Virtual and Augmented Reality

Advanced Graphics & Image Processing

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The slides used in this lecture are the courtesy of Gordon Wetzstein.
From Virtual Reality course: http://stanford.edu/class/ee267/

vir·tu·al re·al·i·ty

vərCH(əw)əl rēʻalədē

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.

vpl research

simulation & training

gaming

education

visualization & entertainment

robotic surgery

virtual travel

remote control of vehicles, e.g. drone

architecture walkthroughs

a trip down the rabbit hole

Exciting Engineering Aspects of VR/AR

- cloud computing
- shared experiences

- CPU, GPU
- IPU, DPU?

- sensors & imaging
- computer vision
- scene understanding

- compression, streaming

- VR cameras

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

- HCI
- applications

images by microsoft, facebook

Where We Want It To Be

image by ray ban

Personal Computer
e.g. Commodore PET 1983

Laptop
e.g. Apple MacBook

Smartphone
e.g. Google Pixel

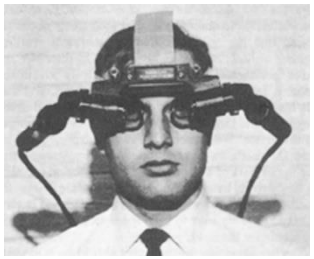
AR/VR
e.g. Microsoft Hololens

???

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 2012-2018

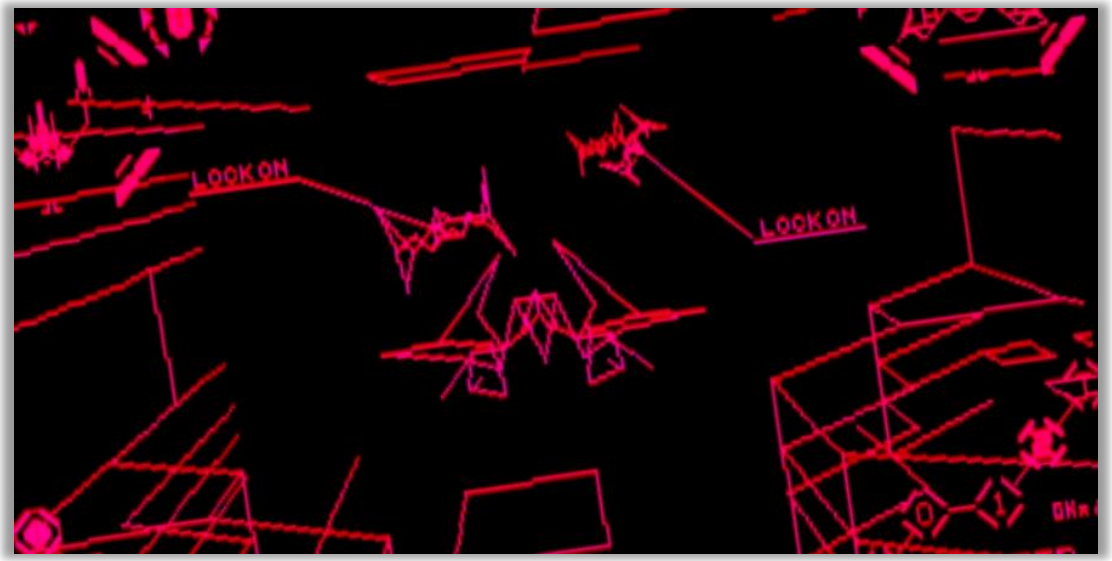
Ivan Sutherland's HMD

- optical see-through AR, including:
  - displays (2x 1" CRTs)
  - rendering
  - head tracking
  - interaction
  - model generation
- computer graphics
- human-computer interaction

I. Sutherland "A head-mounted three-dimensional display", Fall Joint Computer Conference 1968

Nintendo Virtual Boy

- computer graphics & GPUs were not ready yet!

