Output Devices

Today

- Output Devices
  - 3D Printers
  - 2D Displays
  - 3D Displays

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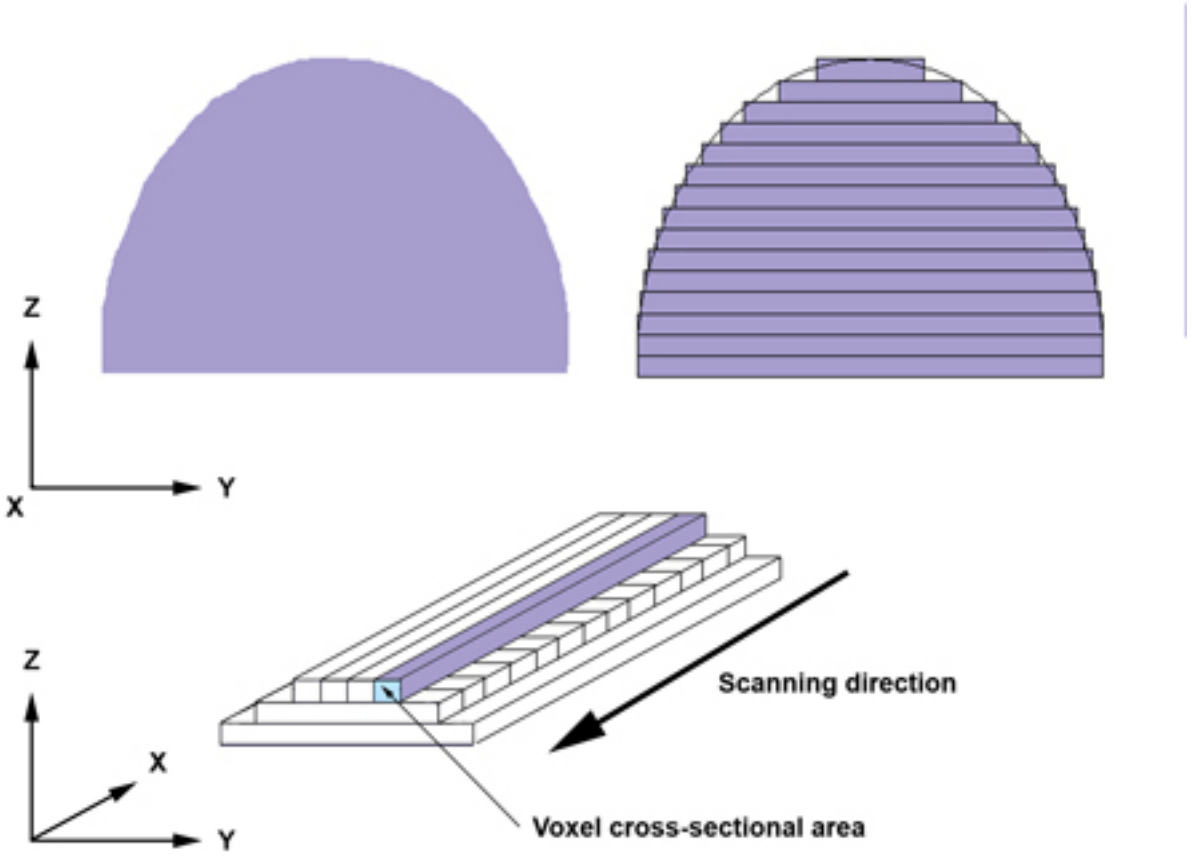
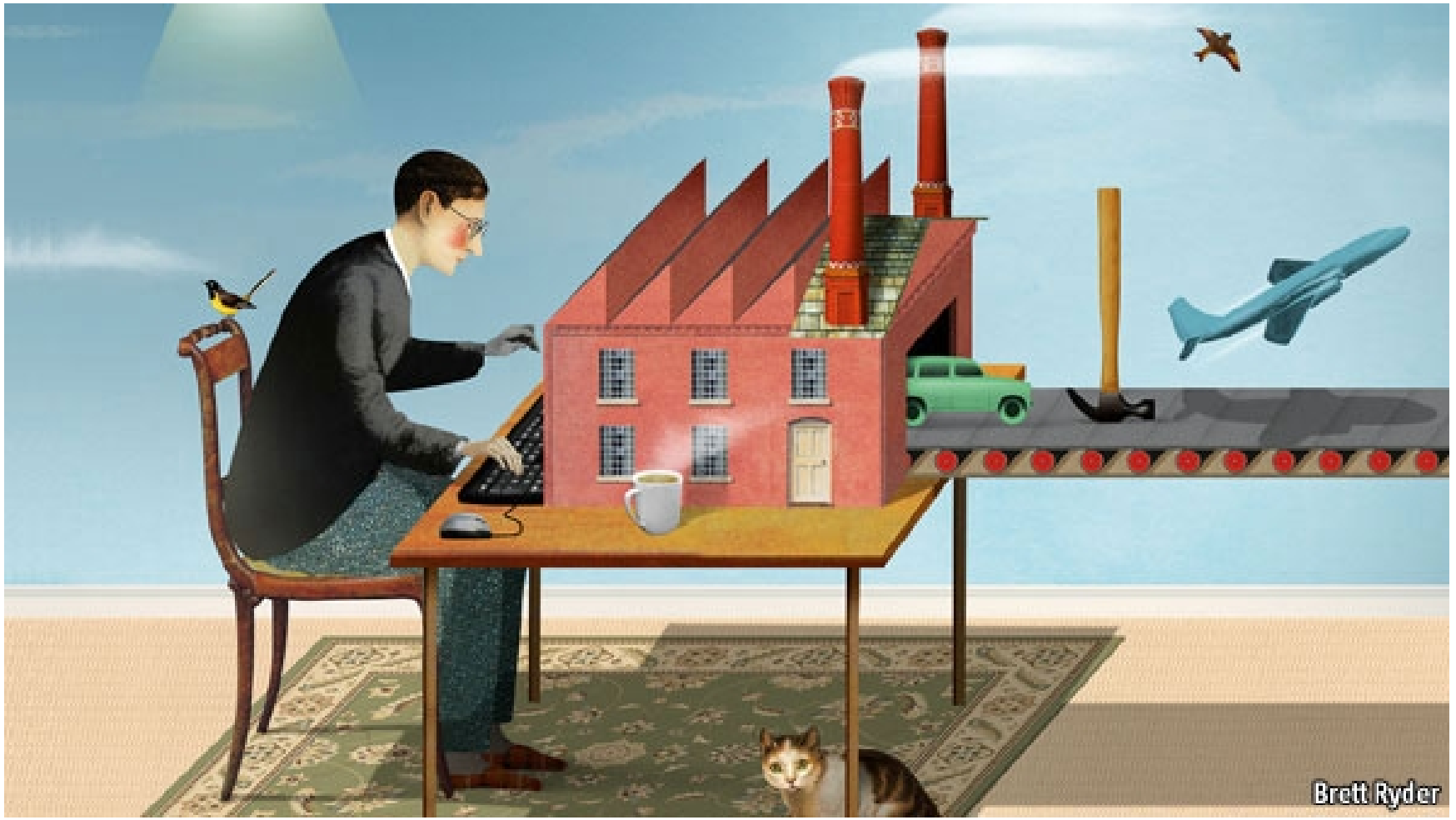
  - 3D Printers
  - 2D Displays
  - 3D Displays

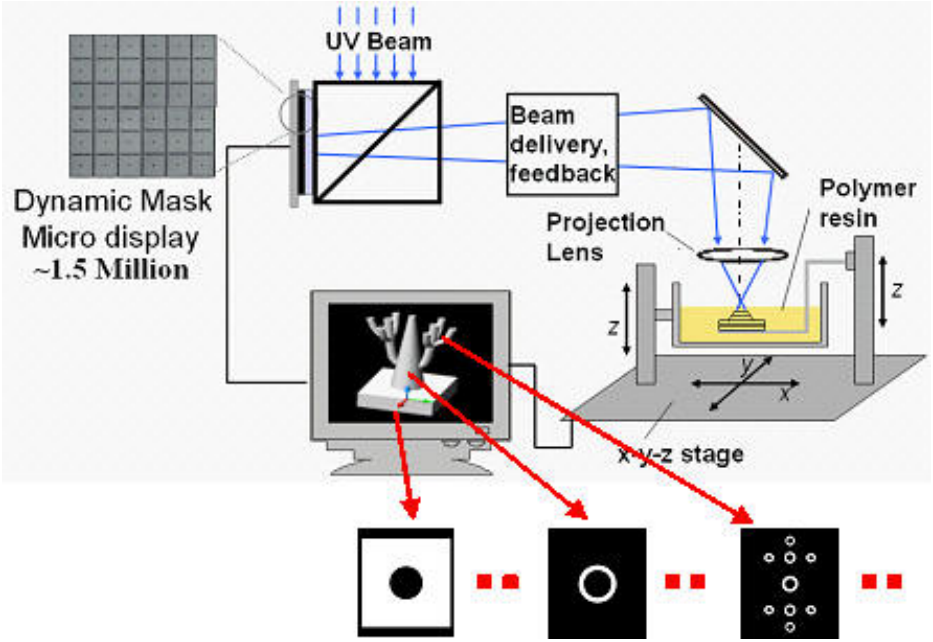
The Additive Manufacturing Process

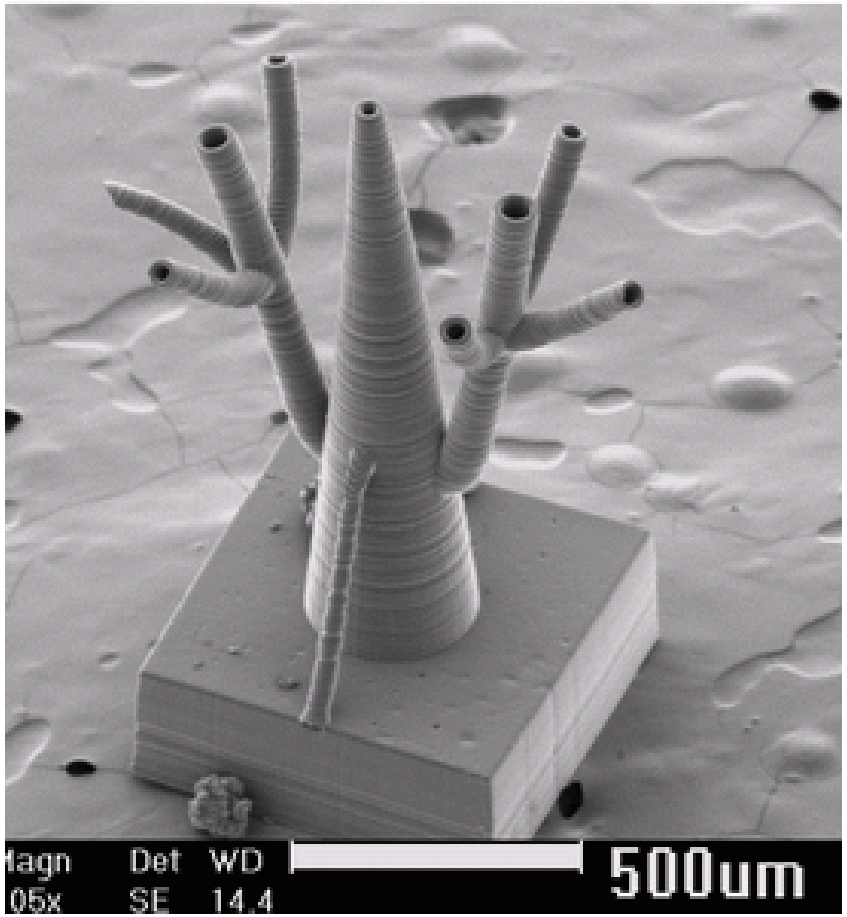


What can we MAKE using 3D printers?



Possibilities: Very Small Objects





Nicholas Fang, MIT

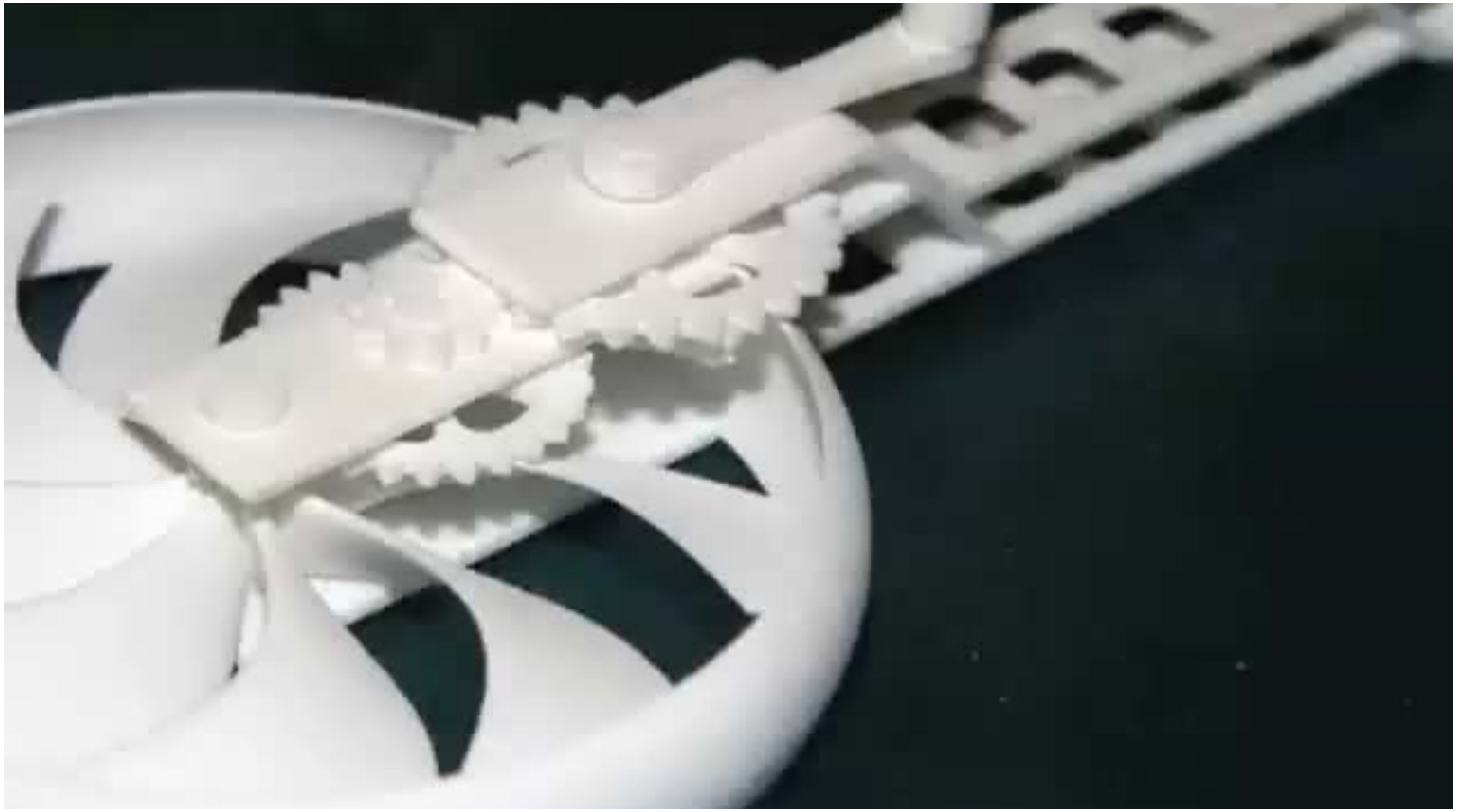
Possibilities: Very Large Objects

D-Space

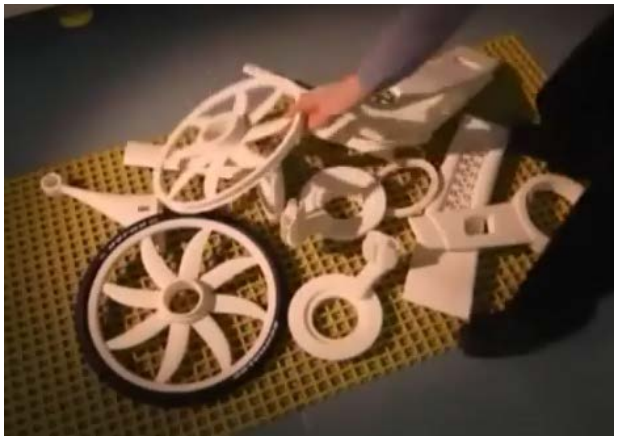
Chopper: Partitioning Models into 3D-Printable Parts

