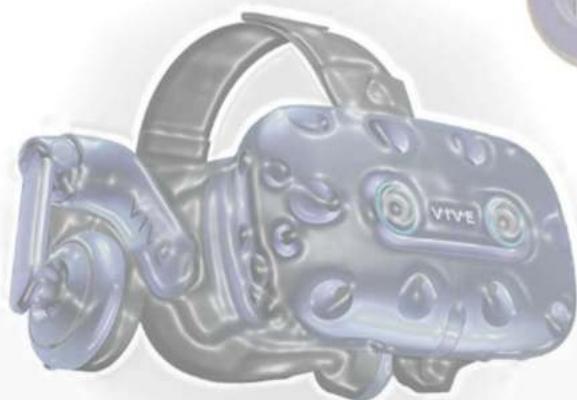


Display Tech. for VR/AR

- introductory

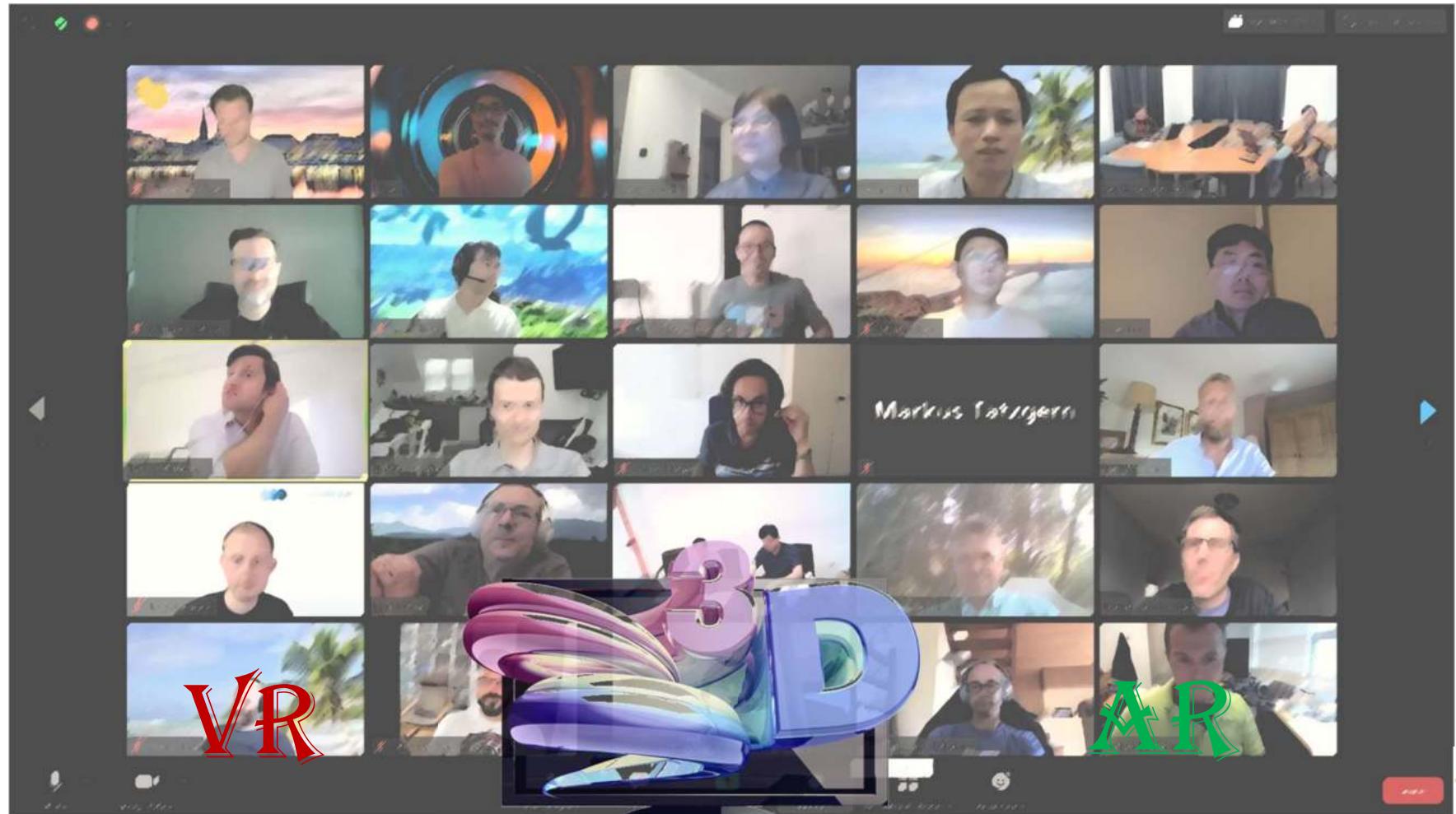


GAMES 204
2022-08



Evan Y. Peng
香港大學
THE UNIVERSITY OF HONG KONG





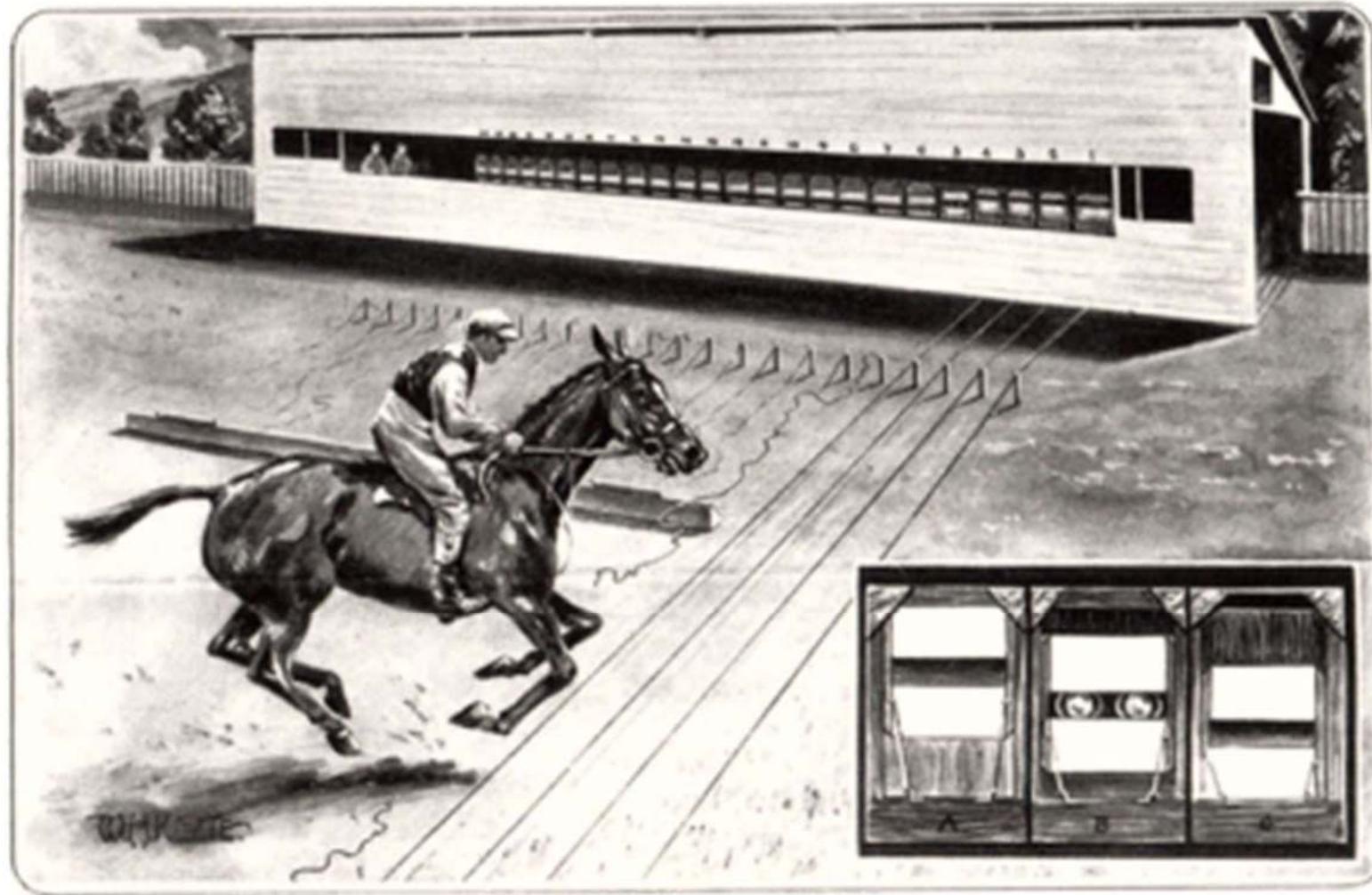
Zoom, zoom, more zooms... The Pandemic Winner





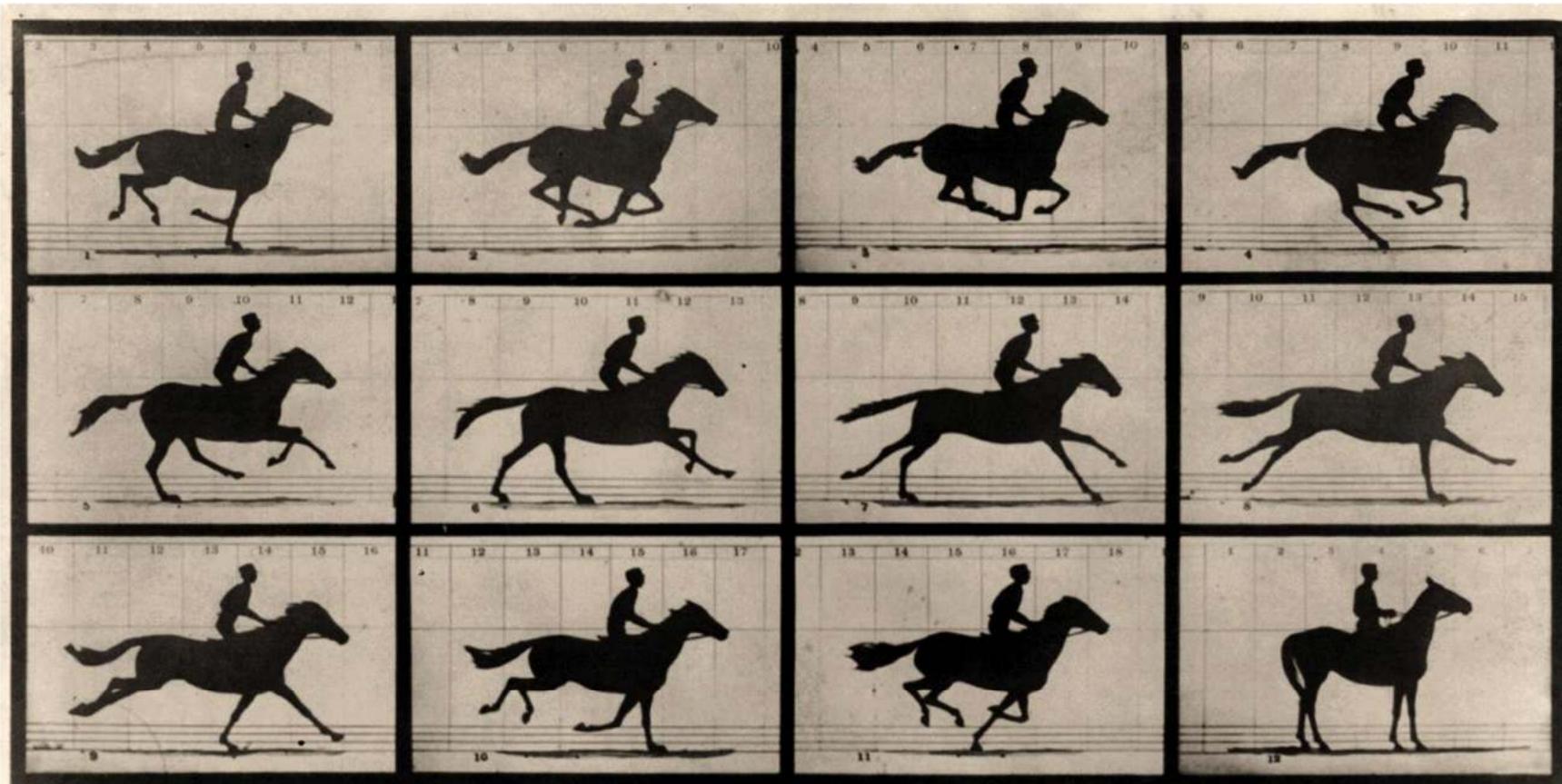
What's Display

Historical Multi-Camera Array at Stanford



Images borrowed from public domain

HKU



Copyright, 1878, by MUYBRIDGE.

