



Virtual and Augmented Reality

Advanced Graphics & Image Processing

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From Virtual Reality course: <http://stanford.edu/class/ee267/>

vir·tu·al re·al·i·ty

vərCH(əw)əl rē'alədē

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.



simulation & training



visualization & entertainment



remote control of vehicles, e.g. drone



gaming



robotic surgery



architecture walkthroughs



education



virtual travel



a trip down the rabbit hole

Exciting Engineering Aspects of VR/AR

- cloud computing
- shared experiences



- compression, streaming



- VR cameras



- CPU, GPU
- IPU, DPU?



- sensors & imaging
- computer vision
- scene understanding

- photonics / waveguides
- human perception
- displays: visual, auditory, vestibular, haptic, ...
- HCI
- applications

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

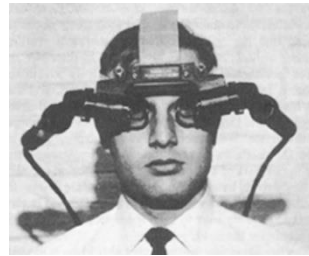
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A Brief History of Virtual Reality

Stereoscopes
Wheatstone, Brewster, ...



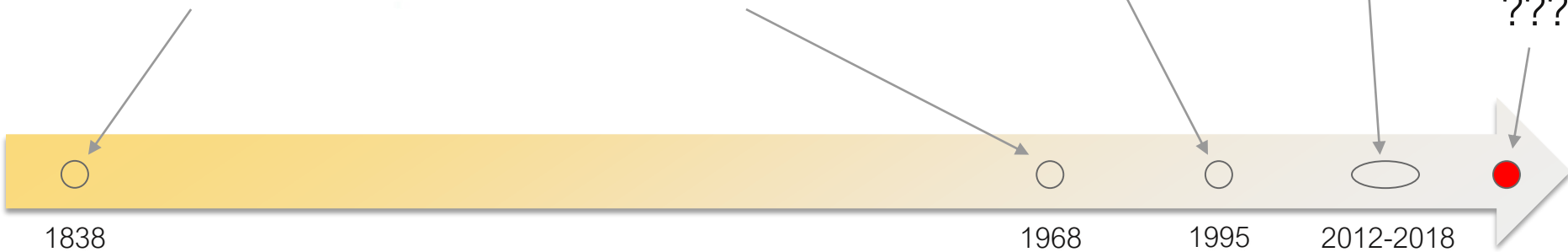
VR & AR
Ivan Sutherland



Nintendo
Virtual Boy



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



Ivan Sutherland's HMD

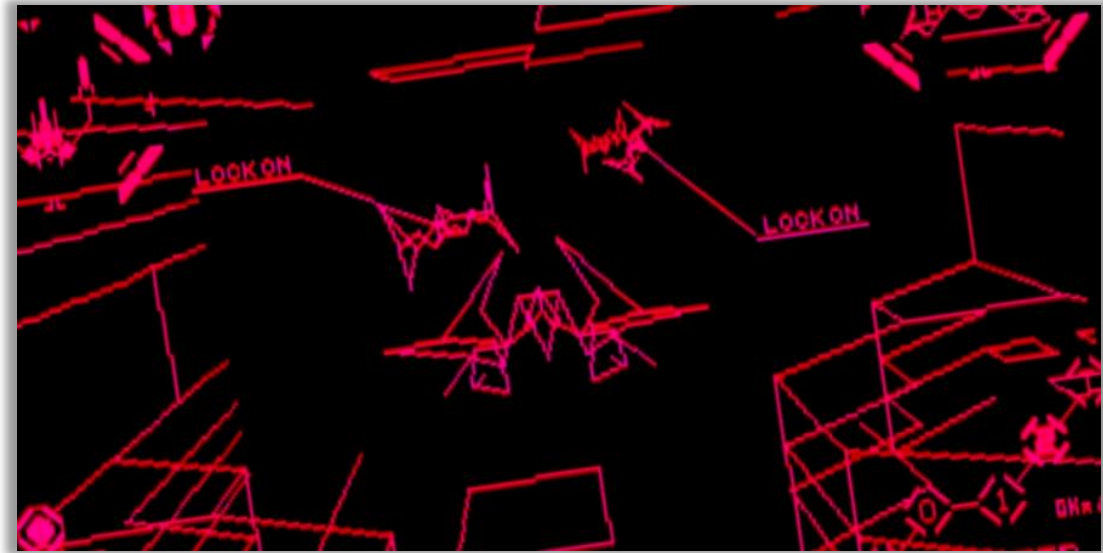
- optical see-through AR, including:
 - displays (2x 1" CRTs)
 - rendering
 - head tracking
 - interaction
 - model generation
- computer graphics
- human-computer interaction



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

Nintendo Virtual Boy

- computer graphics & GPUs were not ready yet!