Luo et al. Siggraph Asia 2012

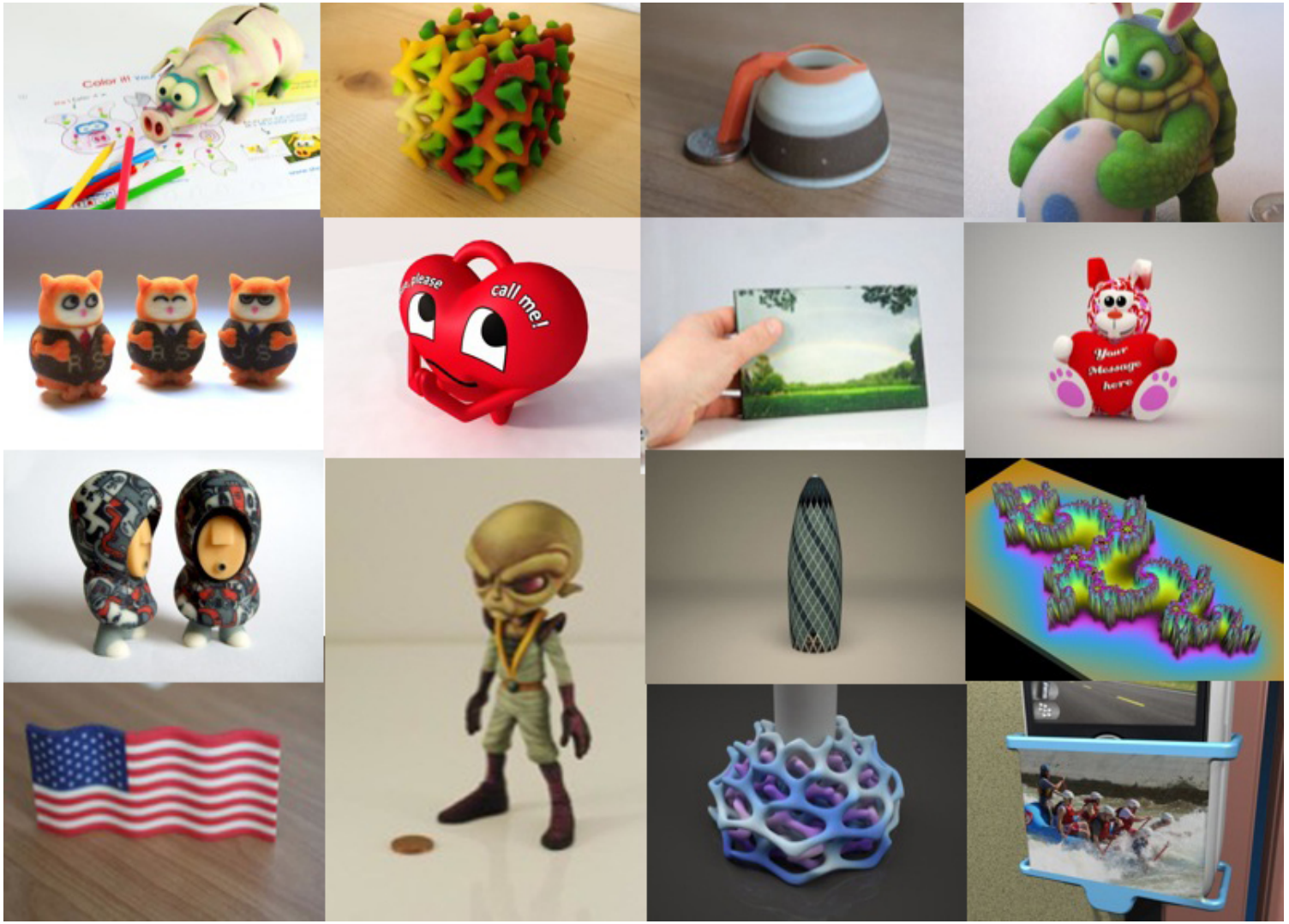
Possibilities: Mechanical Assemblies



Possibilities: Mechanical Assemblies

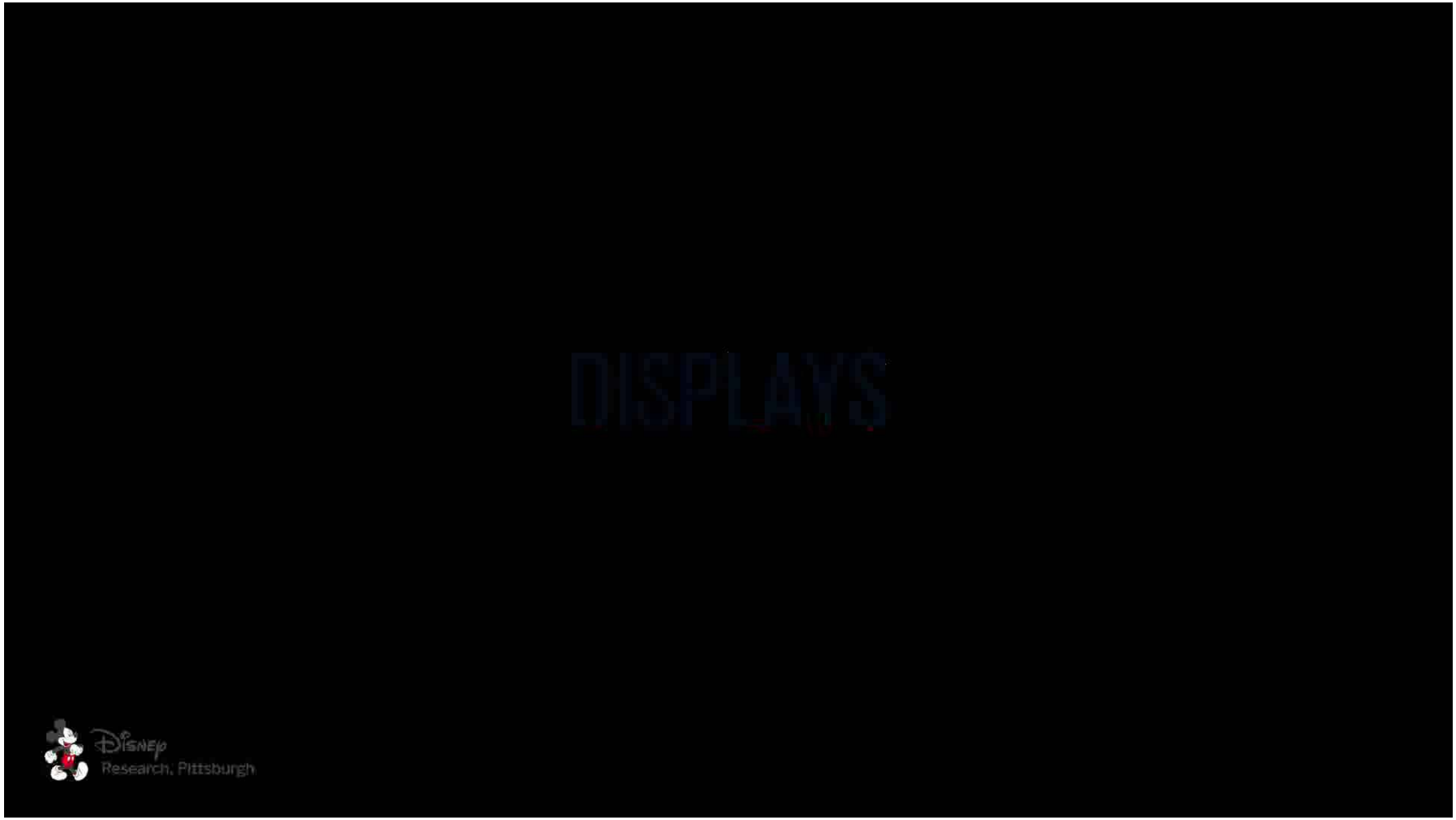


Possibilities: Color and Appearance



Z-Corp Full Color Printers

Possibilities: Optical Components



Willis et al. UIST 2012

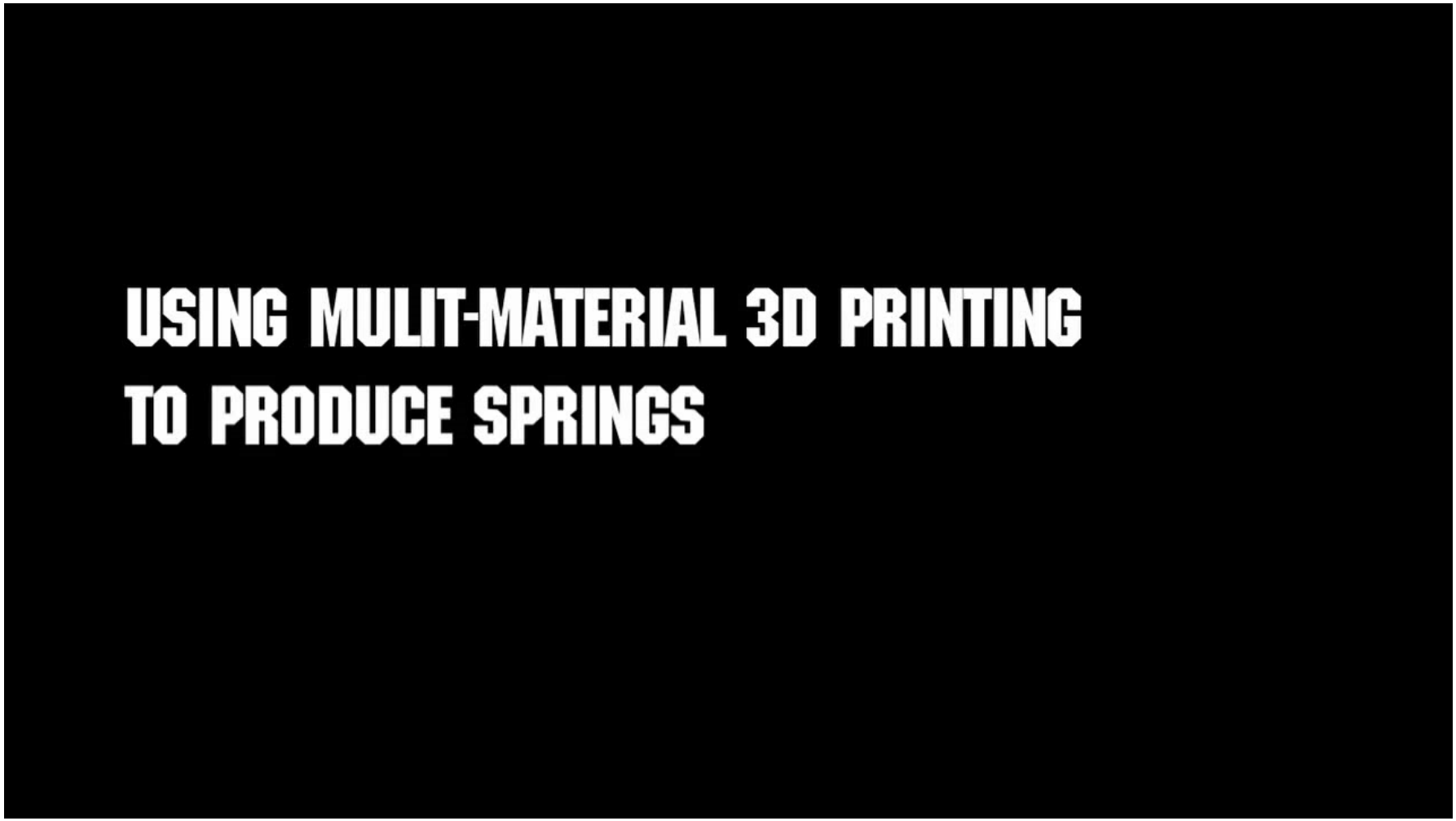
Possibilities: Optical Components

Willis et al. UIST 2012

Possibilities: Flexible Materials

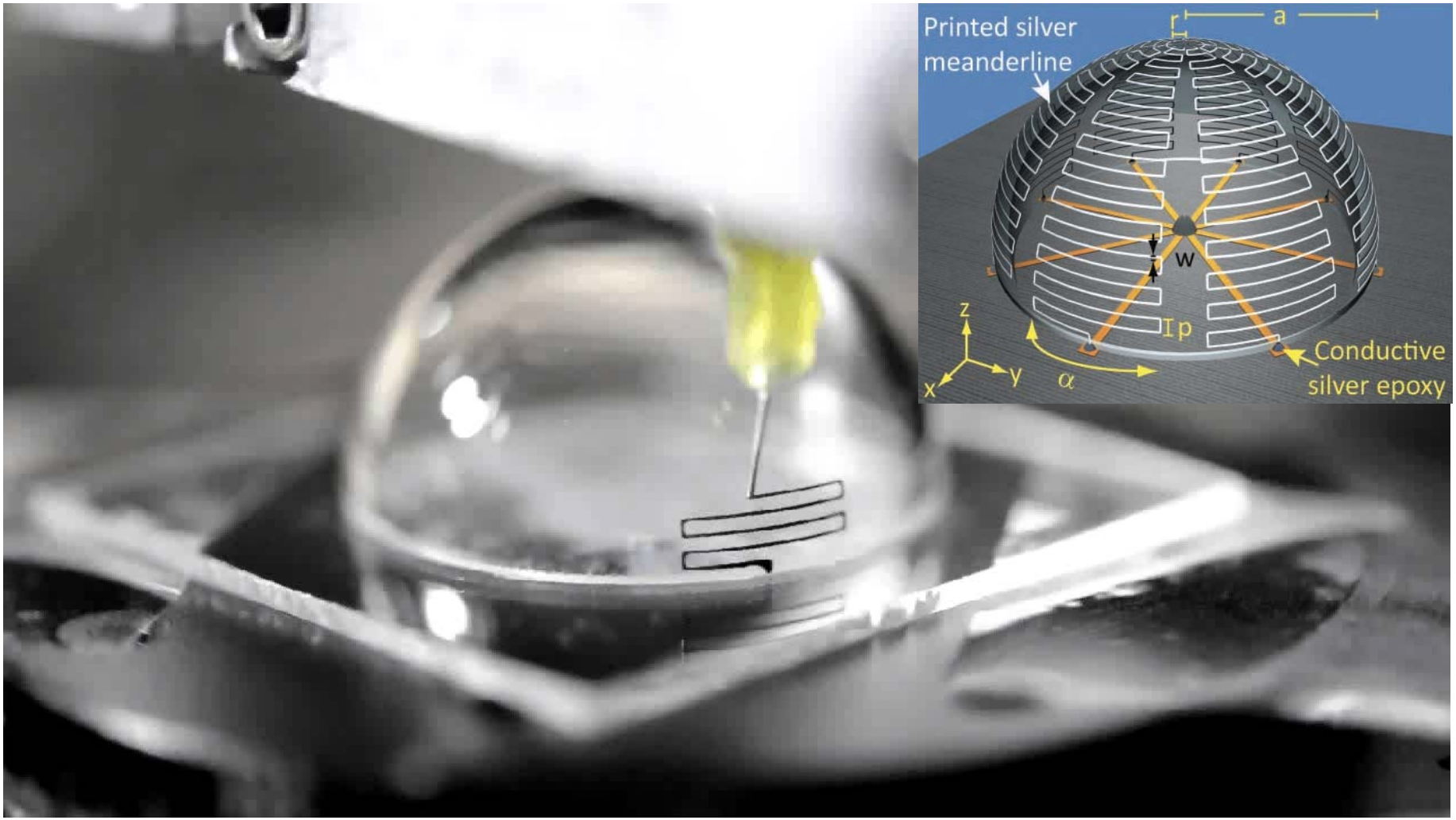
OBJET

Possibilities: Multiple Materials



OBJET

Possibilities: Conductive Materials



Jennifer Lewis, UIUC

Possibilities: Personalized Consumer Products

Continuum Fashion

MyRobotNation

3D Printing Technologies

- Fused Deposition Modeling
- Inkjet 3D Printing
- PolyJet
- Stereolitography
- DLP Printing
- Selective Laser Sintering (SLS)
  Direct Metal Laser Sintering (DMLS)

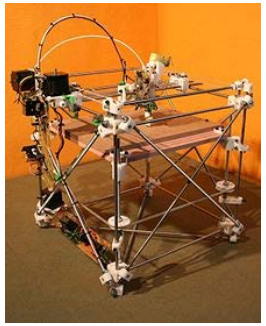
Fused Deposition Modeling (FDM)

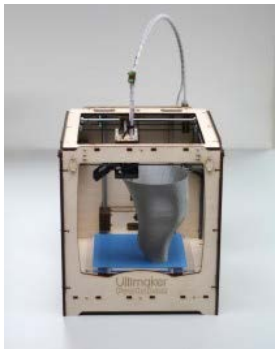
- Thermoplastic materials
  - ABS, ABSi, Polyphenylsulfone, Polycarbonate, Ultem 9085
  - Liquefied and deposited using heated extrusion heads
- Stratasys
  - http://www.stratasys.com
  - Dimension family
- Layer thickness: 0.18 mm
- Limited color
- Support material

Fused Deposition Modeling (FDM)

- Bits from Bytes BFB-3000
  - http://www.bitsfrombytes.com
  - Thermoplastic materials (ABS, PLA)
- RepRap
  - http://*reprap.org*
  - Open source/design
- MakerBot Thing-o-Matic
  - http://*www.makerbot.com/*
  - Open source/design
- Ultimaker
  - http://*ultimaker.com/*
  - Open source/design
- Fab@Home
  - http://www.fabathome.org/