MORSE'S Gallery, 417 Montgomery St., San Francisco.

THE HORSE IN MOTION.

Illustrated by
MUYBRIDGE.

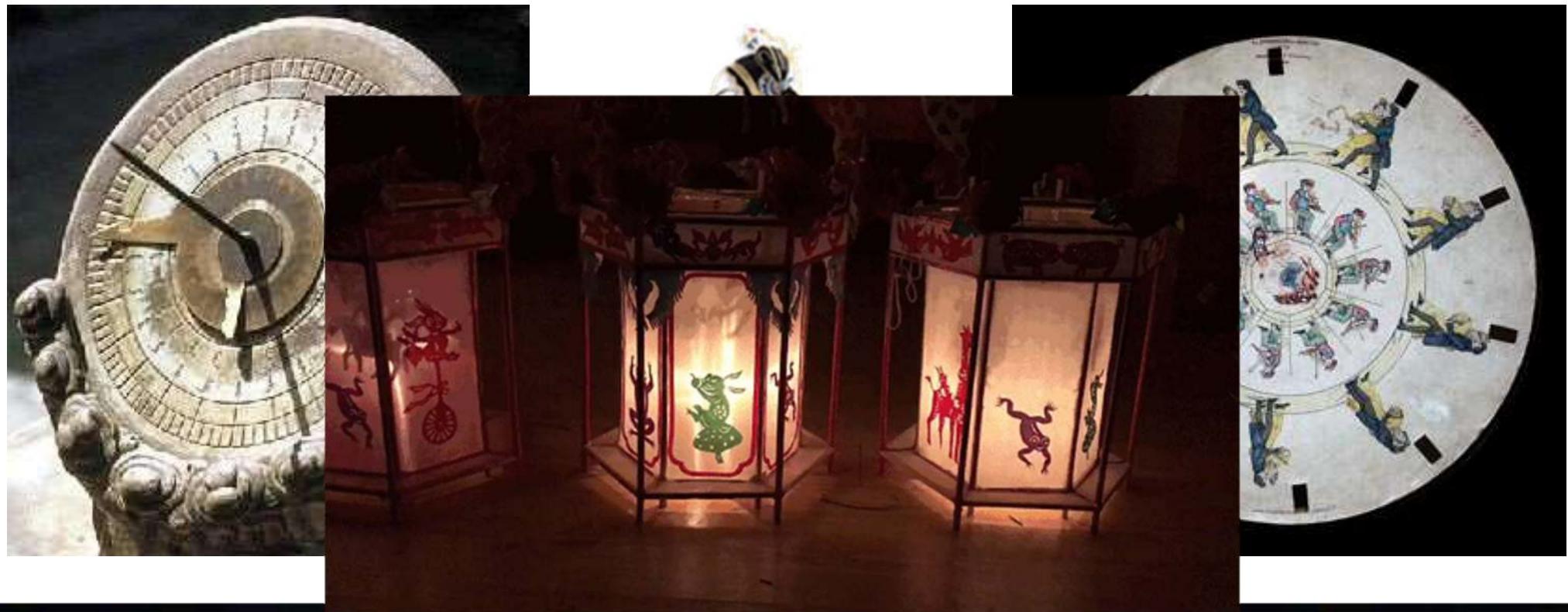
AUTOMATIC ELECTRO-PHOTOGRAPH.

"SALLIE GARDNER," owned by LELAND STANFORD; running at a 1.40 gait over the Palo Alto track, 19th June, 1878.

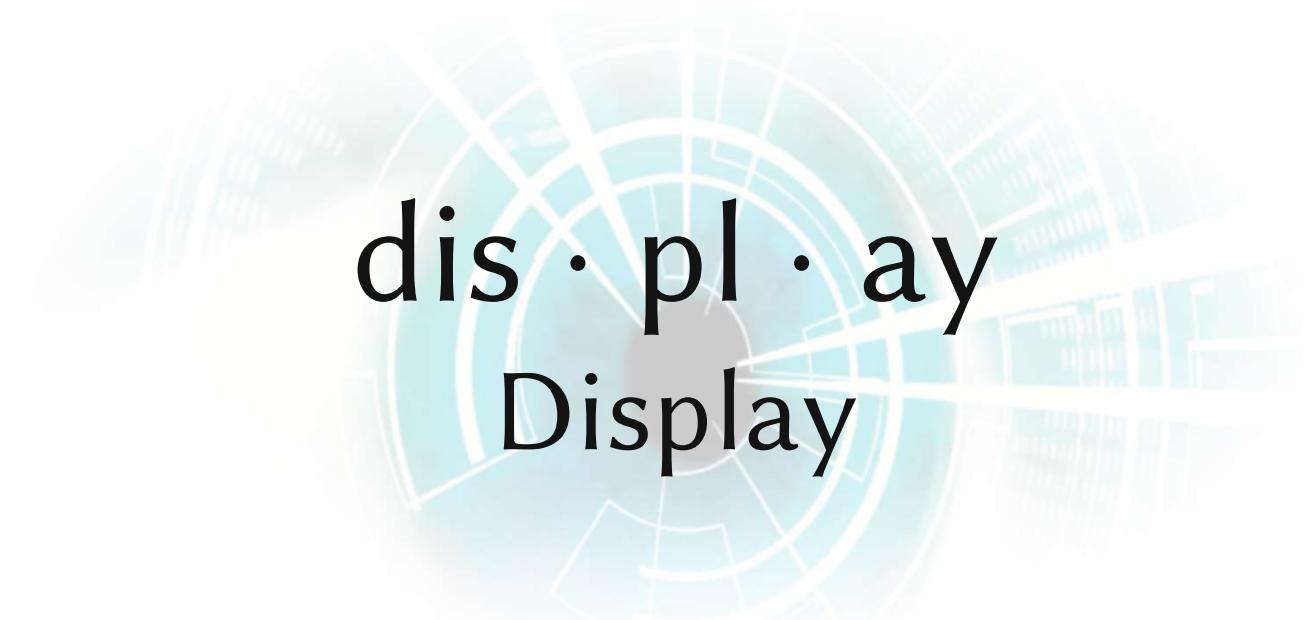
The negatives of these photographs were made at intervals of twenty-seven inches of distance, and about the twenty-fifth part of a second of time; they illustrate consecutive positions assumed in each twenty-seven inches of progress during a single stride of the mare. The vertical lines were twenty-seven inches apart; the horizontal lines represent elevations of four inches each. The exposure of each negative was less than the two-thousandth part of a second.

HKU

Historical Chinese “Displays”



Images borrowed from public domain

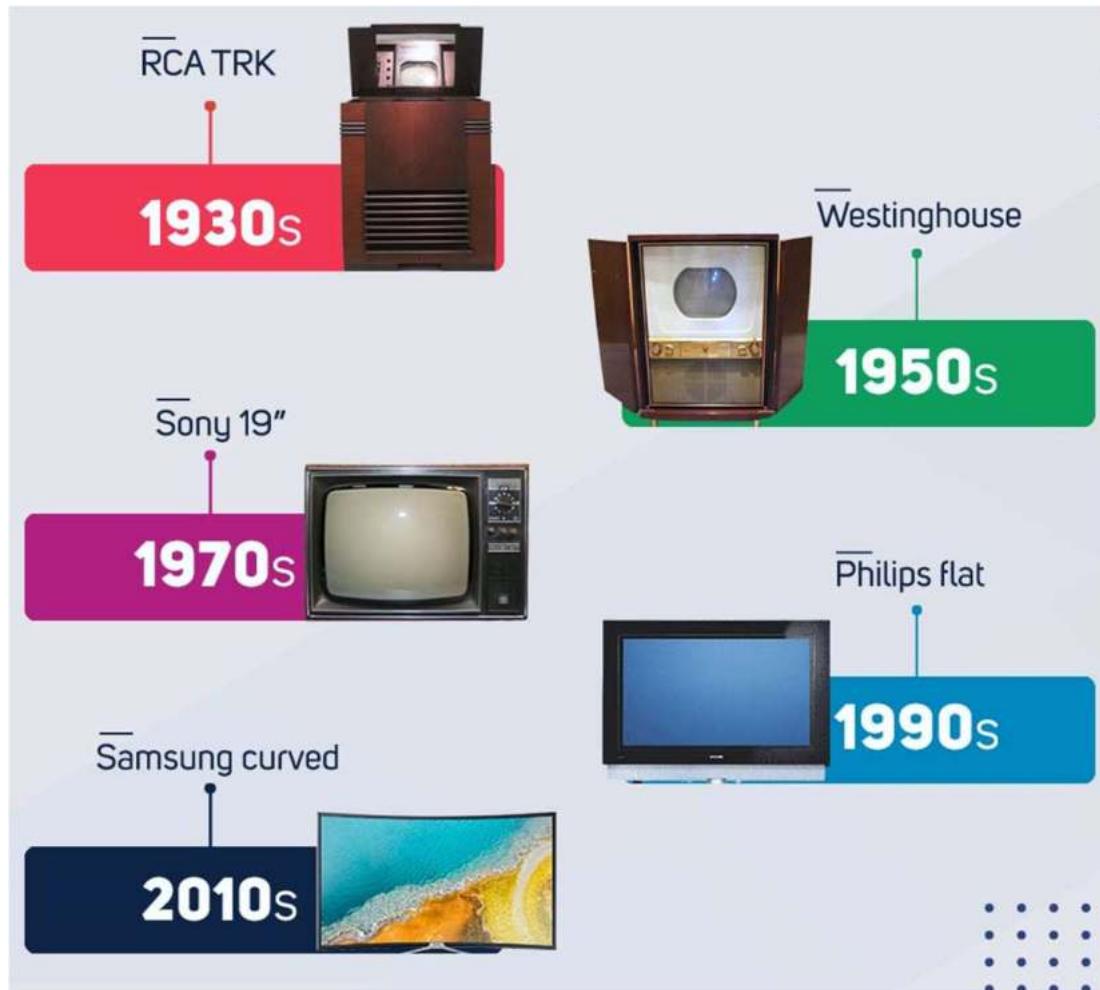


dis · pl · ay

Display

an output device for presentation of information in visual or tactile form (the latter used for example in tactile electronic displays for blind people). When the input information that is supplied has an electrical signal the display is called an electronic display.

Everyone Watches TVs



Images borrowed from public domain

Modern Information Displays



PHILIPS

SONY
make.believe

benQ

ASUS

TCL

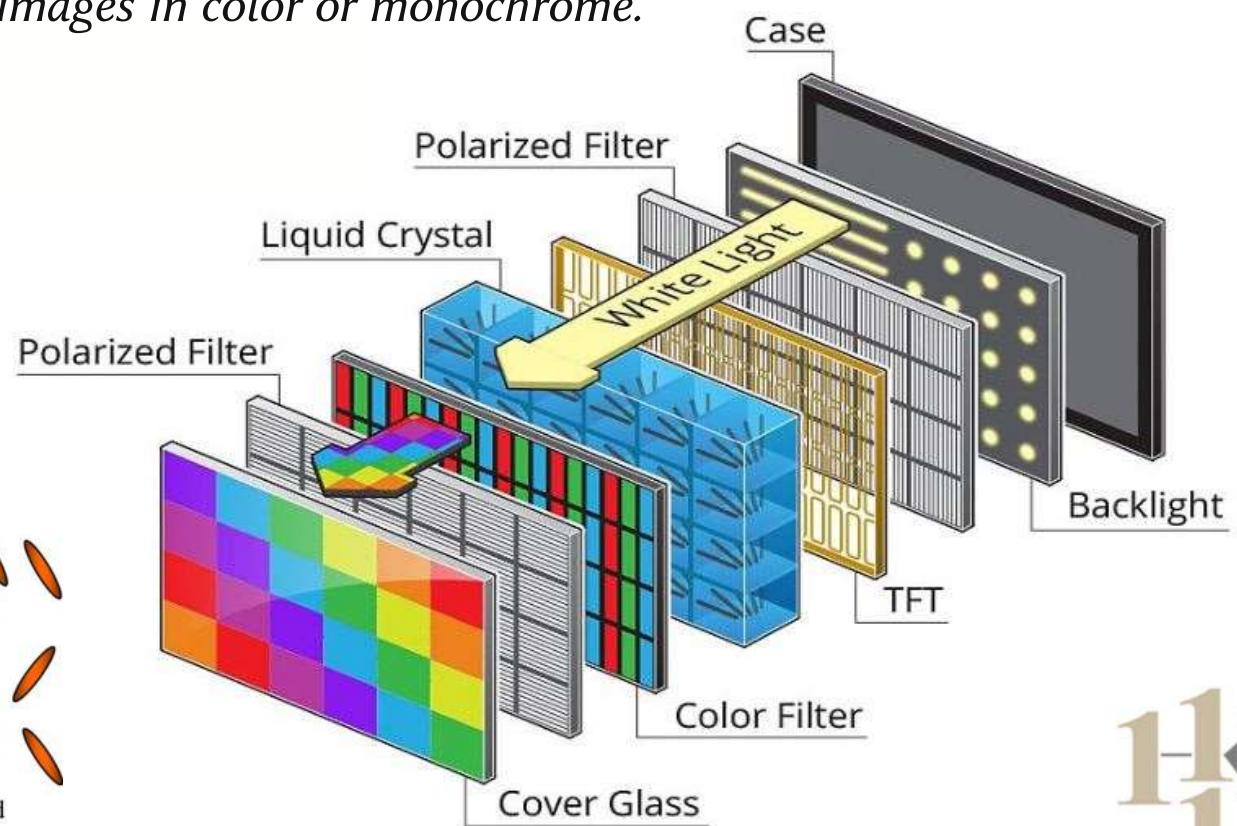
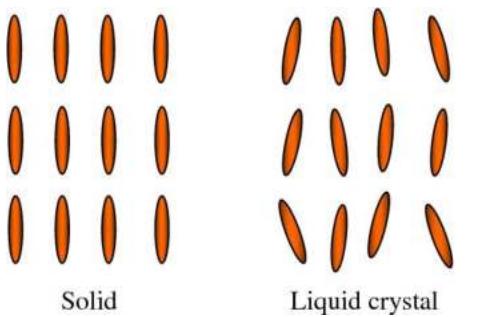
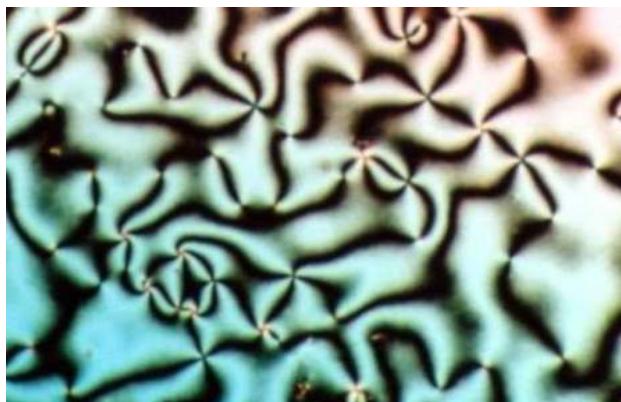
BOE