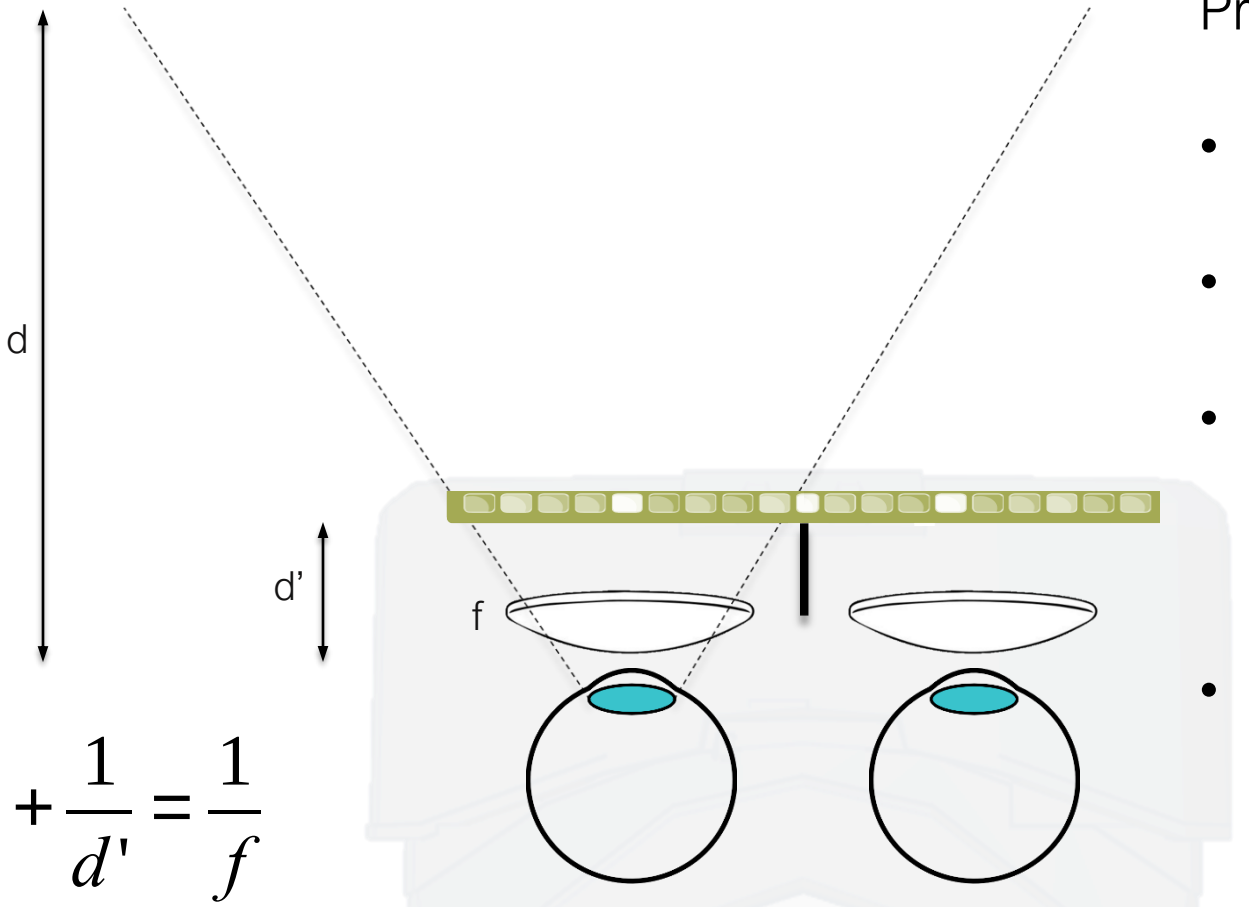


Game: Red Alarm

Where we are now

IFIXIT teardown

Virtual Image

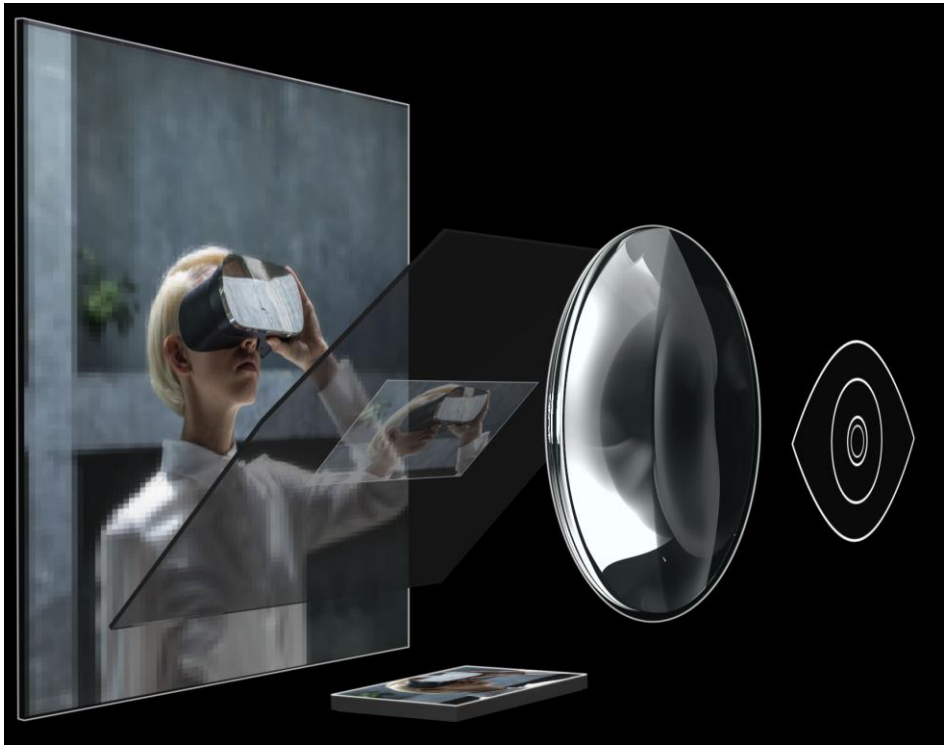


$$\frac{1}{d}+\frac{1}{d'}=\frac{1}{f}$$

Problems:

- fixed focal plane
- no focus cues ☹
- cannot drive accommodation with rendering!
- limited resolution

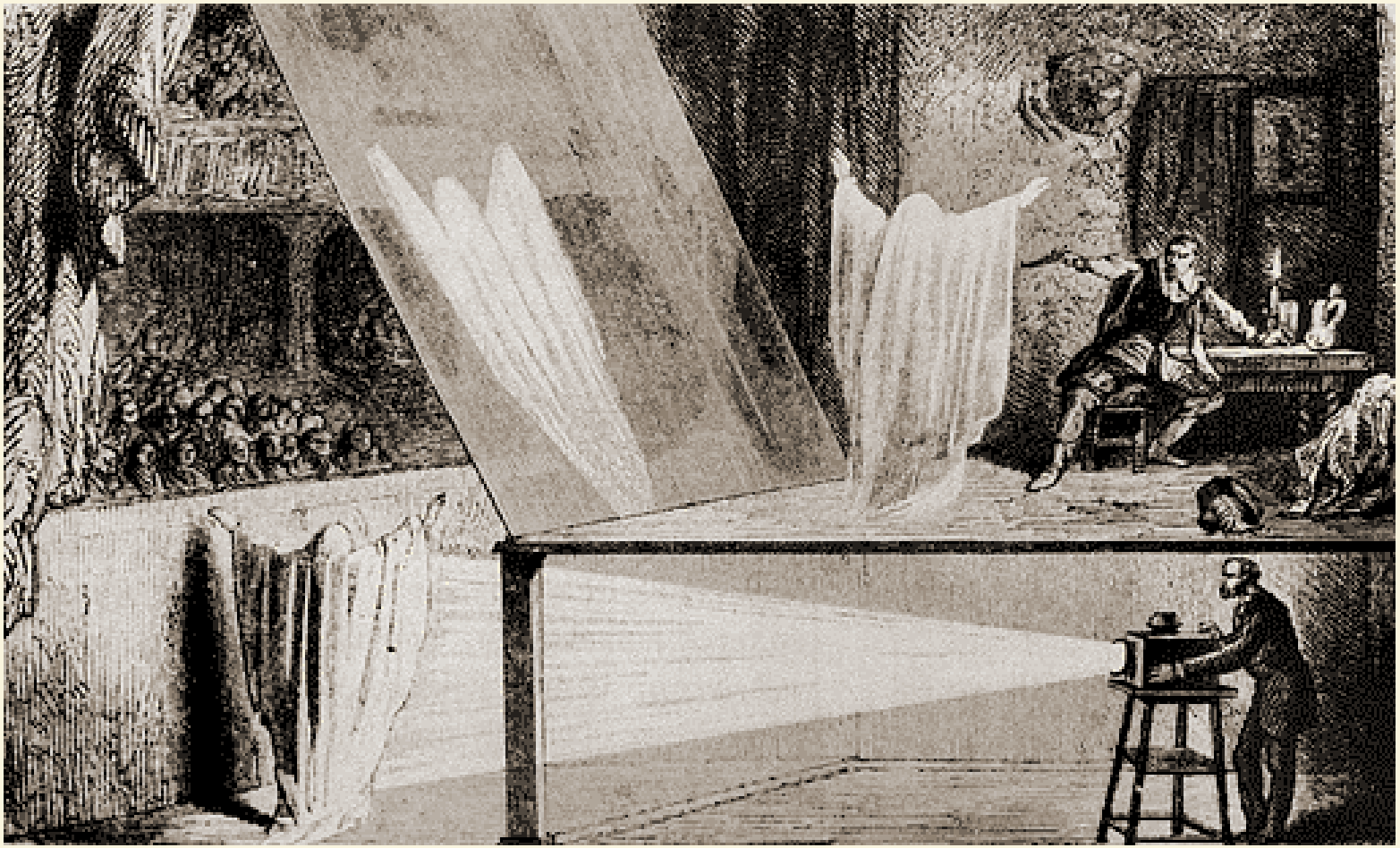
A dual-resolution display



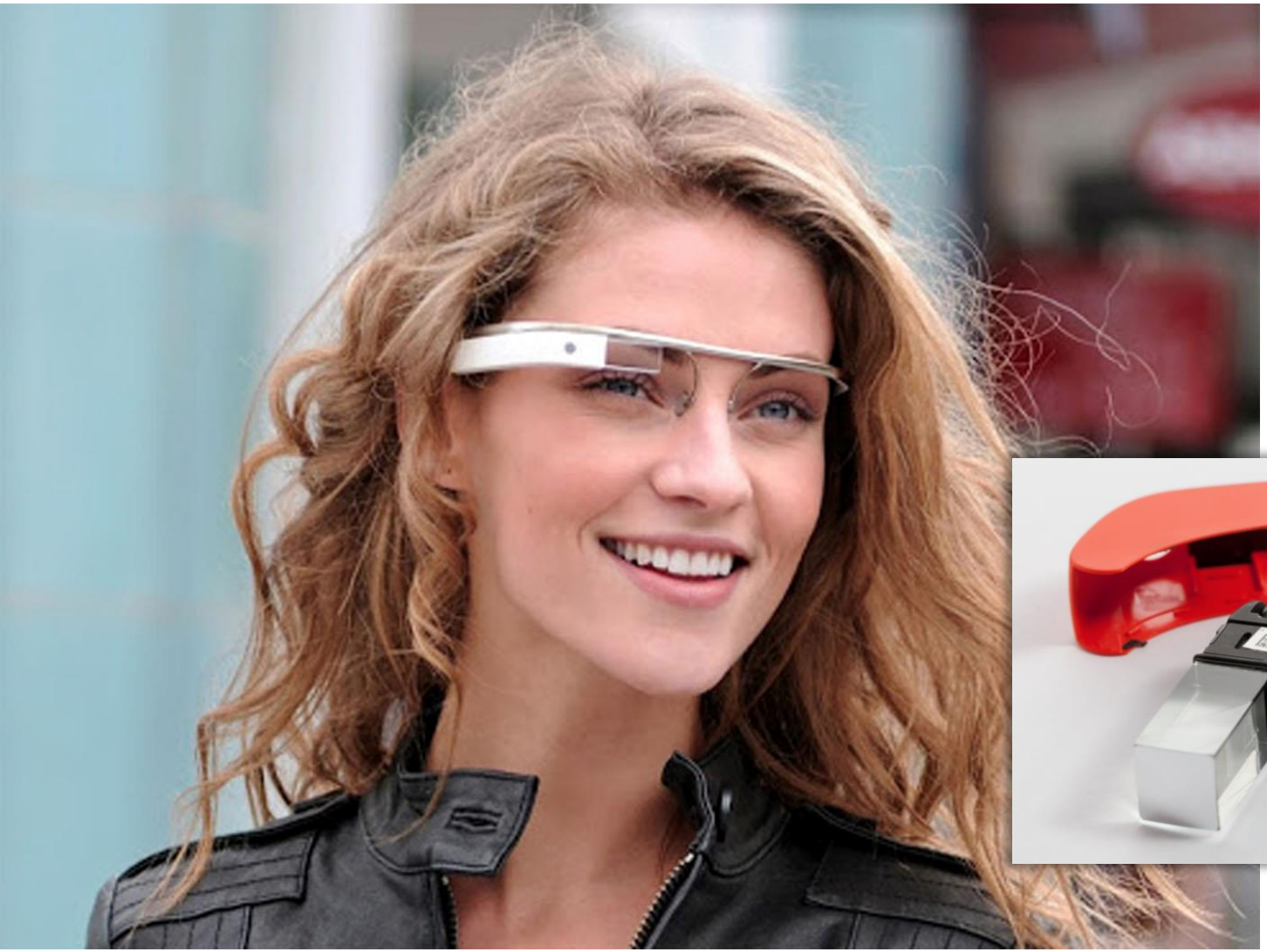
- High resolution image in the centre, low resolution fills wide field-of-view
- Two displays combined using a beam-splitter
- Image from: https://varjo.com/bionic-display/

