

- A common method for measuring visual acuity
  - The chart viewed at 20 (ft) away ~ 6 (m)
  - 20 / **20** = 1.0 → Normal vision (reference)
  - 20 / **>20** = <1.0 → Worse
  - 20 / **<20** = >1.0 → Better

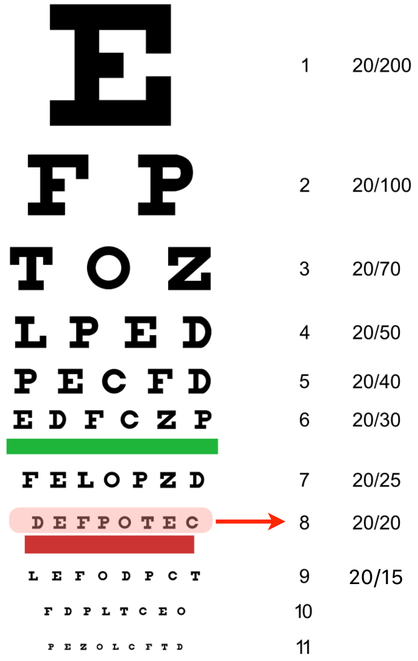
  (일반 시력을 가진 사람이 해당 글자를 읽을 수 있는 최대 거리)

20/20 Normal vision

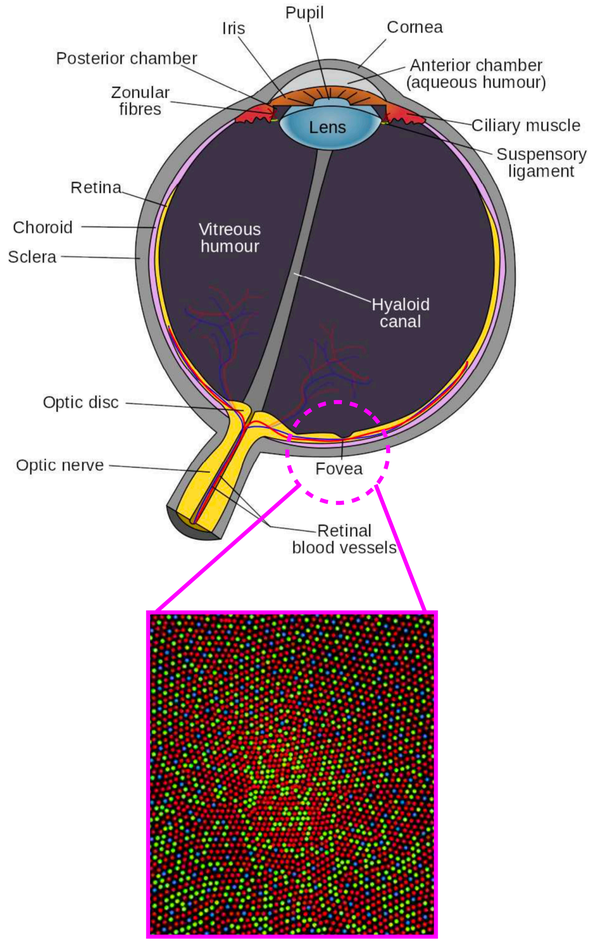
- Each photoreceptor in a fovea covers 1 (arcmin) (= 1/60°)

  e.g.) alphabet E in 20/20 line covers 5 (arcmin)

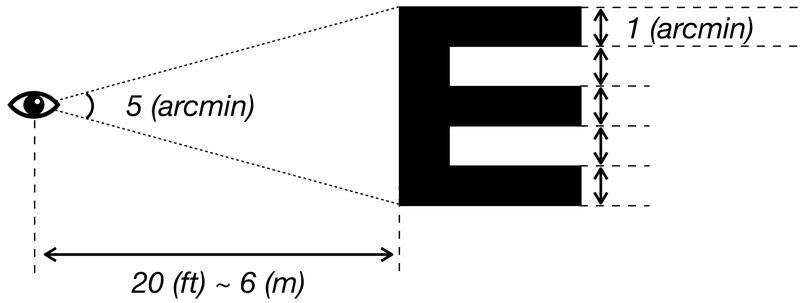
  A pair of black and white lines (1 cycle) should look discernible!