SHARP
TOSHIBA

- CRT (阴极射线管)
- Flat Panel Displays
 - EL (电泳)
 - PDP (等离子)
 - LCD (液晶)
 - OLED (有机发光)
- Projection

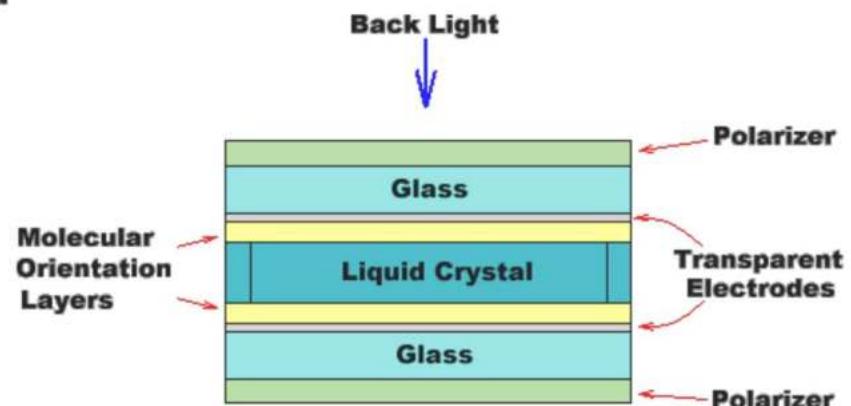
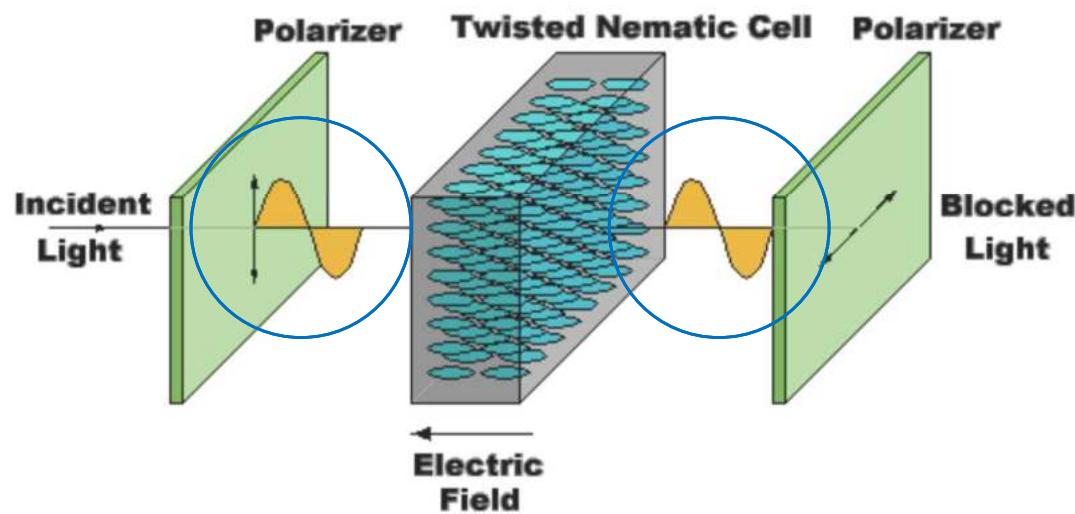
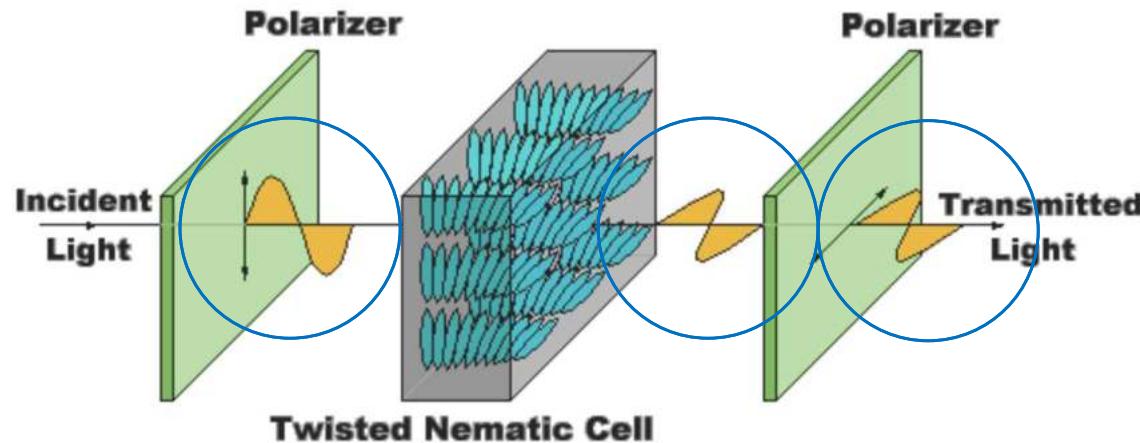
LCD Everywhere

a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals combined with polarizers. Liquid crystals do not emit light directly, instead using a backlight to produce images in color or monochrome.



Images borrowed from public domain

Working Example: TN LCD Panel



Images borrowed from public domain

When Buying a Monitor

Panel Type



TN



VA



IPS



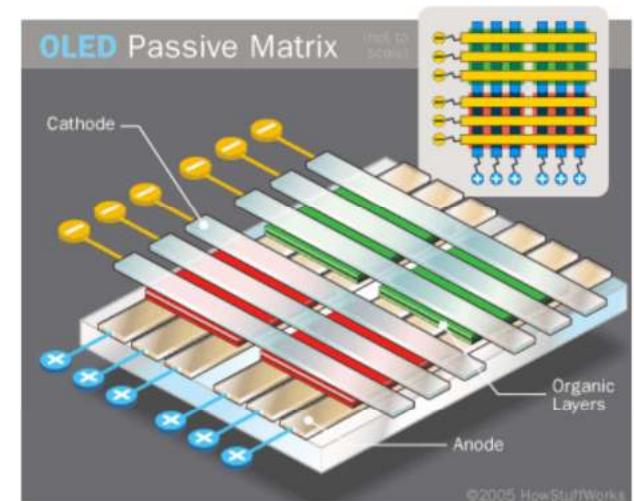
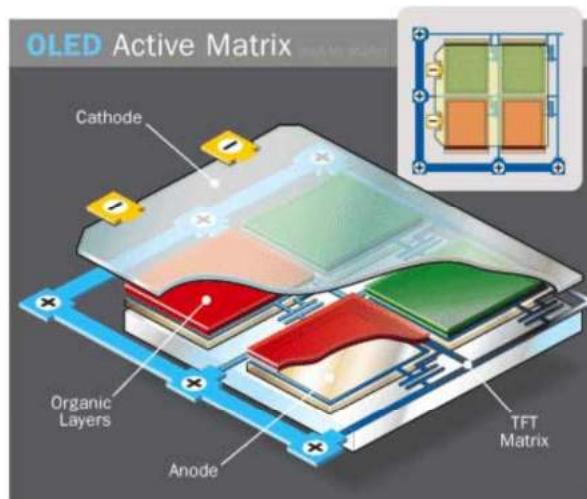
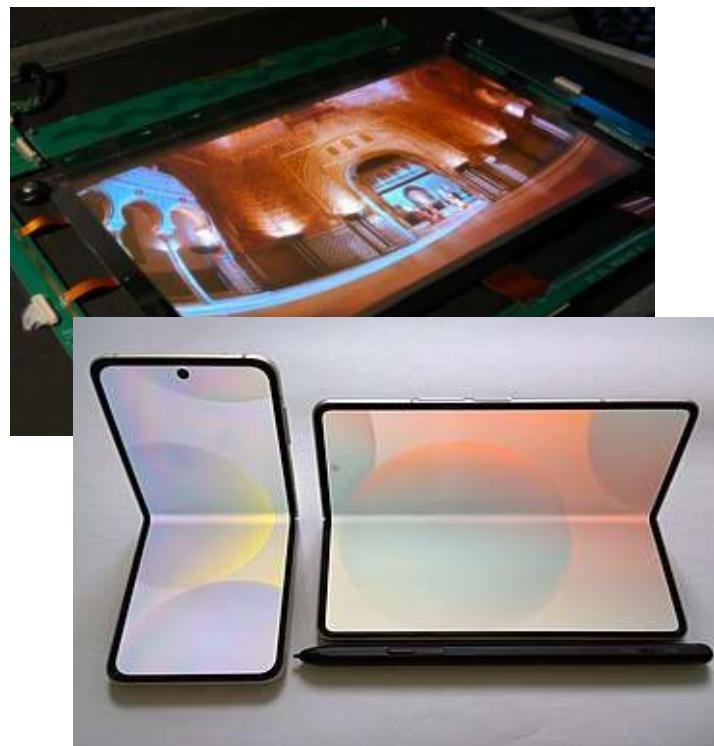
Response Time	<1ms	4-5ms	1-2ms
Color	Poor	Good	Best
Contrast	Good 1000:1	Best 3000:1	Good 1000:1
Viewing Angle	170/160	178/178	178/178

QLED: Quantum Dot Backlight



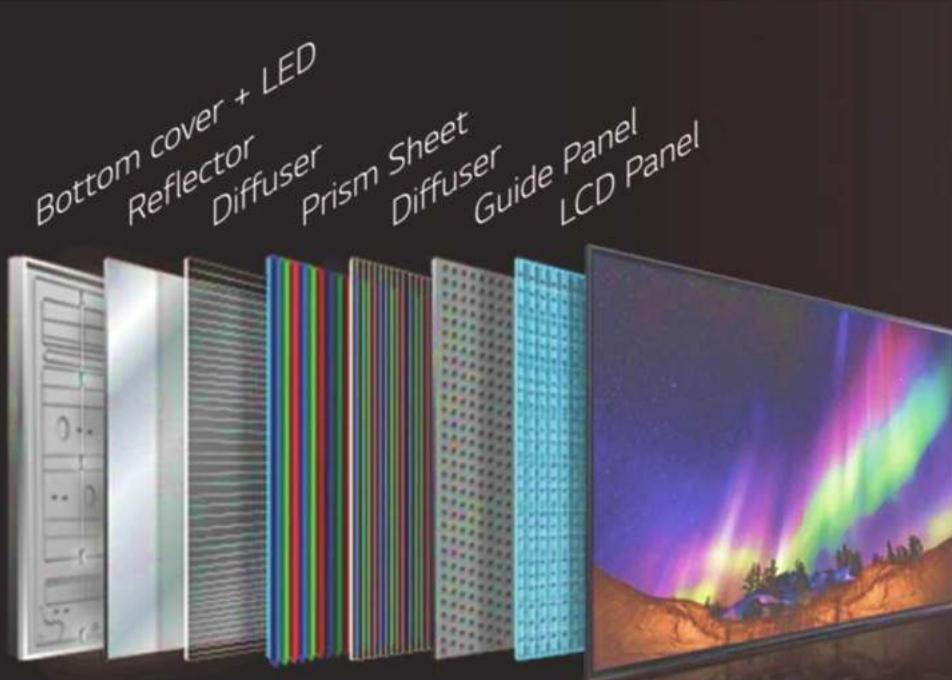
OLED: A Selling Point

a light-emitting diode (LED) in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. This organic layer is situated between two electrodes; typically, at least one of these electrodes is transparent.