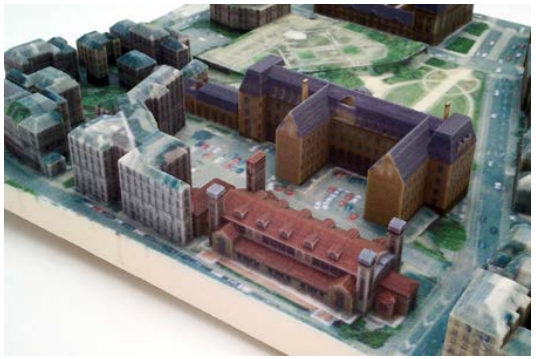






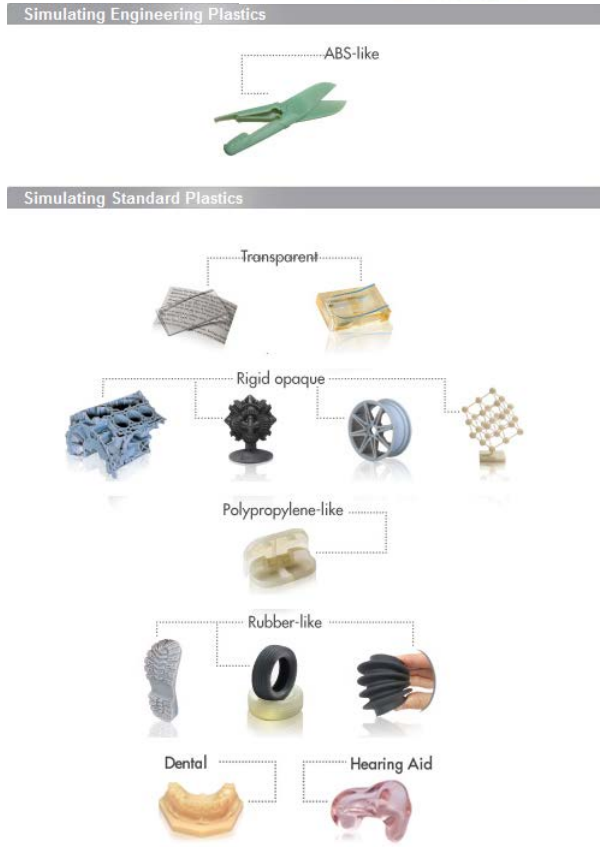
Inkjet 3D Printing

- Plaster powder + CMYK binder
- Uses HP inkjet print heads
- Z-Corp
  - http://www.zcorp.com
  - Z-Printer family
- 390K colors
- 540dpi resolution, 0.1mm layer thickness
- No support material is necessary



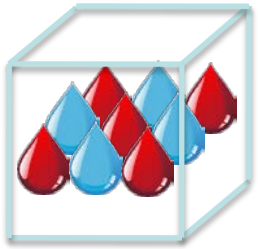
PolyJet

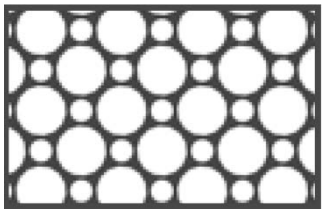
- Acrylic-based photopolymers
  - Jetted liquid is cured
  - Liquid materials can be mixed
- OBJET
  - http://www.objet.com/
  - Connex family
- 2 materials + support
- 16-30 micron layers

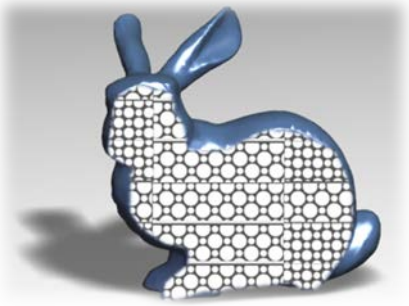


PolyJet Materials

- Rigid and flexible base materials
- Mixed materials
- Spatial arrangements of mixed materials and empty space
- Composite materials applied to arbitrary geometry

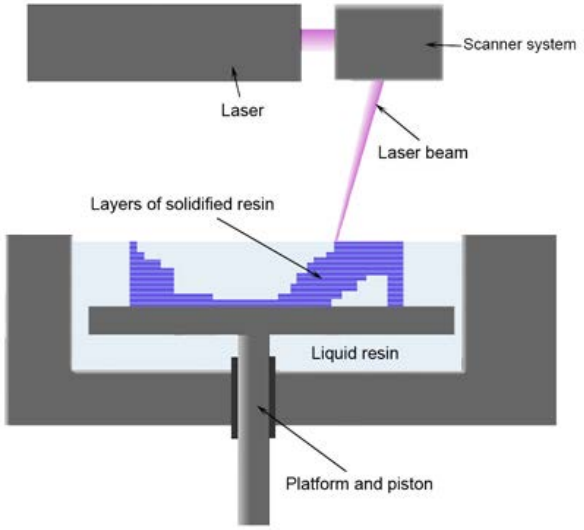






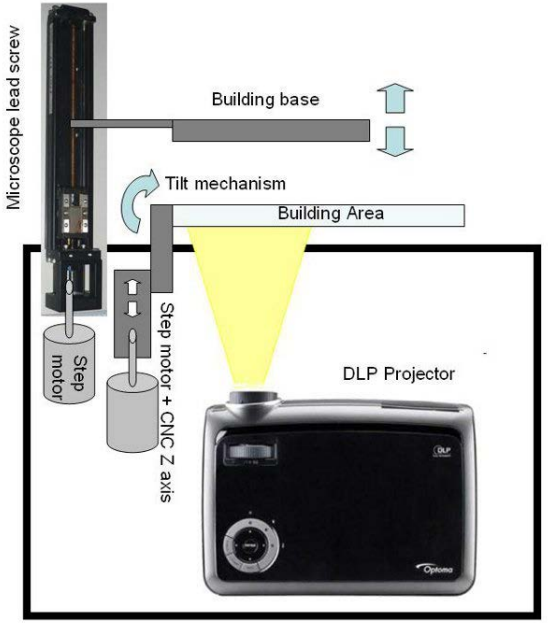
Stereolithography (SLA)

- UV laser cures a liquid resin
- Single material at one time
- Many different materials
- 3D Systems
  - http://www.3dsystems.com
  - iPro family
- Layer thickness: 0.02mm
- Uses 200mW laser
- High resolution



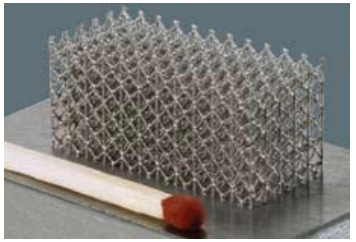
DLP 3D Printing

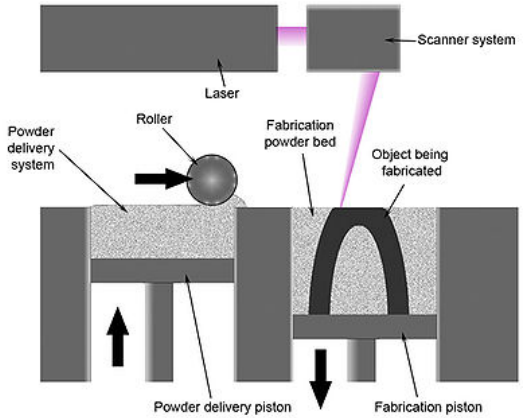
- Uses a DLP Projector
- Cures single photopolymer material
- Z-Corp
  - http://www.zcorp.com
  - Z-Builder Ultra
- EnvisionTec
  - http://www.envisiontec.de
  - Perfactory
- No support material
- Layer thickness 0.1-0.05 mm

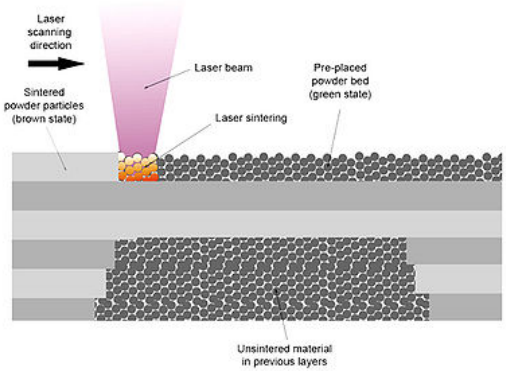


Selective Laser Sintering (SLS)
Direct Metal Laser Sintering (DMLS)

- Focused laser locally melts material
- Different materials are supported
  - plastic, nylon, metal, ceramic, glass
- 3D Systems
  - http://www.3dsystems.com
  - sPro family & Pro DM
- Layer thickness: 0.02 – 0.08mm
- Requires powerful 30W-400W laser







Today

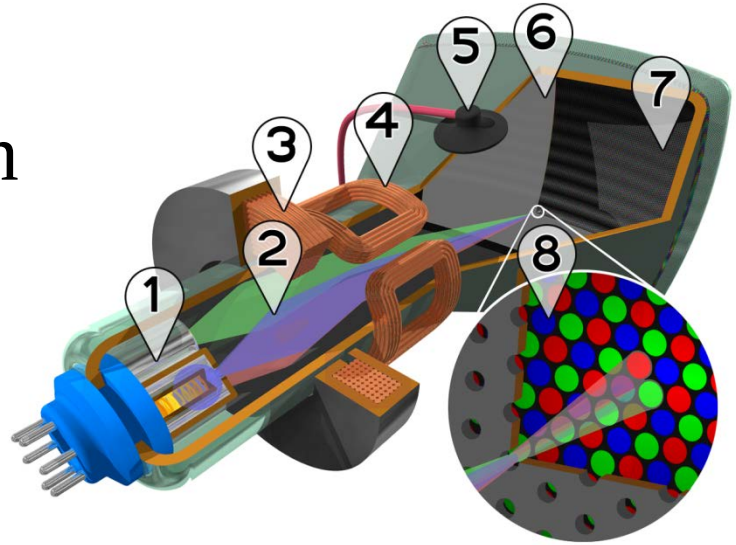
- Output Devices
  - 3D Printers
  - 2D Displays
  - 3D Displays

2D Displays

- Many different technologies
  - Cathode ray tube (CRT) display
  - Liquid crystal display (LCD)
  - Light-emitting diode (LED) display
  - Plasma display panel (PDP)
  - Organic light-emitting diode (OLED) display
  - Digital Light Processing (DLP)
  - Electronic paper
  - …

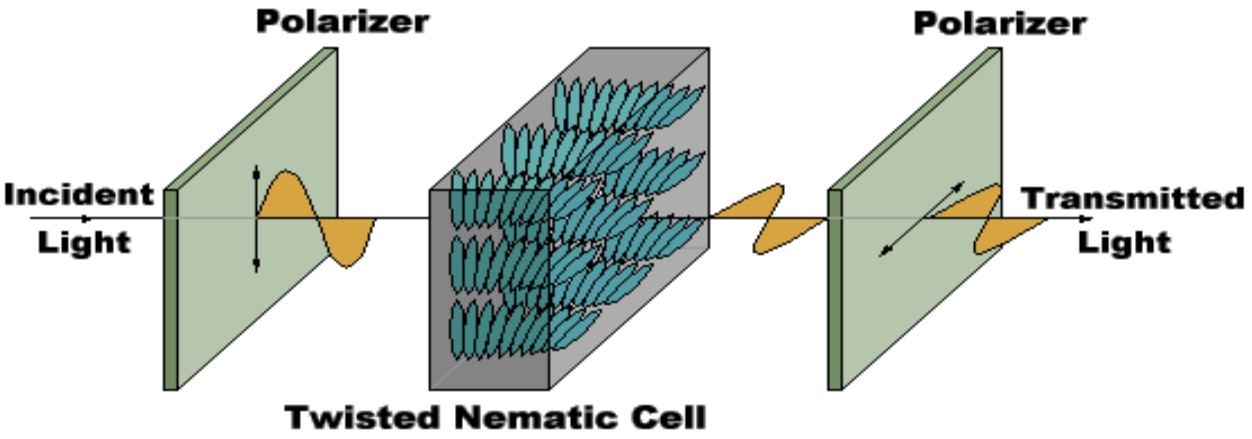
CRT Displays

- Use a vacuum tube
- Electron guns (1) create electron beams (2)
- Coils focus and deflect beams
- Color tubes use three different phosphors which emit RGB
- Fluorescent (phosphor-coated) screen emits light
- The front area is scanned repetitively in fixed pattern called **raster**



Liquid Crystal Displays (LCD)

- Two polarizing filters
  - The axes of transmission are perpendicular to each other
- Polarization modulating properties of liquid crystals
  - Twisted nematics (TN) – naturally twisted
  - Crytstalline state twists polarized light 90º
  - Electric current untwists them, no polarization change



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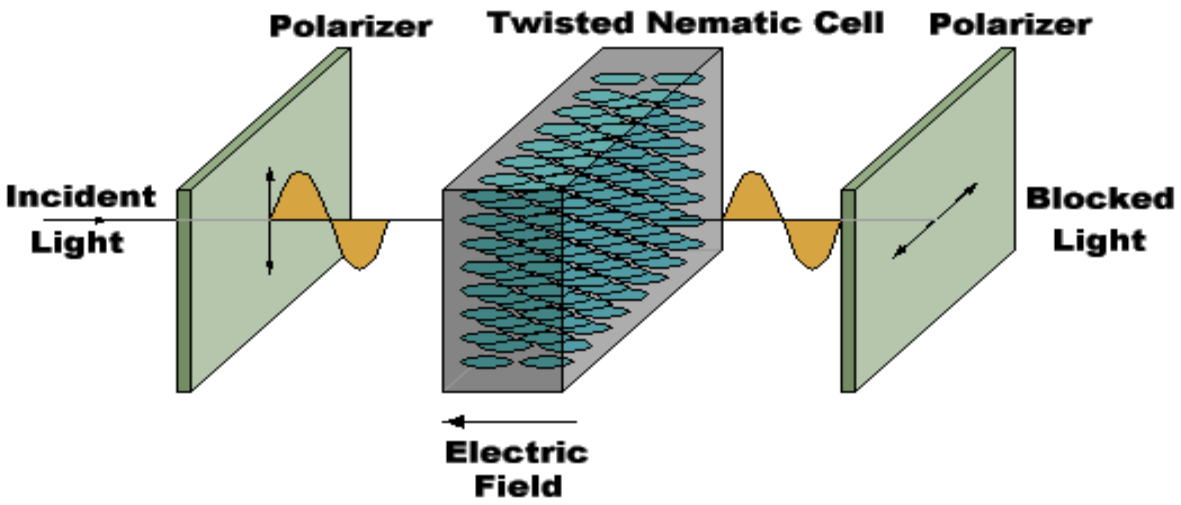


Liquid Crystal Displays (LCD)

- Light can be polarized
- Liquid crystals can transmit light and change light polarization
- The state of a liquid crystal can be changed by electric current
- There are transparent conductors

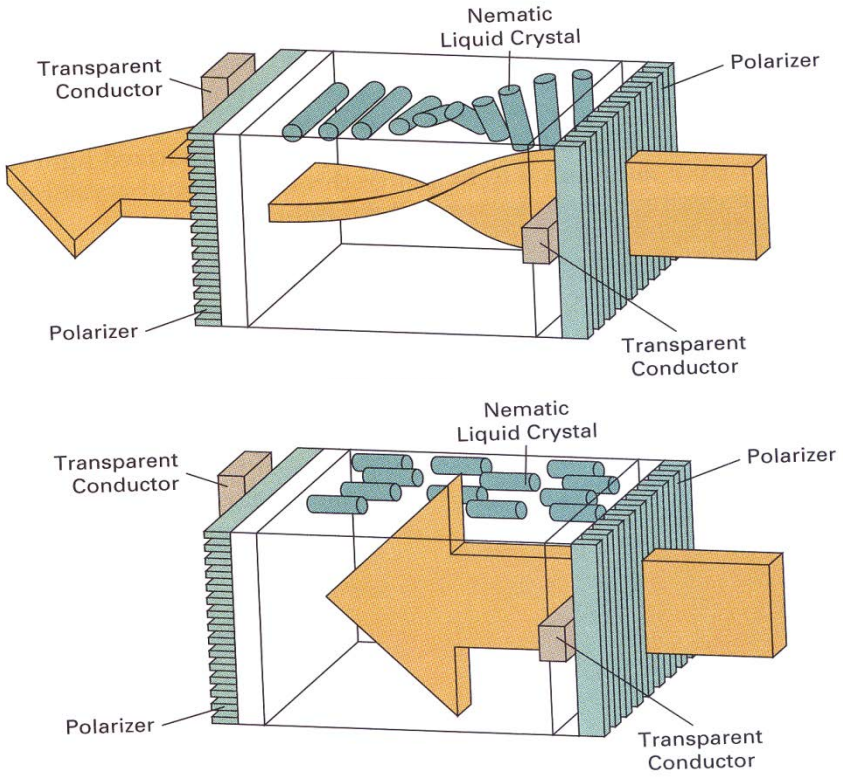
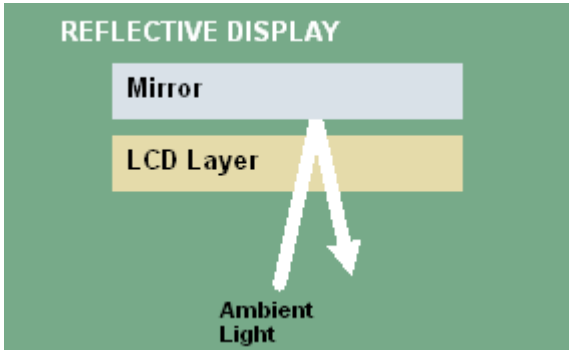