Augmented Reality

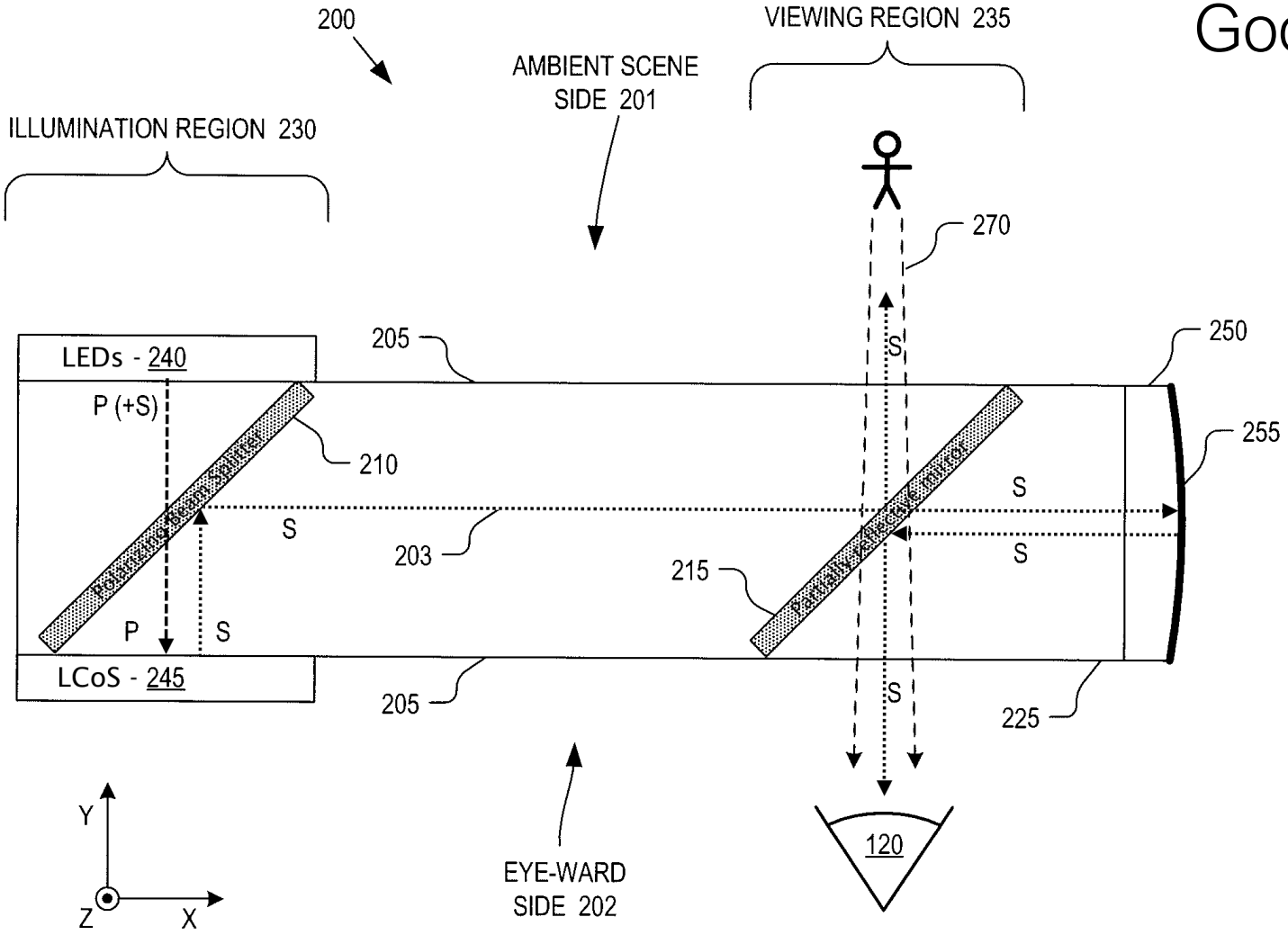
Pepper's Ghost 1862



Google Glass



Google Glass



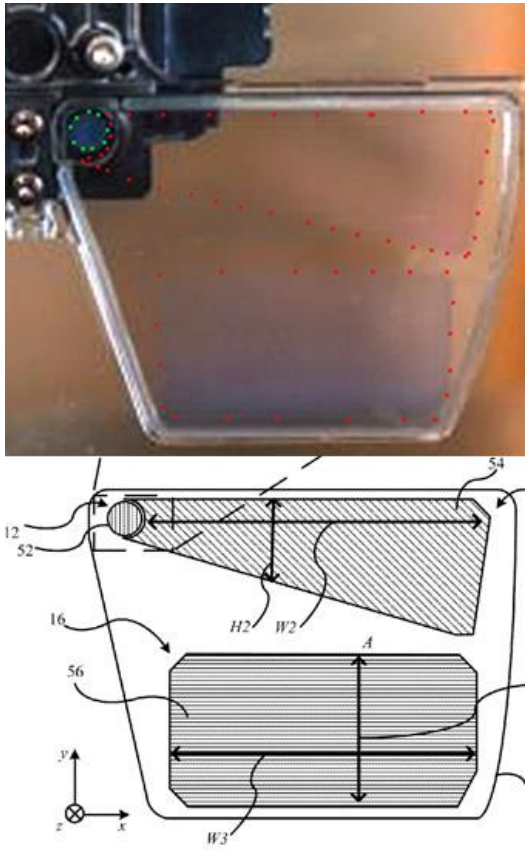
Meta 2

- Larger field of view (90 deg) than Glass
- Also larger device form factor

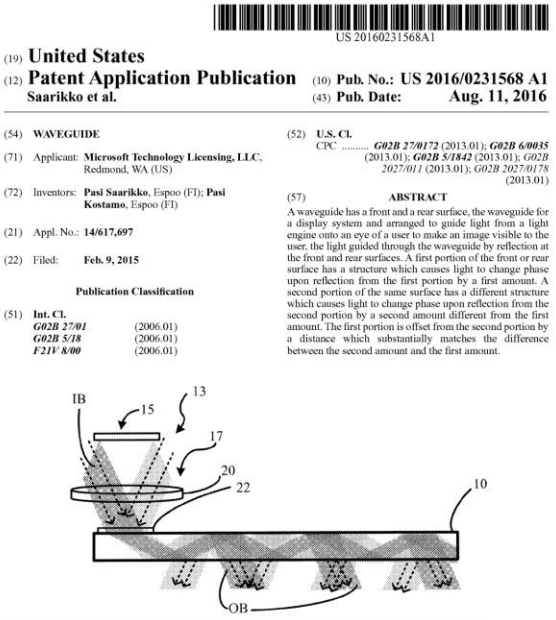
Microsoft HoloLens

Microsoft HoloLens

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



US 2016/0231568 Fig. 3B



US 20160231568A1

(19) **United States**

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Saarikko et al.

(10) **Pub. No.: US 2016/0231568 A1**
(43) **Pub. Date: Aug. 11, 2016**

(54) **WAVEGUIDE**

(71) Applicant: **Microsoft Technology Licensing, LLC**, Redmond, WA (US)

(72) Inventors: **Pasi Saarikko**, Espoo (FI); **Pasi Kostamo**, Espoo (FI)

(21) Appl. No.: **14/617,697**

(22) Filed: **Feb. 9, 2015**

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G02B 5/18 (2006.01)
F21V 8/00 (2006.01)

