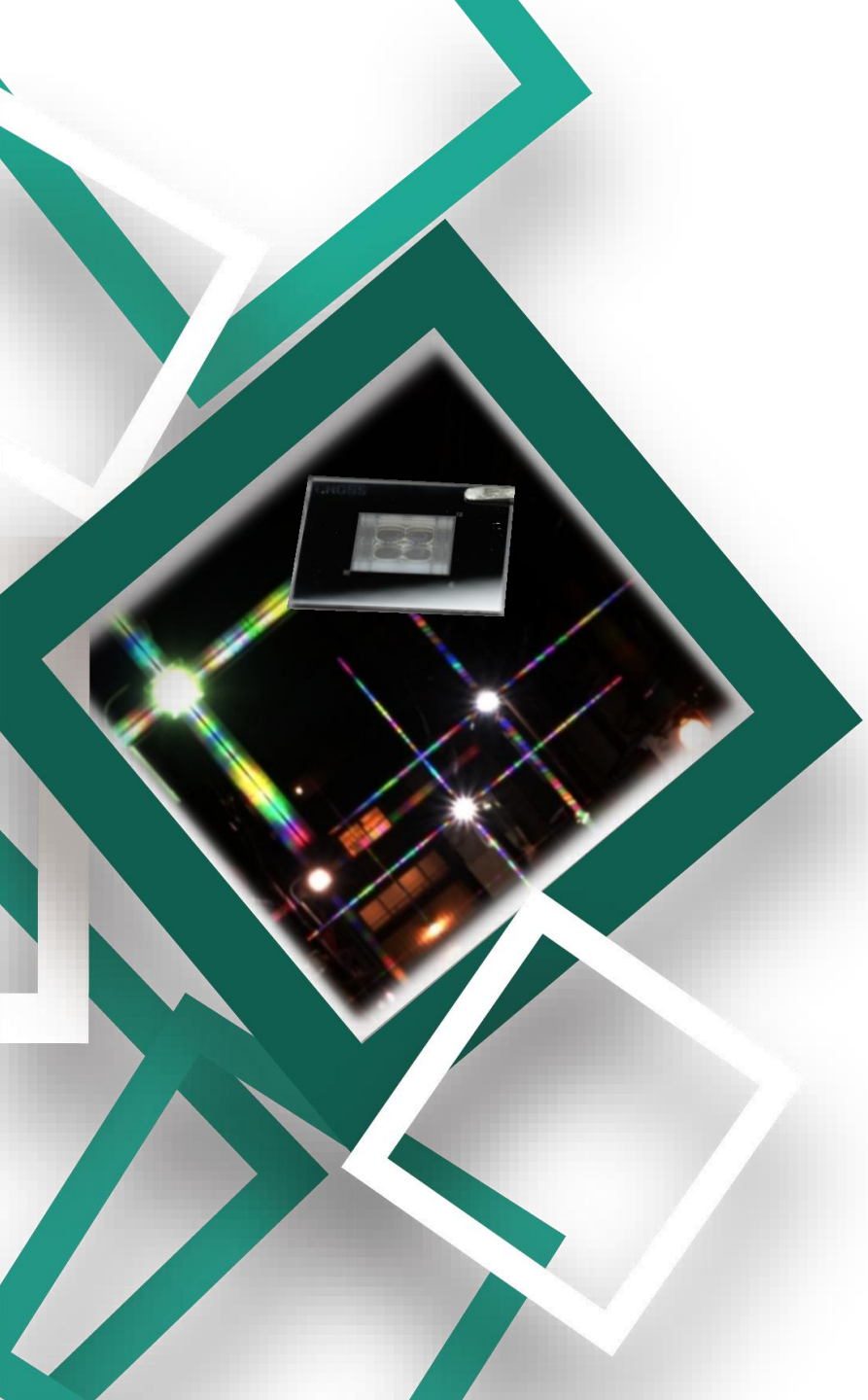
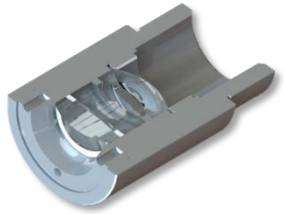
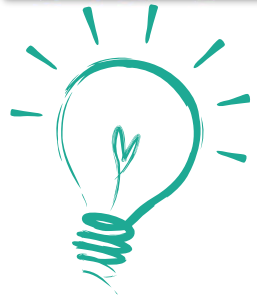






Computational Imaging

Lecture 07: Display Tech, for VR/AR - Introductory

Qilin Sun（孙启霖）

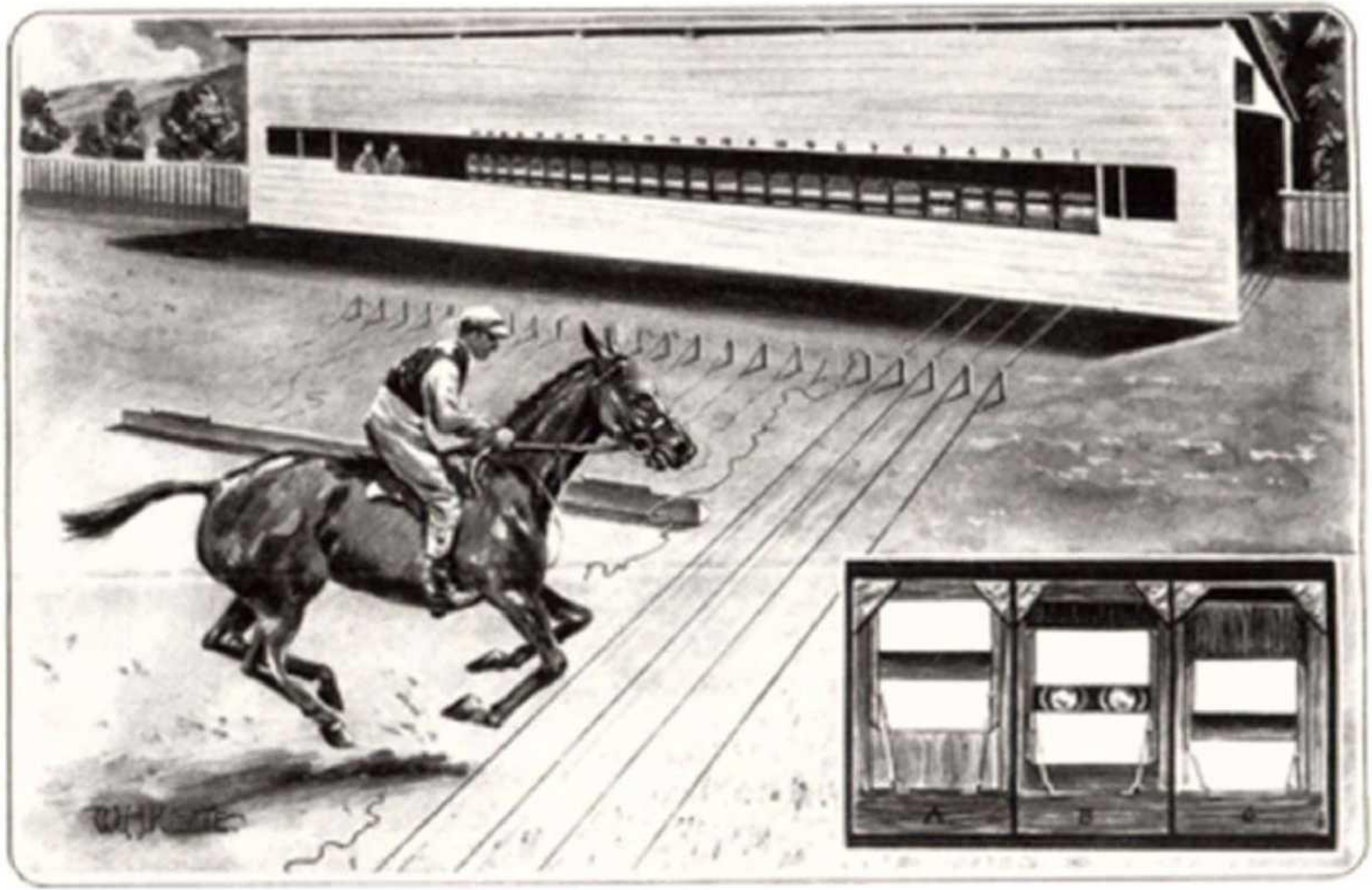
School of Data Science

The Chinese University of Hong Kong, Shenzhen

- What's Display
- Projectors Are Alternative
- Would Metaverse Really Come
- Virtual Reality
- Augmented Reality
- What's Next