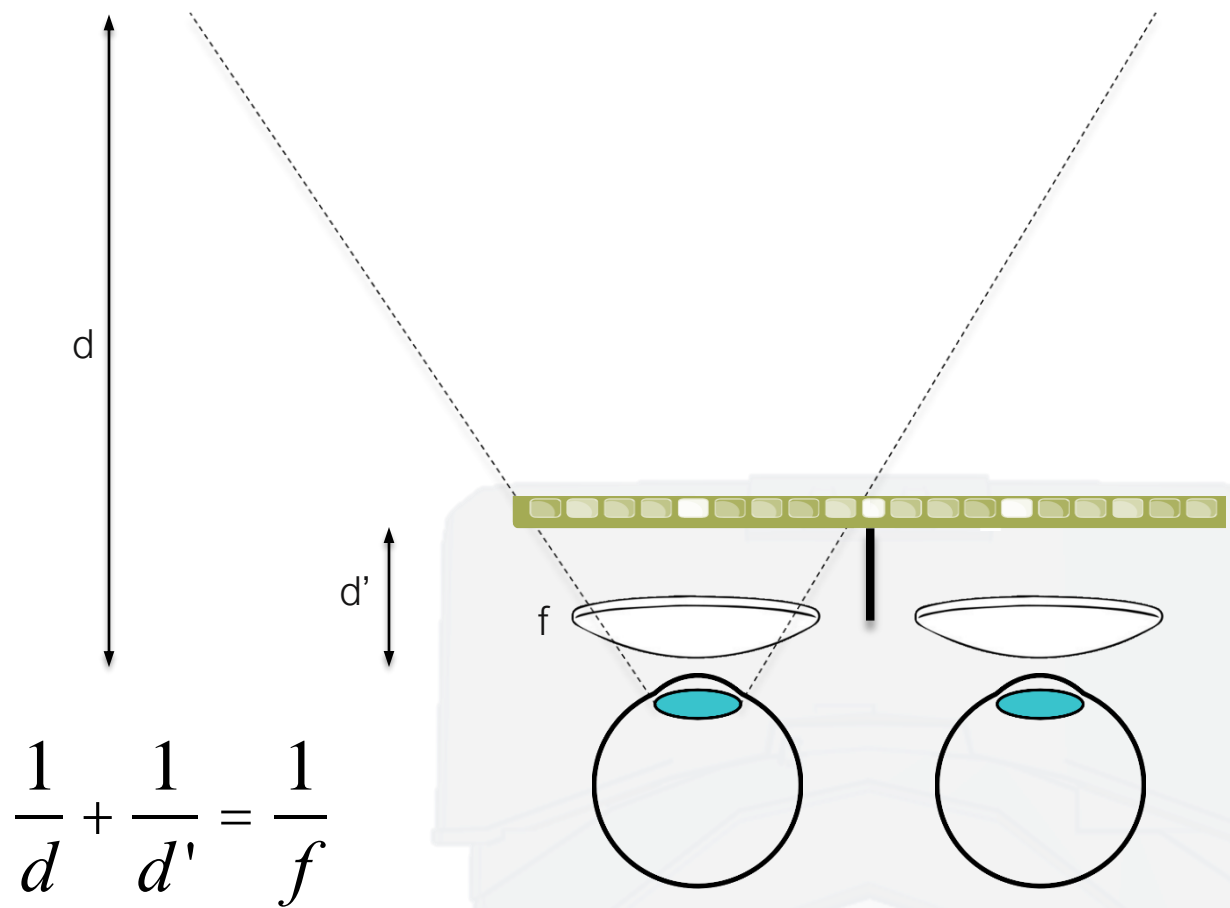
Game: Red Alarm

Where we are now



IFIXIT teardown

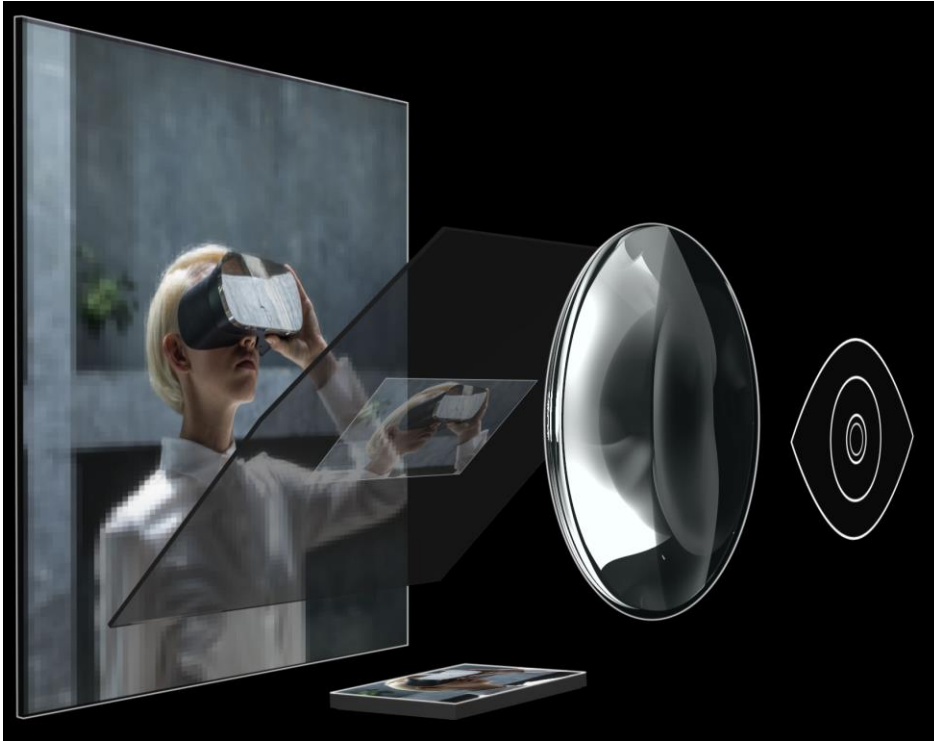
Virtual Image



Problems:

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

A dual-resolution display

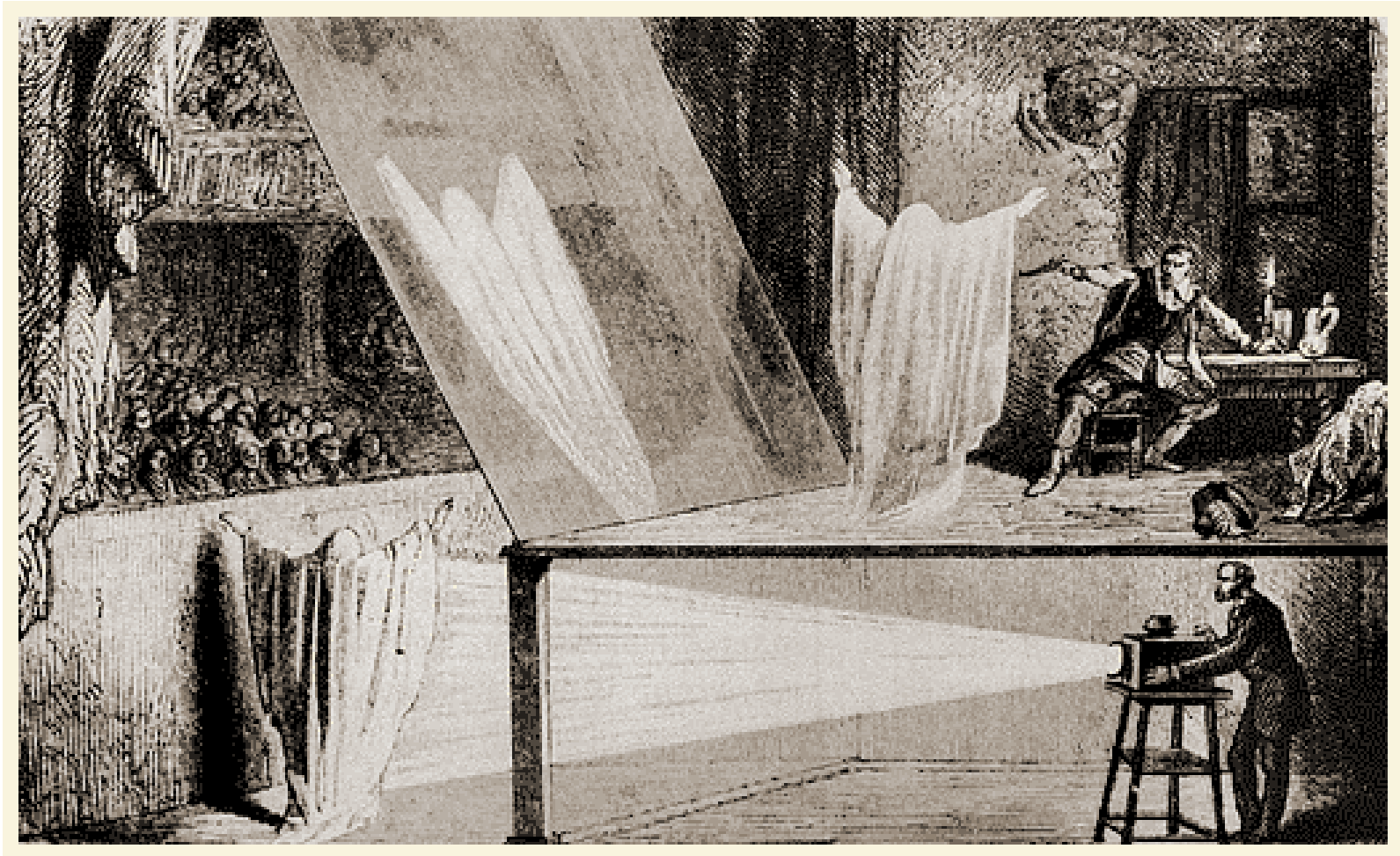


- ▶ High resolution image in the centre, low resolution fills wide field-of-view