Images borrowed from public domain

LCD v.s. OLED



Multilayer Structure | **LCD(LED)**

Passive (BLU needed)
Limited contrast but lower cost



OLED | Simple Structure

Self-emissive
Great light efficiency and contrast but higher cost



Projectors Are
Alternative

SLMs for Shaping Light

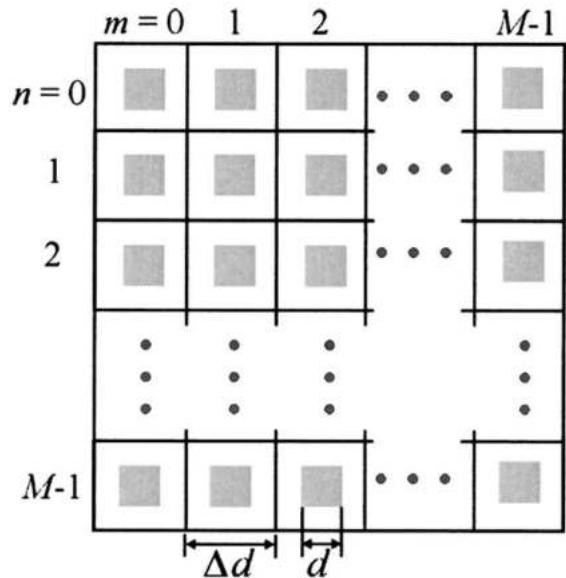
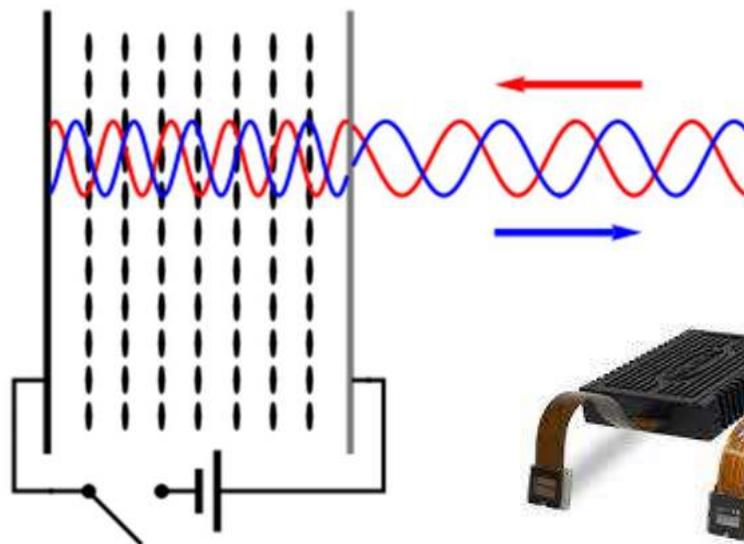


Fig. 1. Geometry of the $M \times M$ phase-only spatial light modulator with a square pixel length d while Δd is the period length. The active phase-encoding area of a pixel is shaded gray.

[Palima et al. 2006]



*Pixel pitch
Resolution
Grayscale
Modulation range
Refresh rate*

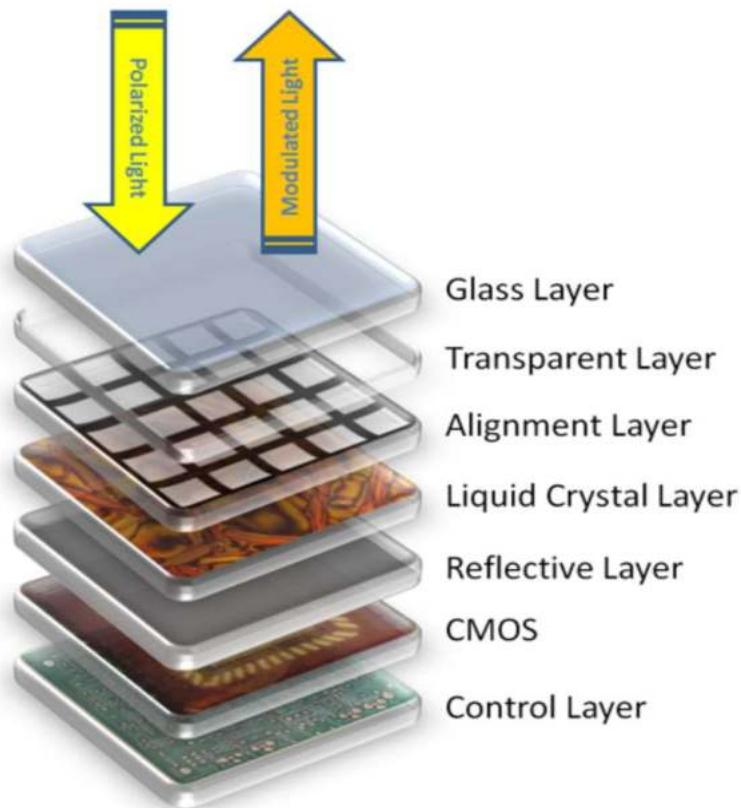


HAMAMATSU
PHOTON IS OUR BUSINESS

 **TEXAS
INSTRUMENTS**

SLM: Liquid Crystal on Silicon (LCoS)

a miniaturized reflective active-matrix liquid-crystal display or "microdisplay" using a liquid crystal layer on top of a silicon backplane.

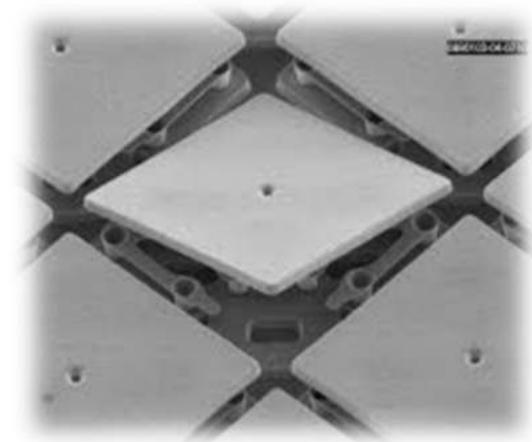
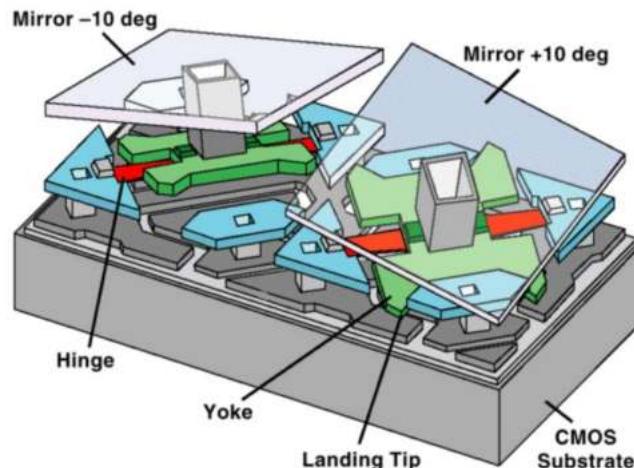


- Basically, a reflective LCD
- Standard component in projectors and head-mounted displays, e.g., google glass
- Without the 2nd polarizer: phase modulation device

Images borrowed from public domain

SLM: Digital Micromirror Device (DMD)

a microoptoelectromechanical system (MOEMS) that is the core of the trademarked digital light processing (DLP) projection technology, basically micro-mirrors array.



- MEMS device
- Binary states (+/- 10 deg.)
- Grayscale via pulse width modulation (PWM)

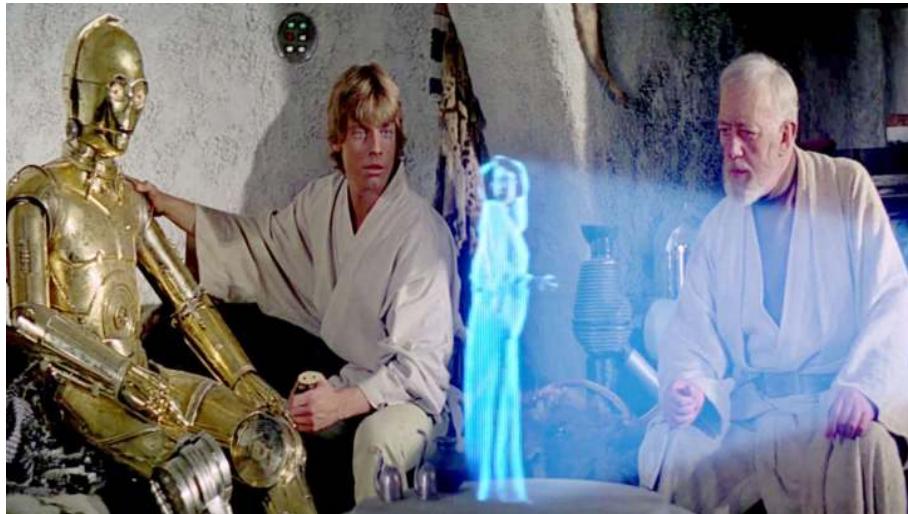


Images borrowed from public domain



Would Metaverse
Really Come





Images borrowed from public domain

Future Display and Visualization Scenarios



Images borrowed from public domain, credits @ Sony, ETH/UNC, Nvidia, Microsoft, etc.



vir·tu·al re·al·ity

VR

the computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors.



Message from National Academy of Engineering

“**Enhance Virtual Reality**” is 1 of 14 grand challenges for engineering in the 21st century

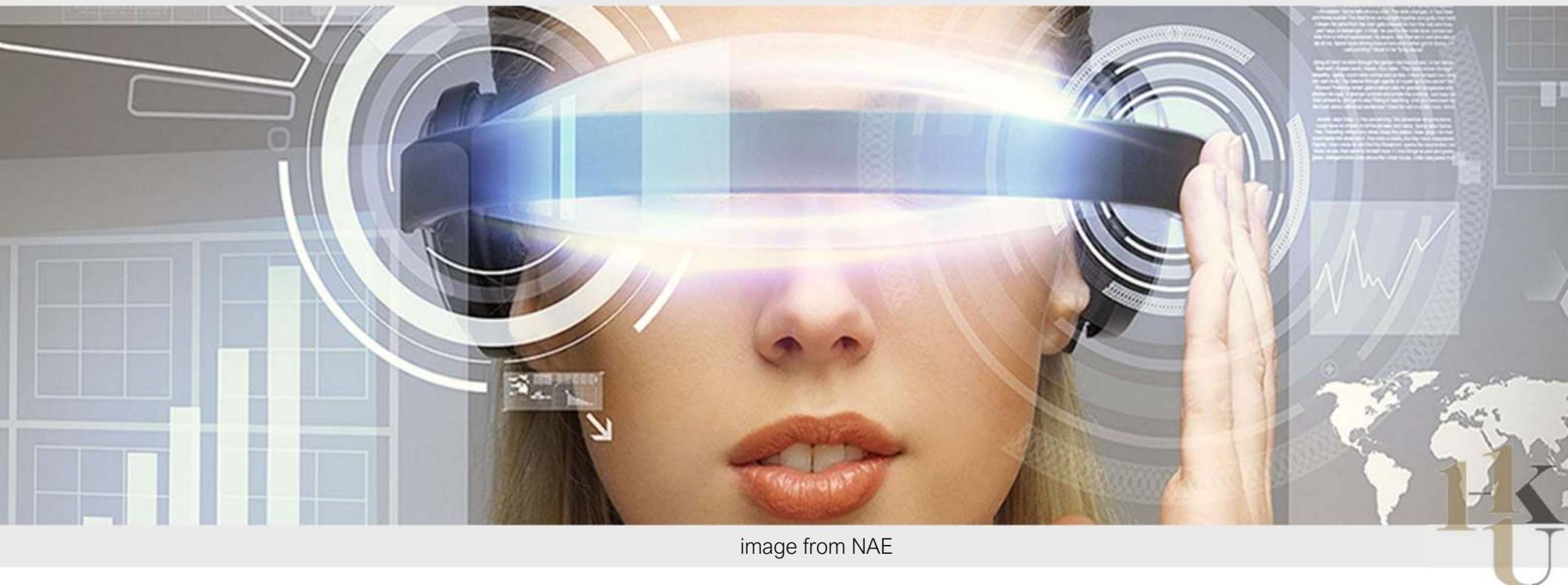


image from NAE



Scott Song for USC Roski Eye Institute

“Fun” Engineering Aspects of VR/AR

- HCI
- applications
- cloud computing
- shared experiences



- VR cameras
- Compression, streaming
- photonics / waveguides
- human perception
- displays: visual, auditory, haptic, ...