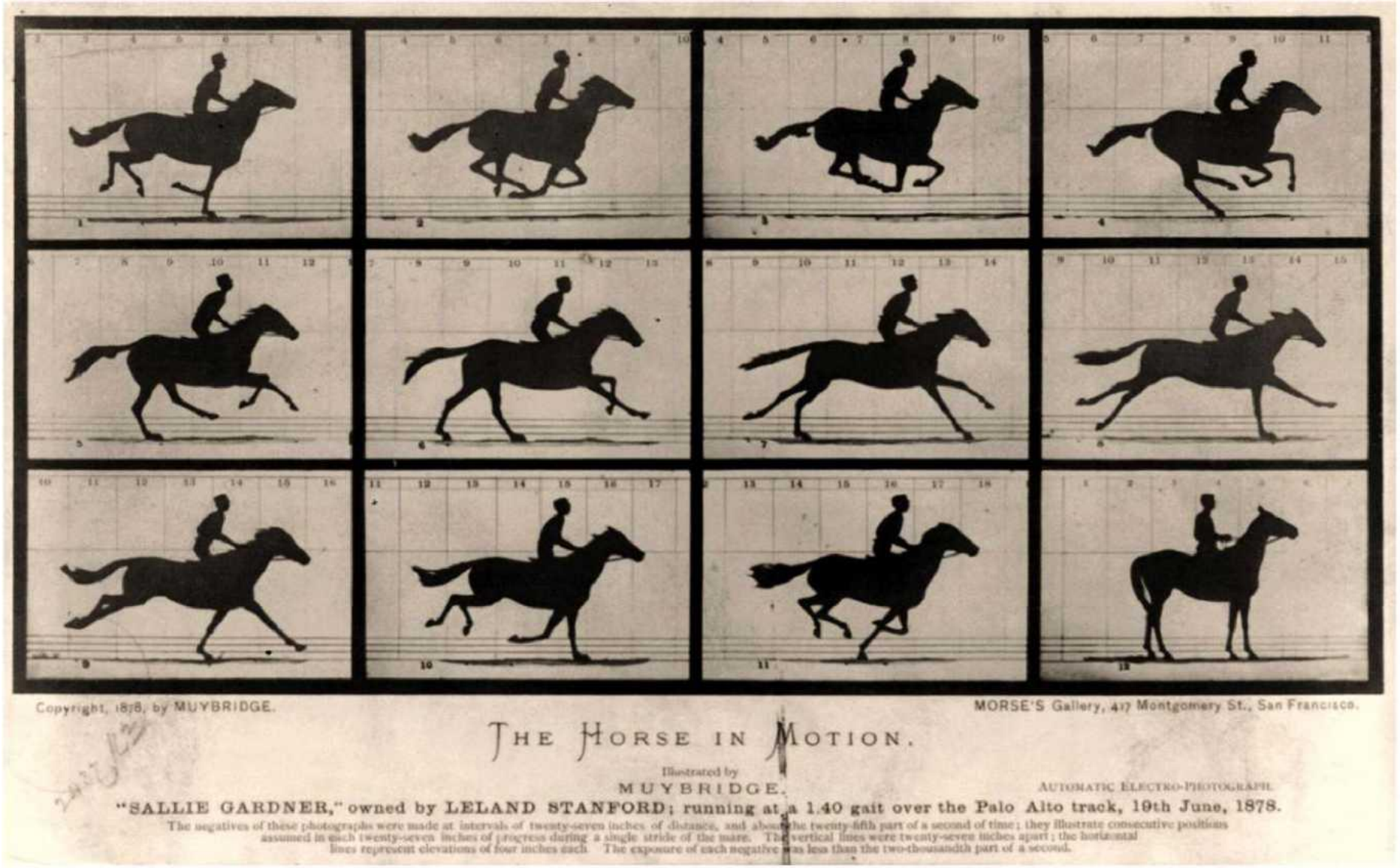
What's Display

Historical Multi-Camera Array at Stanford



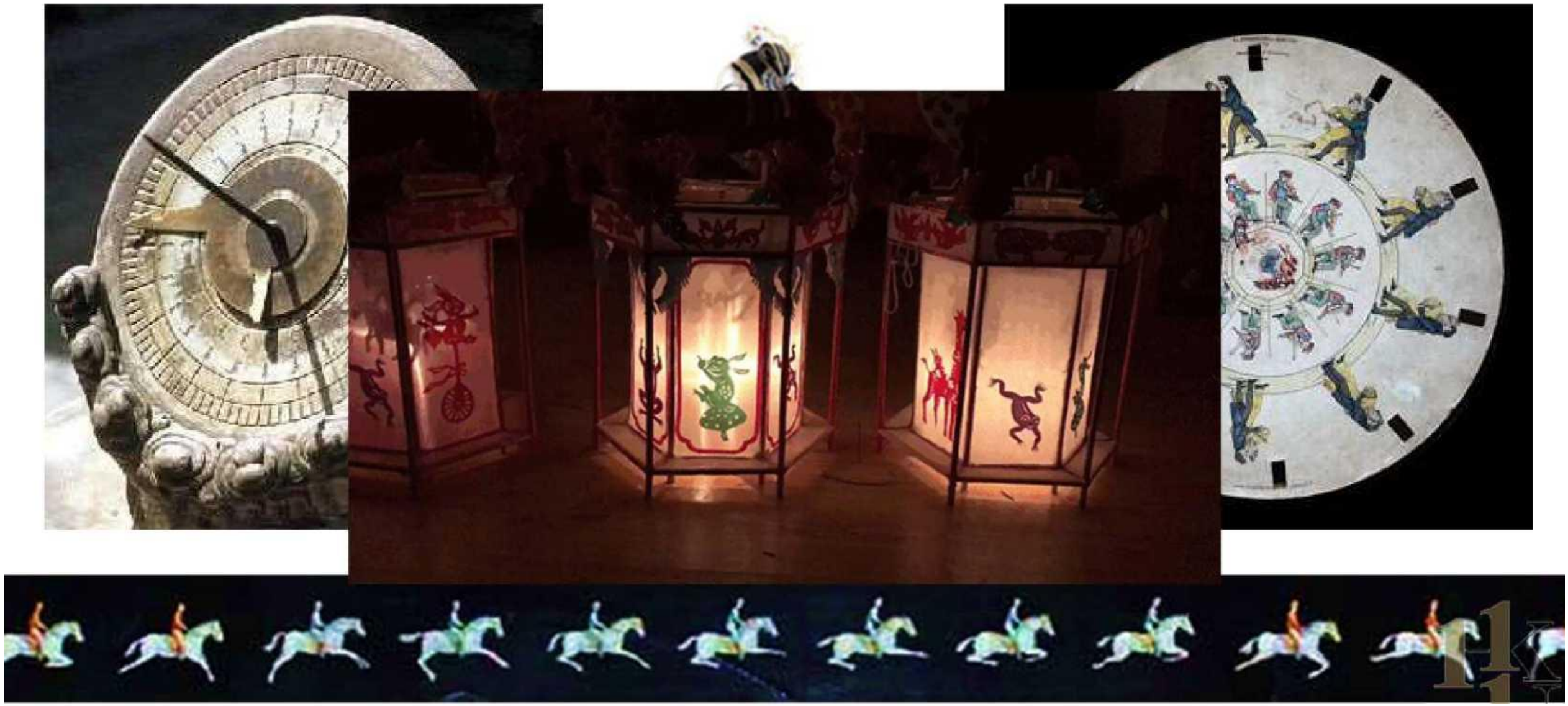
Images borrowed from public domain

Historical Multi-Camera Array at Stanford



Images borrowed from public domain

Historical Chinese "Displays"



Images borrowed from public domain

Defination

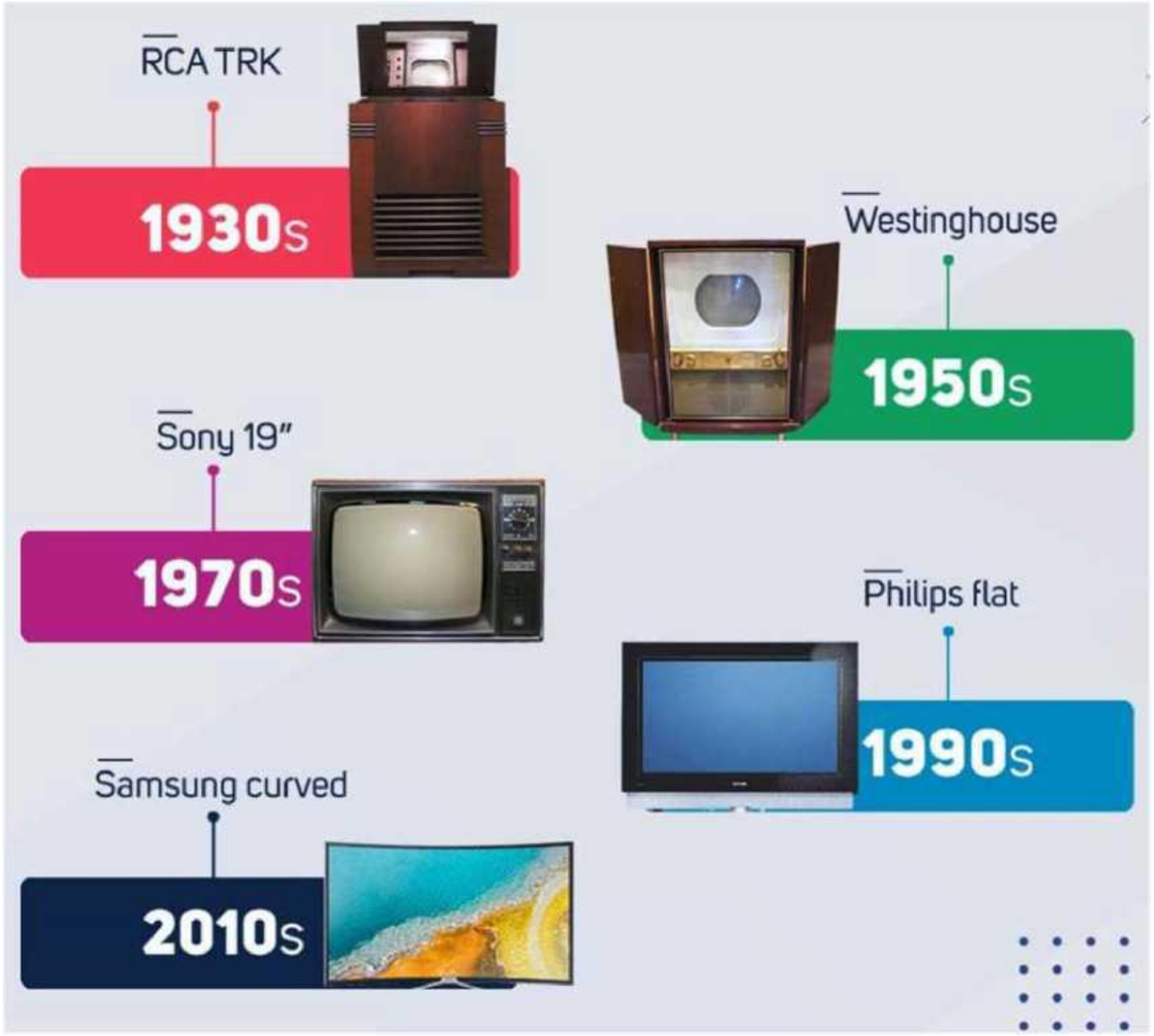
dis·pl·ay

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

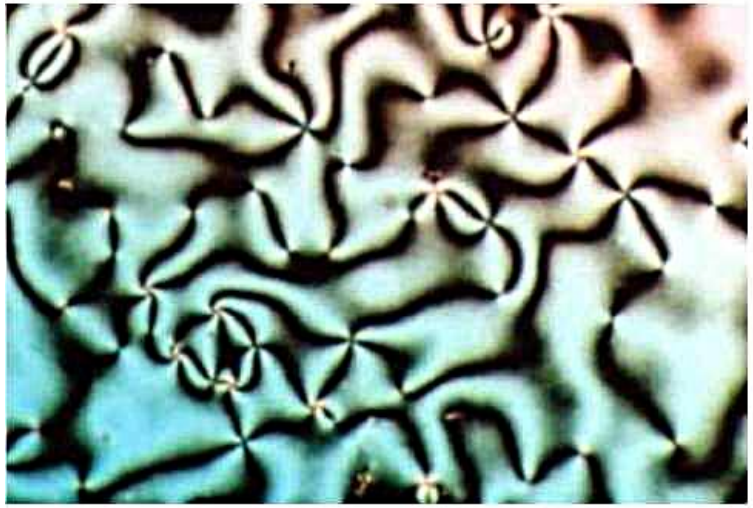
Modern Information Displays

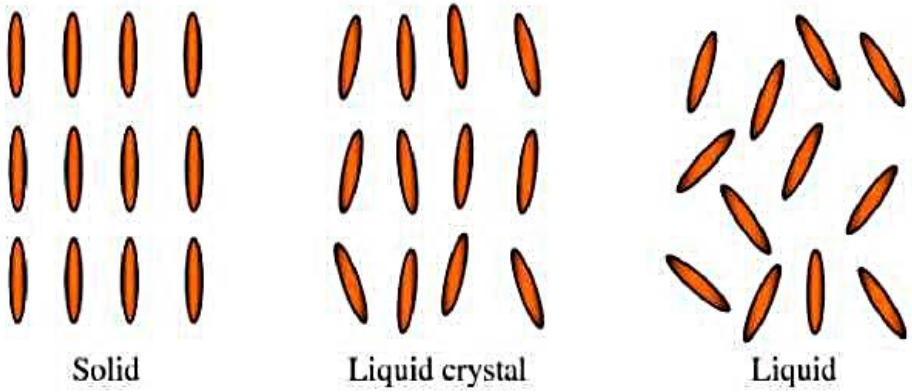
- CRT(cathode-ray tube)
- Flat Panel Displays
  - EL(ElectroLuminescent)
  - PDP(plasma display panel)
  - LCD(liquid-crystal display)
  - OLED (organic light-emitting diode)
- Projection