Snellen eye chart



Photoreceptor cells distributed in a mosaic pattern



20/20 Normal vision and display resolution

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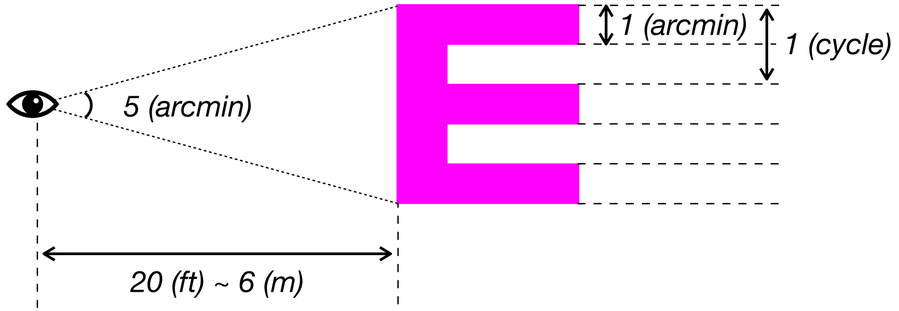
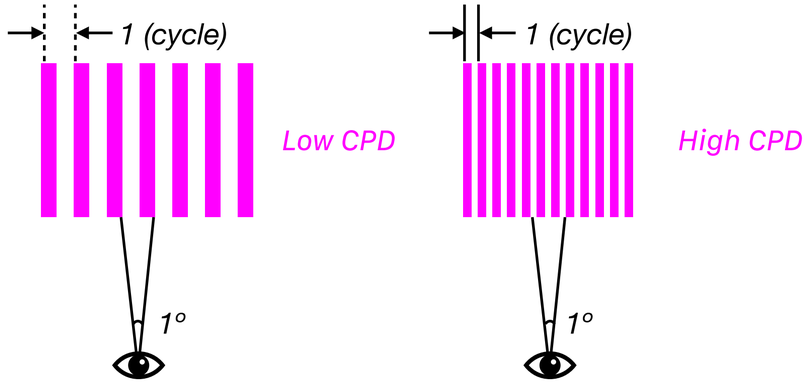
20/20 Normal vision (cont'd.)

- A letter extends over 5 (arcmin)
- A pair of black and white lines (1 cycle) should look discernible!

  → 2.5 (cycle) per 5 (arcmin)

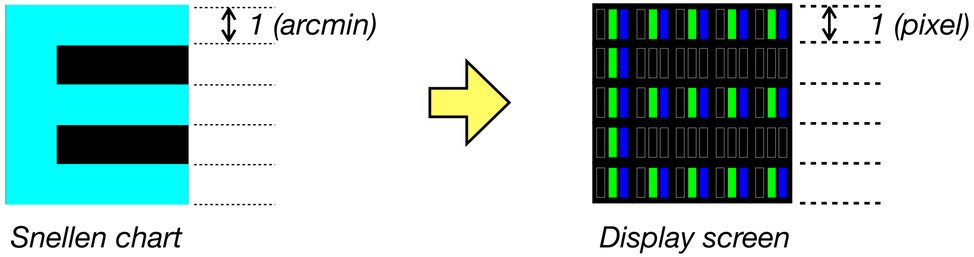
  → 1 (cycle) per 2 (arcmin)





$$\frac{1\ \text{cycle}}{2\ \text{arcmin}} = \frac{1\ \text{cycle}}{\frac{2}{60}\ \text{deg}} = 30\ (\text{cpd})$$

How display pixels should look



Resolution requirement for normal vision

$$\therefore \frac{1\ \text{pixel}}{1\ \text{arcmin}} = \frac{1\ \text{pixel}}{\frac{1}{60}\ \text{deg}} = 60\ (\text{ppd})$$

*Figure not drawn to scale

Display resolution vs. application

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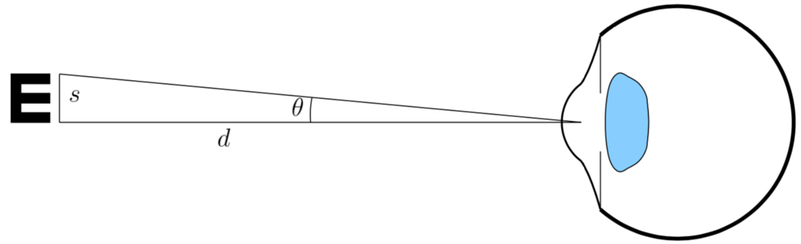
Required pixel resolution for applications