- CPU, GPU
- IPU, DPU?

- sensors & imaging
- computer vision
- scene understanding

Where We Want It To Be



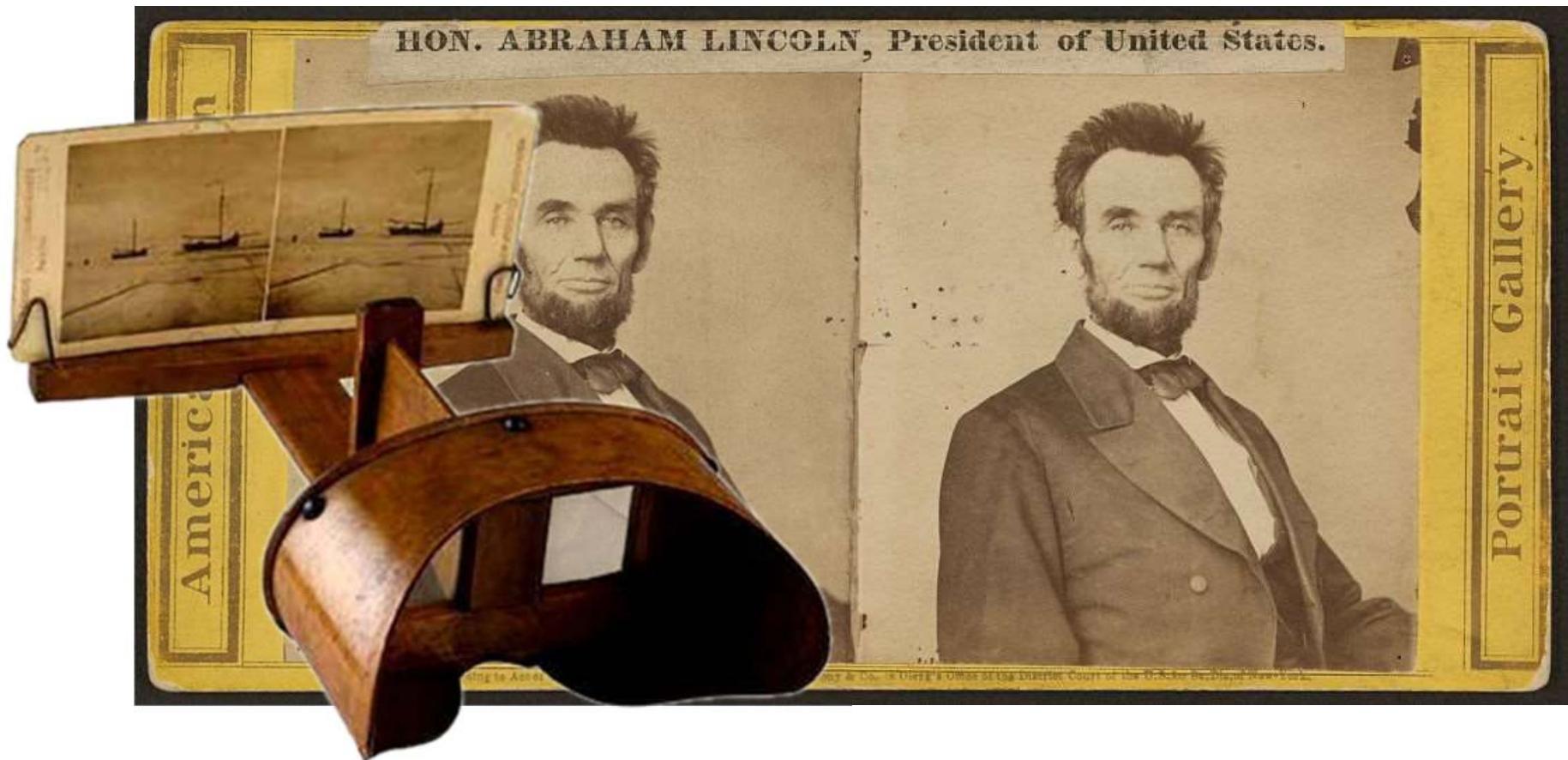
HKU

image by ray ban

Wait A Second...



Stereoscopic Displays

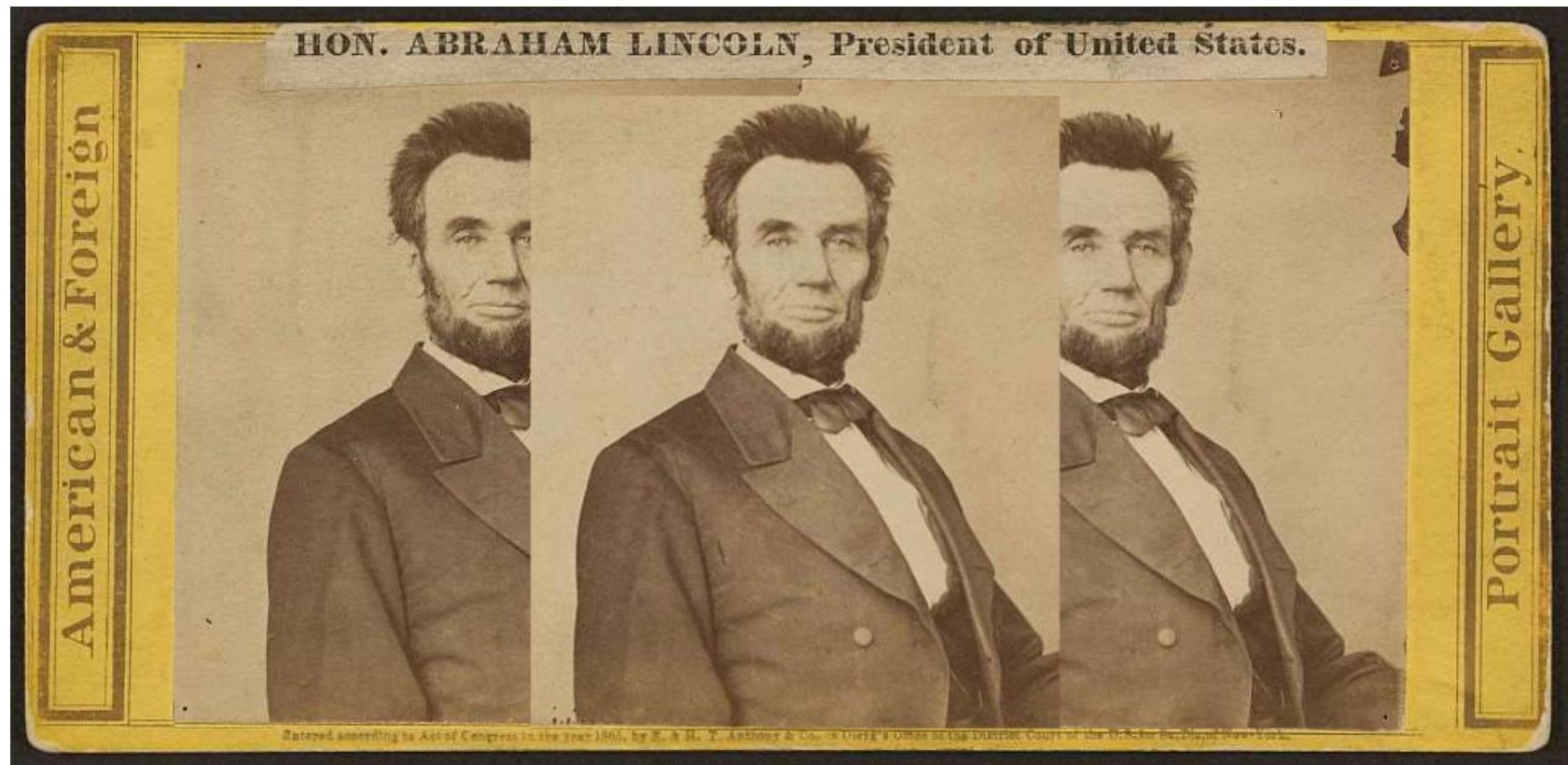


Charles Wheatstone., 1841. Stereoscope.

Walker, Lewis E., 1865. Hon. Abraham Lincoln, President of the United States. Library of Congress



Stereoscopic Displays



HKU

A Brief History of Virtual Reality

Stereoscopes

Wheatstone, Brewster, ...



VR & AR

Ivan Sutherland



Image credits @ G Wetzstein

A Brief History of Virtual Reality

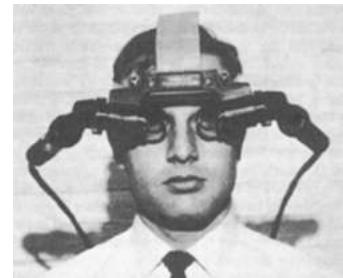
Stereoscopes

Wheatstone, Brewster, ...



VR & AR

Ivan Sutherland



Nintendo

Virtual Boy



1838

1968

1995

2012-now

Image credits @ G Wetzstein

A Brief History of Virtual Reality

Stereoscopes

Wheatstone, Brewster, ...



VR & AR

Ivan Sutherland



Nintendo

Virtual Boy



VR explosion

Oculus, Sony, HTC, MS, ...



1838

1968

1995

2012-now

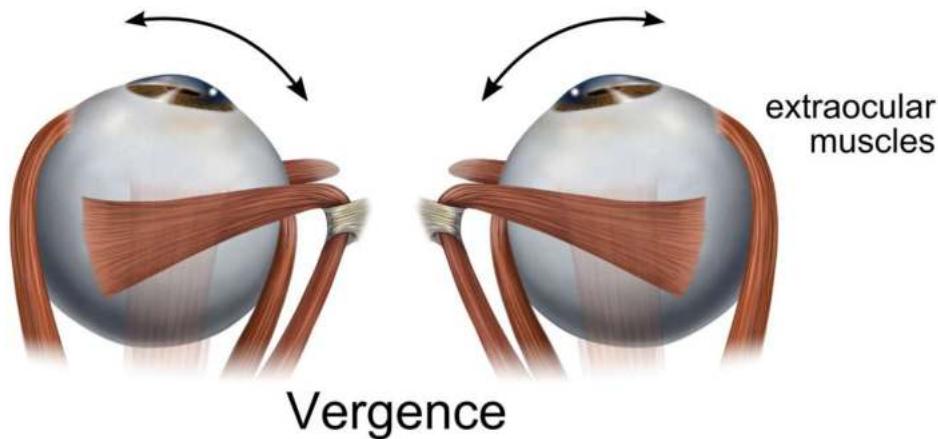
Image credits @ G Wetzstein



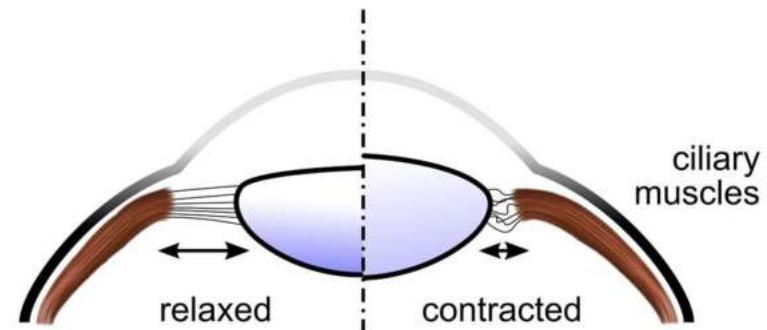
Image credits @ G Wetzstein

Oculomotor Cue

Stereopsis (Binocular)



Focus Cues (Monocular)



Visual Cue



Binocular Disparity



Retinal Blur

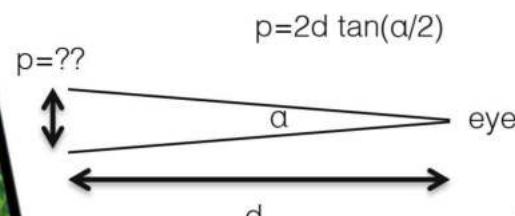
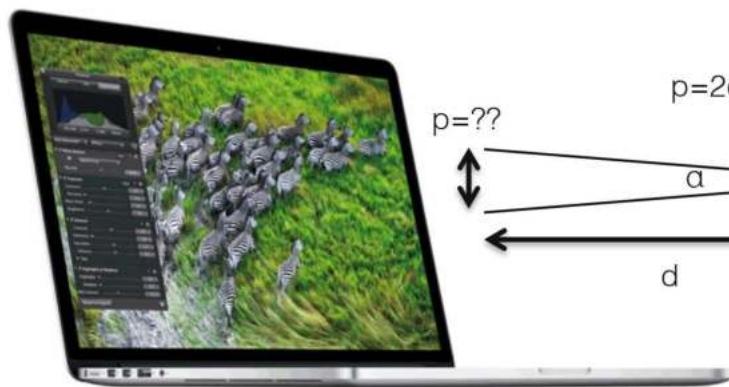
Image credits @ G Wetzstein

Know Yourself: Human Visual System (HVS)



- visual acuity: 20/20 is ~1 arc min
- field of view: ~190° monocular, ~120° binocular, ~135° vertical
- temporal resolution: ~60 Hz (depends on contrast, luminance)
- dynamic range: instantaneous 6.5 f-stops, adapt to 46.5 f-stops
- color: everything in the CIE xy diagram; distances are linear in CIE Lab
- depth cues in 3D displays: vergence, focus, conflicts, (dis)comfort
- accommodation range: ~8cm to ∞ , degrades with age

Apple Inc.