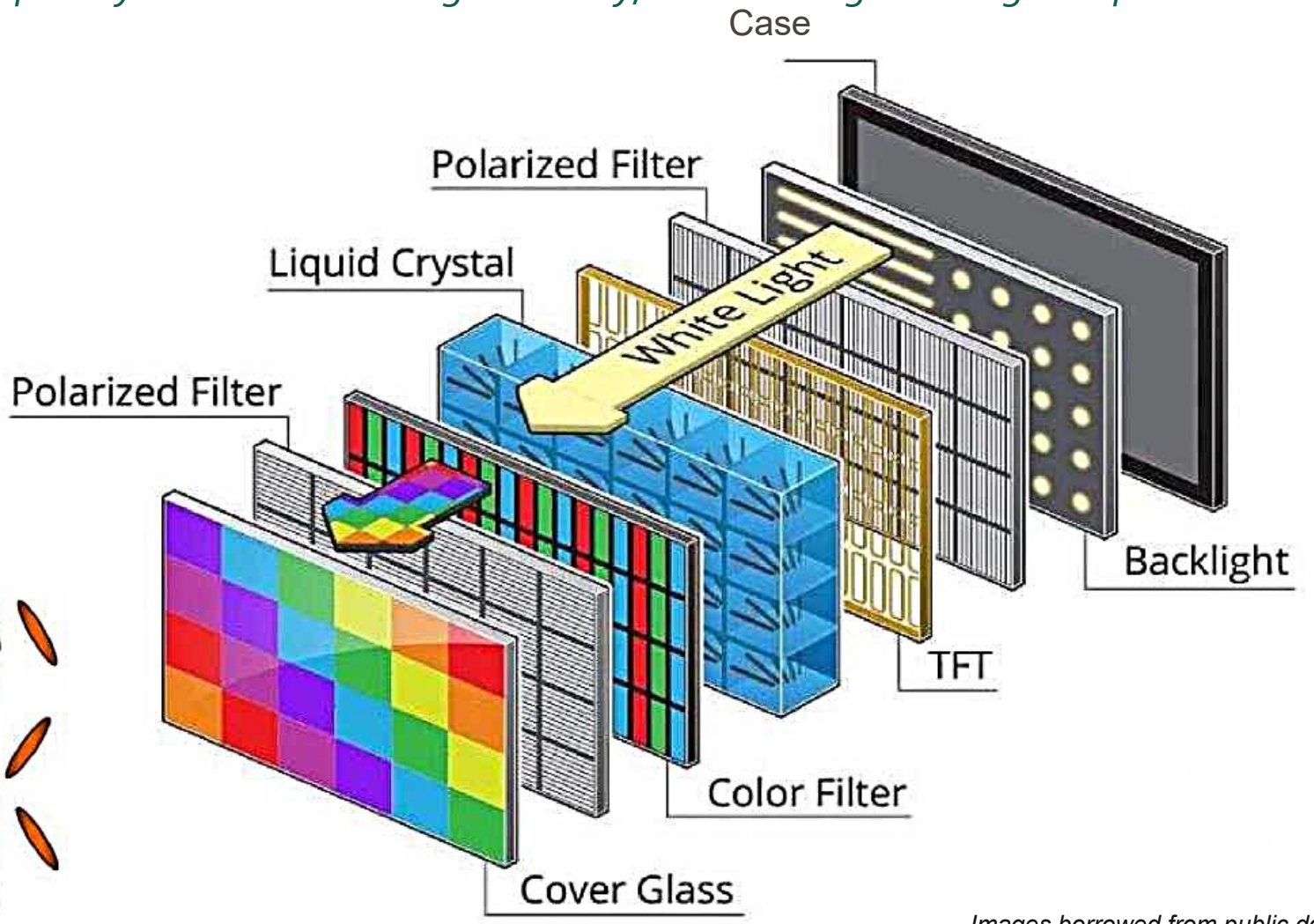
Images borrowed from public domain

LCD Everywhere

a flat-panel display or other electronically modulated optical device that uses the ligh t-modula ting 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.

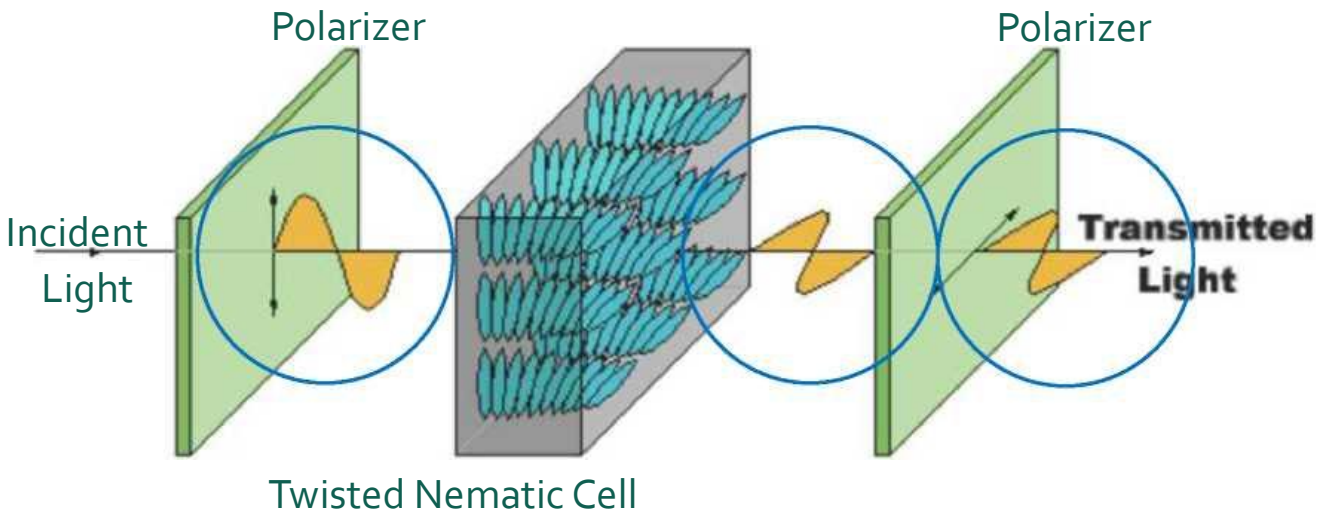




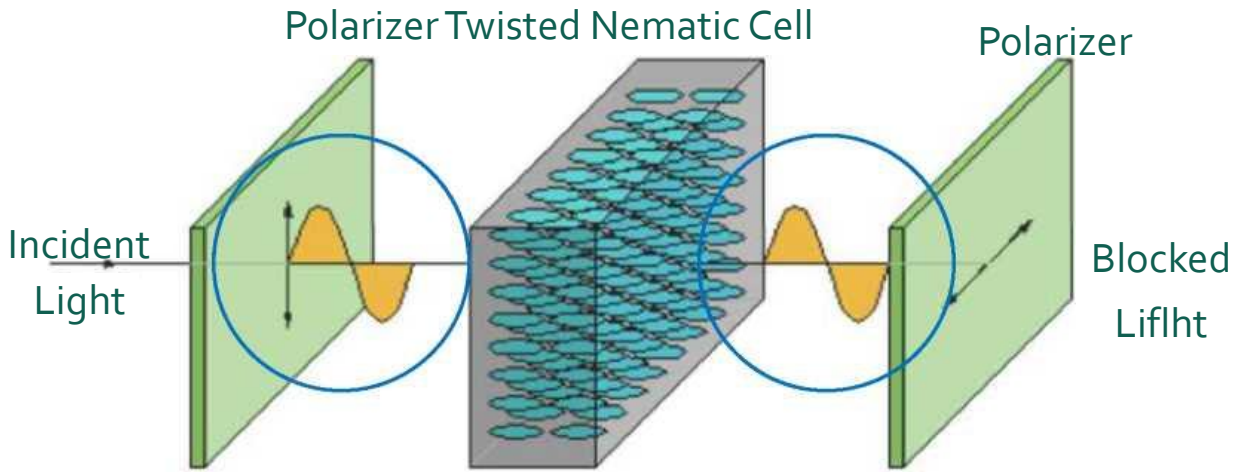


Images borrowed from public domain

Working Example： TN LCD Panel

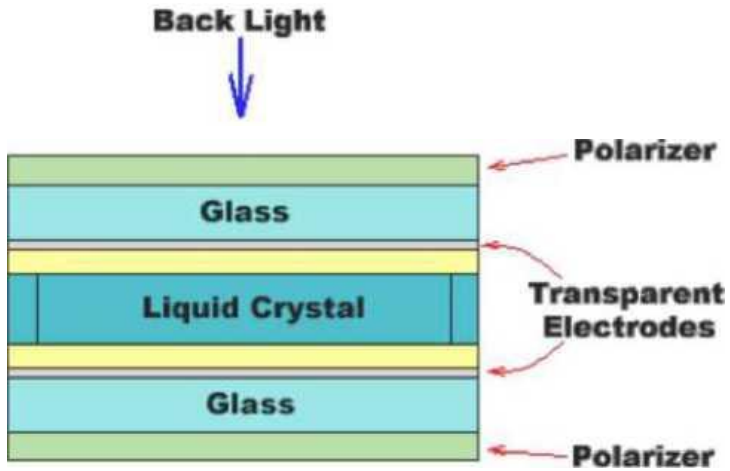


Twisted Nematic Cell



Electric Field

I Molecular Orientation Layers



Images borrowed from public domain

When Buying a Monitor

Panel Type

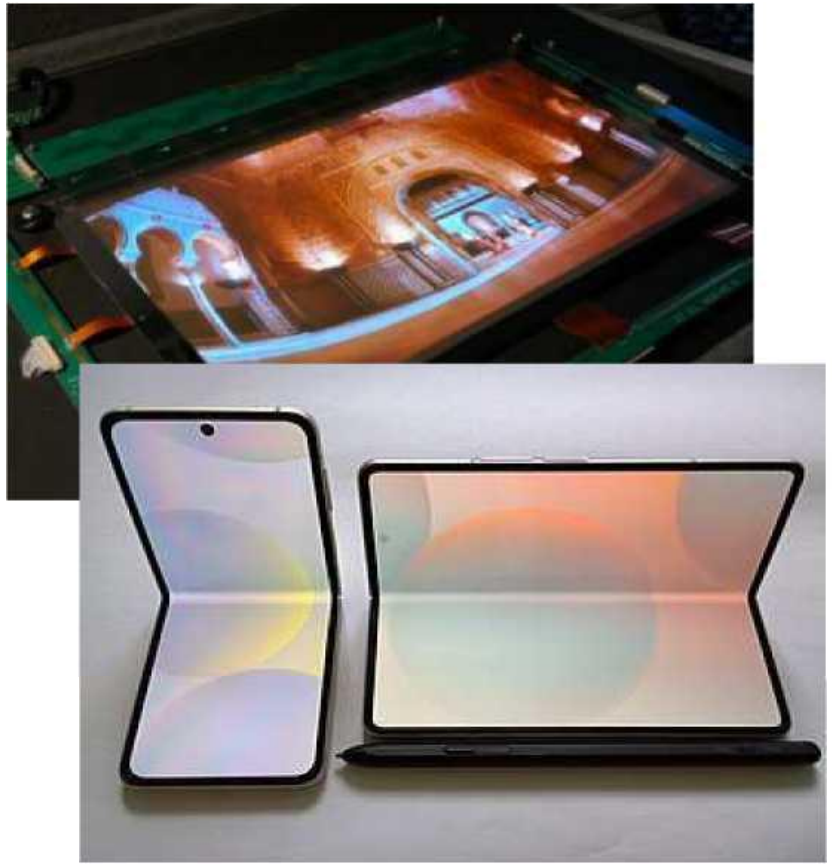
	TN	VA	IPS
Response Time	<1ms	4-5ms	1-2ms
Color	Poor	Good	Best
Contrast	Good 1000:1	Best 3000:1	Good 1000:1
Viewing Angle	170/160	178/178	178/178

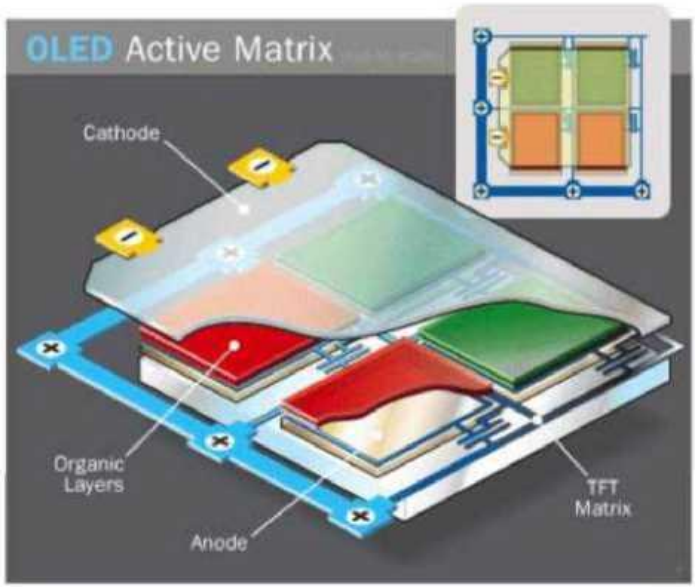
Images borrowed from public domain

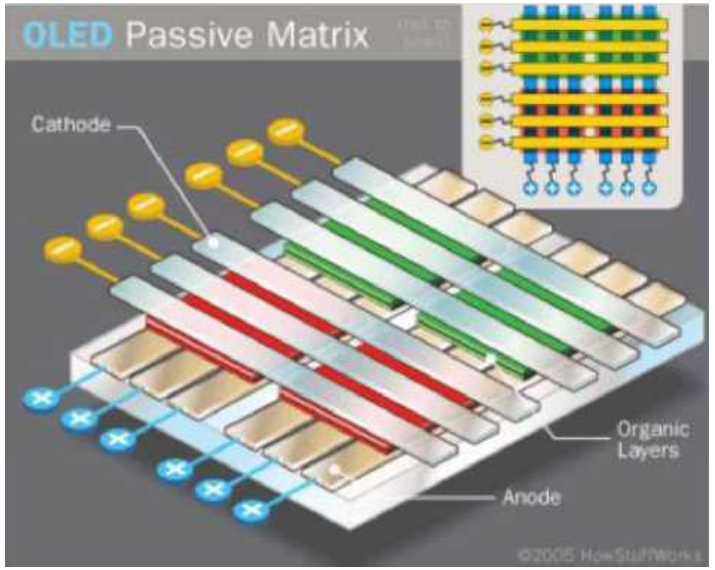
QLED： Quantum Dot Backlight

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.