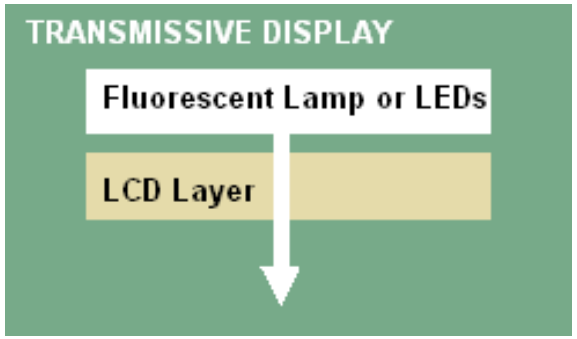
Figure 2.16 from
Hearn and Baker

Liquid Crystal Displays (LCD)

- Reflective LCDs
  - Use ambient light and a reflective surface

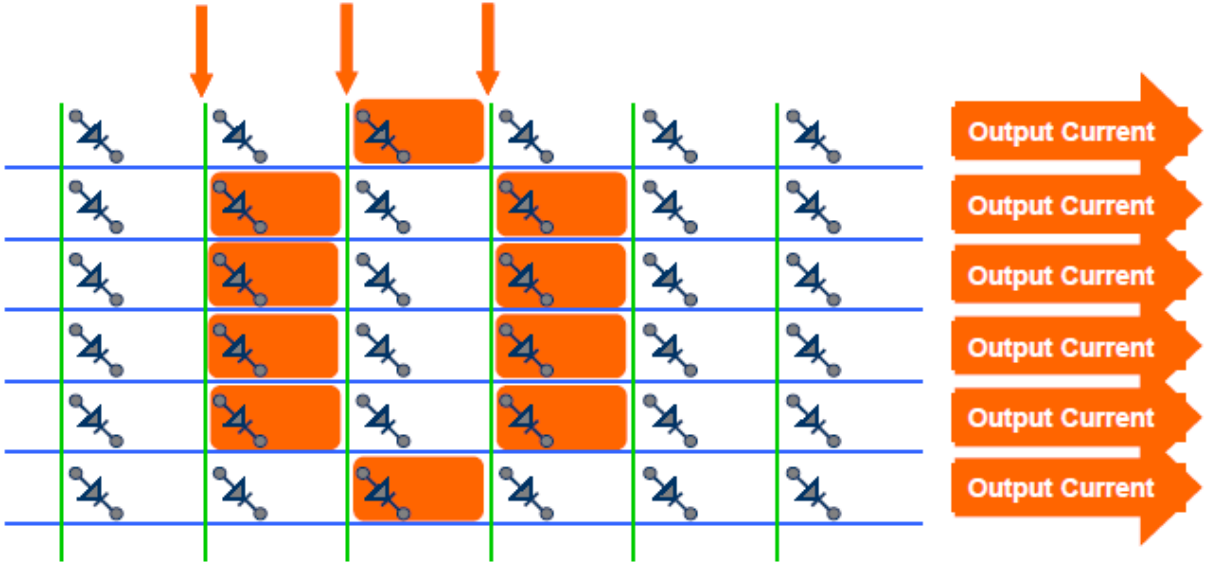


- Transmissive LCDs
  - Use backlight (fluorescent lamp or LEDs)



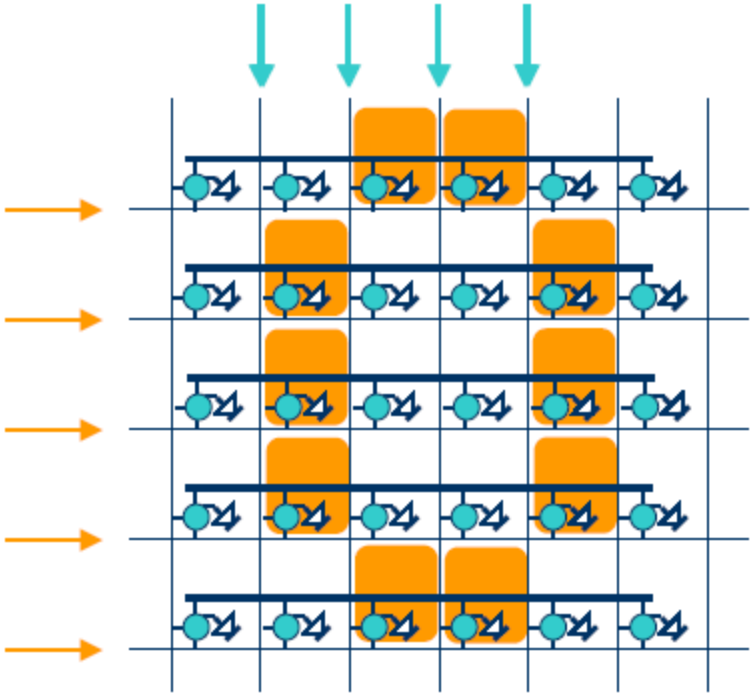
Addressing LCDs: Passive Matrix

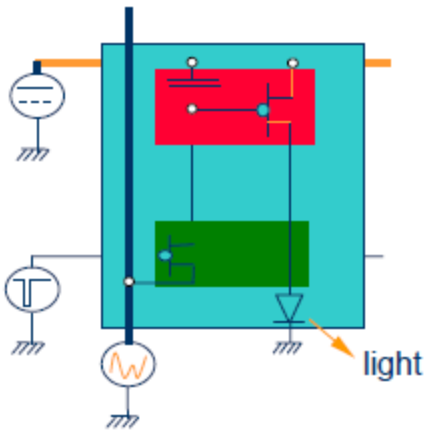
- Pixel must maintain its state when other pixels are addressed
- $m + n$ signals needed to address $m \times n$ display
- To address pixel (i , j) apply voltage to column i and set ground to row j



Addressing LCDs: Active Matrix

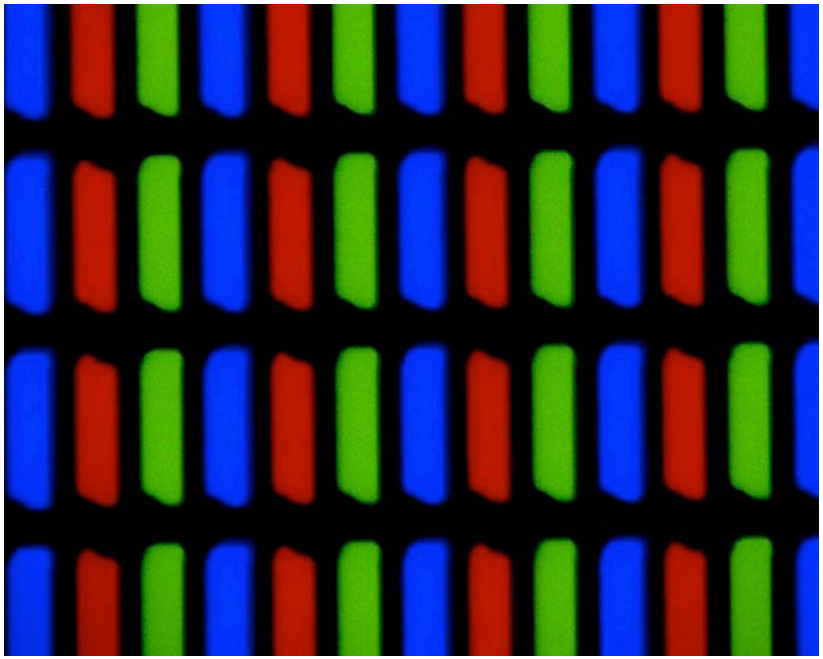
- Each pixel is attached to a switch device that maintains pixel's state when other pixels are addressed
- Thin film transistors (TFTs) are the most common





What About Color?

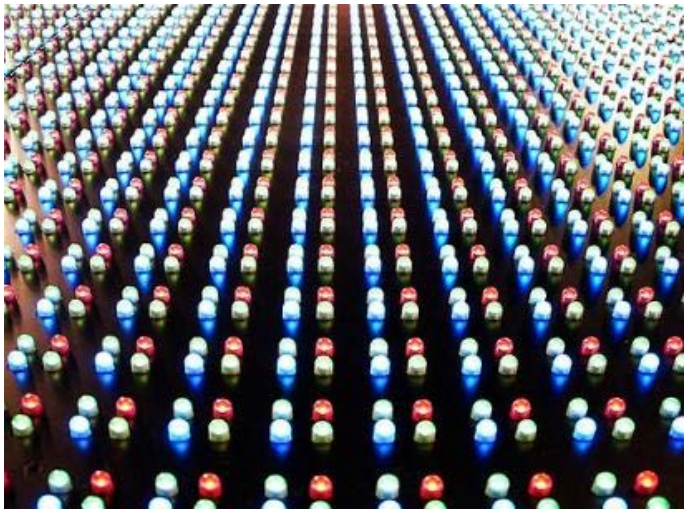
- A color filter is inserted as an additional layer
- Each pixel is composed of a red, green, and blue subpixel
- The individual colors blend together even when the display is viewed from a close distance



A 300x close-up view of a typical LCD display

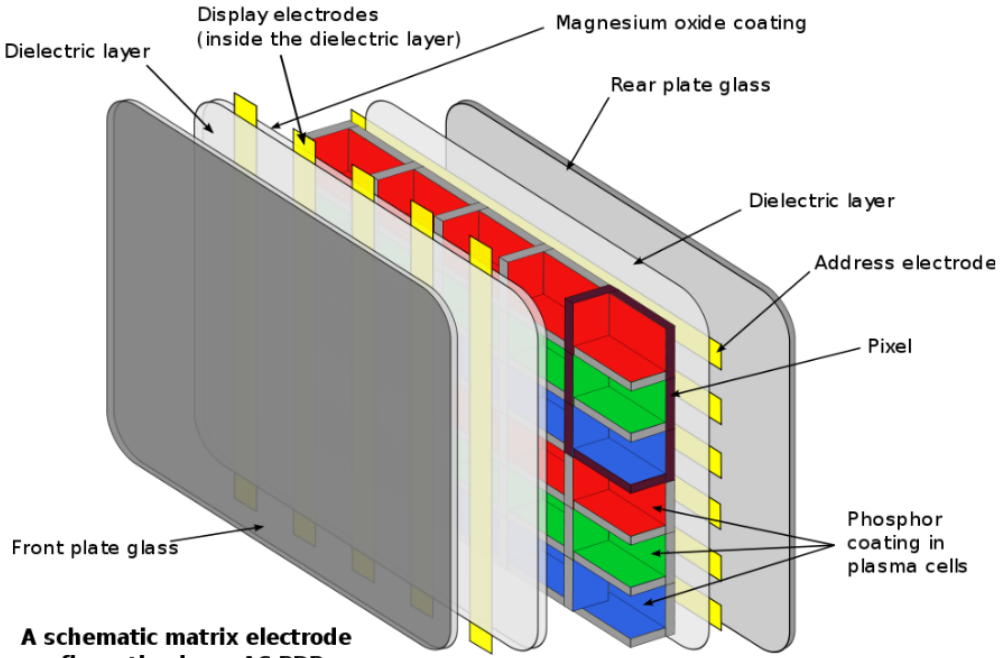
Light-Emitting Diode (LED) Displays

- Use light-emitting diodes as displays
- A cluster of RGB diodes forms a full-color pixel
- RGB diodes can be packaged together



Plasma Display Panels (PDPs)

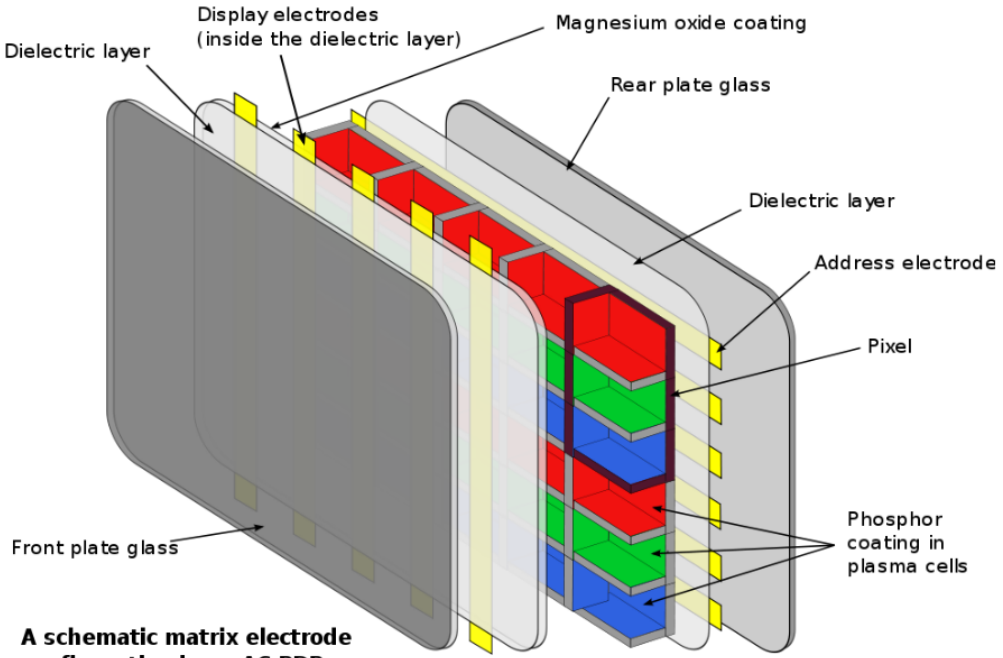
- A panel has an array of tiny cells
- Each cell is filled with a noble gas (e.g., neon, xenon)
- Each cell acts as a tiny “neon lamp” when voltage is applied across the cell



A schematic matrix electrode configuration in an AC PDP

Plasma Display Panels (PDPs)

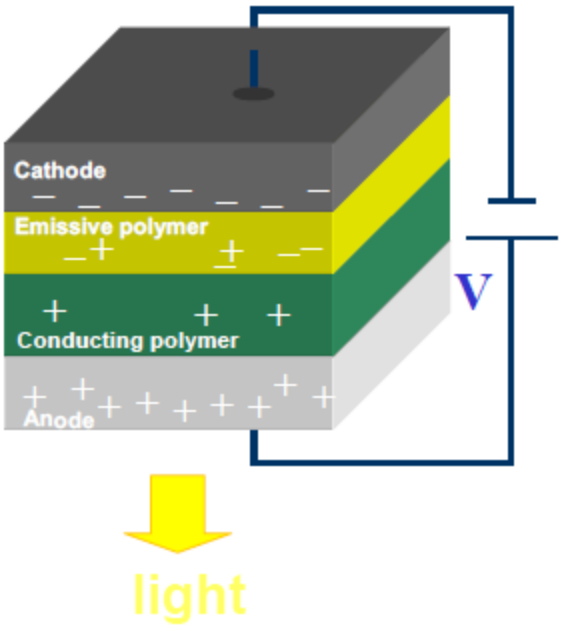
- Each pixel is made of 3 subpixel cells RGB
- Each subpixel cell is coated with a different phosphor
- UV photons emitted by the plasma excite phosphor
- Crossing electrodes create a voltage between front and back

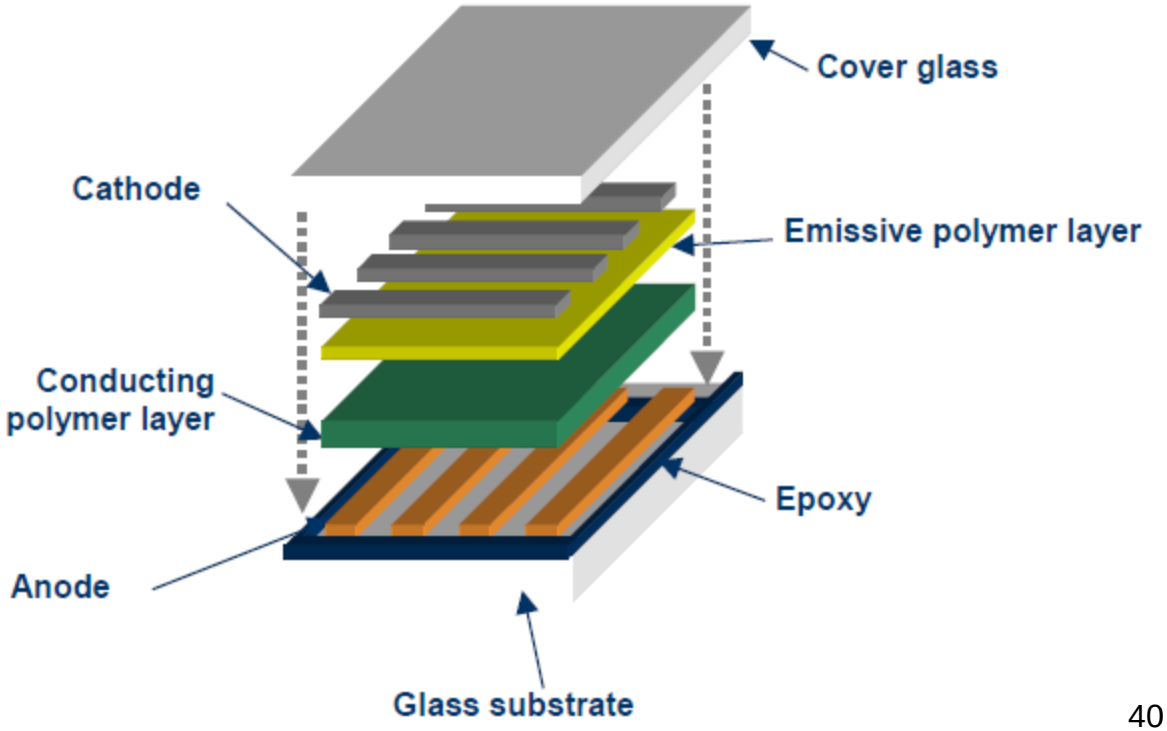


A schematic matrix electrode configuration in an AC PDP

Organic Light-Emitting Diode (OLED)