- ▶ Two displays combined using a beam-splitter
- ▶ Image from: <https://varjo.com/bionic-display/>

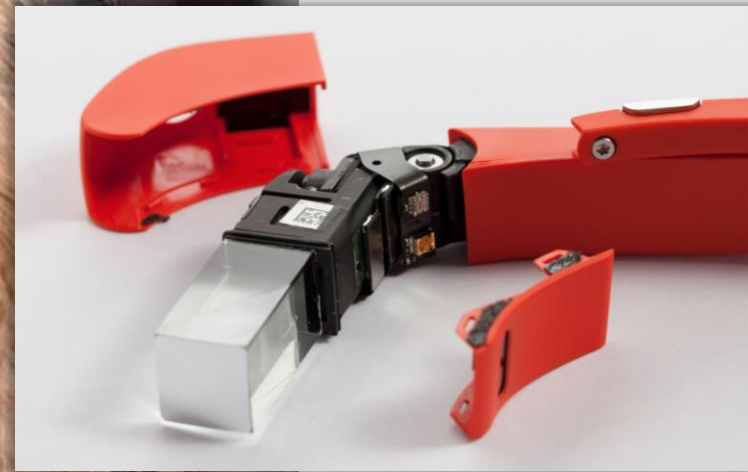
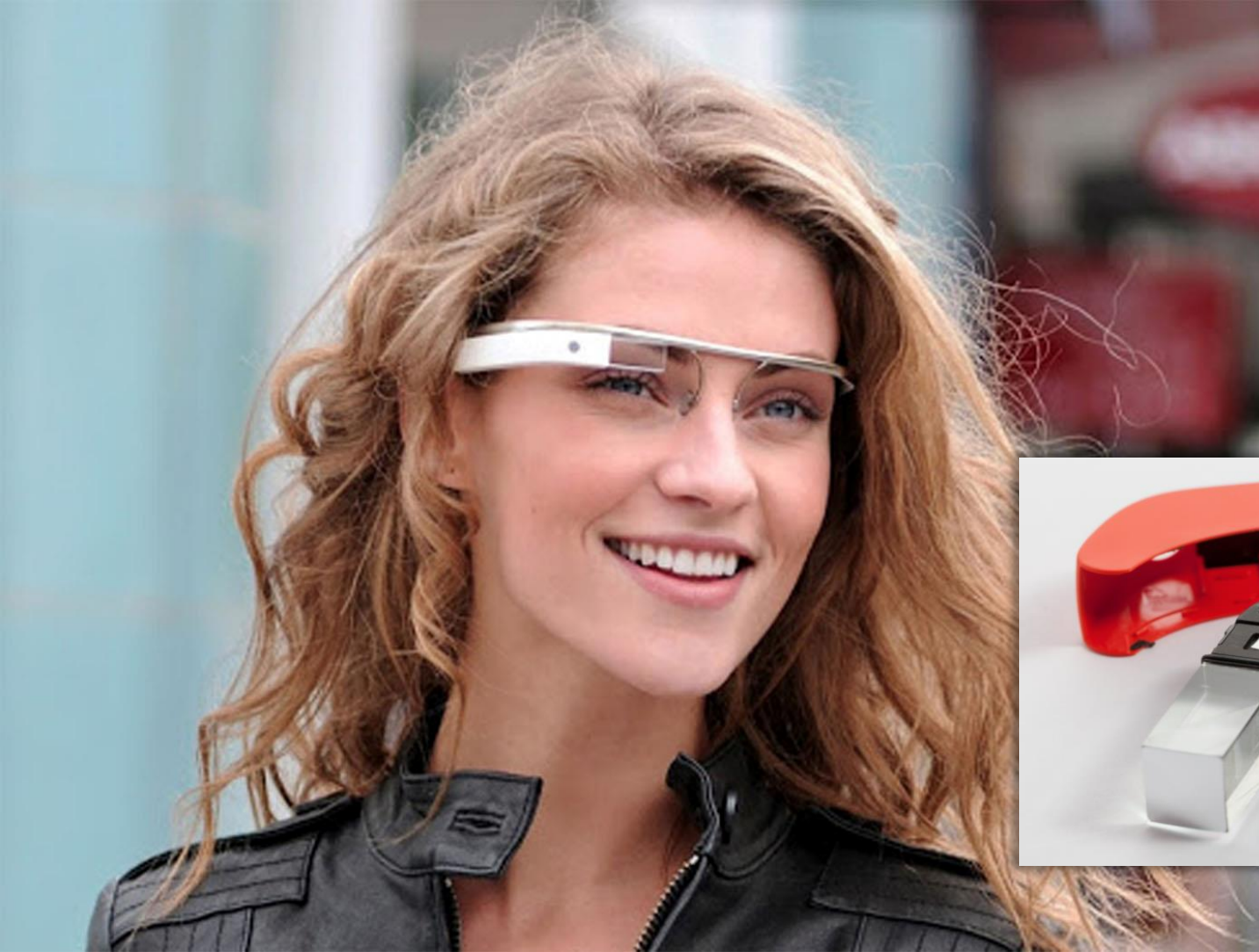
Augmented Reality