LCD v.s. OLED

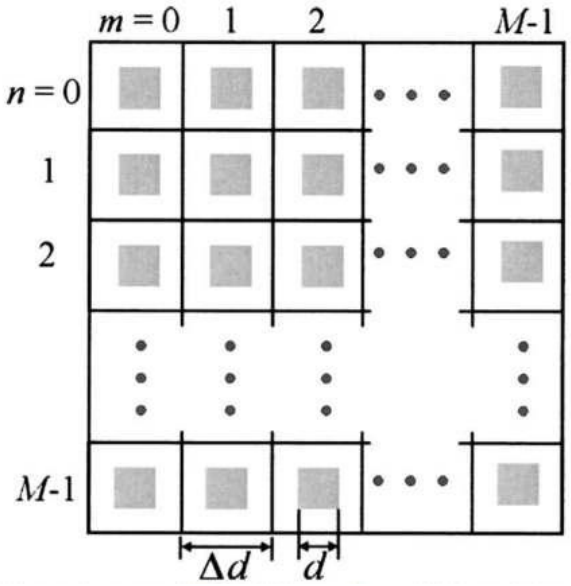
Structure | LCD(LED) OLED | Structure

Passive (BLU needed) Self-emissive

Limited contrast but lower cost Great light efficiency and contrast but higher cost

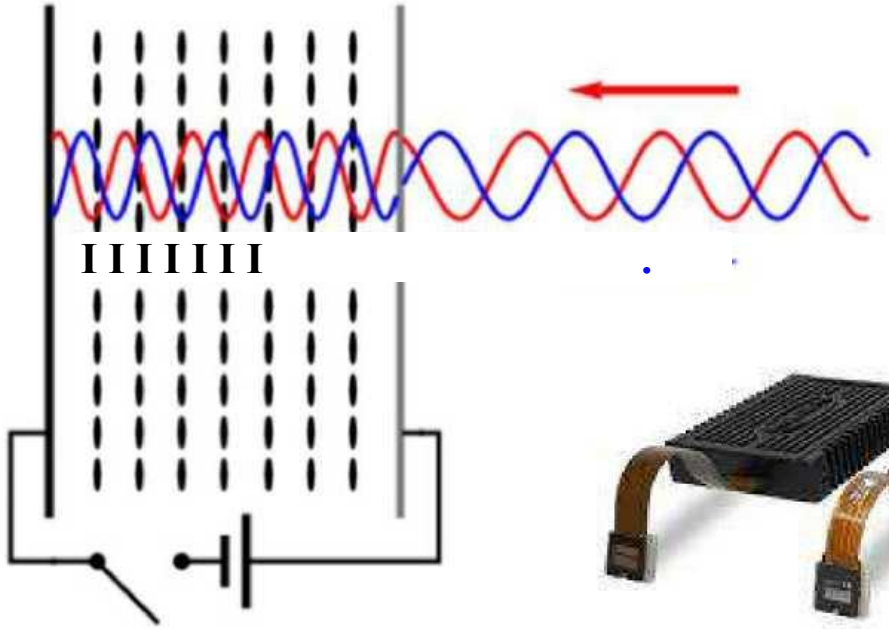
Projectors Are Alternative

SLMs for Shaping Light



Geometry of the M x M phase-only spatial light modulator with a square pixel length d while M 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

HOLOEYE

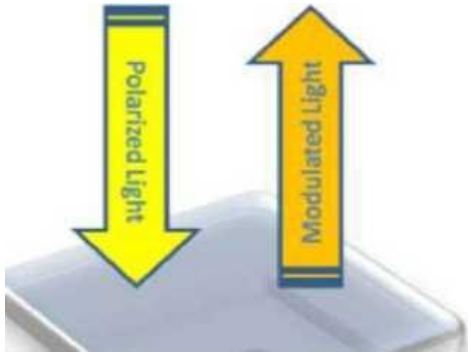
santec

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.



Glass Layer

Transparent Layer

Alignment Layer

Liquid Crystal Layer

Reflective Layer

CMOS

Control Layer

Basically, a reflective LCD

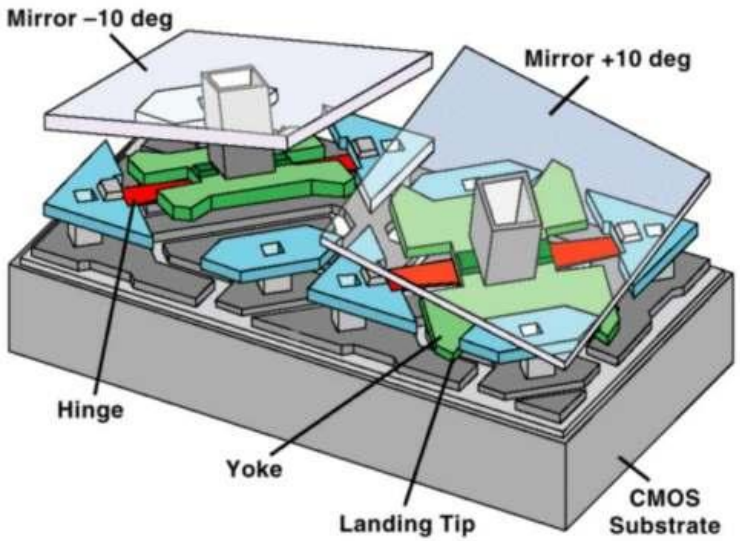
Standard component in projectors and head-mounted displays, e.g., google glass

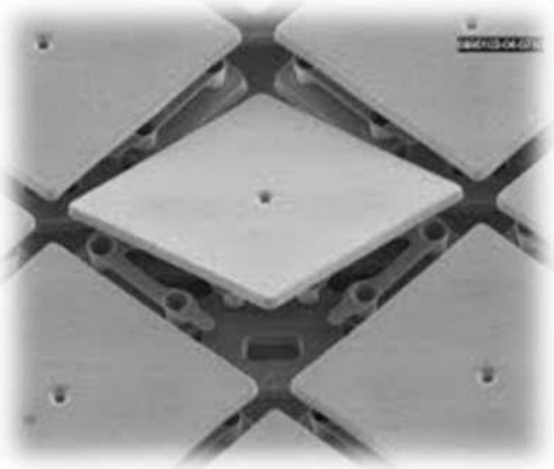
Without the 2nd polarizer: phase modulation device

Images borrowed from public domain

SLM: Digital Micromirror Device (DMD)

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





MEMS device

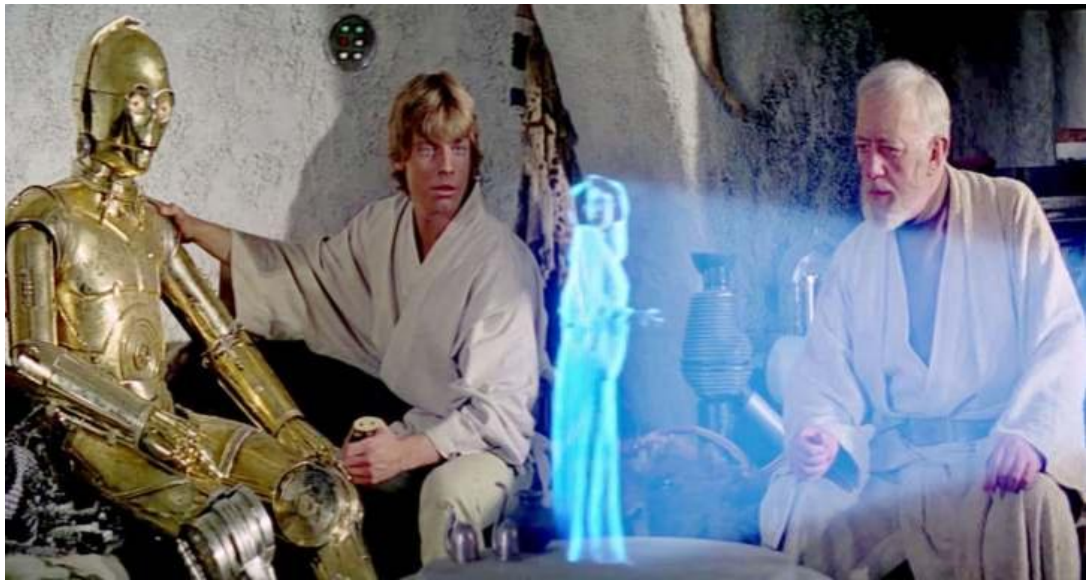
- Binary states (+/- 10 deg.)
- Grayscale via pulse width modulation (PWM)

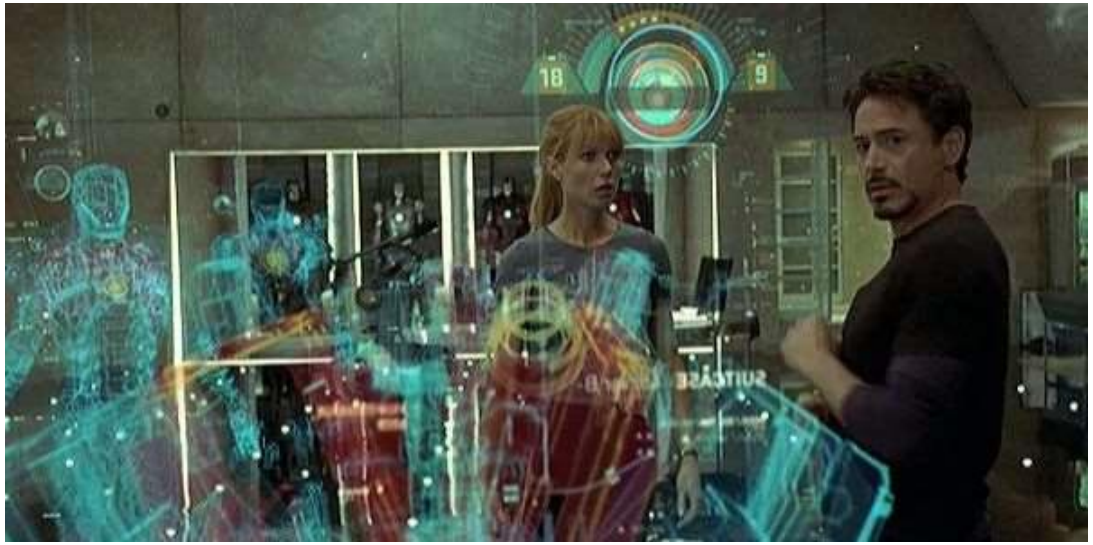
DLP®
TEXAS INSTRUMENTS

Images borrowed from public domain

Would Metaverse Really Come

Metaverse





Future Display and Visualization Scenarios

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

vir·tu·al re·al·i·ty
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.

image from NAE

Message from National Academy of Engineering

"Enhance Virtual Reality[55] is 1 of 14 grand challenges for engineering in the 21st century

Raster File Formats

Fun" Engineering Aspects of VR/AR

- HCI
- applications

- CPU, GPU
- IPU, DPU?

