EE 147 / 247A Guest Lecture: Optical MEMS

Ming C. Wu
University of California, Berkeley
Electrical Engineering & Computer Sciences Dept. & Berkeley Sensor and Actuator Center (BSAC)
Optical MEMS

• MEMS are well-suited for interaction with light
  – Structural dimensions ~ wavelength
  – Small displacement has large effect (e.g., ON-OFF switching)
    • Interferometric devices: $\Delta d \sim 0.25 \lambda$
    • Scanning devices: $\Delta \theta \sim$ a few degrees
  – Photon has no mass
    • Does not need large-force actuators
  – MEMS enables large-scale systems
    • E.g., 1000x1000 display or optical switches
Texas Instruments
Digital Micromirror Devices (DMD)

~ 1 million DMD’s on a chip

http://www.dlp.com/dlp/resources/dmmd.asp

Grating Light Valve (GLV)

Moving Ribbon

Fixed Ribbon

Air Gap

Silicon Substrate

Up: Reflection
Ribbons held up by tensile stress

Down: Diffraction
Ribbons pulled down electrostatically
Qualcomm MEMS’ Interferometric Modulator (iMOD)

- Reflection display based on MEMS interferometric modulator (iMOD)
- Similar to Fabry-Perot etalon, Fast response (10s microseconds)
- Manufactured in FPD fab lines

http://www.qualcomm.com/qmt/
Pixtronix Digital MEMS Shutter

(PerfectLight)

Digital Micro Shutter (DMS)

- Same backlight unit as LCD
- MEMS on glass substrate with TFT circuits
- Leverage on LCD manufacturing
- Time multiplexed 3-color LED
- Low temperature process

- 105% NTSC color gamut,
- 24 bit color depth,
- 170° viewing angle
- Backlight efficiency = 60%
- High contrast (1000:1)

http://www.pixtronix.com/technology/index.asp
LIDAR
Optical Phased Array using Digital Micromirrors

In collaboration with Texas Instruments
3D Imaging: Kinect
Glass
Google Cardboard
Basic Optics for Virtual Reality Display
Optofluidics

- Tutorials on Microfluidics
- Tunable lens (zoom lens)
- Display
  - Electrowetting, E-ink
- Optical manipulation
  - Optical tweezers
  - Optoelectronic tweezers
  - Near field trapping (plasmonic tweezers, slot waveguide)
- Zero mode waveguide for single molecule analysis
  - Next Gen sequencing
- Optofluidic microscope
- Bubble switch
E-Ink

Electronic Paper Display (EPD)

Cross-Section of Electronic-Ink Microcapsules

- Top Transparent Electrode
- Positively charged white pigment chips
- Clear Fluid
- Negatively charged black pigment chips
- Bottom Electrode

Subcapsule addressing enables hi-resolution display capability

PORTABLE READER

(600x800, 167 ppi)

Amazon Kindle

FLEXIBLE WALL CLOCK

Citizen

www.eink.com

NOTE: Copyright E Ink Corporation, 2002. Image not drawn to scale - for illustration purposes only.
Electrofluidic Display

Self-Assembly of Pigment Liquid

Zero Mode Waveguide for Single Molecule Analysis
Optoelectronic Tweezers

Optical Conveyor Belt

- **Programmable**: Trapping and manipulation using a digital projector
- 10,000x lower power than conventional optical tweezers
- Massively parallel: 30,000 individually controlled traps

Digital Micromirrors
DLP® Chip – Micromirrors

2.0kV 28.5mm x4.50k SE(L) 12/17/01

DLP slides courtesy of Dr. Larry Hornbeck (TI)
History of DMD

1987
- Dr. Larry Hornbeck invents Digital Micromirror Device, known as the DLP® Chip

1996
- First commercial DLP projector system ships; enables first ultra portable 6lb projector

2004
- DLP receives first Emmy® Award for Outstanding Achievement in Engineering Development (DLP Cinema)

2009
- DLP becomes #1 supplier of MEMS technology worldwide and to current date have shipped more than 33 million DLP chipsets

- Consumer devices begin to ship worldwide featuring DLP Pico Projectors
- DLP Cinema® now in over 50,000 theatres worldwide. More theatres showing digital movies than film
- New DLP development kit launches letting developers to embed the DLP® Chip into nontraditional markets
- DLP takes display to the automobile with a vision for a digital console and Head Up Display

http://www.dlp.com/technology/dlp-history/default.aspx
Digital Micromirror Device (DMD)

Texas Instruments

L. Hornbeck, Electronic Imaging, 1997
Grey Scale of DMD Projector: Pulsewidth Modulation Technique

(Note: for clarity, only central column is addressed and no light source is shown)

DMD

(1111)
(1001)
(0100)
(0010)
(0001)
(0000)

(Sensations of Gray Shades By Viewer’s Eye)

(4-Bit Example)

L. Hornbeck, Electronic Imaging, 1997
Projection Display Using Digital Micromirror Display (DMD)
References


• http://www.dlp.com/