Steven Jobs said 300dpi
(286dpi in math)

tablet, 12" away,
resolvable pixel:

$$p=2*12''*\tan(1 \text{ arc min } /2)=0.0035''$$



Where We Are Now



IFIXIT teardown

HKU

Naïve Magnifier-type VR Displays

Oculus Rift



Sony Morpheus



DuroVis Dive



VrAse



Zeiss Cinemizer



Avegant Glyph



Hasbro My3D

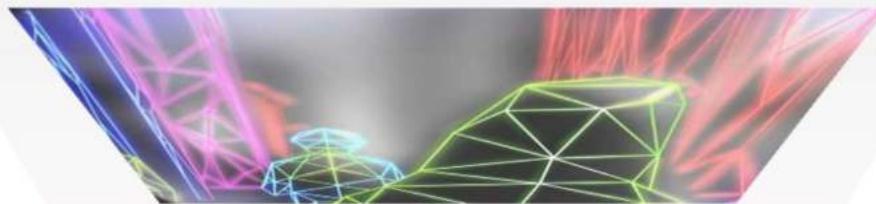


Altergaze The logo consists of the letters "H" and "K" in gold, with "U" in grey, all connected by a horizontal bar.

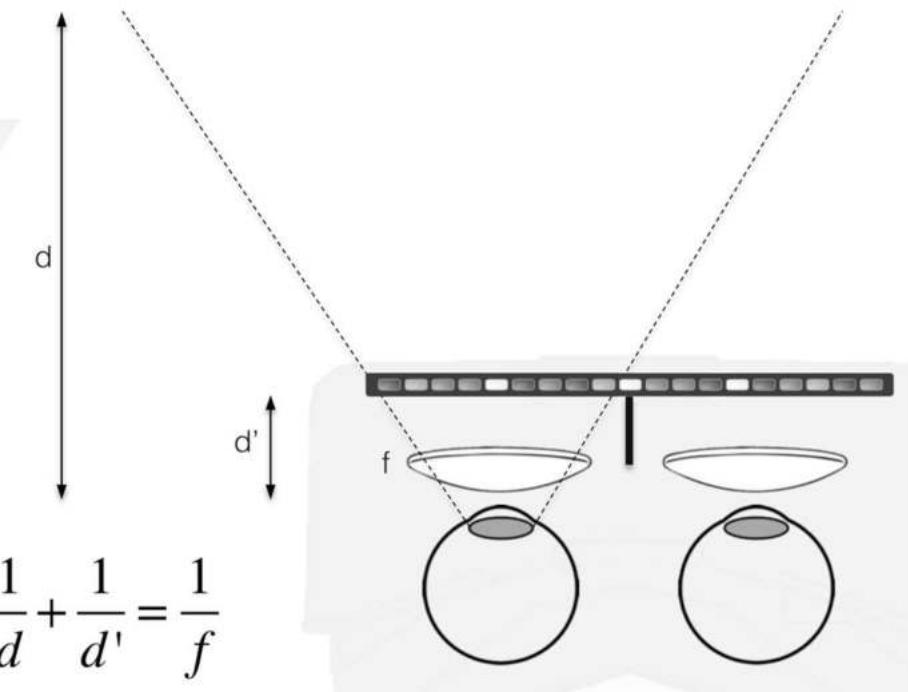
Images borrowed from public domain

Naïve Magnifier-type VR Displays

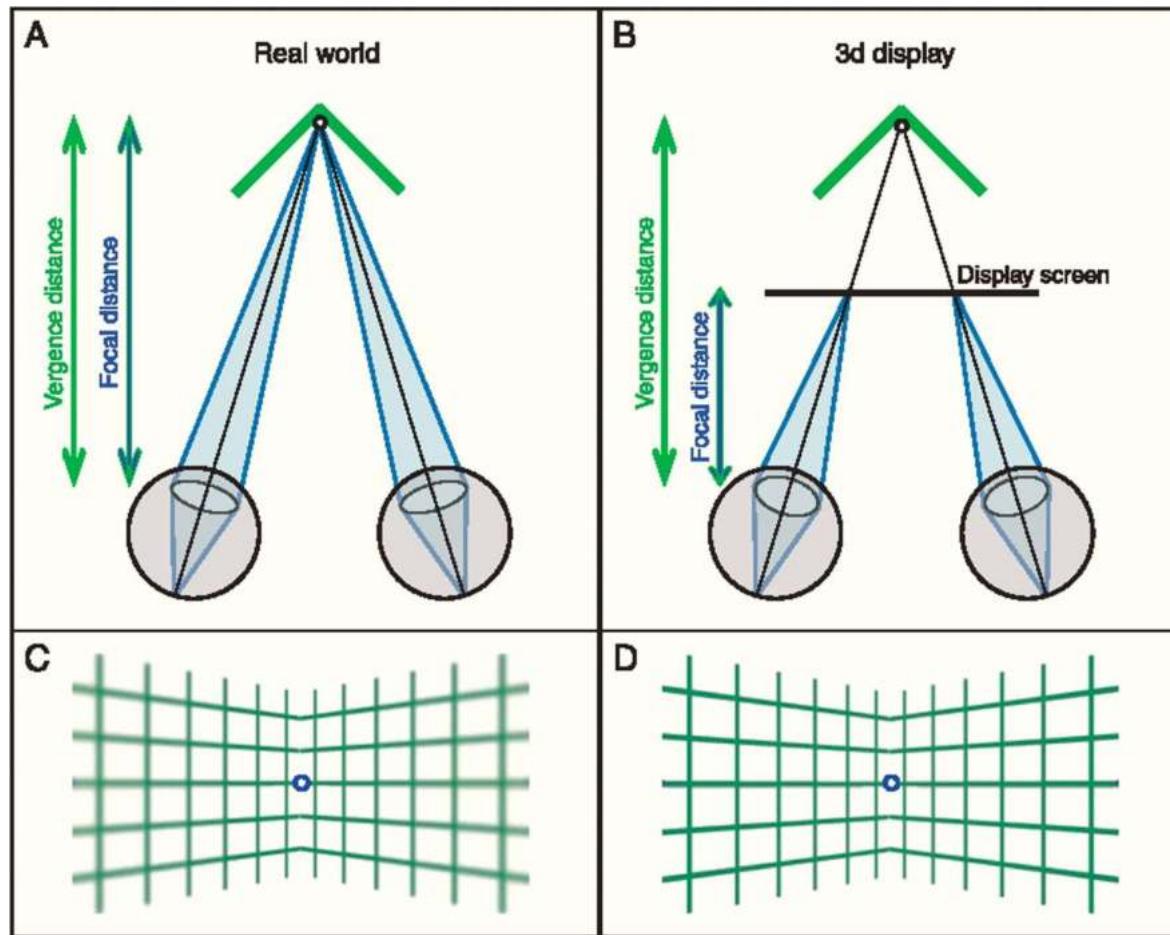
Virtual Image



- fixed focal plane,
lacking focus cues



Vergence-Accommodation Conflict (VAC)



effects

- visual discomfort
- visual fatigue
- nausea
- diplopic vision
- eyestrain
- compromised quality
- pathologies in developing visual system
- ...

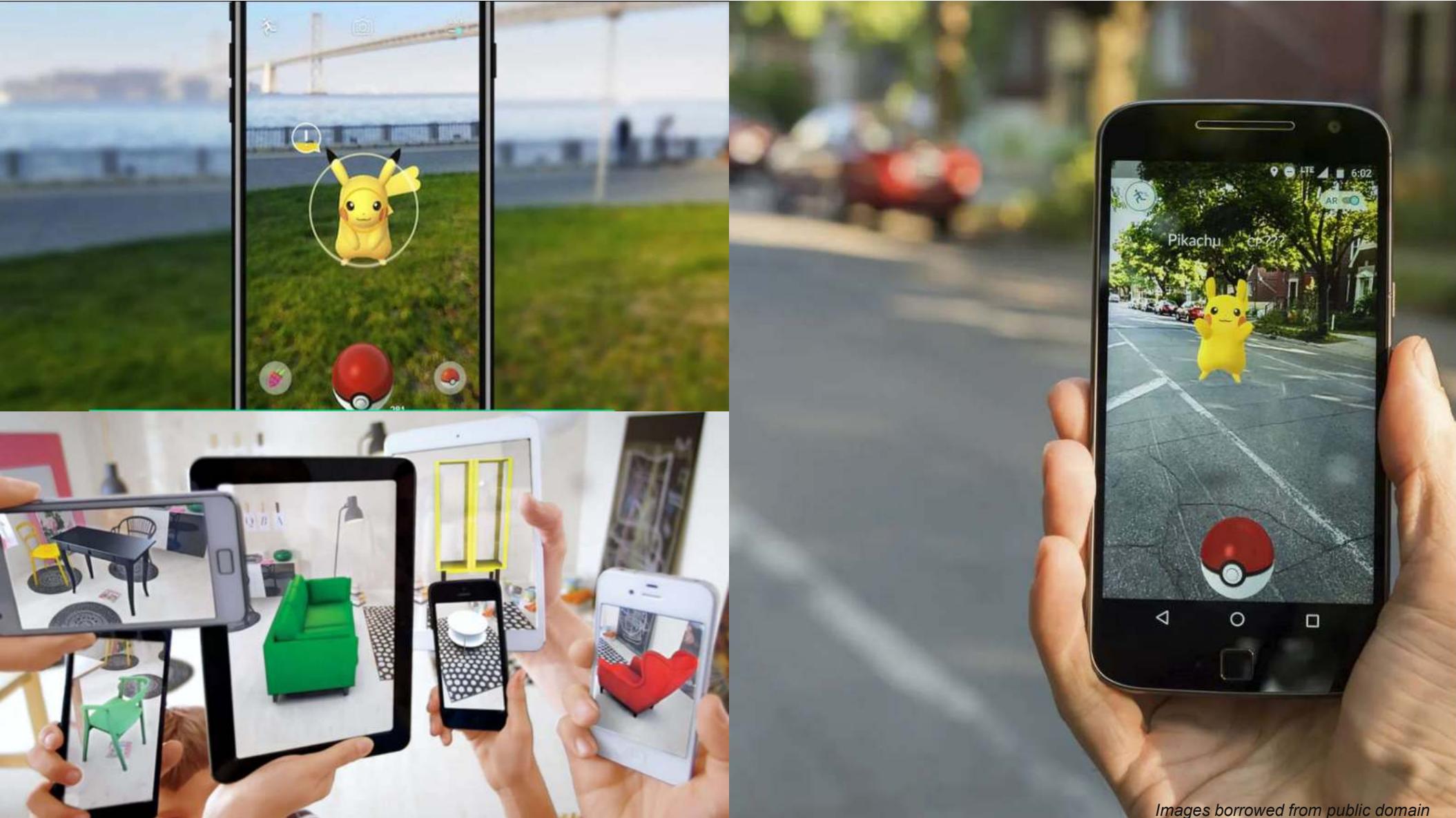


aug·men·ted re·al·i·ty

AR

an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, and olfactory.