cloud computing

shared experiences

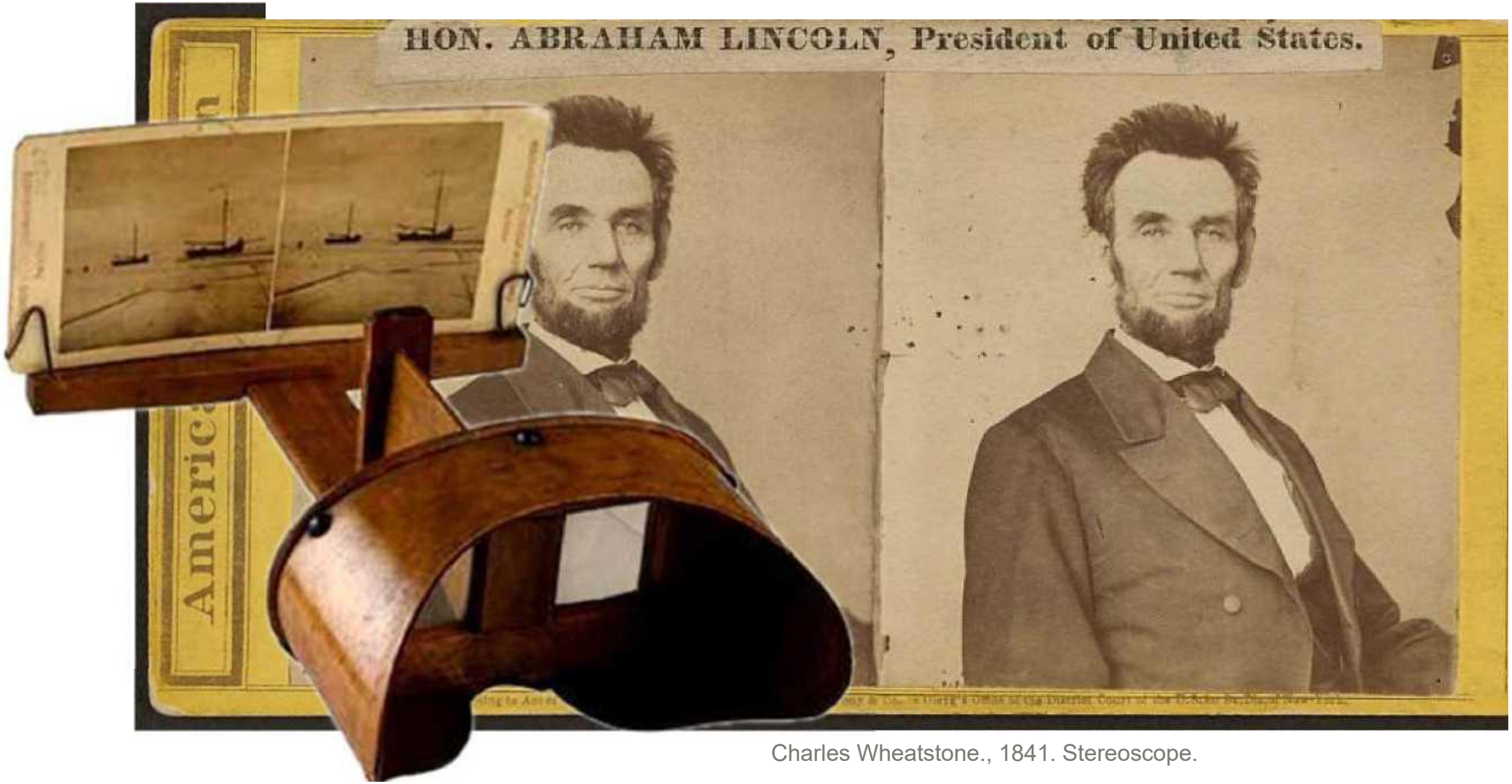
- sensors & imaging
- computer vision
- scene understanding

- VR cameras
- Compression, streaming

- photonics / waveguides
- human perception
- displays: visual, auditory, haptic, …

Where We Want It To Be

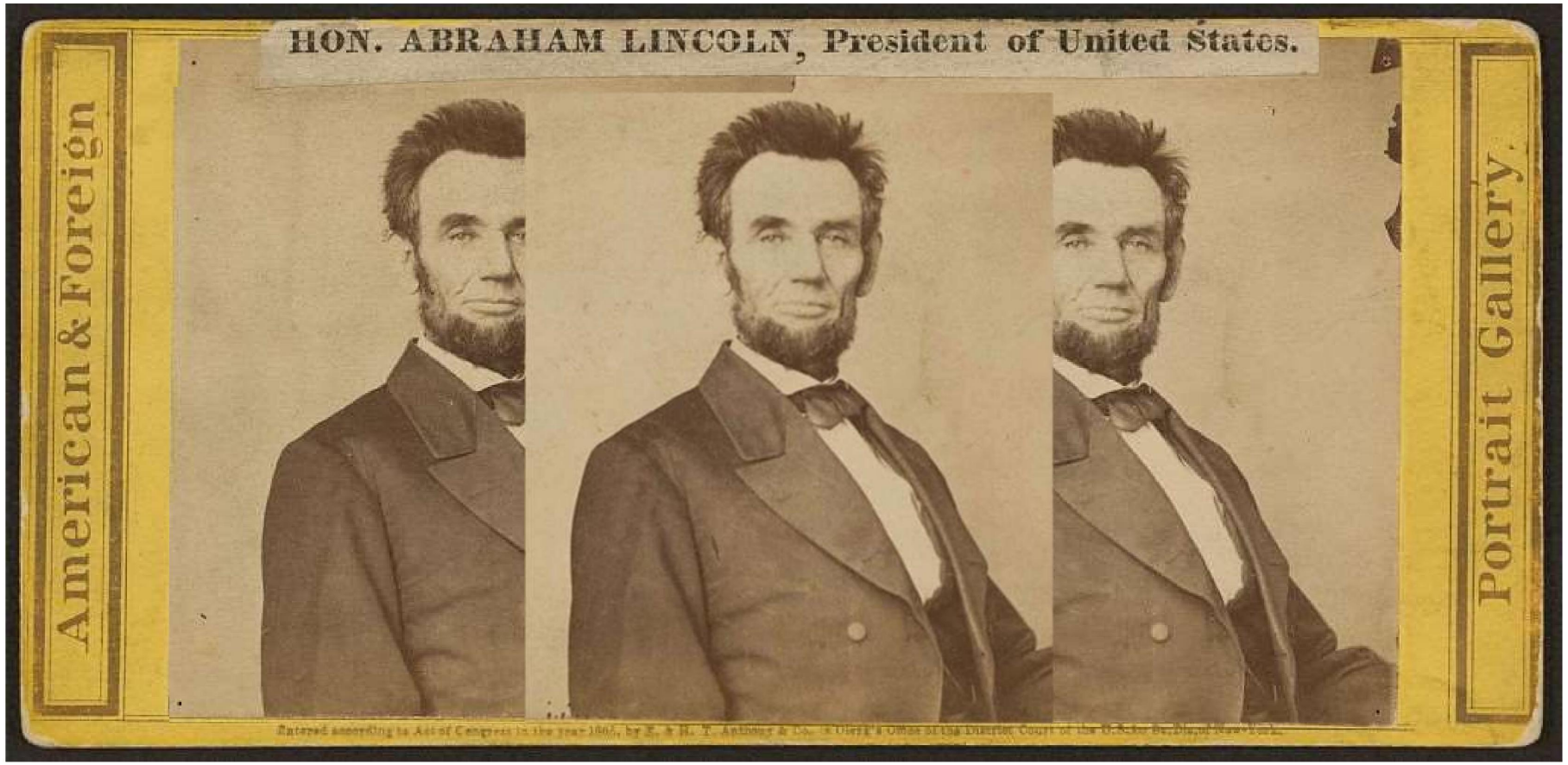
Stereoscopic Displays



Charles Wheatstone., 1841. Stereoscope.

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

Stereoscopic Displays



Charles Wheatstone., 1841. Stereoscope.

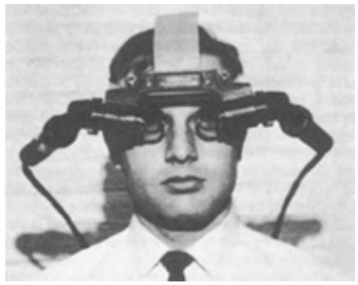
Walker, Lewis E., 1865. Hon. Abraham Lincoln, President of the United States. Library of Congi

A Brief History of Virtual Reality

香港中文大學(深圳)
The Chinese University of Hong Kong, Shenzhen

Stereoscopes
Wheatstone, Brewster, ...

VR & AR
Ivan Sutherland



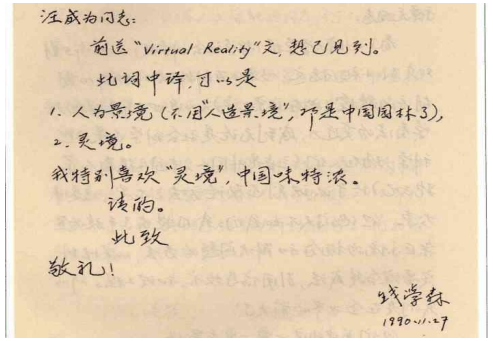
Nintendo Virtual Boy

VR explosion
Oculus, Sony, HTC, MS, ...

???

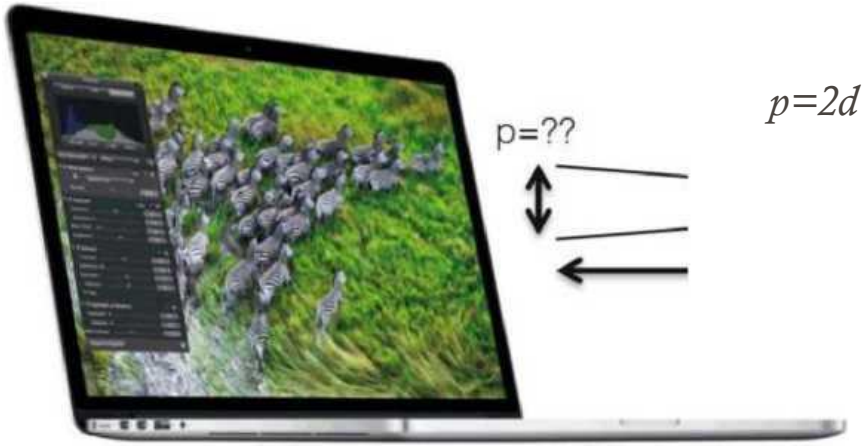
1838 1968 1995 2012-2022

People's scientist Qian Xuesen once served
in 1990 named
"virtual reality technology"
as "Ling Jing" ("spiritual realm") .