- Use organic materials that produce light under voltage
- Two types: small molecules, light-emitting polymers
- Both passive and active matrix
- Single-layer, bilayer, and multi-layer

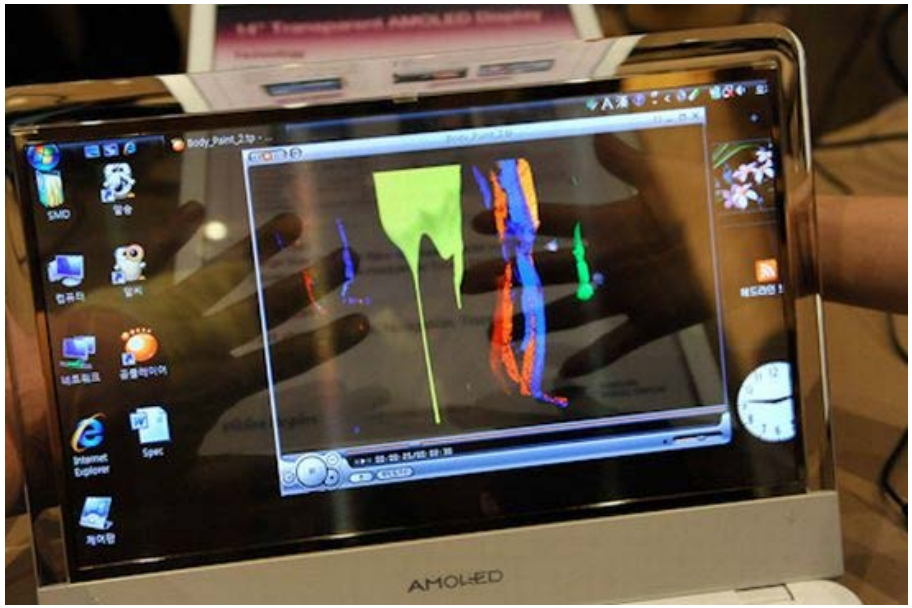




Organic Light-Emitting Diode (OLED)

- Very good power efficiency
- Light weight, flexible, transparent
- Fast response time, large viewing angle
- But … current cost is high and lifespan is low

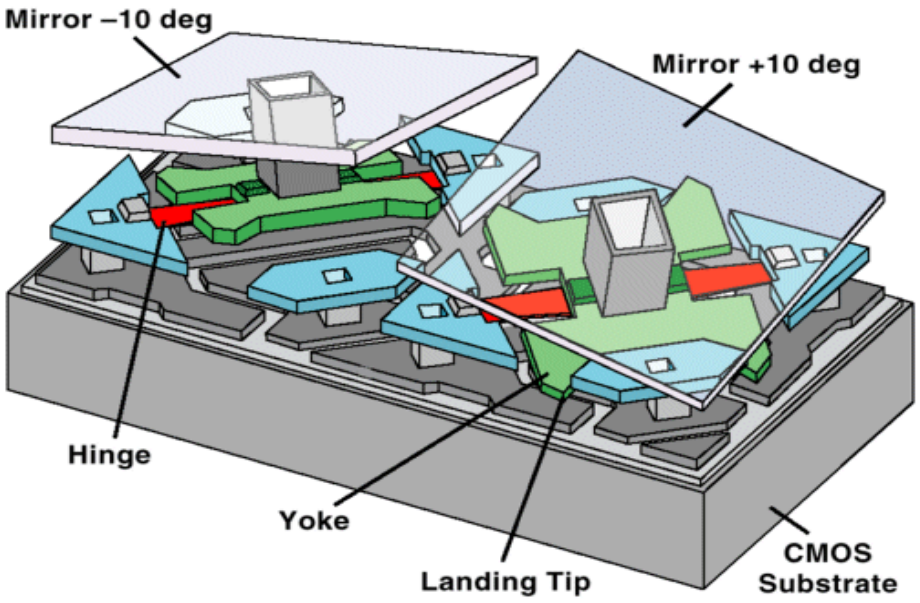
OLED Display by Sony

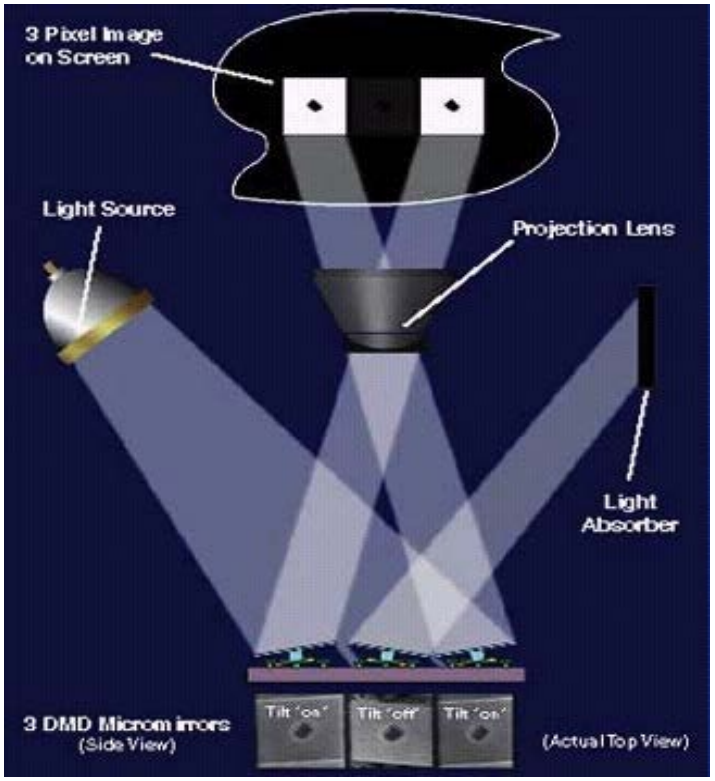


Transparent OLED Display by Samsung

Digital Light Processing (DLP)

- Uses Digital Micromirror Devices (DMDs)

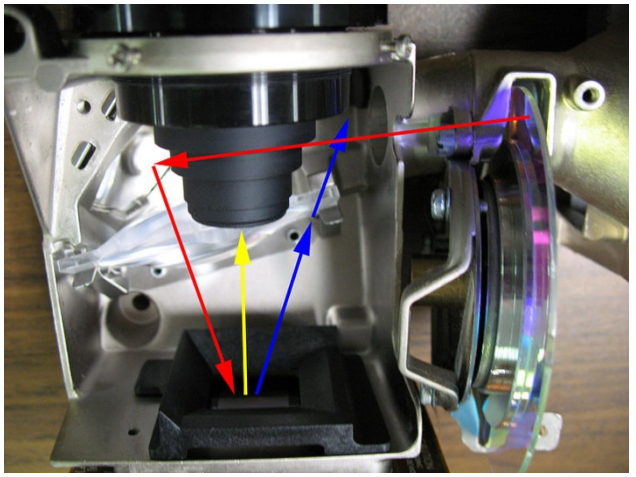


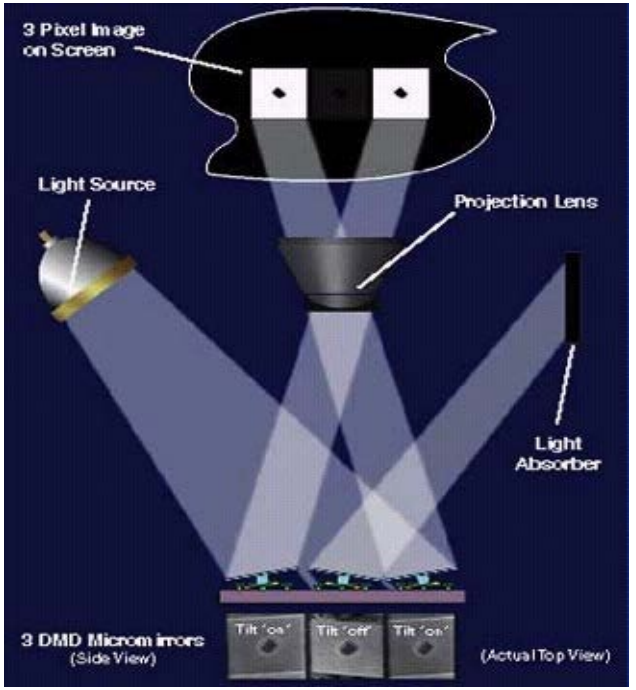


Digital Light Processing (DLP)

- Grey levels obtained by modulating pulse width
- Color produced using a color wheel or three-chip DLP
- Very good resolution
- Very bright

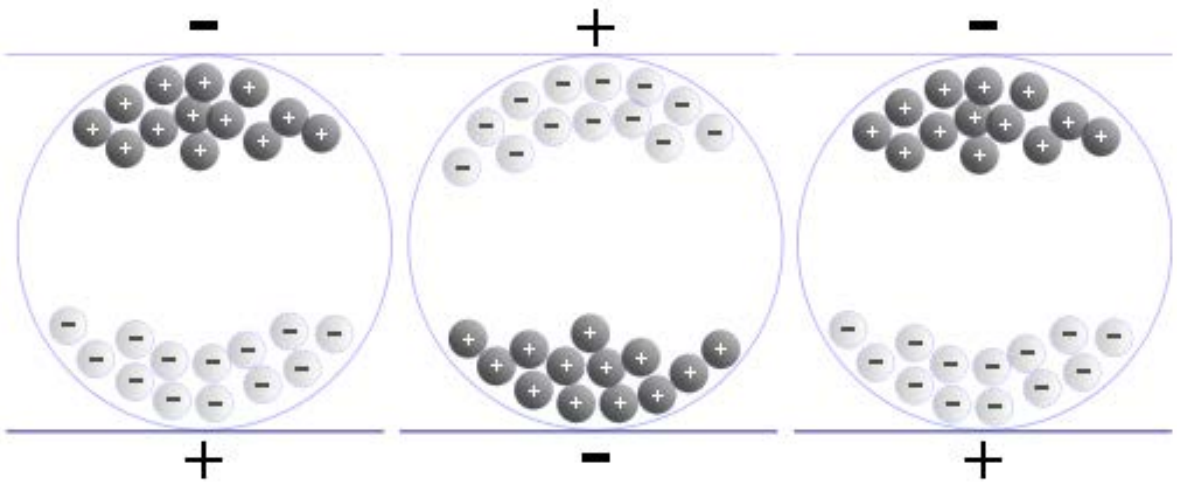
- Used for rear-projection TV sets and digital projectors





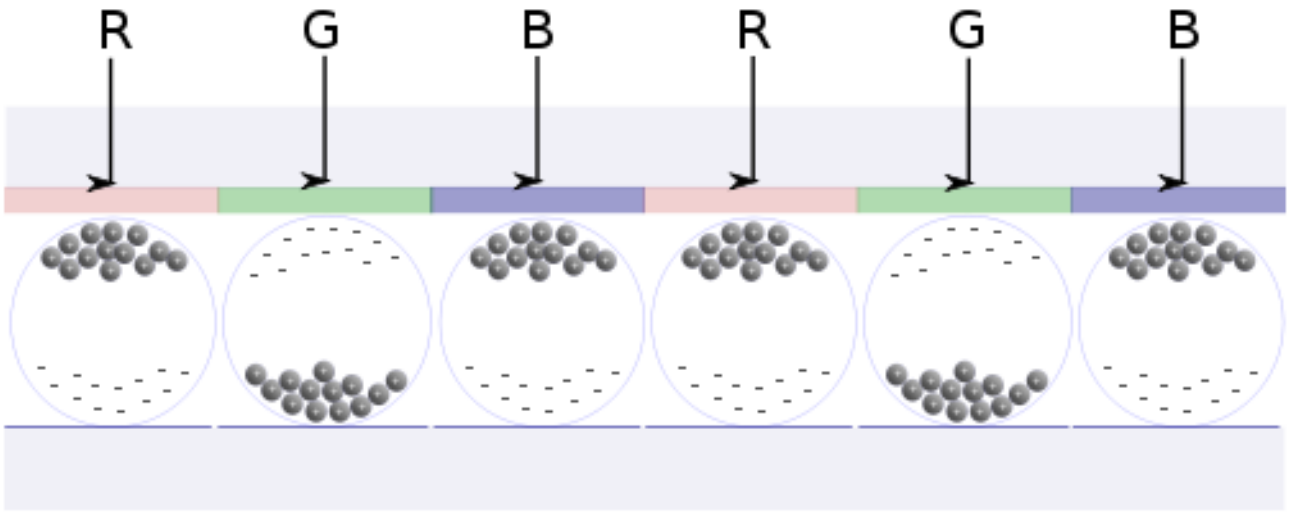
Electronic Paper: Reflective Displays

- Electrophoretic displays are the most popular
  - E Ink (Kindle, Nook, etc.)
- Microcapsules filled with electrically charged white particles suspended in an oily solution with black dye
- White particles moved up or down by applying a voltage to specific pairs of electrodes



Electronic Paper: Reflective Displays

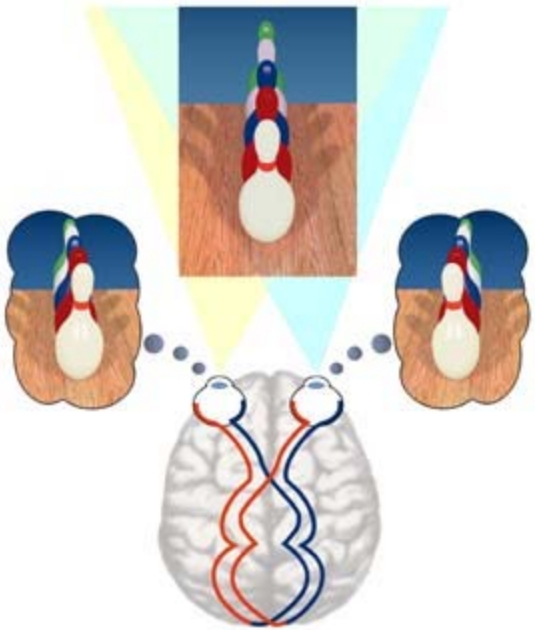
- Color can be produced by using a thin colored RGB filter
  - But the overall reflectance is reduced
- Low power usage
  - Power is only drawn when the display is updated
- Low refresh rate

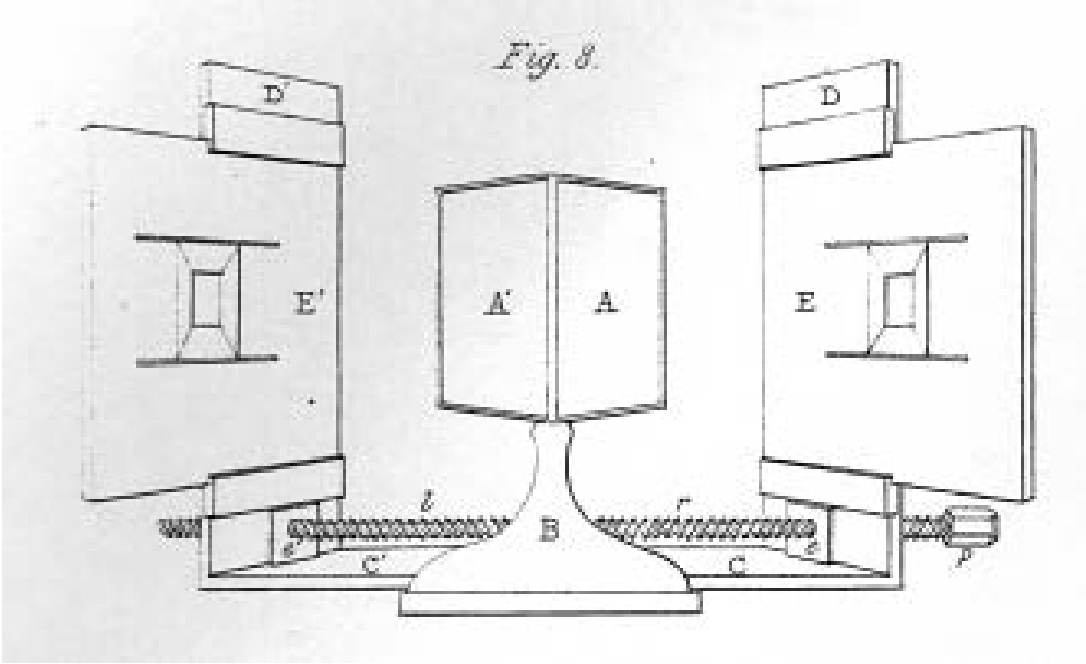


Today

- Output Devices
  - 3D Printers
  - 2D Displays
  - 3D Displays
    - Depth Perception
    - Stereoscopic Displays
    - Autostereoscopic Displays & Multiview Autostereoscopic Displays
    - Volumetric Displays