Images borrowed from public domain



Microsoft HoloLens



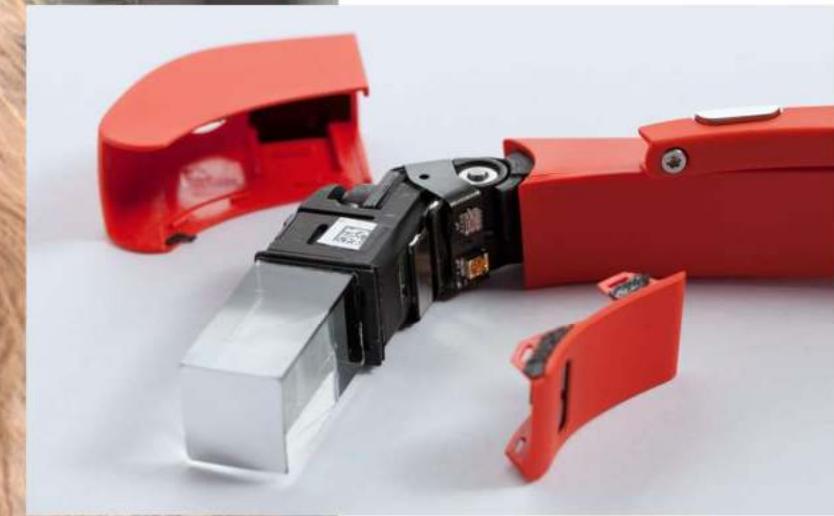
Meta 2



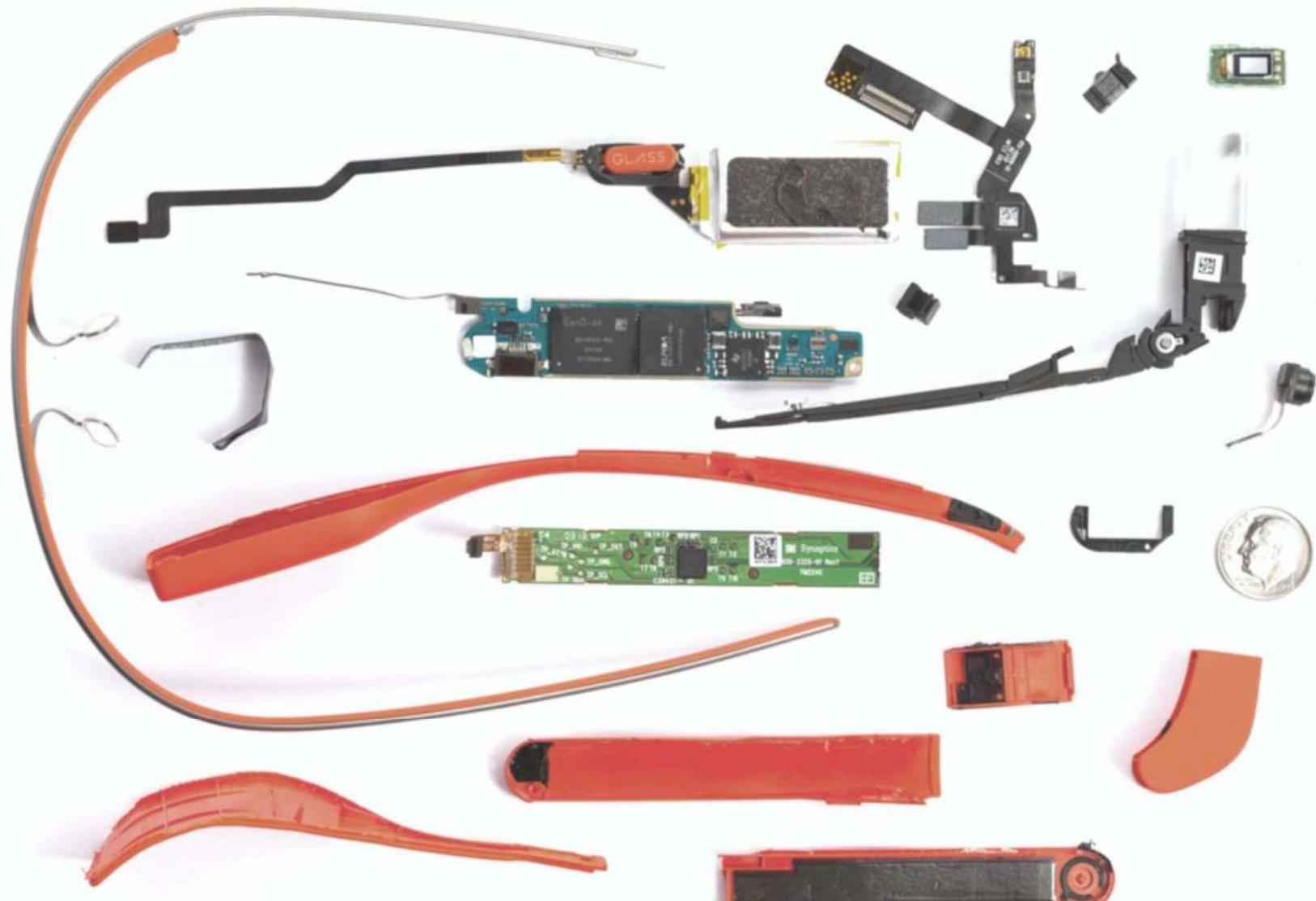
Magic Leap One

Images borrowed from public domain

See-through AR Displays



Images borrowed from public domain

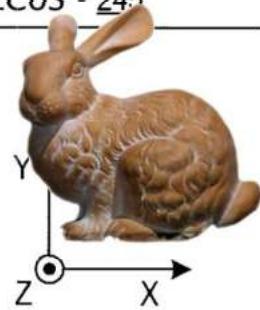
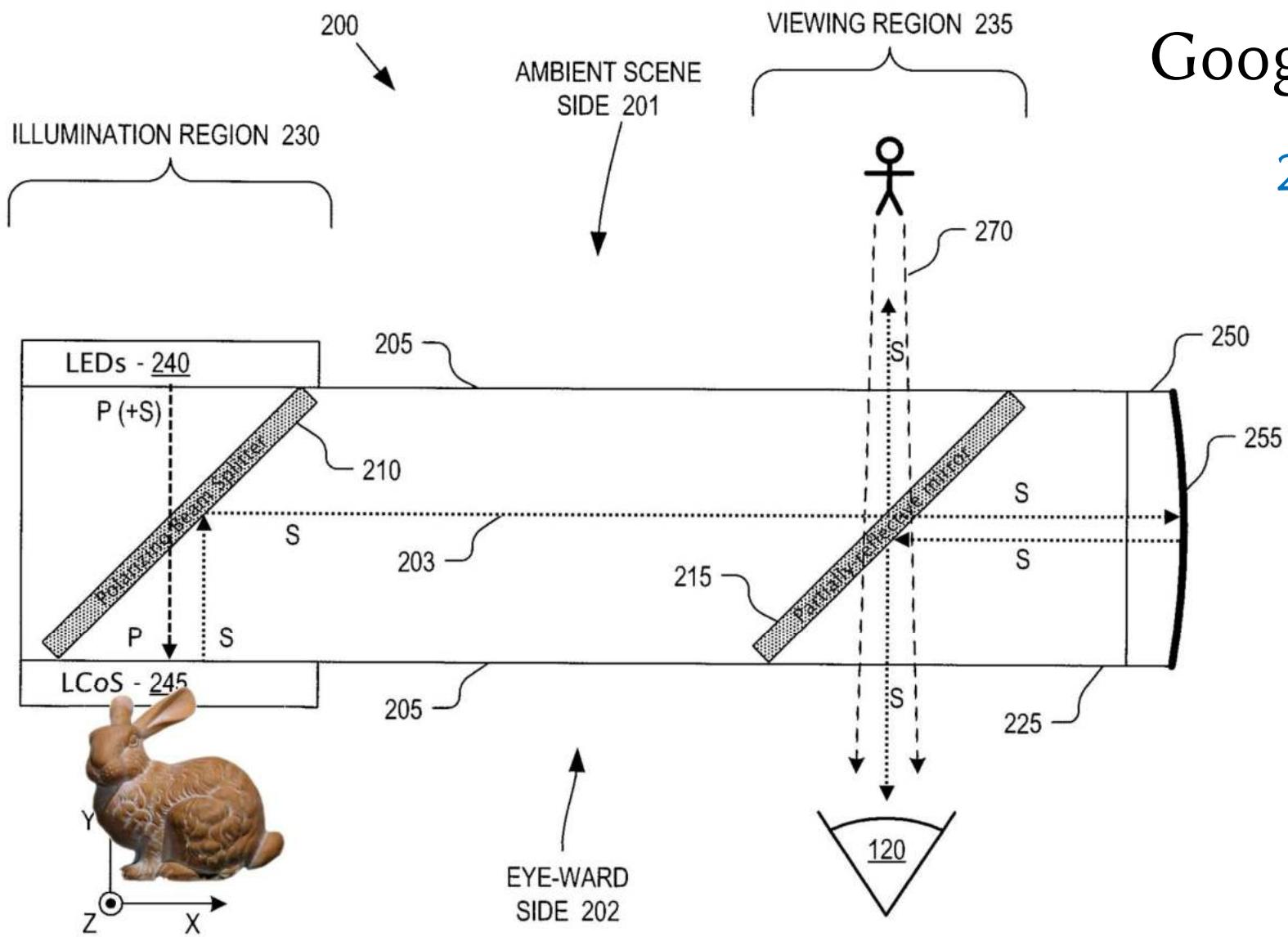