Recall 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 8, degrades with age



$p = 2d \tan(o/2)$

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

Naive Magnifier-type VR Displays

Oculus Rift

Sony Morpheus

DuroVis Dive

VrAse

3D Matters

Zeiss Cinemizer

Avegant Glyph

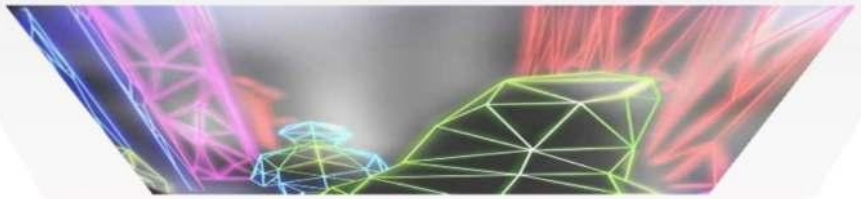
Hasbro My3D

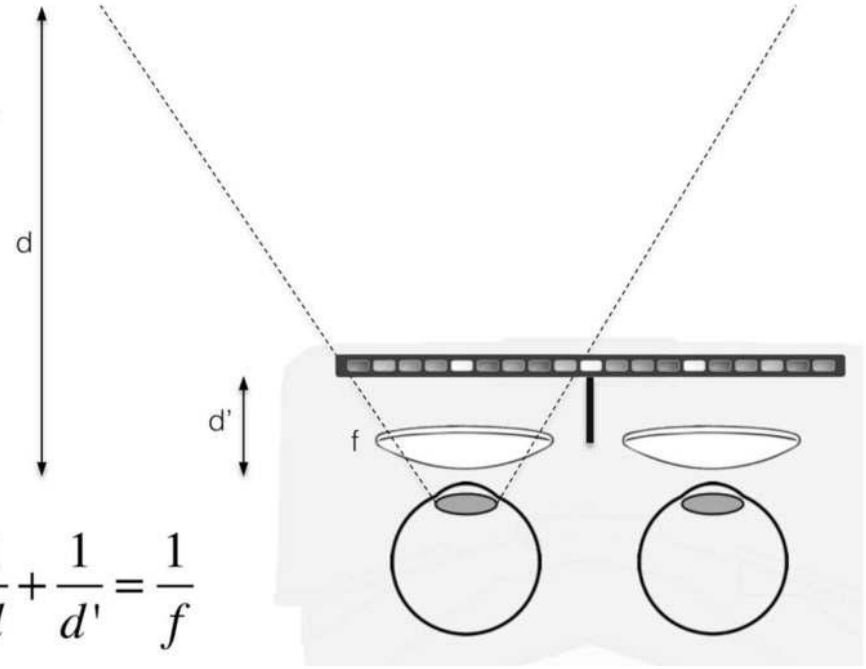
Altergaze

Images borrowed from public domain

Naive Magnifier-type VR Displays

Virtual Image





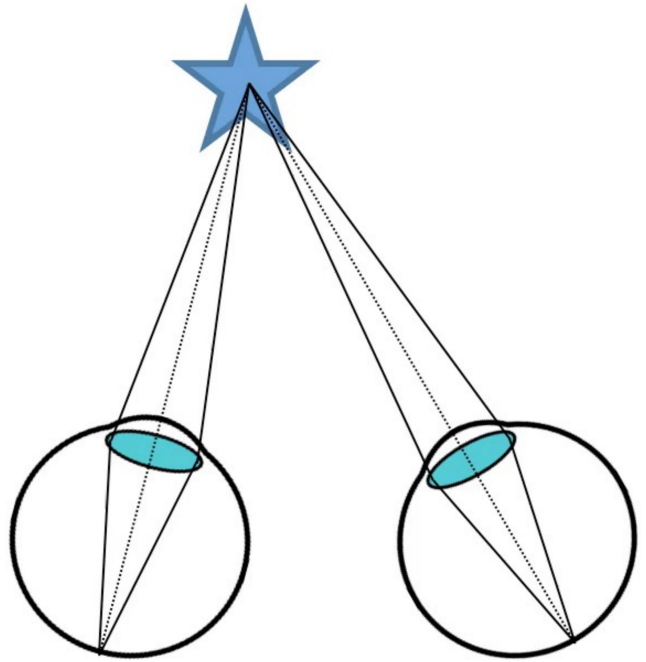
$$\frac{1}{d}+\frac{1}{d'}=\frac{1}{f}$$

- Fixed focal plane
- No focus cues
- Cannot drive accommodation with rendering!

Accommodation – Vergence Conflict

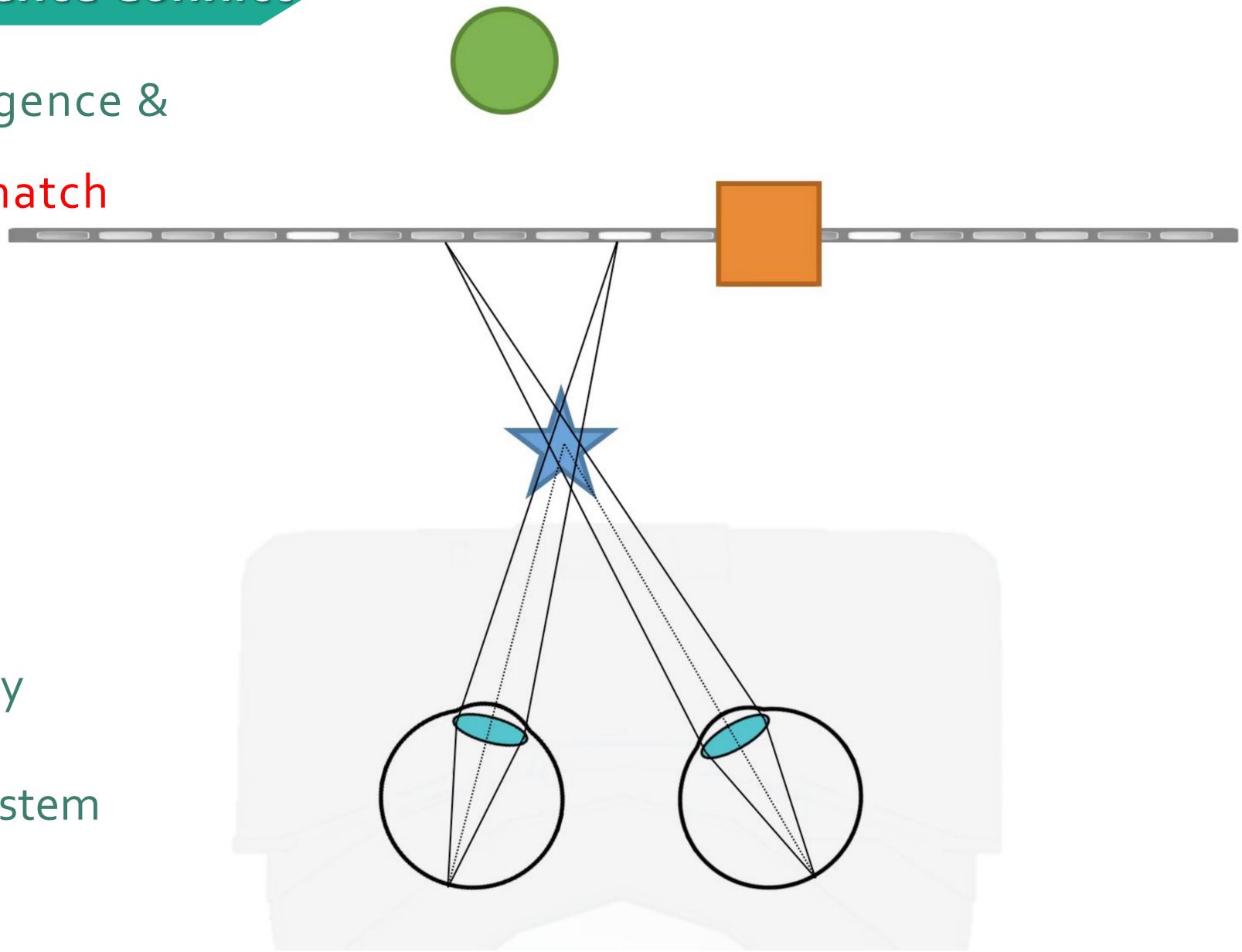
Real World: **Vergence** &

Accommodation Match!



Accommodation – Vergence Conflict

Current VR Displays: Vergence & Accommodation Mismatch



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.