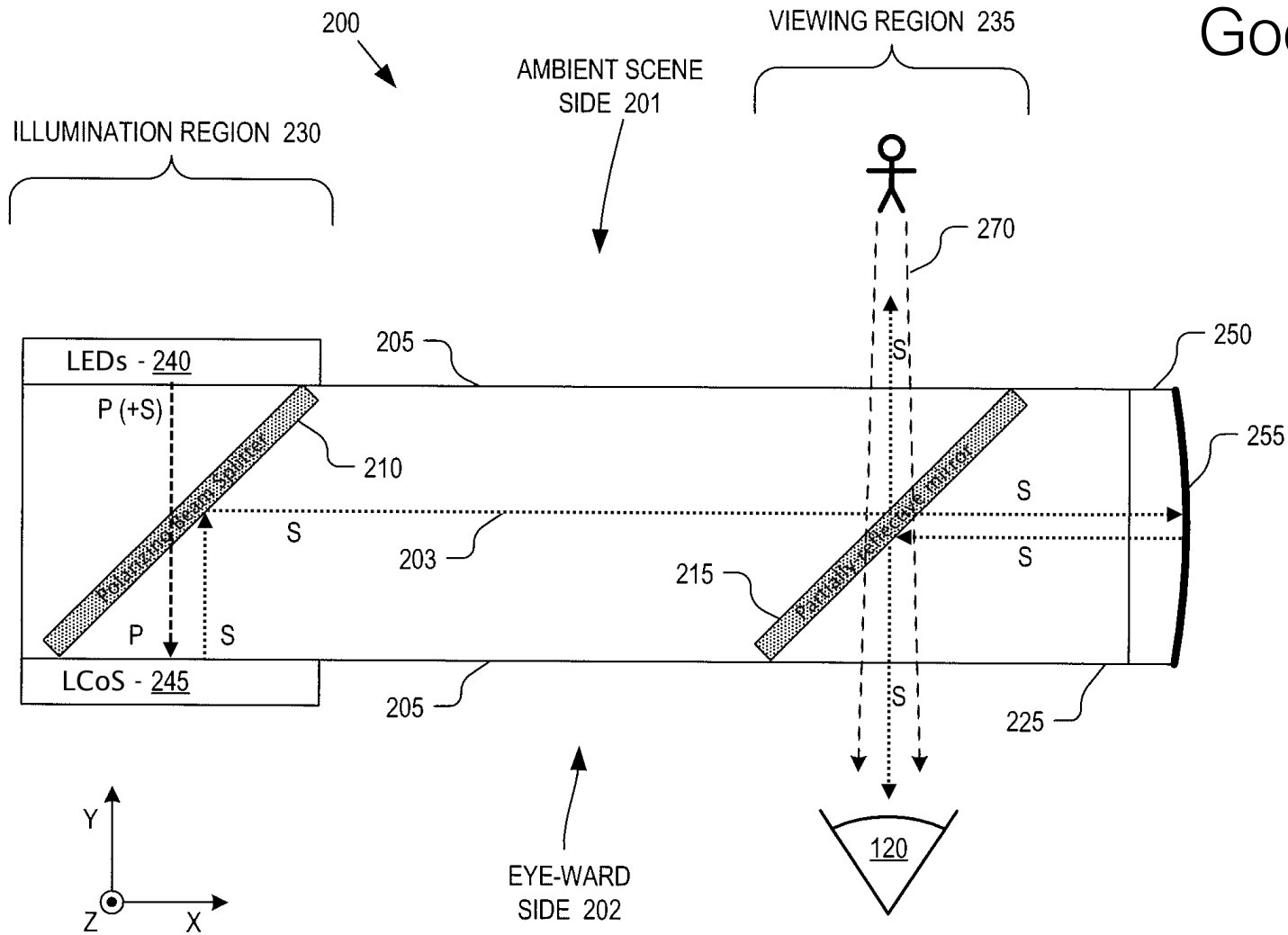
Pepper's Ghost 1862



Google Glass



Google Glass



Meta 2

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

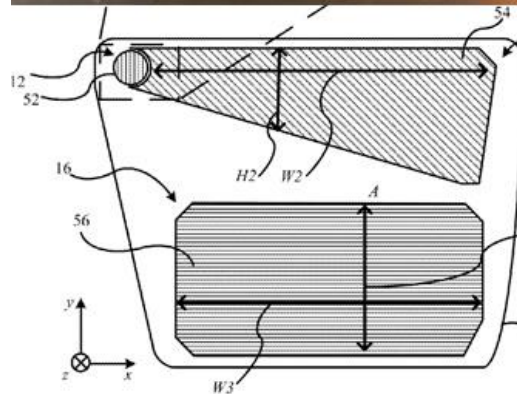
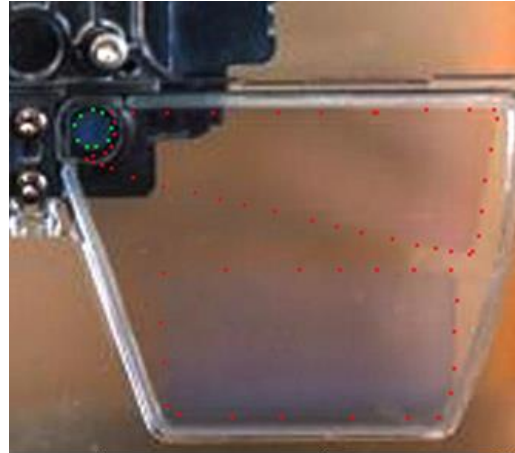


Microsoft HoloLens



Microsoft HoloLens

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



US 2016/0231568

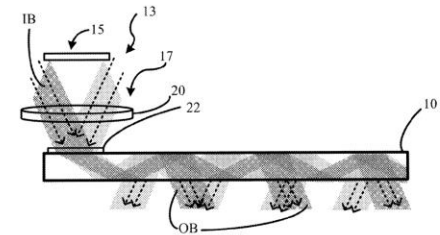
Fig. 3B



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 Saarikko et al. (43) **Pub. Date:** Aug. 11, 2016

(54) **WAVEGUIDE** (52) **U.S. CL.**
 (71) Applicant: **Microsoft Technology Licensing, LLC**,
 Redmond, WA (US) CPC: **G02B 27/0172** (2013.01); **G02B 6/0035**
 (2013.01); **G02B 5/1842** (2013.01); **G02B**
2627/011 (2013.01); **G02B 2027/0178**
 (2013.01)
 (72) Inventors: **Pasi Saarikko**, Espoo (FI); **Pasi**
Kostamo, Espoo (FI) (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.
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 (22) Filed: **Feb. 9, 2015**
Publication Classification
 (51) **Int. Cl.**
G02B 27/01 (2006.01)
G02B 5/18 (2006.01)
F21V 8/00 (2006.01)