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CPC ***G02B 27/0172*** (2013.01); ***G02B 6/0035*** (2013.01); ***G02B 5/1842*** (2013.01); *G02B 2027/011* (2013.01); *G02B 2027/0178* (2013.01)

(57) **ABSTRACT**

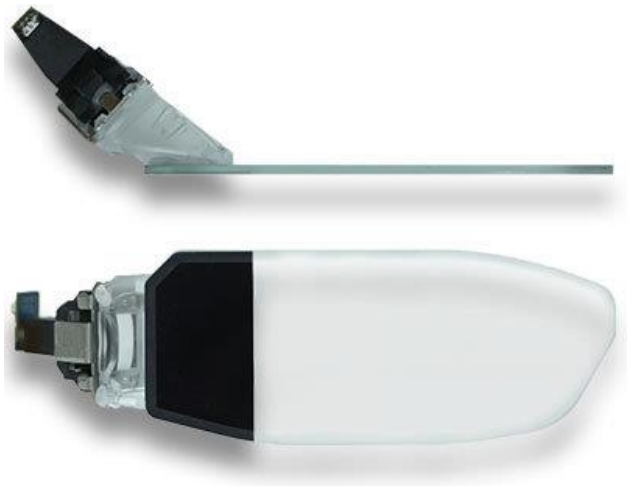
A waveguide has a front and a rear surface, the waveguide for a display system and arranged to guide light from a light engine onto an eye of a user to make an image visible to the user, the light guided through the waveguide by reflection at the front and rear surfaces. A first portion of the front or rear surface has a structure which causes light to change phase upon reflection from the first portion by a first amount. A second portion of the same surface has a different structure which causes light to change phase upon reflection from the second portion by a second amount different from the first amount. The first portion is offset from the second portion by a distance which substantially matches the difference between the second amount and the first amount.