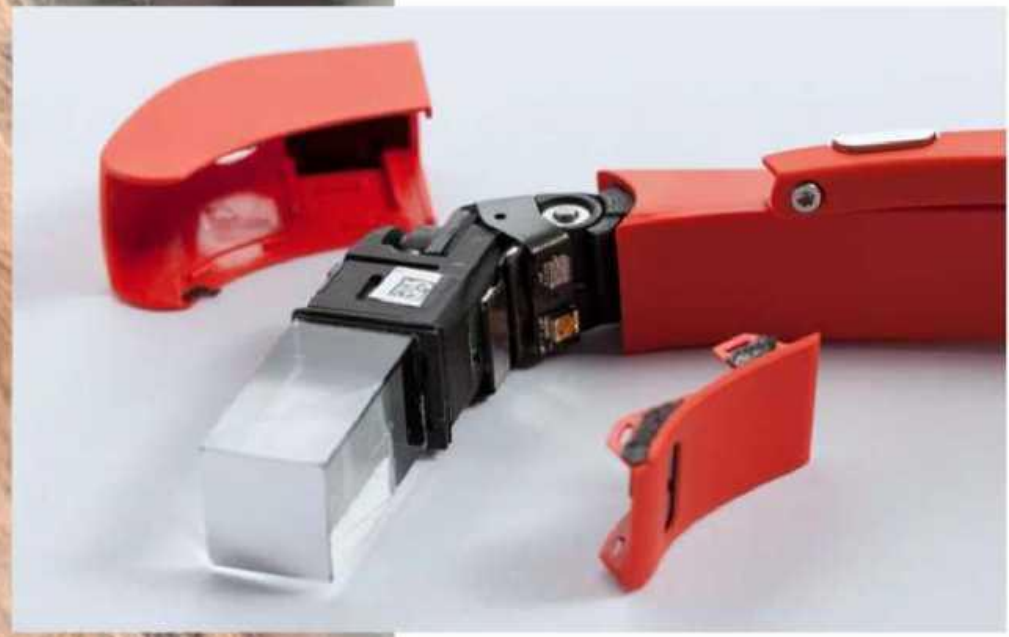
image from NAE

Images borrowed from public domain


Images borrowed from public domain
Microsoft Hololens
Meta 2
Magic Leap One

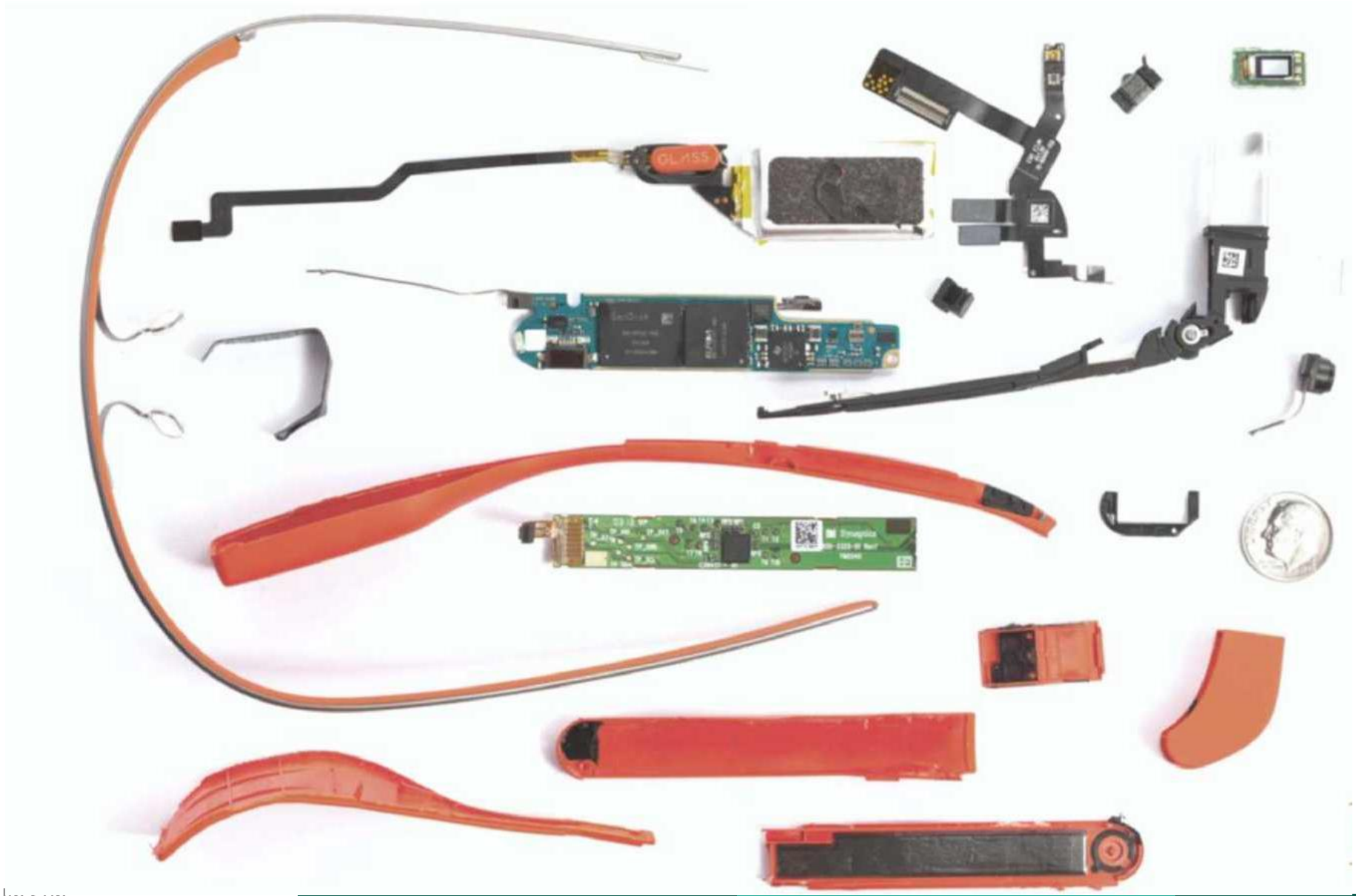
See-through

AR Displays

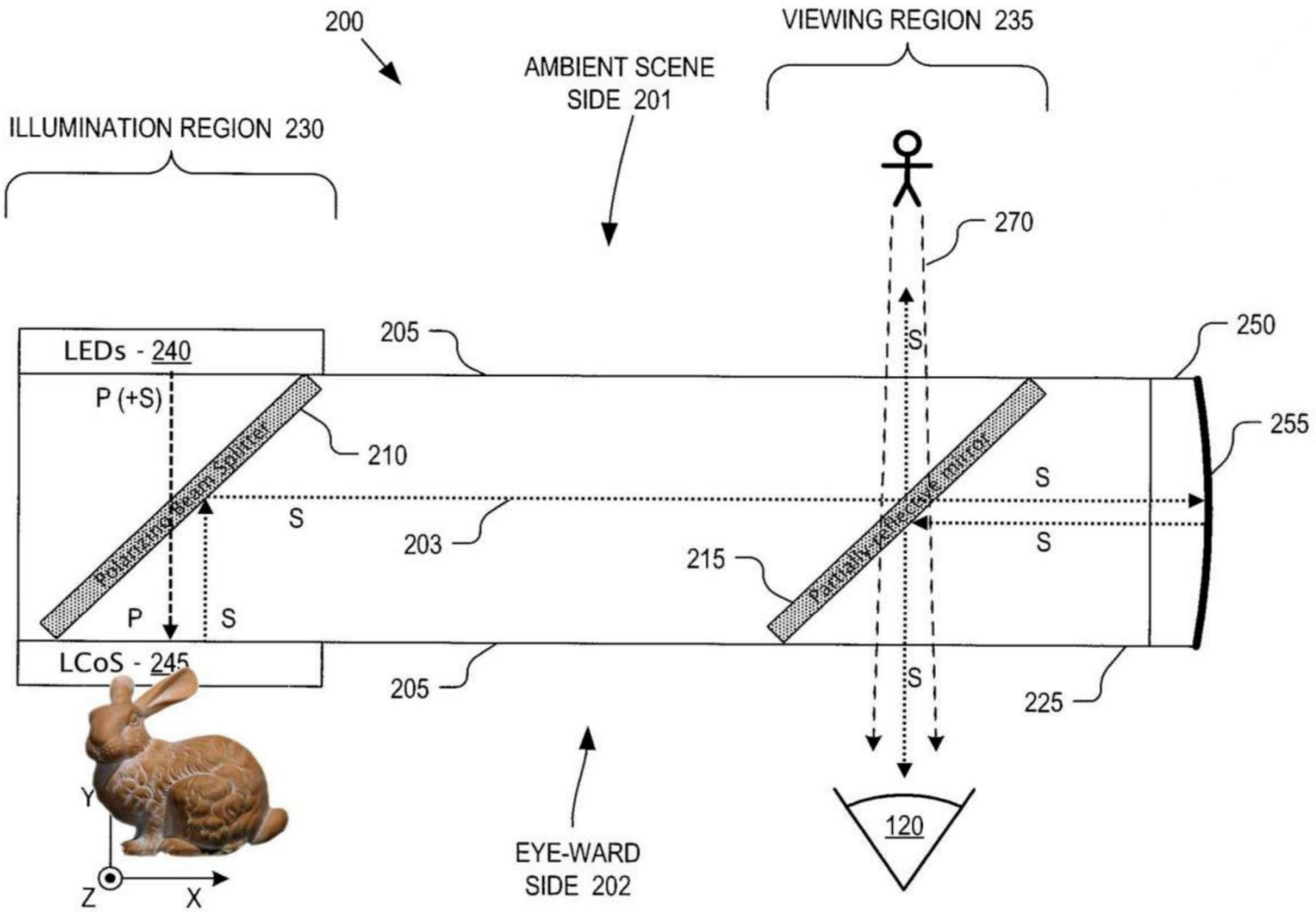


Images borrowed from public domain

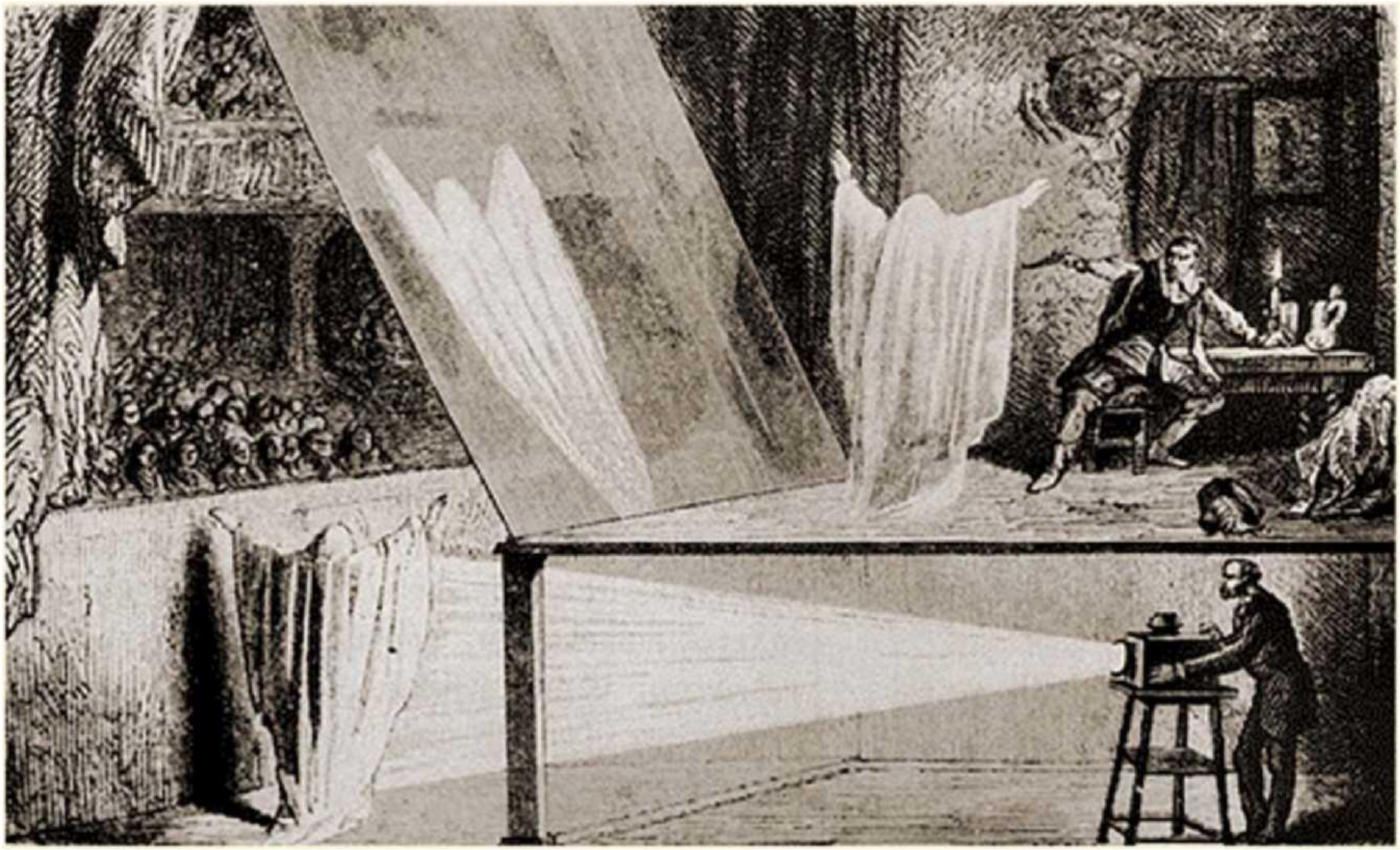
Where We Are Now



Google Glass



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

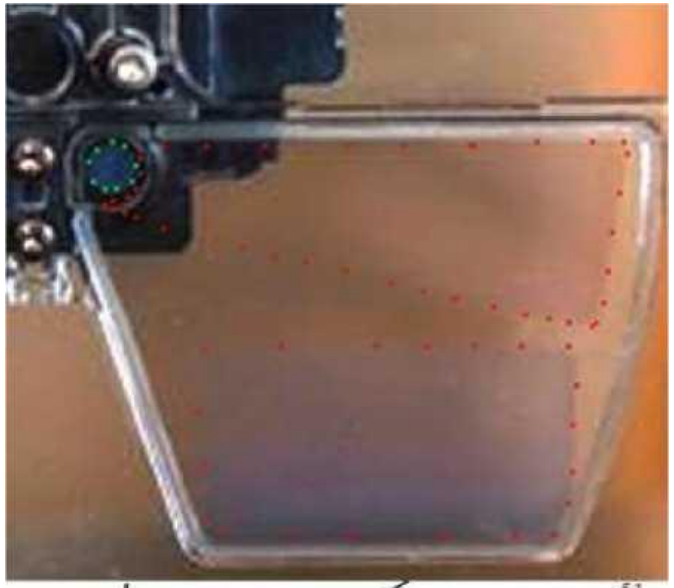


See-through AR Displays —Waveguide

Microsoft HoloLens

HoloLens

- diffraction grating (SRG)
- small FOV (30 °x17 °), but good image quality



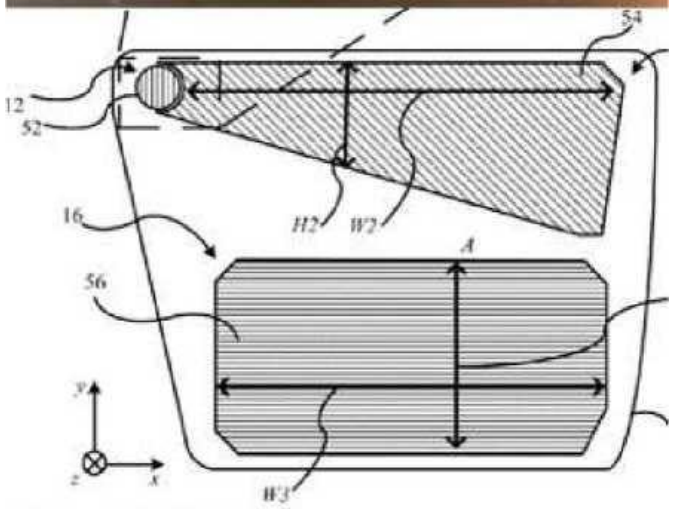
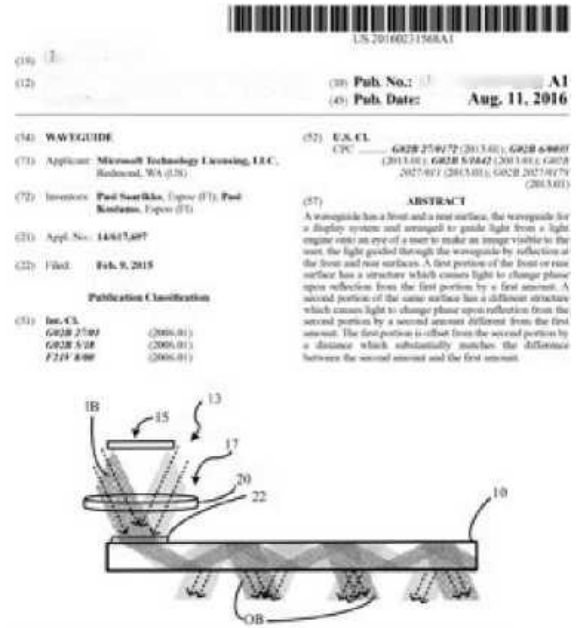
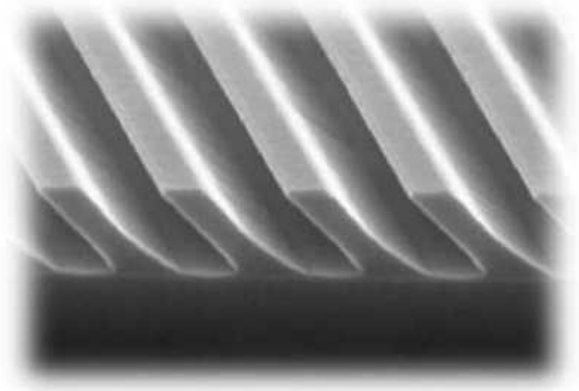