Images borrowed from public domain

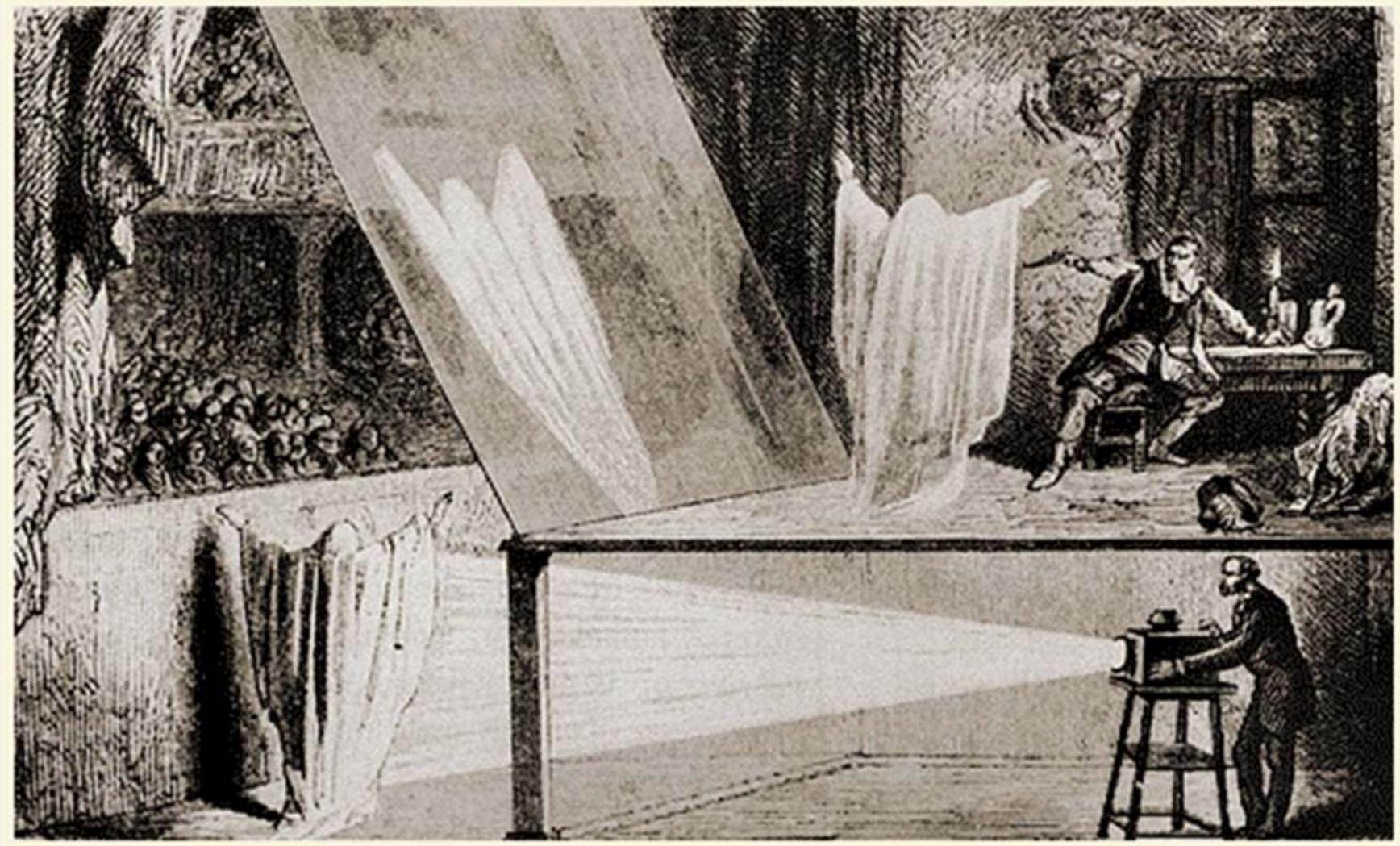
HKU

Google Glass

2010s



See-through AR Displays - *Pepper's Ghost* 1862



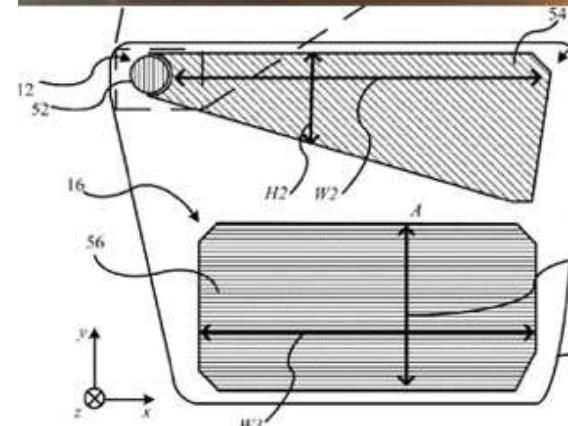
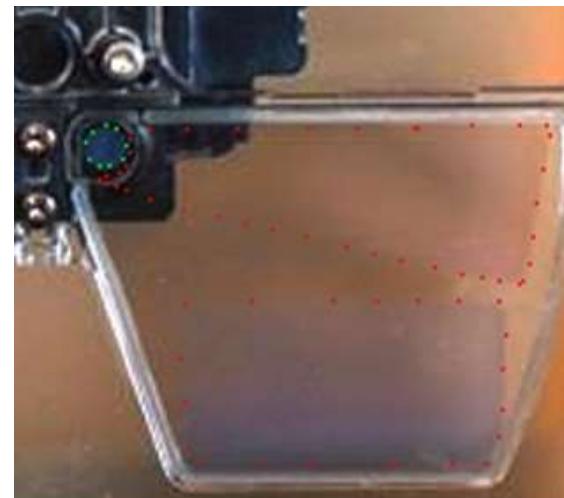
See-through AR Displays - *Waveguides*



Microsoft HoloLens

MS HoloLens 1

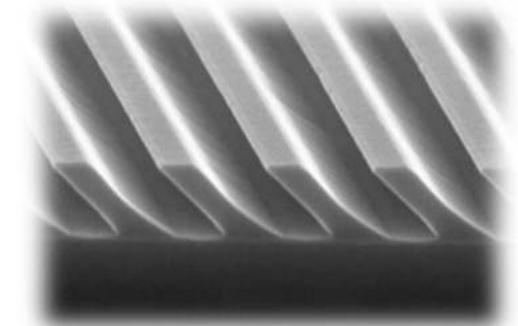
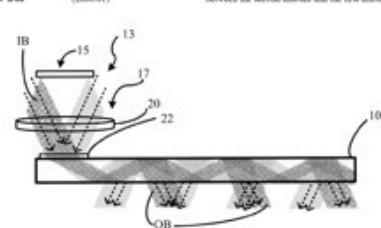
- diffraction grating (SRG)
- small FOV ($30^\circ \times 17^\circ$),
but good image quality



US 2016/0231568

Fig. 3B

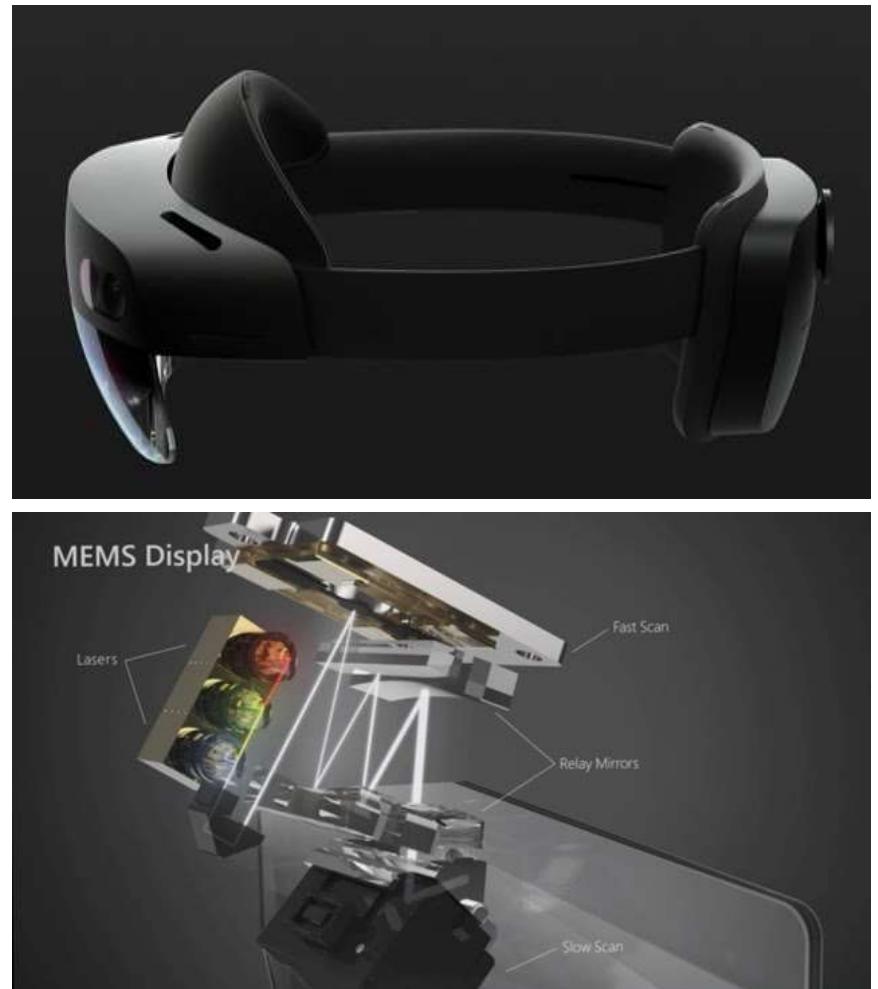
(19) United States	(20) Pub. No.: US 2016/0231568 A1
(12) Patent Application Publication	(43) Pub. Date: Aug. 11, 2016
Saarikko et al.	
(54) WAVEGUIDE	(52) U.S. CL.
(71) Applicant: Microsoft Technology Licensing, LLC, Redmond, WA (US)	CPC: G02B 27/077 (2013.06); G02B 6/008 (2013.06); G02B 5/642 (2013.06); G02B 2027/07 (2013.06); G02B 2027/0778 (2013.06)
(72) Inventor: Pekka Saarikko, Espoo (FI); Pasi Kontamo, Espoo (FI)	
(21) Appl. No. 14/607,897	
(22) Filed: Feb. 9, 2015	
	Publication Classification
(51) Int. CL. G02B 27/07 G02B 5/64 F21F 8/00	(2006.01) (2006.01) (2006.01)



Images borrowed from public domain

MS HoloLens 2

- laser-scanning waveguide display
- claimed 2K resolution per eye (2,560x1,440), probably via “interlaced” scanning
- field of view: 52° diagonally (3:2 aspect, 47 pixels per visual degree)
- far from sufficient...



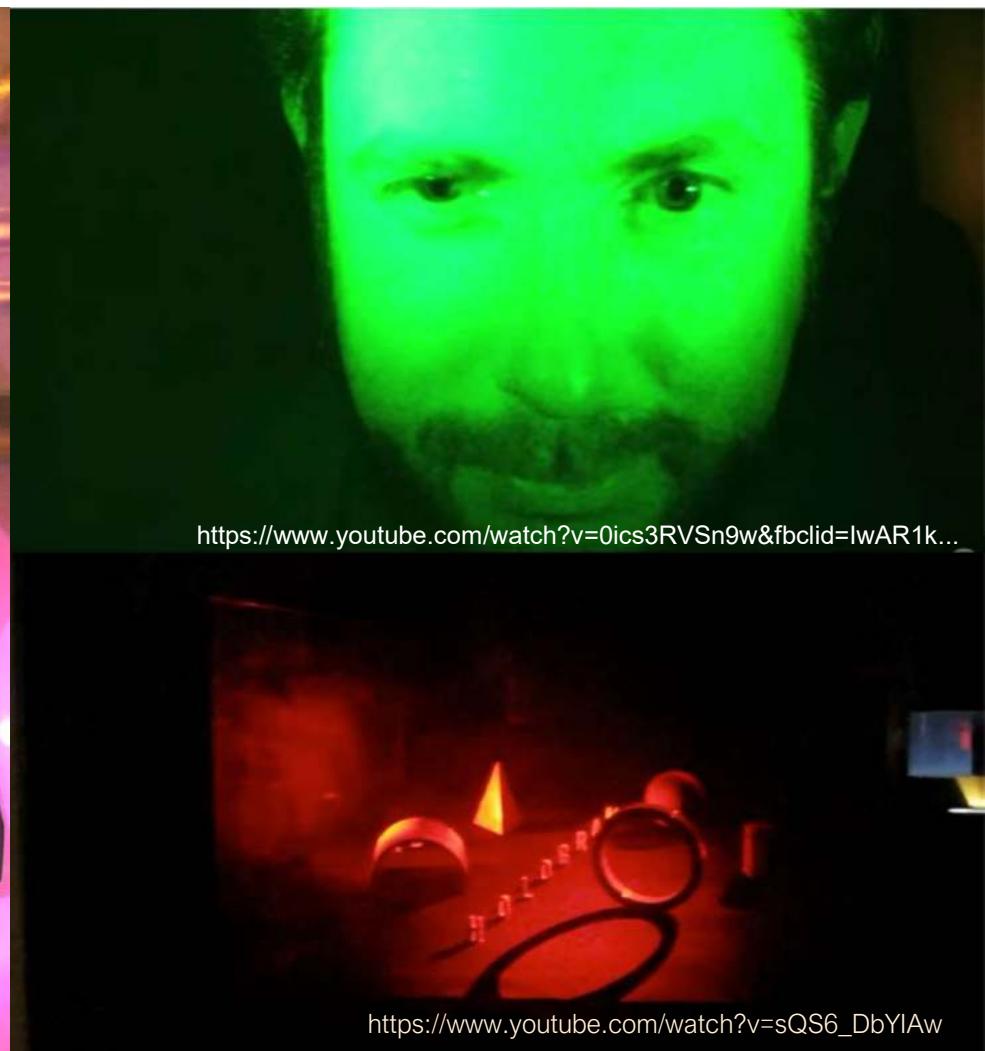
Images borrowed from public domain



What's Next



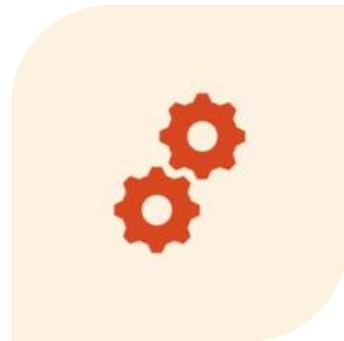
Holographic Displays (Holograms)



Time-multiplexed Neural Holography: Flexible CGH Framework with Natural Defocus (*SIGGRAPH 22'*, Stanford's work)



Computational Displays: Bridging the Disciplines



COMPUTER
SCIENCE /
OPTIMIZATION



ELECTRONICS /
DEVICES /
SENSORS



OPTICS /
PHOTONICS /
HUMAN VISION



WeChat Official Account: *IntelligentOptics*

Intelligent Optics Sharing

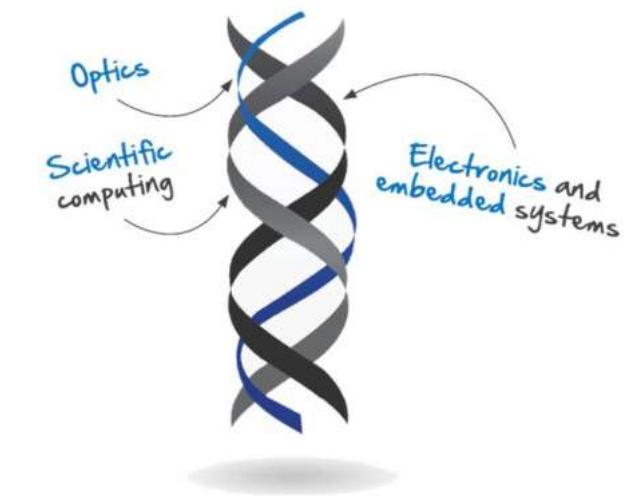


感知 | 计算

Web: eee.hku.hk/~evanpeng/



Thank
You



Thank
You