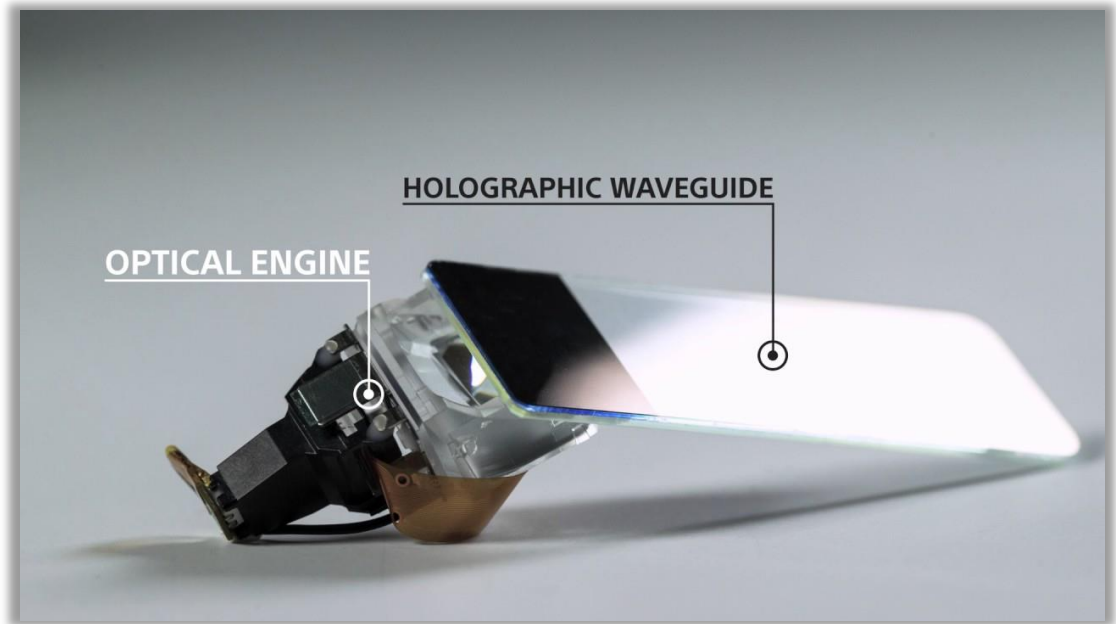
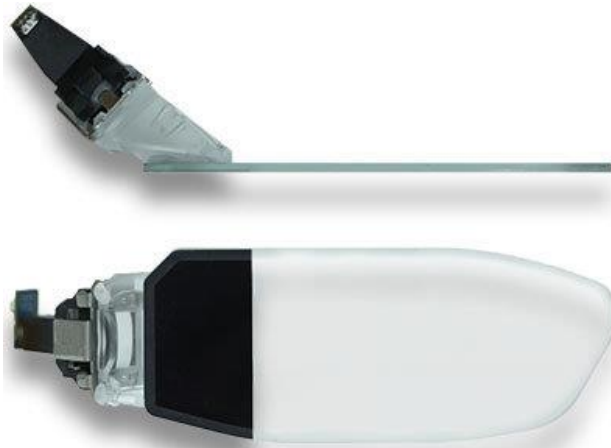
Zeiss Smart Optics