- Determined by viewing distance (*d*)!
- Feature size (*s*) within a given viewing angle (θ) at a distance (*d*)

$$s = d\tan\theta$$



Examples

- Commonly, pixels within 1º for normal vision $\geq 60\ (pixels)$
- TV – *d* = 1.8 (m) = 71 (inch)
  - Feature size within 1º – $s = d\tan\theta = 71\tan 1^\circ = 1.23\ (inch)$

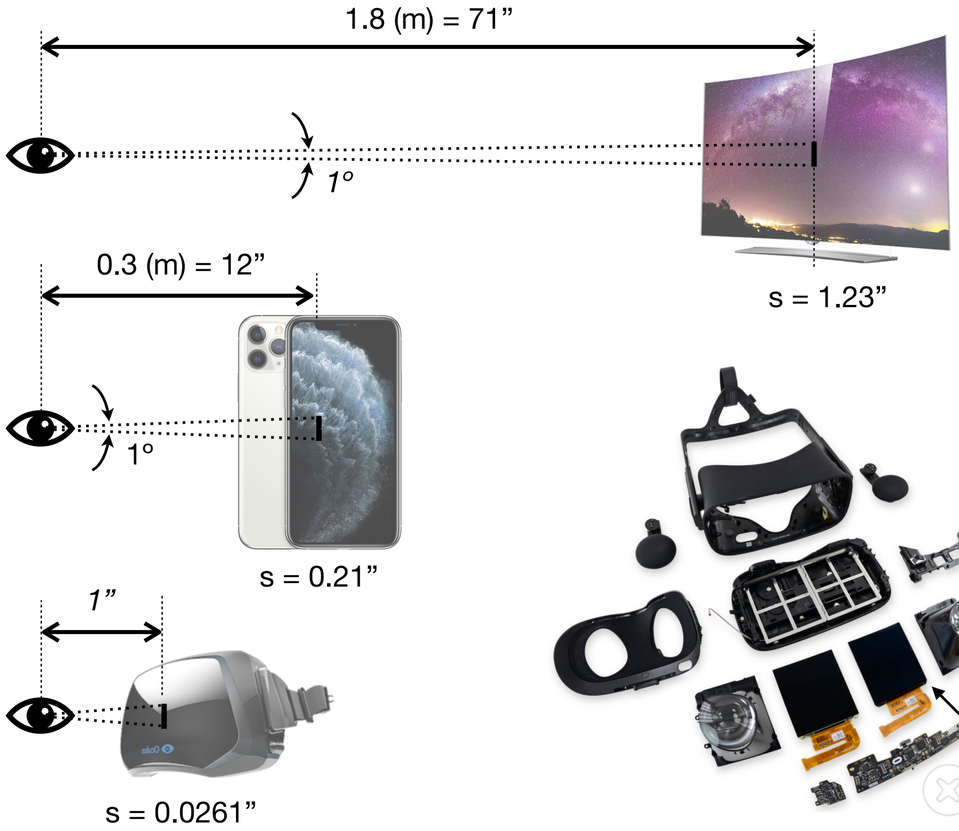
$$Res \geq 60\ (pixels) \div 1.23\ (inch) = 48\ (ppi)$$

- Phone: *d* = 0.3 (m) = 12 (inch)
  - Feature size of 1º – $s = d\tan\theta = 12\tan 1^\circ = 0.21\ (inch)$

$$Res \geq 60\ (pixels) \div 0.21\ (inch) = 286\ (ppi)$$

- VR: *d* = 1 (inch) (Reduced by magnifying lens than actual)
  - Feature size of 1º – $s = d\tan\theta = 1\tan 1^\circ = 0.0261\ (inch)$

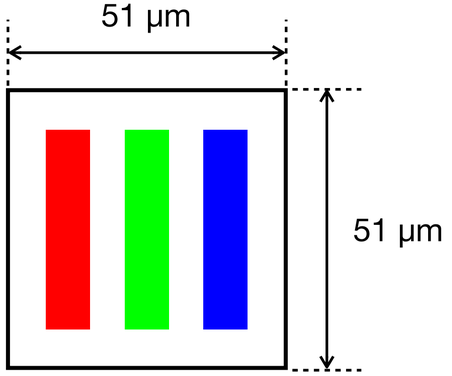
$$Res \geq 60\ (pixels) \div 0.0261\ (inch) = \boxed{2{,}291\ (ppi)}$$