Binocular Vision - Stereopsis

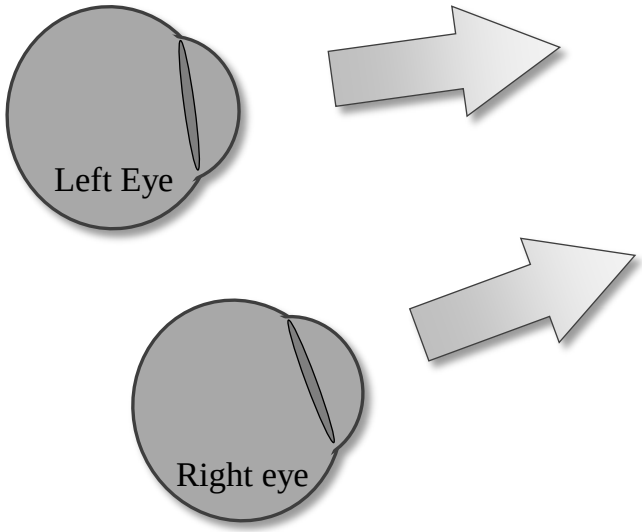




Sir Charles Wheatstone, 1838

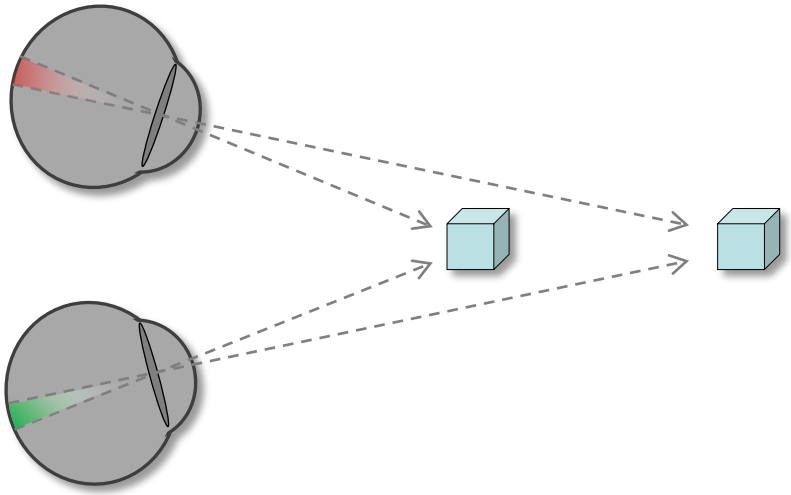
Stereo on a Flat Display

- Active
  - Liquid crystal shutter glasses / time multiplexing
- Passive
  - Polarized glasses
  - Anaglyph
  - Super-anaglyph



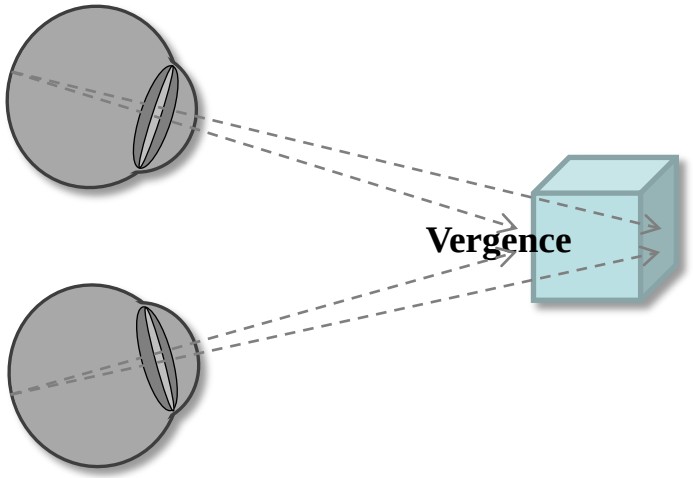
Depth Perception

- We see depth due to depth cues
- Stereoscopic depth cues:
  - binocular disparity



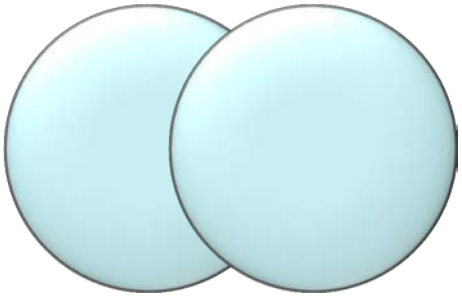
Depth Perception

- We see depth due to depth cues
- Stereoscopic depth cues:
  - binocular disparity
- Ocular depth cues:
  - accommodation,
  - vergence



Depth Perception

- We see depth due to depth cues
- Stereoscopic depth cues:
  - binocular disparity
- Ocular depth cues:
  - accommodation,
  - vergence
- Pictorial depth cues:
  - occlusion,
  - size,
  - shadows …



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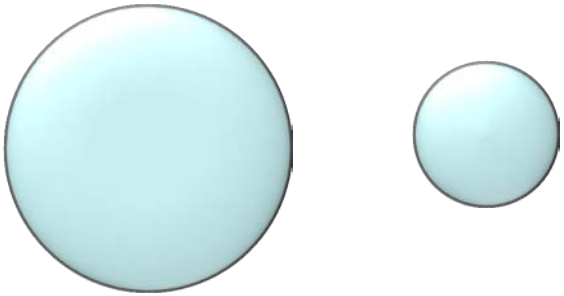

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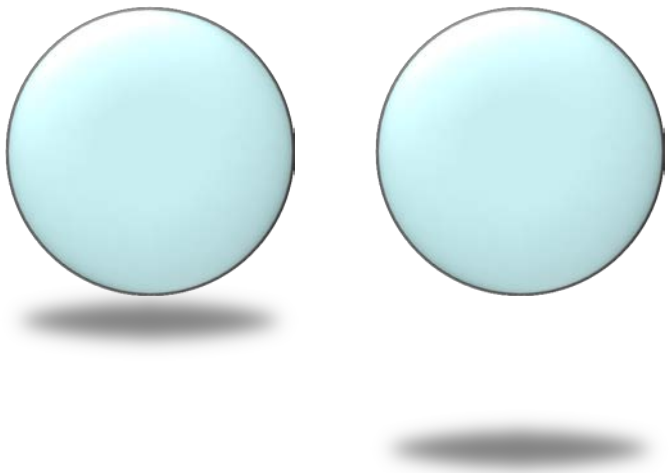

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  - binocular disparity
- Ocular depth cues:
  - accommodation,
  - vergence
- Pictorial depth cues:
  - occlusion,
  - size,
  - shadows …

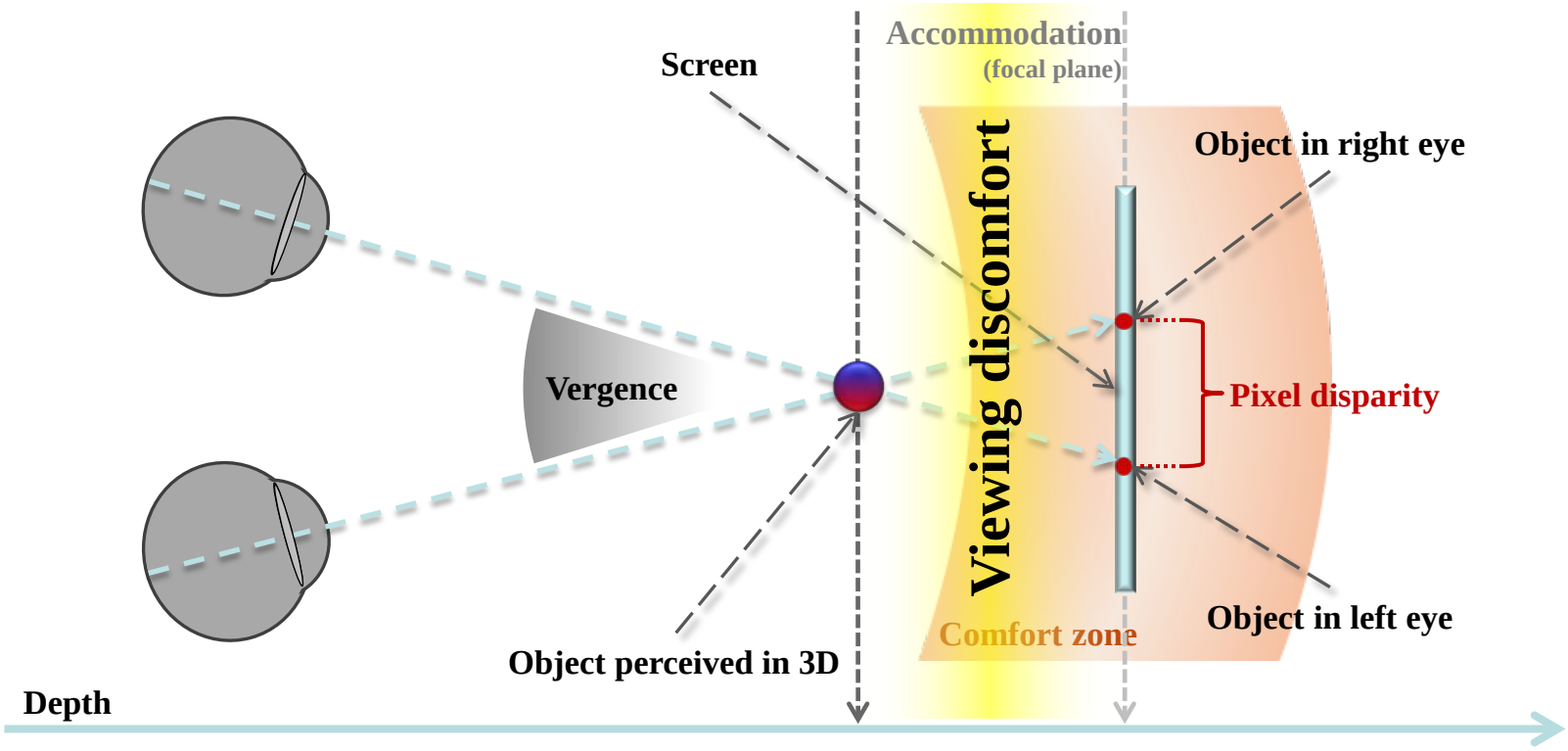
Challenge:
Consistency is required!