Fig. 3B





Images borrowed from public domain

HoloLens

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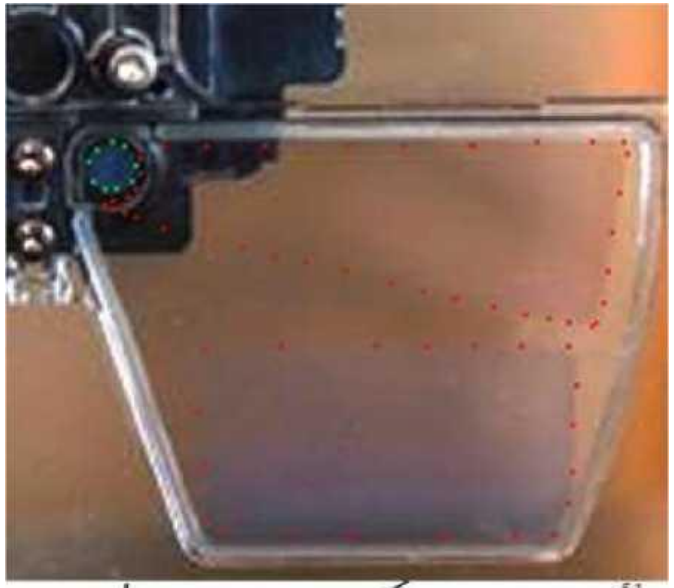


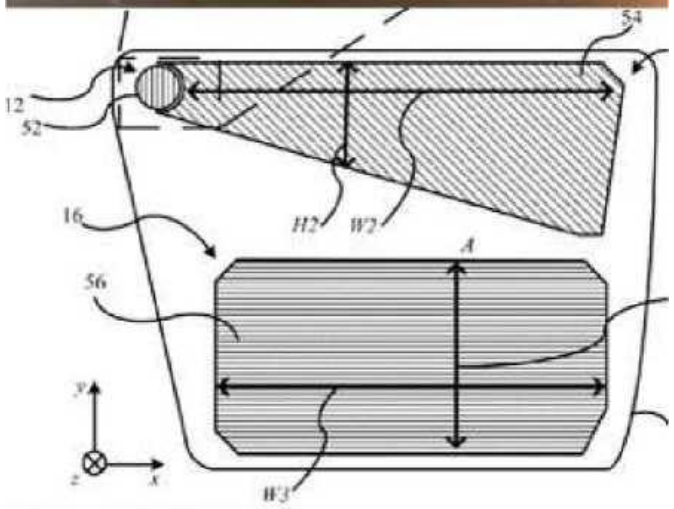
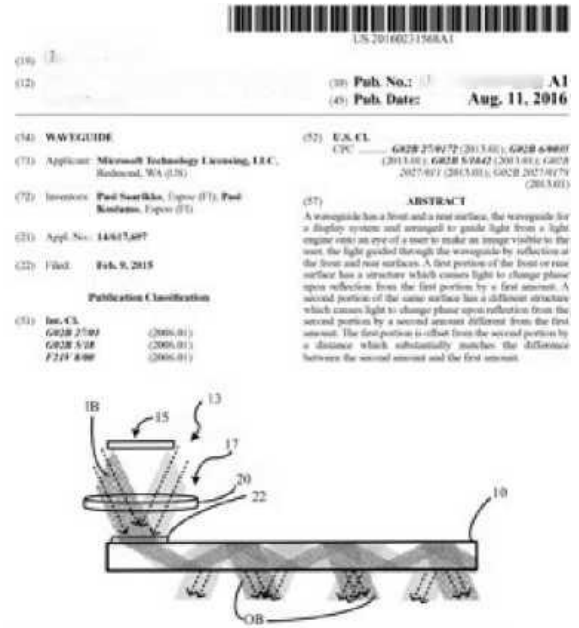
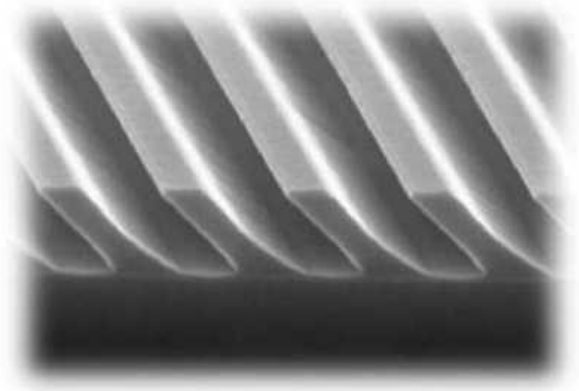


Fig. 3B

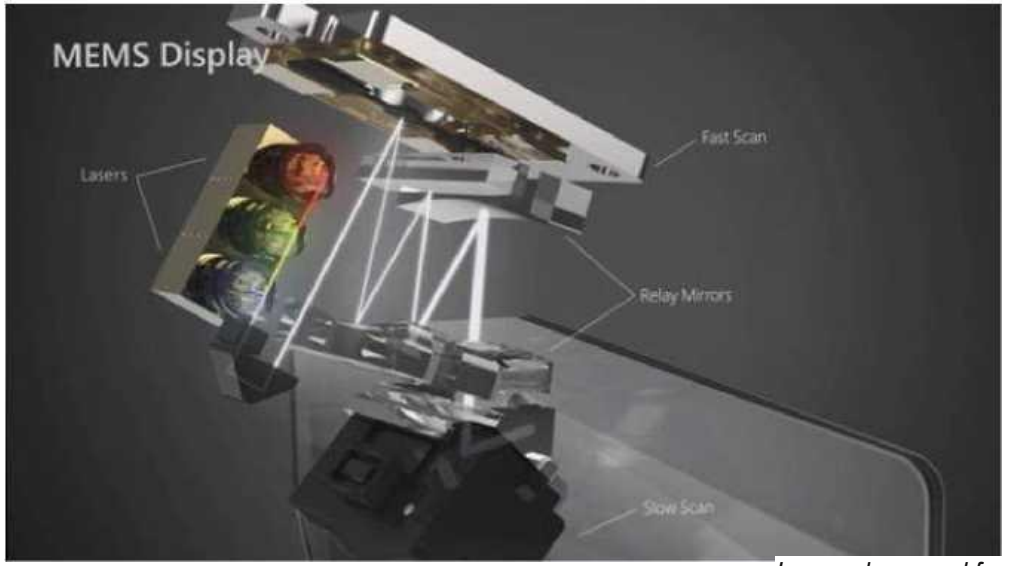




Images borrowed from public domain

See-through AR Displays —Waveguide

- 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…

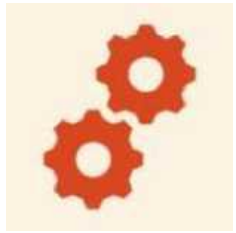


Images borrowed from public domain

What's Next

Holographic Displays (Holograms)

Computational Displays:Bridging the Disciplines

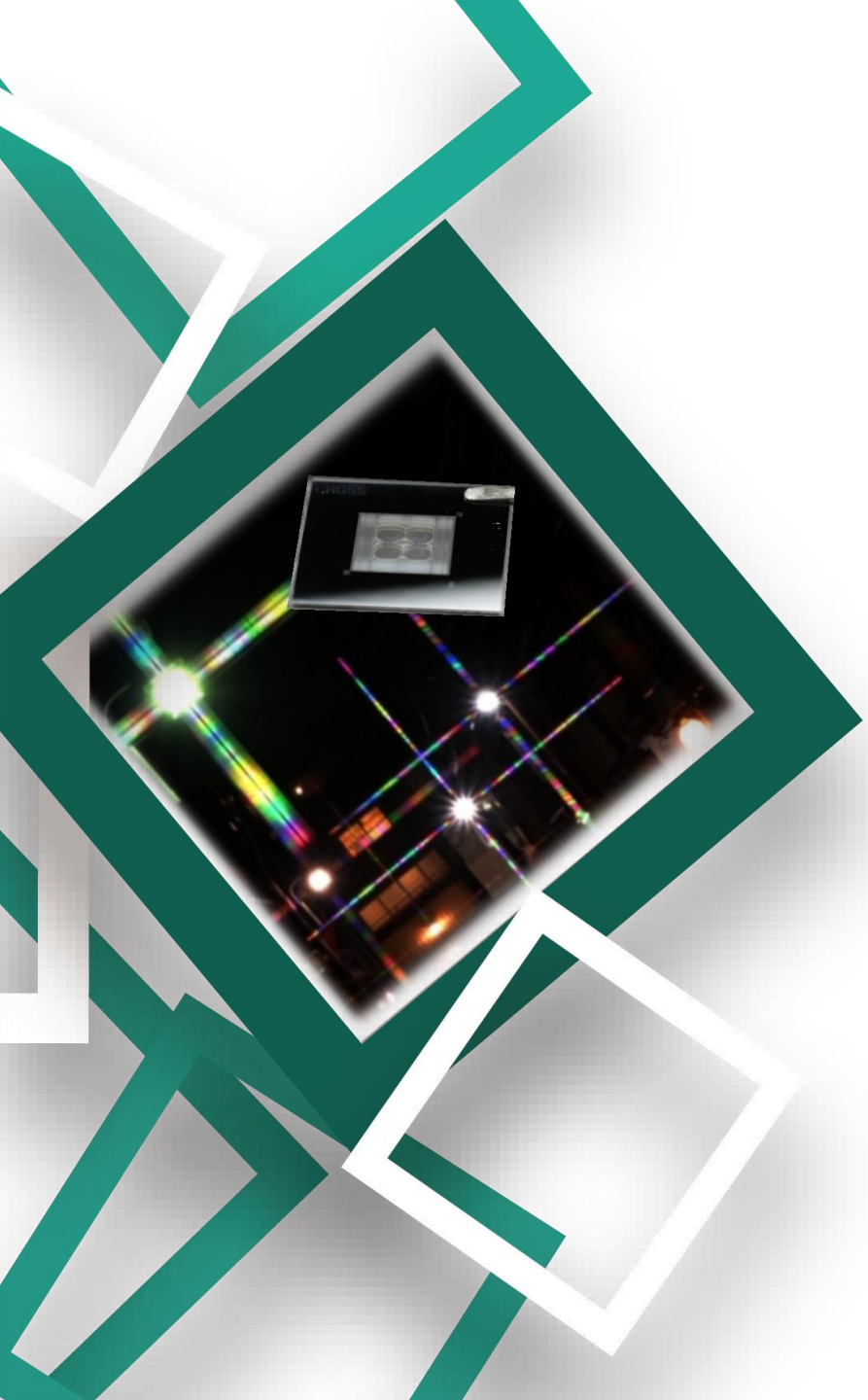


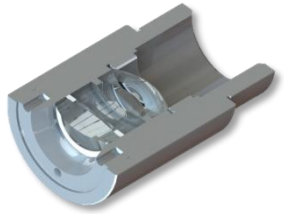
COMPUTER SCIENCE / OPTIMIZATION

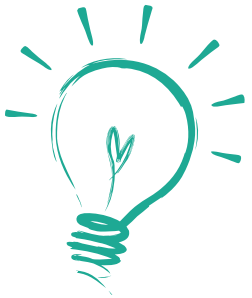
ELECTRONICS / DEVICES / SENSORS

OPTICS / PHOTONICS / HUMAN VISION

- What's Display
- Projectors Are Alternative
- Would Metaverse Really Come
- Virtual Reality
- Augmented Reality
- What's Next







Thank You!

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点昀技术（Point Spread Technology）