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

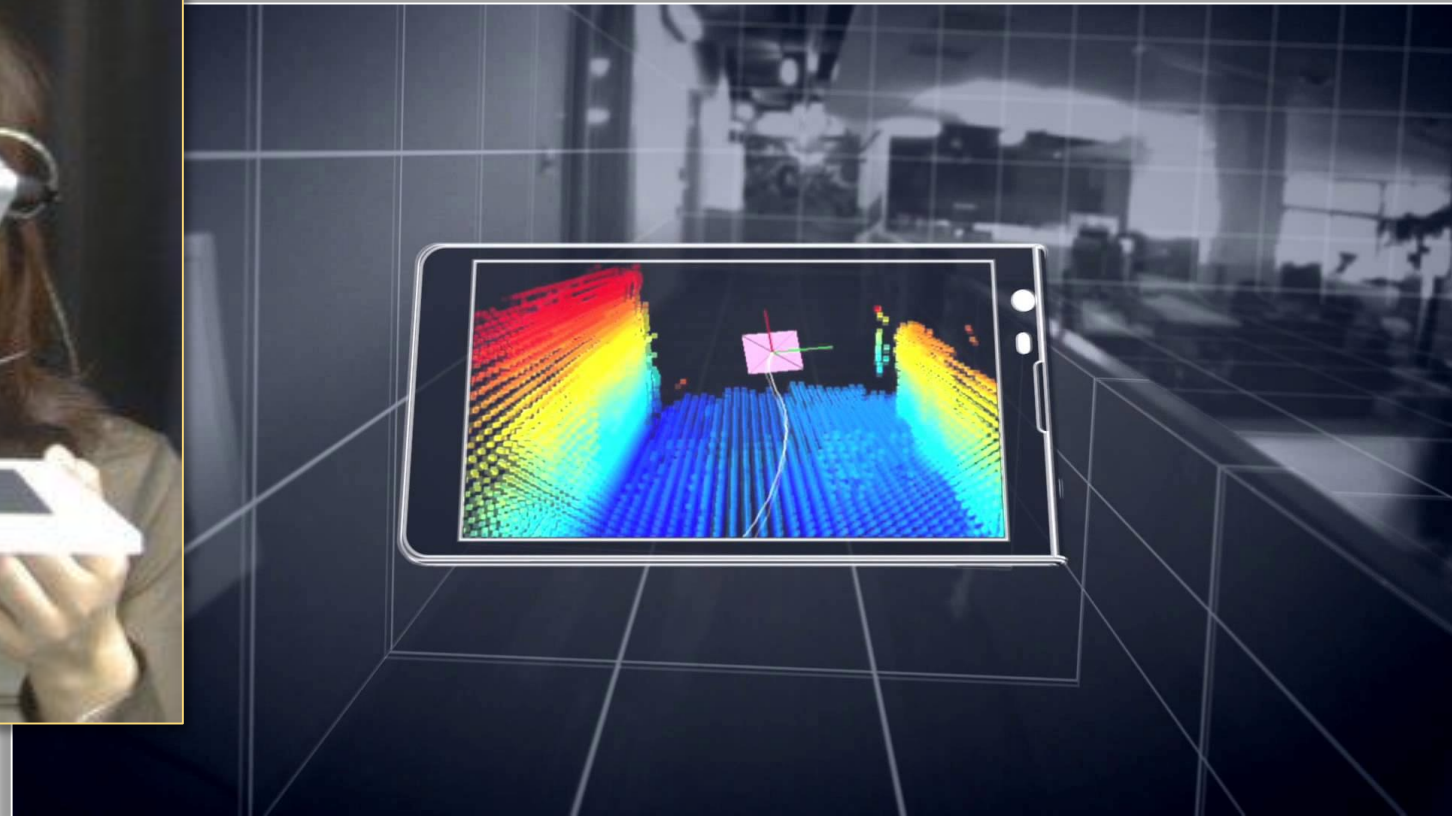
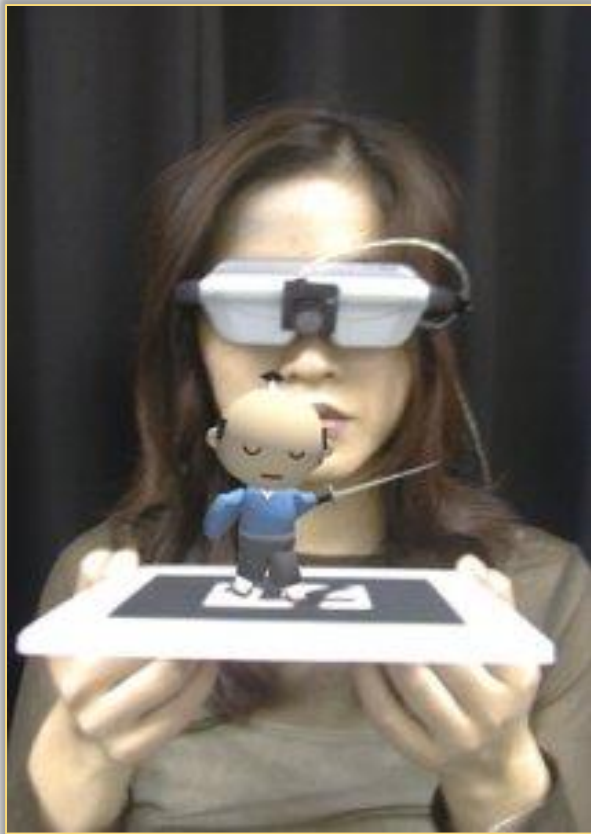


Sony IMX-001

- 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



References

- ▶ LaValle "Virtual Reality", Cambridge University Press, 2016
 - ▶ <http://vr.cs.uiuc.edu/>
- ▶ Virtual Reality course from the Stanford Computational Imaging group
 - ▶ <http://stanford.edu/class/ee267/>