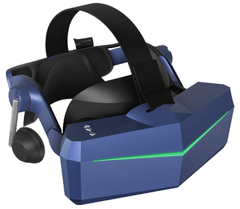


Pixel size vs. application

Galaxy S21 Ultra

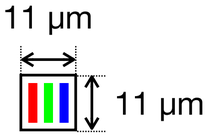
$$\text{Res} = 515\ (\text{ppi}) \longrightarrow \frac{0.0254\ (m)}{515\ (\text{pixels})} = 50\ (\mu m/\text{pixel})$$





Pimax 8k X

$$\text{Res} = 2{,}291\ (\text{ppi}) \longrightarrow \frac{0.0254\ (m)}{2{,}291\ (\text{pixels})} = 11\ (\mu m/\text{pixel})$$



*∴Both OLED devices and circuits should be made **5x** smaller!*

Problems in high-resolution μ-OLED

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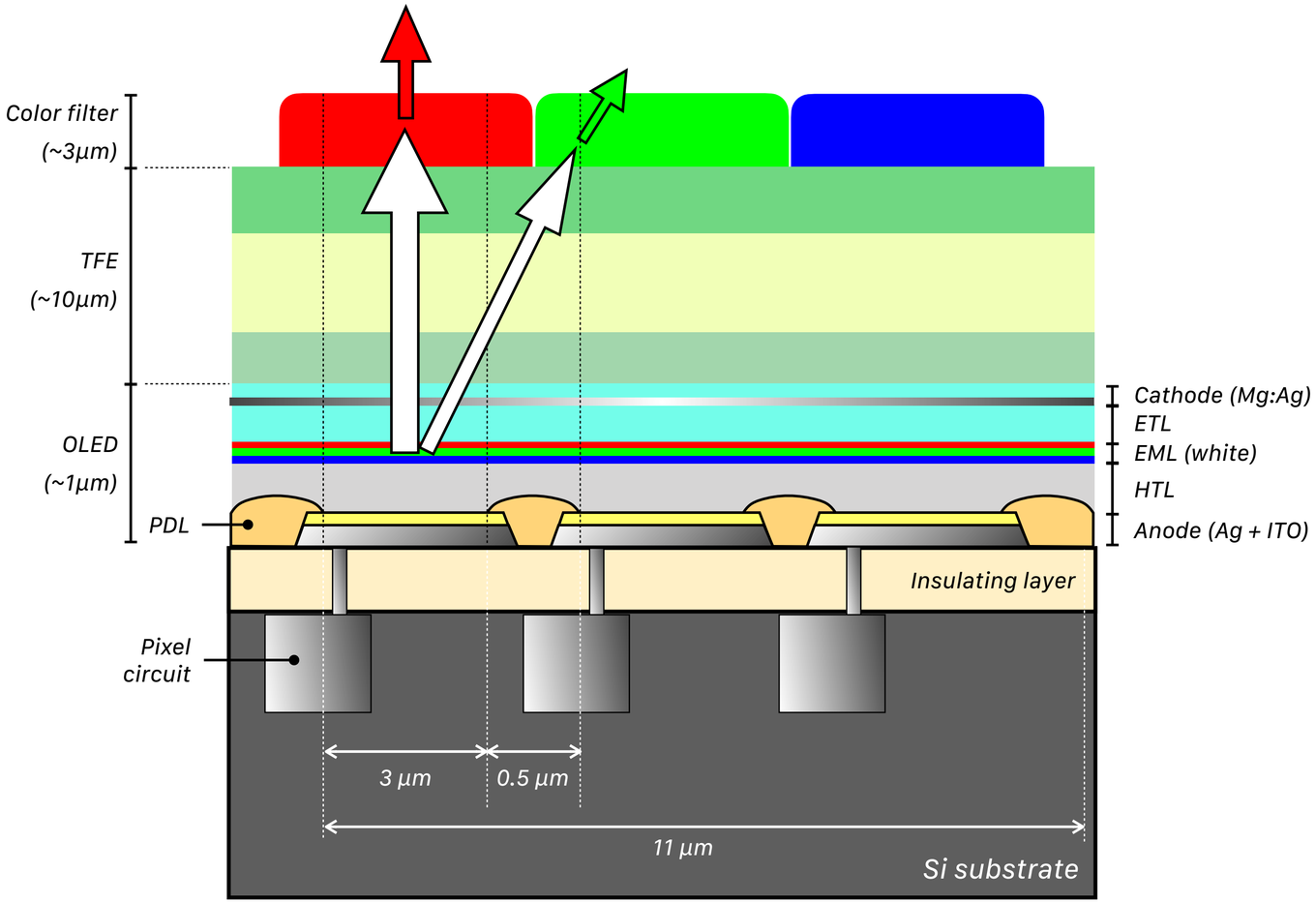
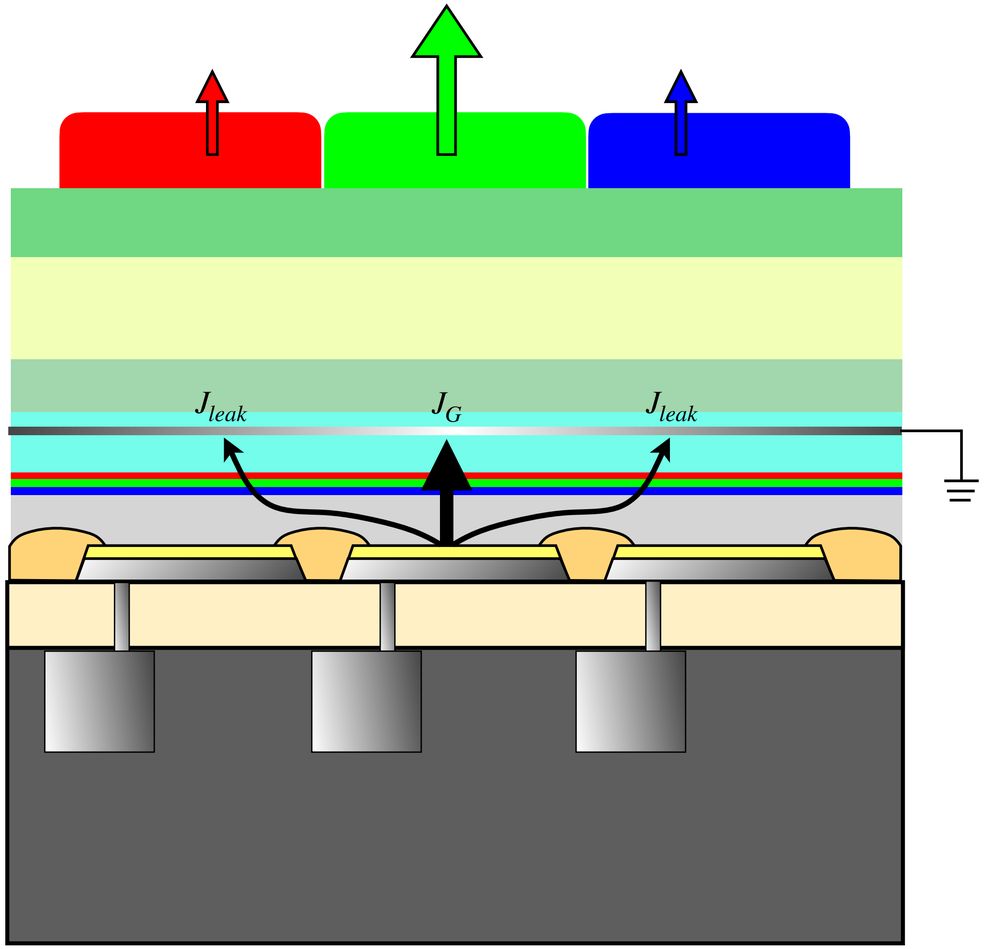
Optical crosstalk



- *Small pixel size & short distance between adjacent pixels*
- *Isotropic OLED emission profile*
- *Long OLED-CF distance (>10 μm)*