Disparity & Occlusion Conflict

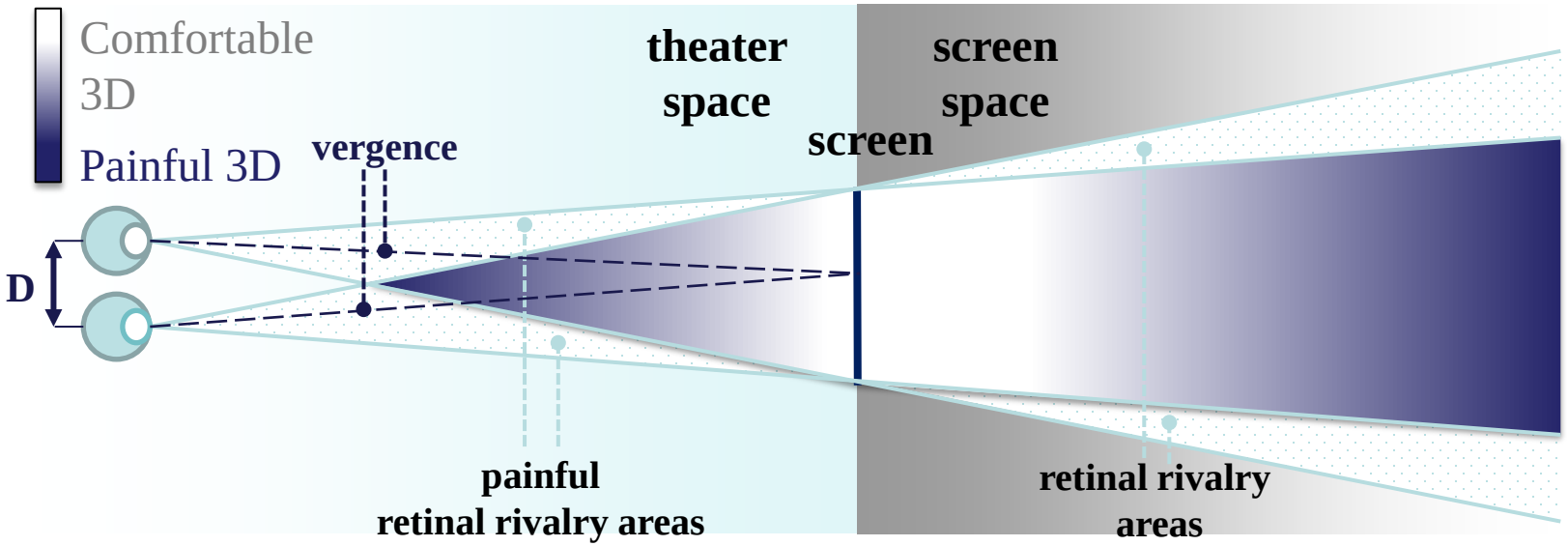
Objects in front

Disparity & Occlusion Conflict

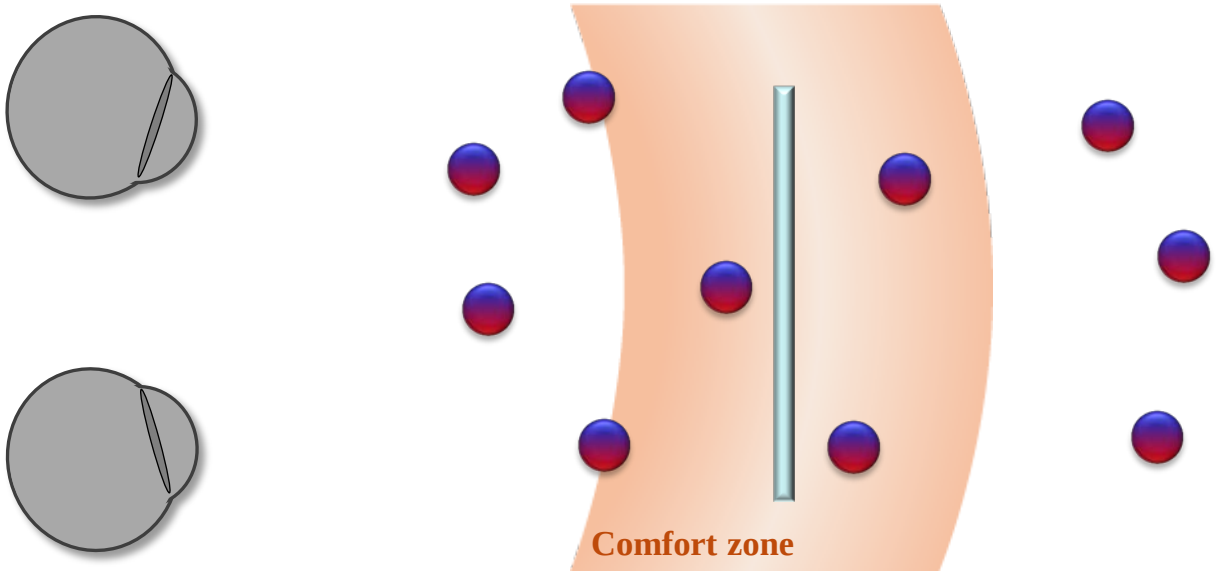
Conflicting Depth Cues



Stereoscopic Comfort Zone

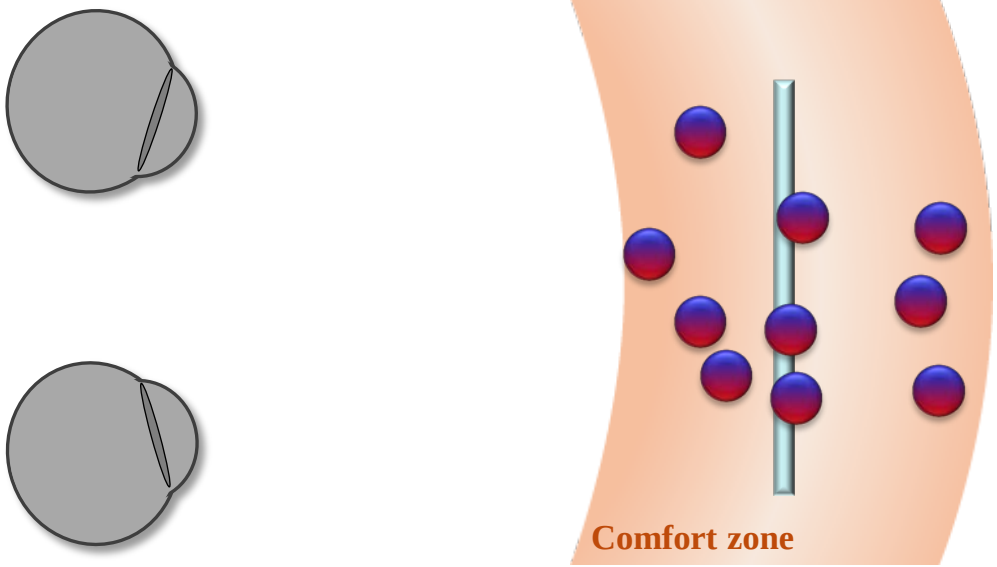


Depth Manipulation



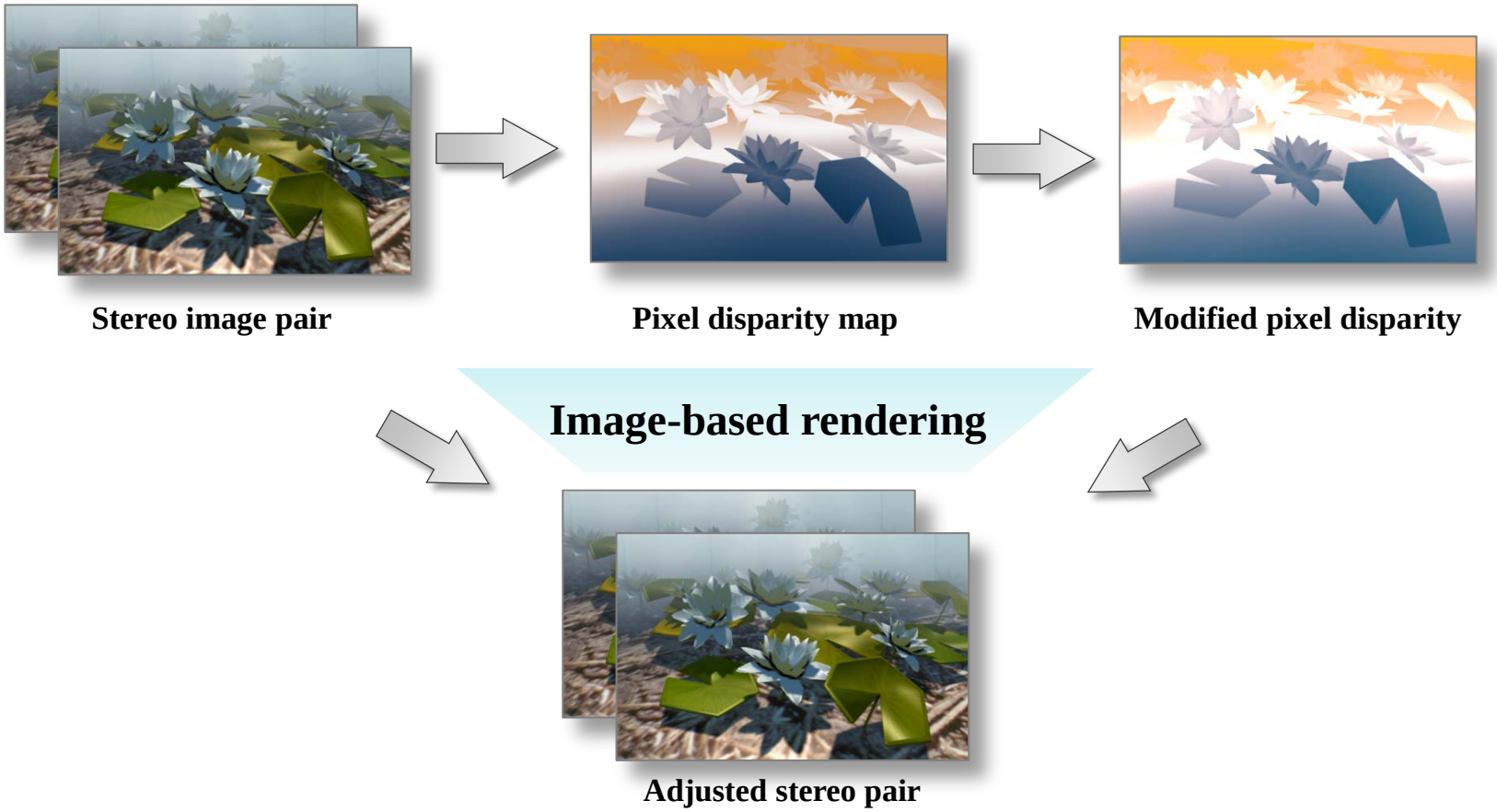
Viewing discomfort

Depth Manipulation



Viewing comfort

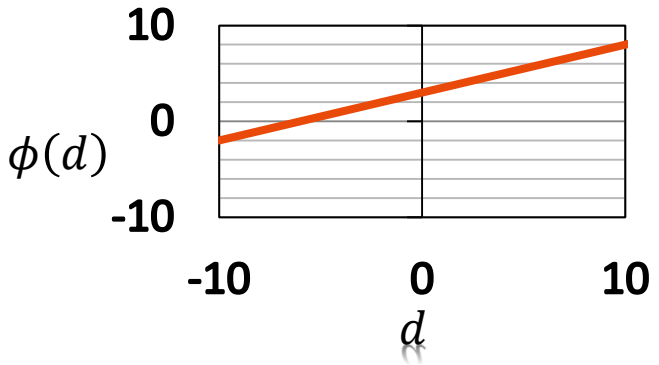
Disparity Remapping

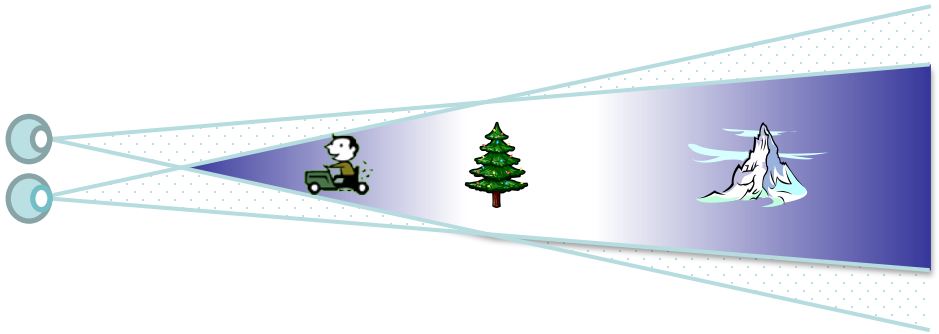


Disparity Remapping Operators

- Linear Remapping

$$\phi(d) = .5d + 3$$

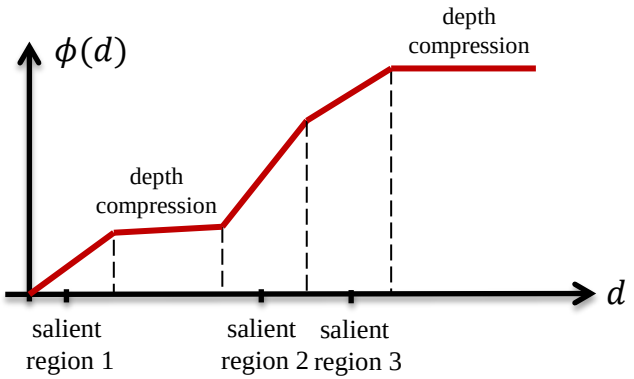


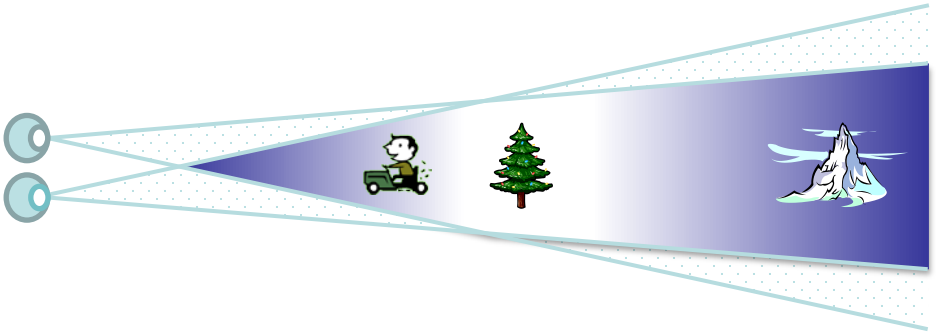


Disparity Remapping Operators

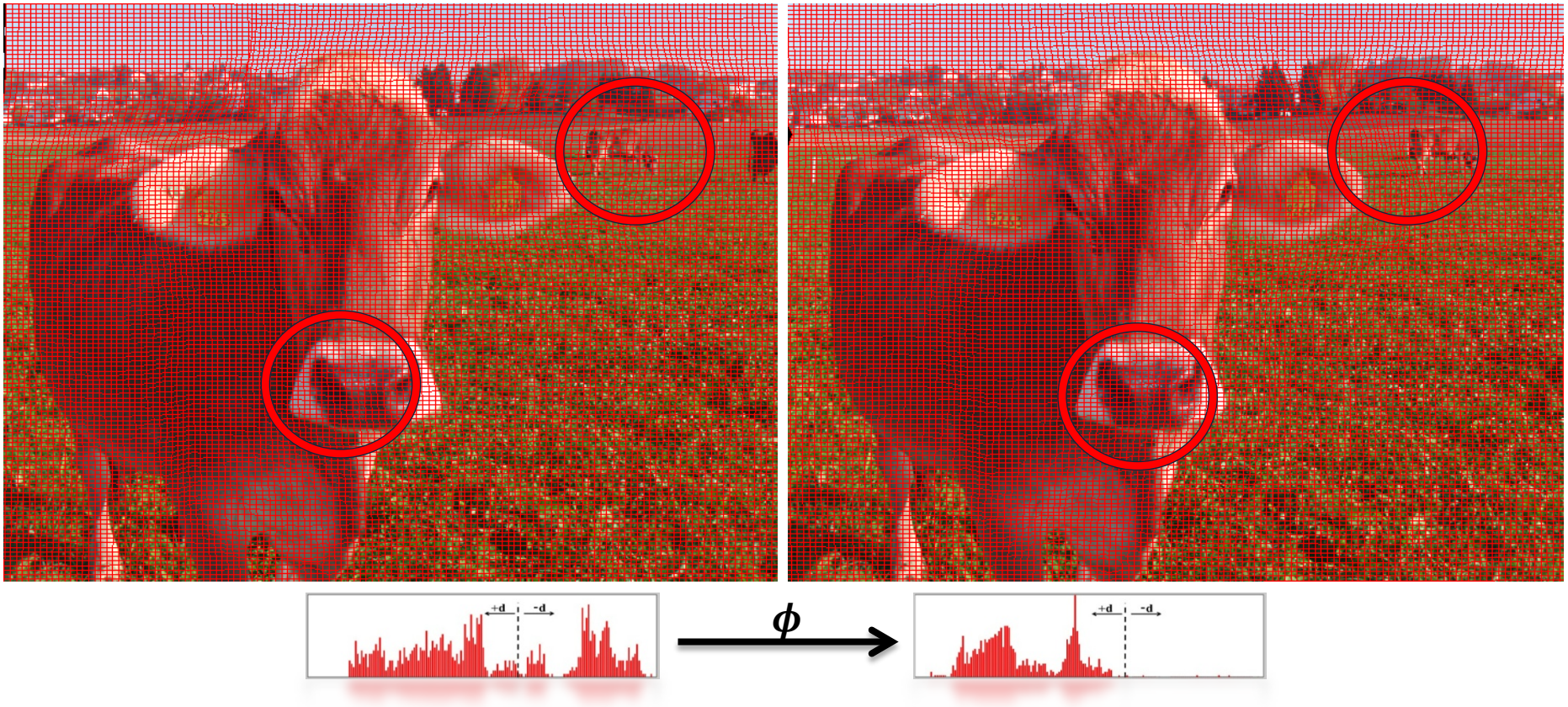
- Nonlinear Remapping

$$\phi(d,x,y) = \begin{cases} d, & (x,y,d) \in [\ \text{  }, \text{  }, \text{  }\ ] \\ \log(1+d), & \text{otherwise} \end{cases}$$





Disparity Remapping: An Example



Exceeded Depth & Correction

input

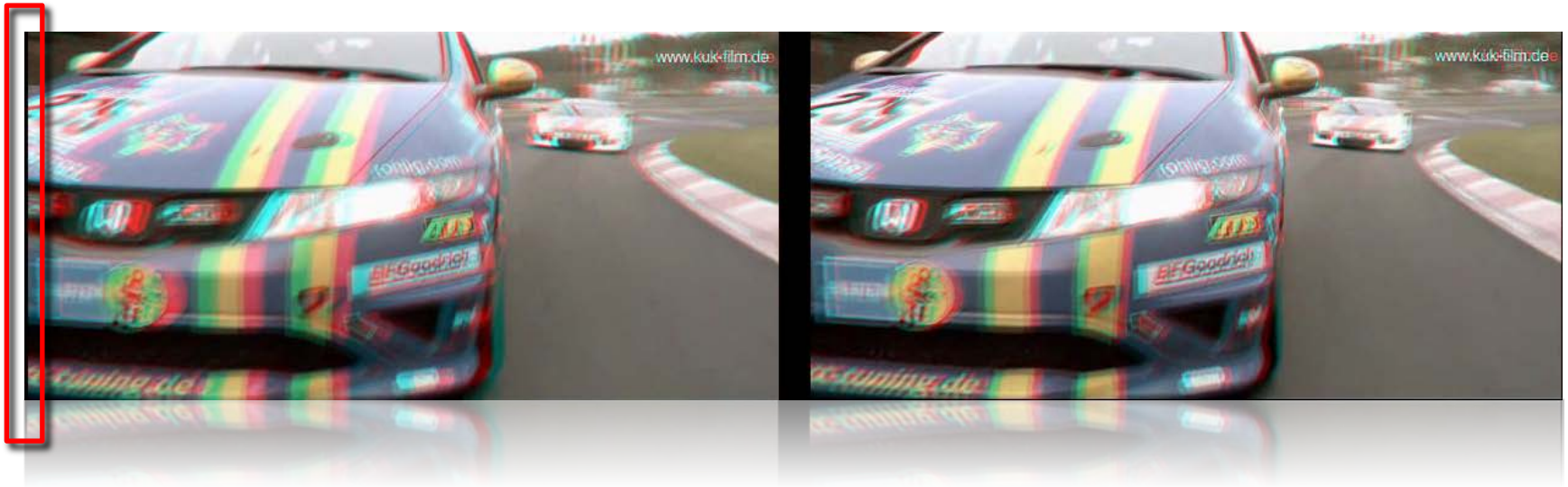
output

Non-Linear Automatic Stereo Correction

- Framing Problem

Non-Linear Automatic Stereo Correction

- Framing Problem



Non-Linear Automatic Stereo Correction

- Framing Problem

Non-Linear Automatic Stereo Correction

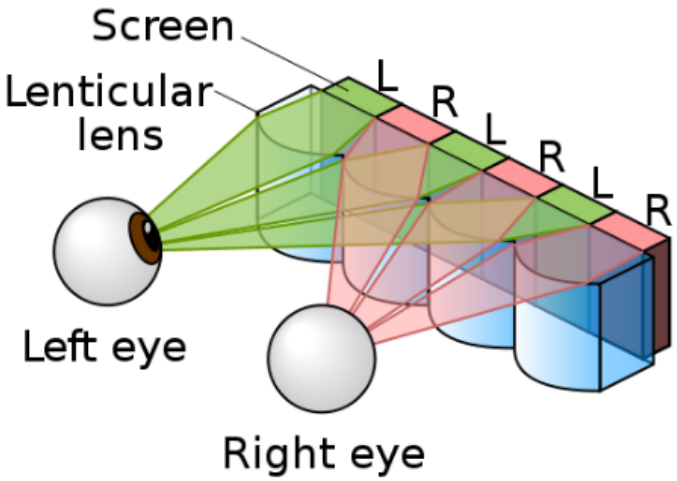
- Framing Problem

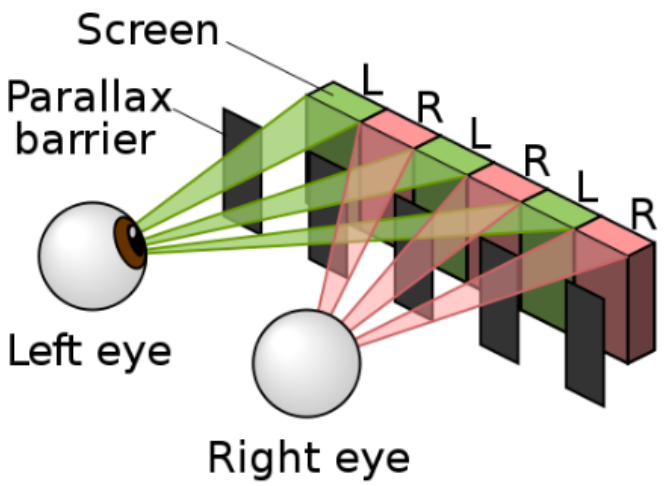
Today

- Output Devices
  - 3D Printers
  - 2D Displays
  - 3D Displays
    - Depth Perception
    - Stereoscopic Displays
    - Autostereoscopic Displays & Multiview Autostereoscopic Displays
    - Volumetric Displays

Autostereoscopic Displays

- Binocular parallax without glasses
- Two different types
  - Lenticular lenslets
  - Parallax barrier (front)