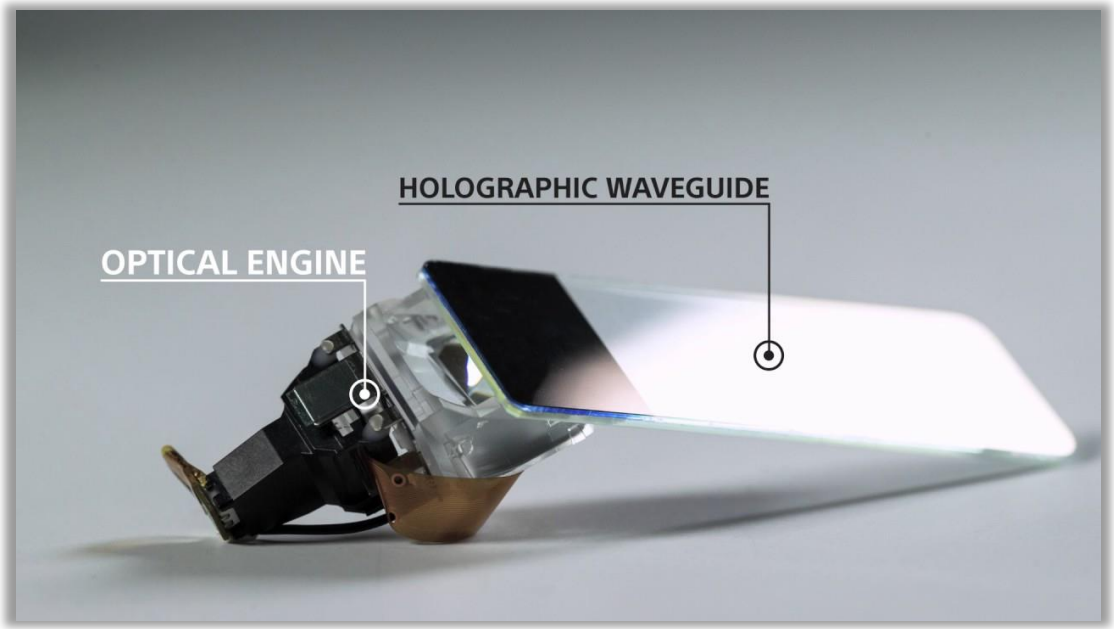
Zeiss Smart Optics

- great device form factor
- polycarbonate light guide – easy to manufacture and robust
- smaller field of view (17 deg)