Electrical crosstalk



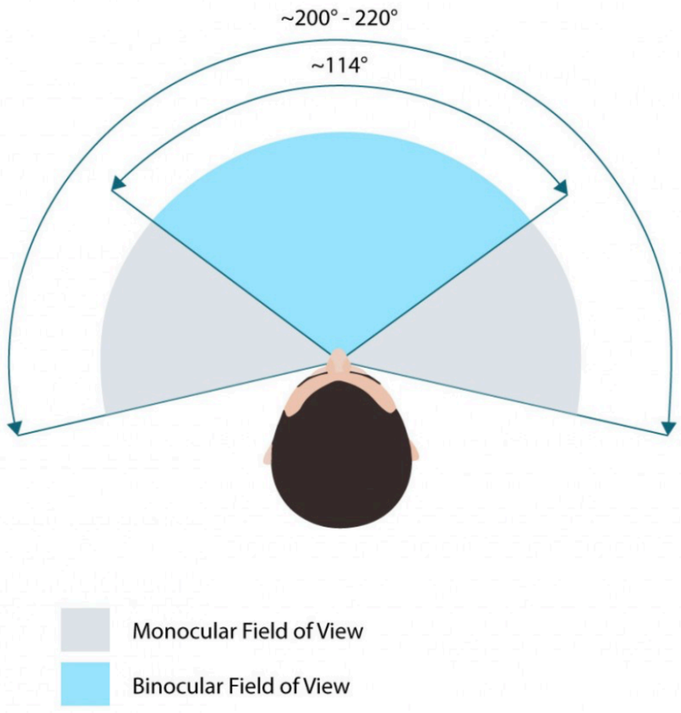
- *Short pixel-to-pixel distance*
- *Highly conductive HTL*

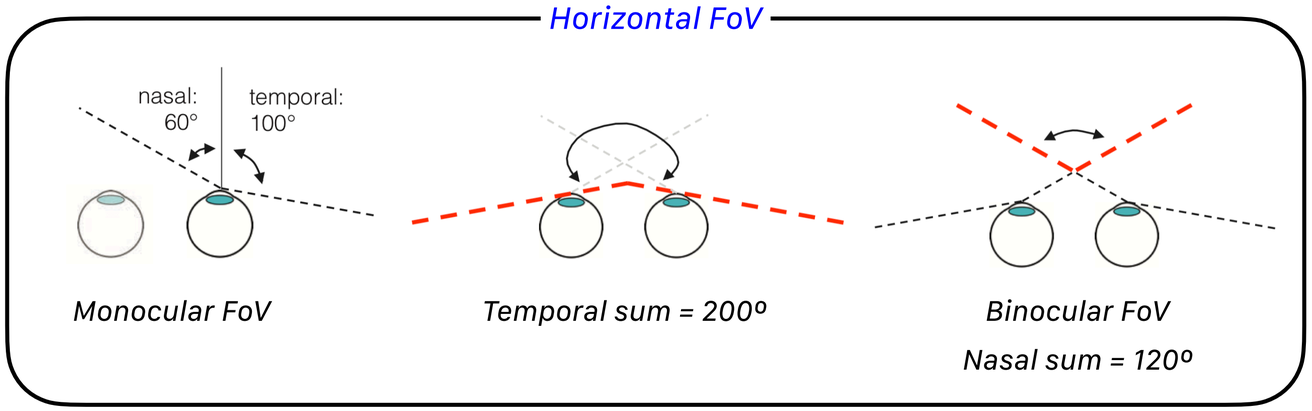
Figure not drawn to scale!

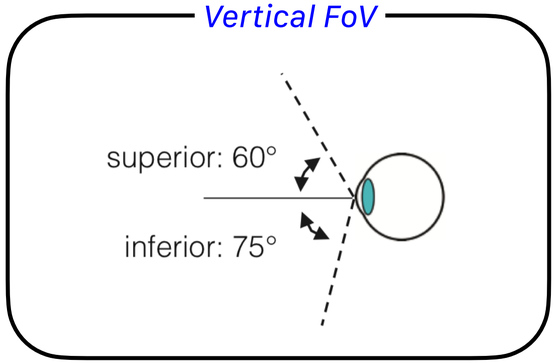
Field of view

Field of view

- Extent of the observable world that is seen at any given moment







Required display resolution per eye

- Required pixel density for normal vision: $60\ (ppd)$
  - Ideal – $hFoV \times vFoV = 160^\circ \times 135^\circ \longrightarrow Res = 9{,}600 \times 8{,}100$
  - Realistic – $hFoV \times vFoV = 120^\circ \times 80^\circ \longrightarrow Res = 7{,}200 \times 4{,}800$

    c.f.) 8k TV – $Res = 7{,}680 \times 4{,}320$