Autostereoscopic Displays

- Binocular parallax without gla
- Two different types
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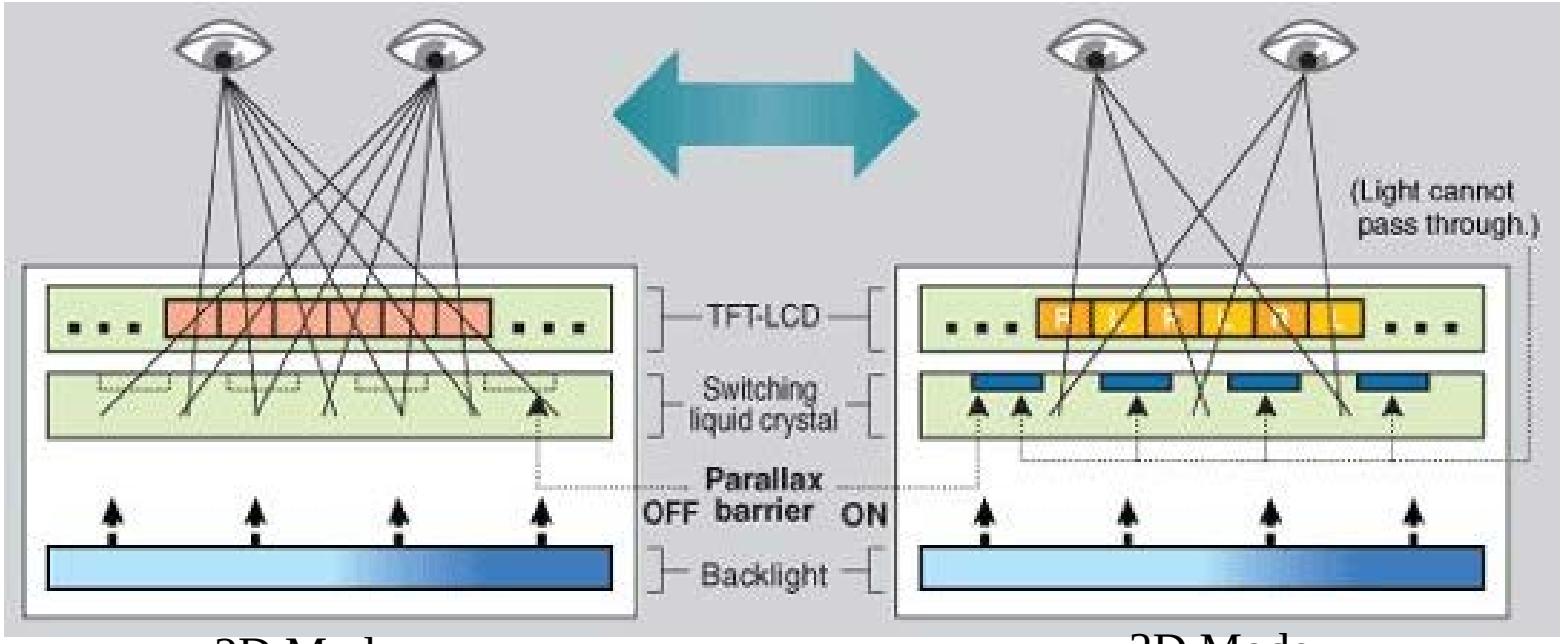
LG Optimus 3D

Nintendo 3DS

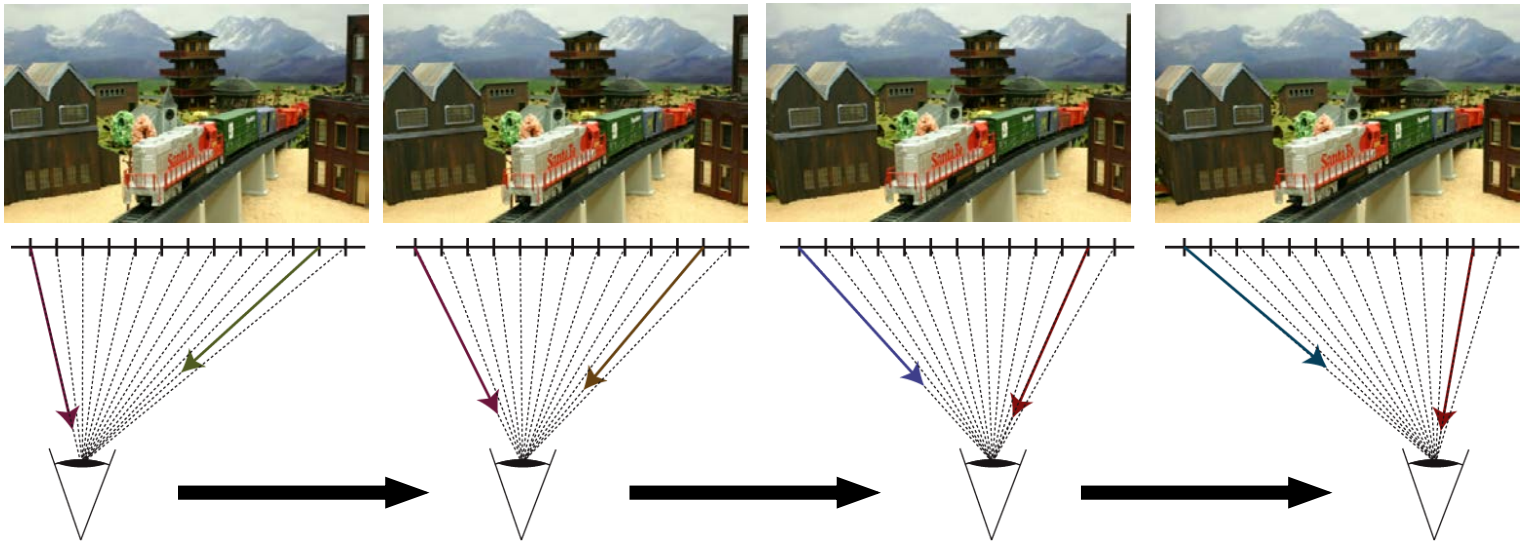


2D Mode

3D Mode

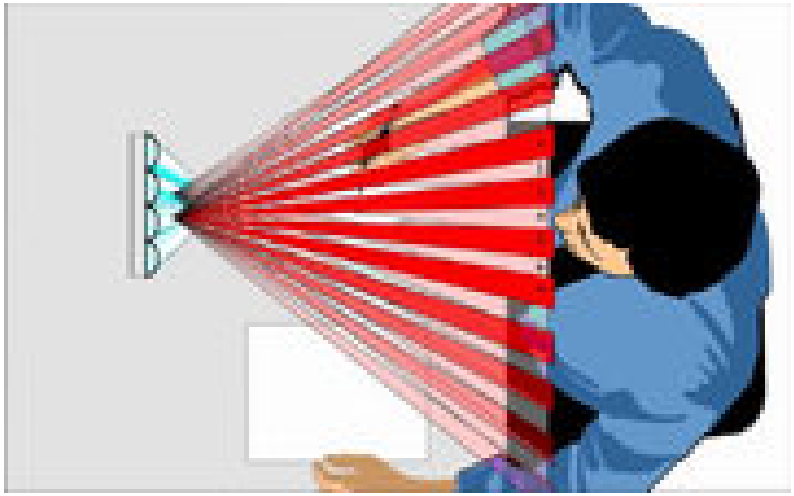
Multiview Autostereoscopic Displays

- Encode n-views
- Immersive: binocular and motion parallax
- Unobtrusive: no glasses
- Multiuser: no head tracking



Multiview Autostereoscopic Displays

- Holografika: equivalent of 45 and more views
- Others: 8,9,16, …



Real-time 3D TV

- Real-time capture using a camera array
- Real-time transmission
- Multiview autosterescopic display

Technical Challenges

- Interperspective Antialiasing

No Antialiasing

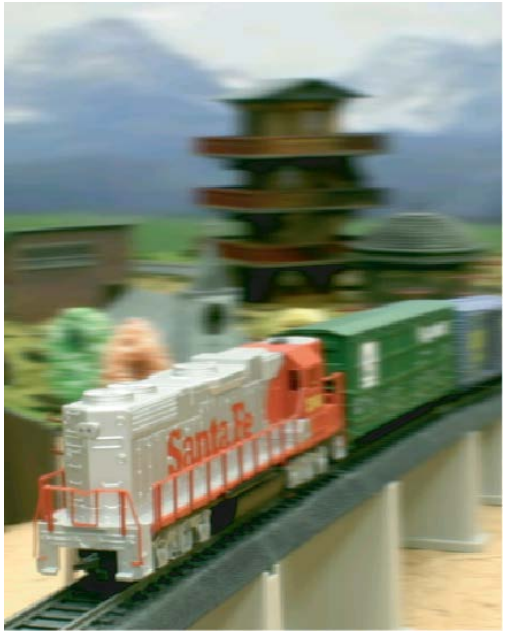
Antialiasing

Technical Challenges

- Disparity Remapping

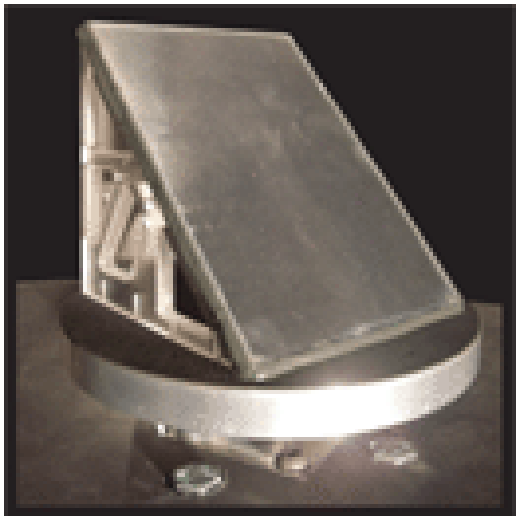
Direct Mapping

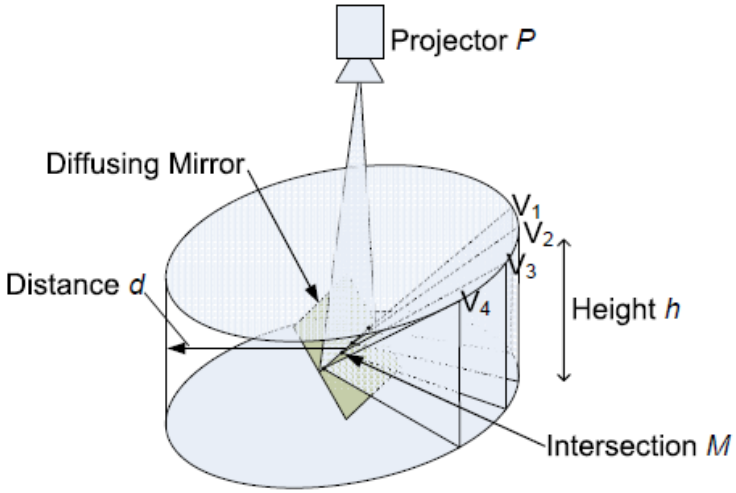
Display Adapted Mapping

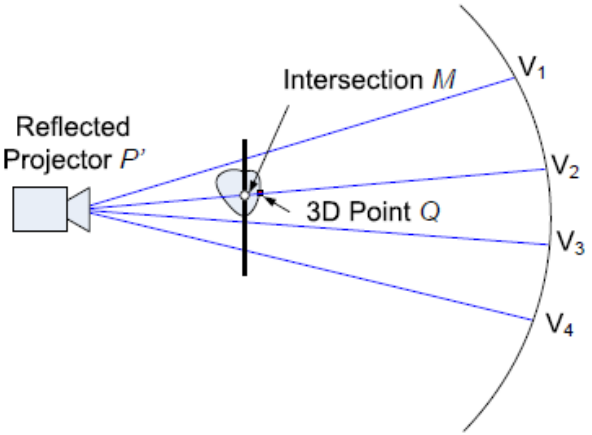


360º Multiview Autostereoscopic Display

- High-speed DLP projection using standard graphics hardware
  - 15-20 fps & 288 images per rotation
- Anisotropic spinning mirror
  - Specular in horizontal direction
  - Scattering in vertical direction







360º Multiview Autostereoscopic Display

Today

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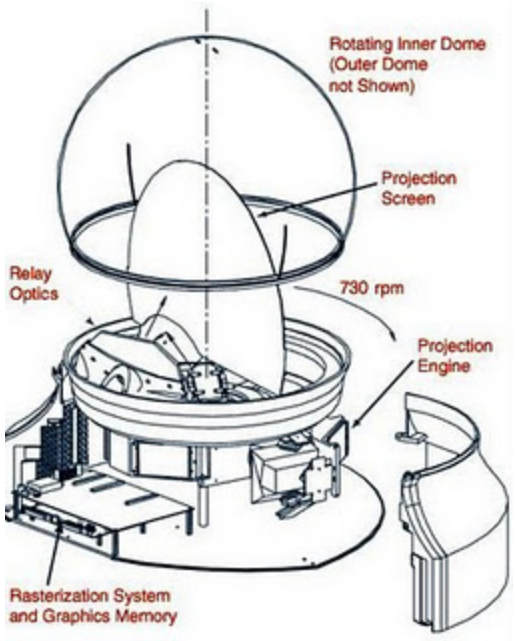
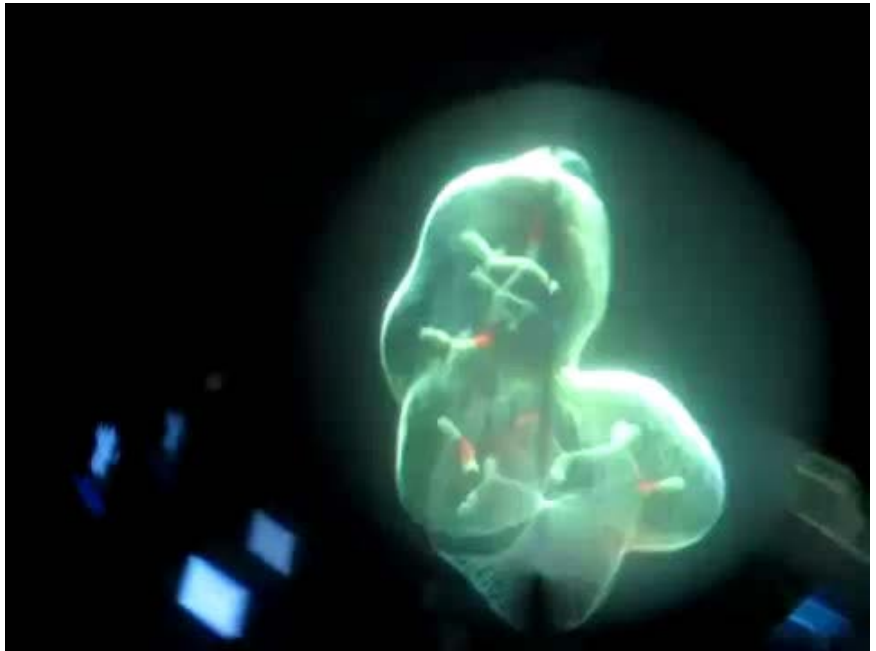
    - Depth Perception
    - Stereoscopic Displays
    - Autostereoscopic Displays & Multiview Autostereoscopic Displays
    - Volumetric Displays

Volumetric Displays

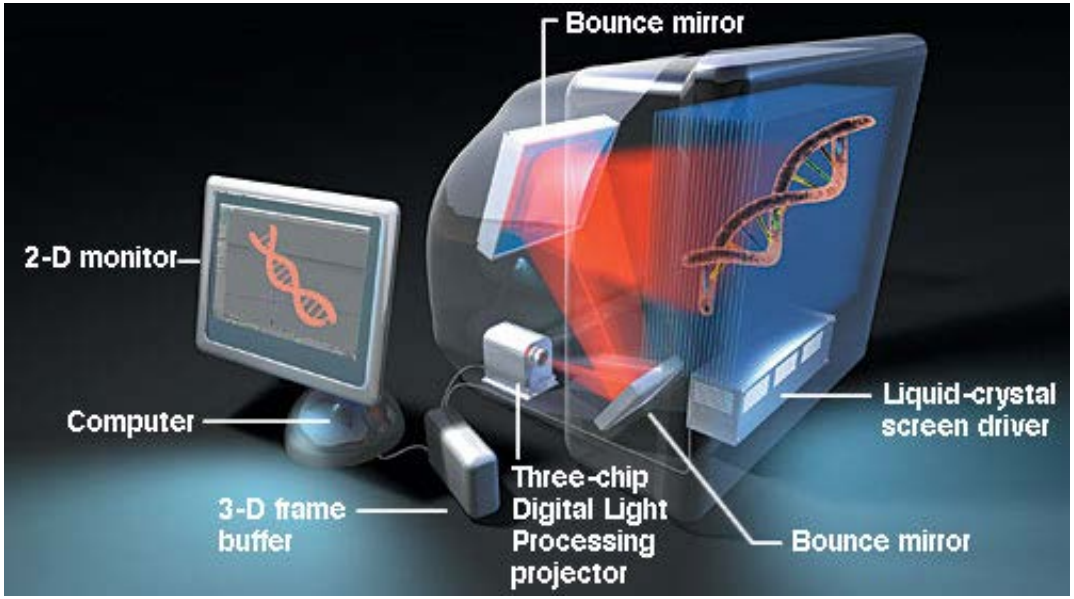
- Swept-volume displays
  - Use moving (e.g., rotating) parts that “sweep” the display volume
  - Images created by projection or surface LEDs
  - Usually no occlusions





Volumetric Displays

- Static volume displays
  - No moving parts
  - Addressable volume of space elements
  - Transparent in the off state, luminous/opaque in on state



DepthCube

That’s All For Today