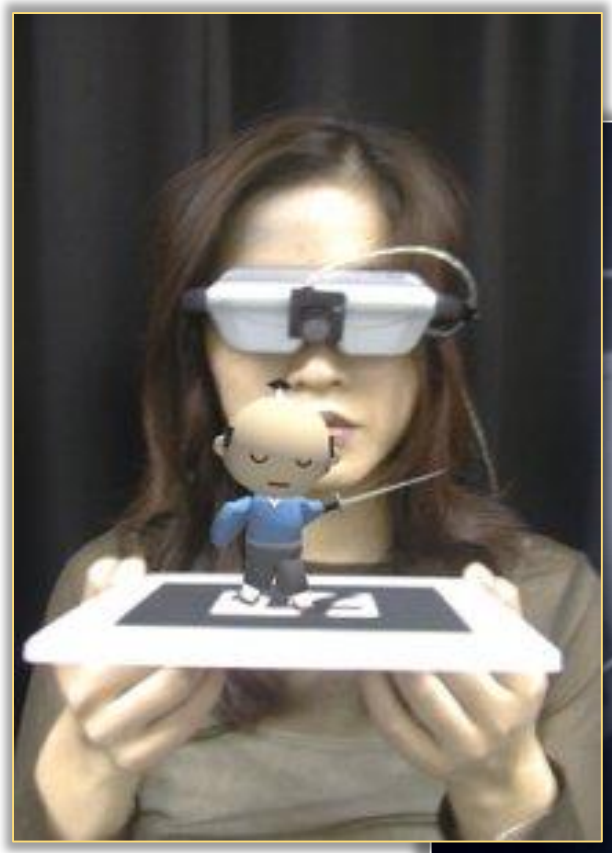
Sony IMX-001

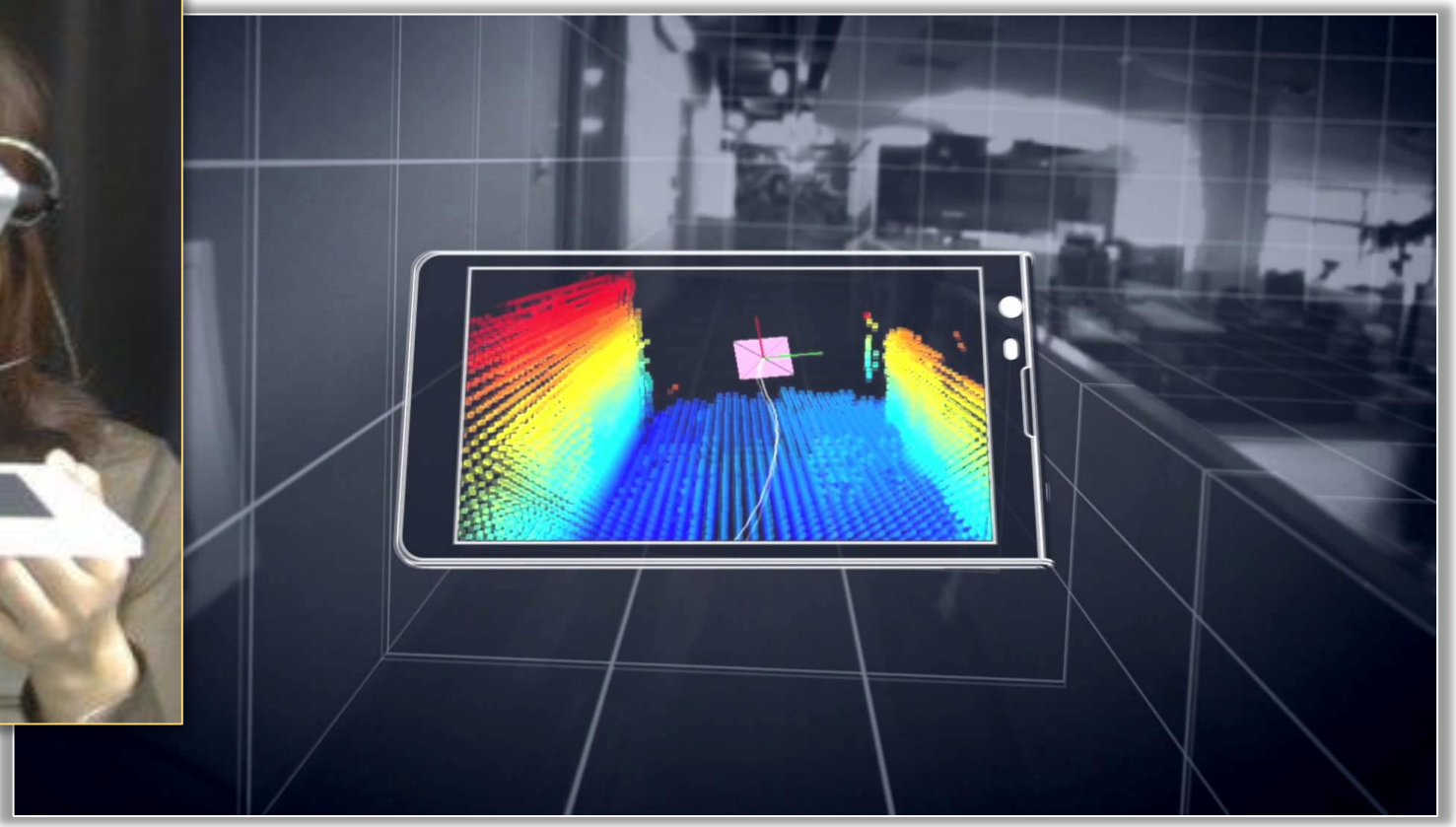
- also great form factor
- small FOV (9x6 deg)
- monochrome





Video AR: ARCore, ARKit, ARToolKit, …



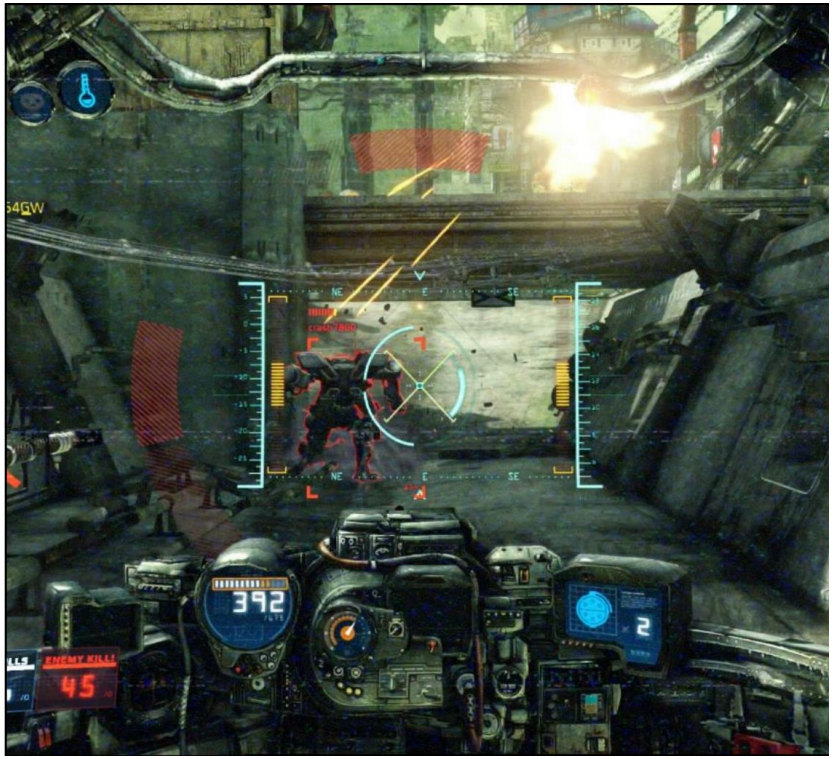


VR/AR challenges

- Latency (next lecture)
- Tracking
- 3D Image quality and resolution
- Reproduction of depth cues (last lecture)
- Rendering & bandwidth
- Simulation/cyber sickness
- Content creation
  - Game engines
  - Image-Based-Rendering

Simulation sickness

- Conflict between vestibular and visual systems
  - When camera motion inconsistent with head motion
  - Frame of reference (e.g. cockpit) helps
  - Worse with larger FOV
  - Worse with high luminance and flicker



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- Virtual Reality course from the Stanford Computational Imaging group
  - http://stanford.edu/class/ee267/