投影顯示之微機電晶片技術

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Outline

1. Introduction & applications (DMD)
2. Signal delivery
3. Projection display
4. Comparison : DMD vs. LCOS
5. Color expression and gray scale
6. Key structures & Process
7. Actuation
8. Grating Light Valve Display - Diffraction
9. iMOD display – Reflection & Interference (Iridigm)
10. Micro Display –Scanning
11. Conclusion_Video

顯示科技與半導體技術

- 影像顯示器
  - CRT
  - 平面電視
    - OLED/PLED(中小尺寸)
    - LC TV
    - (CNT-) FED
    - PDP
  - 投影電視
    - LC-based
    - DMD-based
    - LCOS-based
  - 微顯示器 — Micro-display
  - 電子書 — E-ink,…
  - 超大螢幕 — LED Display

顯示技術 vs. TV 尺寸

LCD TV : 20 ~ 40’

PDP :30 ~ 50’

Projection TV : 40 ~ 60’

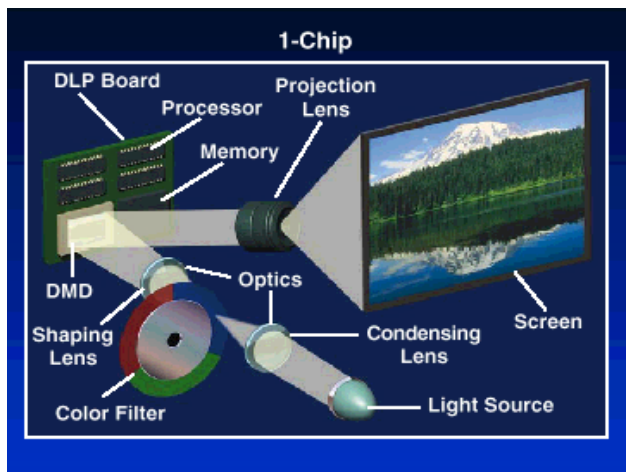
(Super Large: LED display)

Digital Light Processing （DLP）

- **Introduction:**
- DLP is a semiconductor-based MEMS array of fast,reflective digital light switch that precisely control light from a source to a projection screen using a binary pulsewidth modulation technique.
- The mirror can reflect light in one of two directions,according to the state(0 or 1)of an underlying CMOS memory cell.

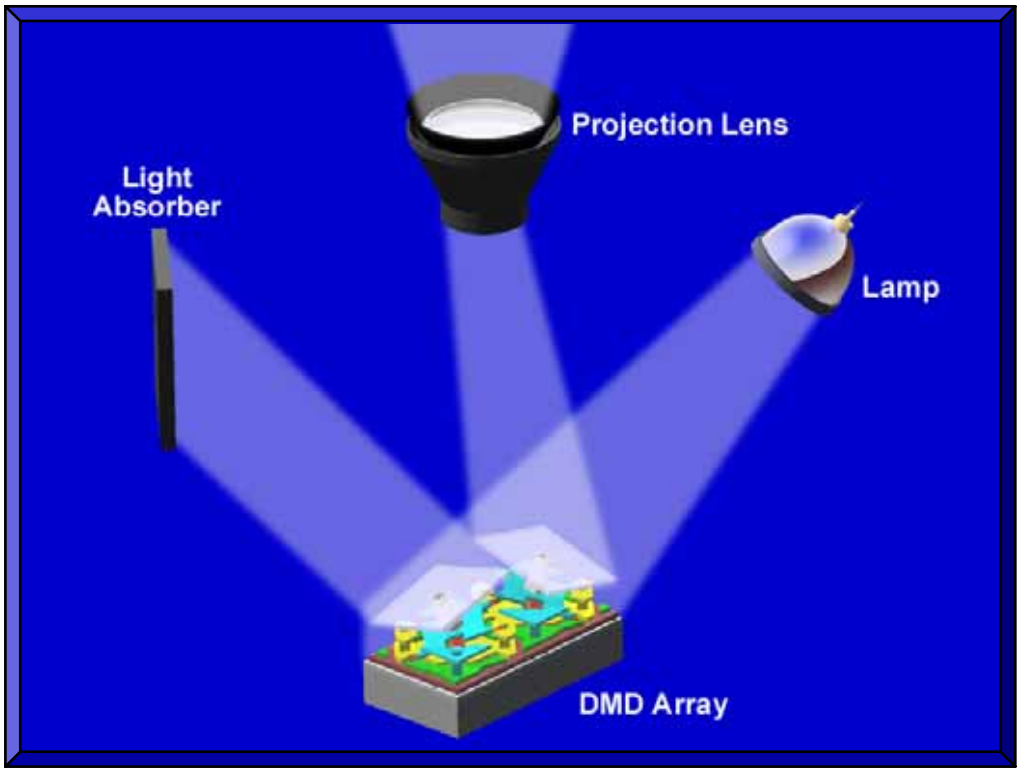
Fans in a stadium reflecting light toward a blimp

Source: www.ti.com/dlp



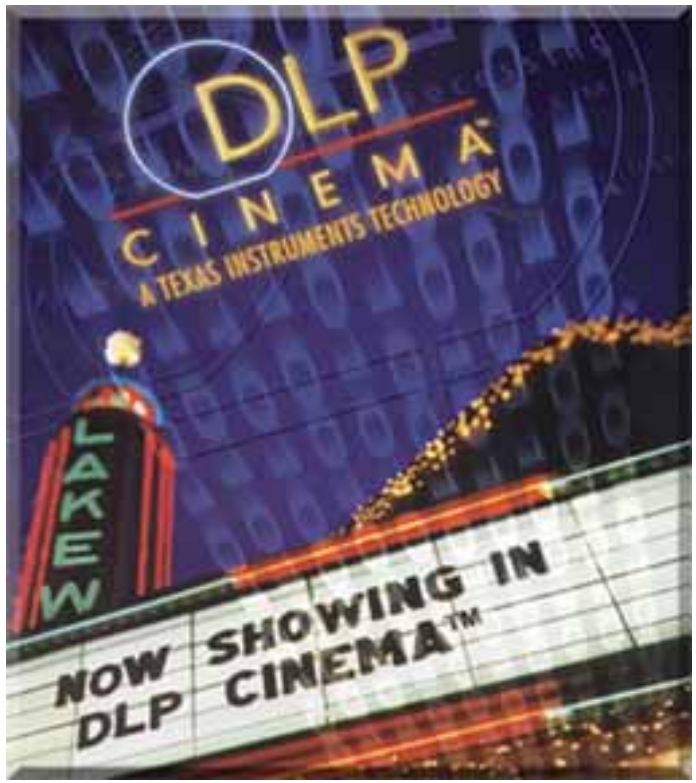
Digital Light Processing （DLP）-Pixel

How DLP™ Technology Works



Application 2: DLP Cinema

DLP™ Large Venue

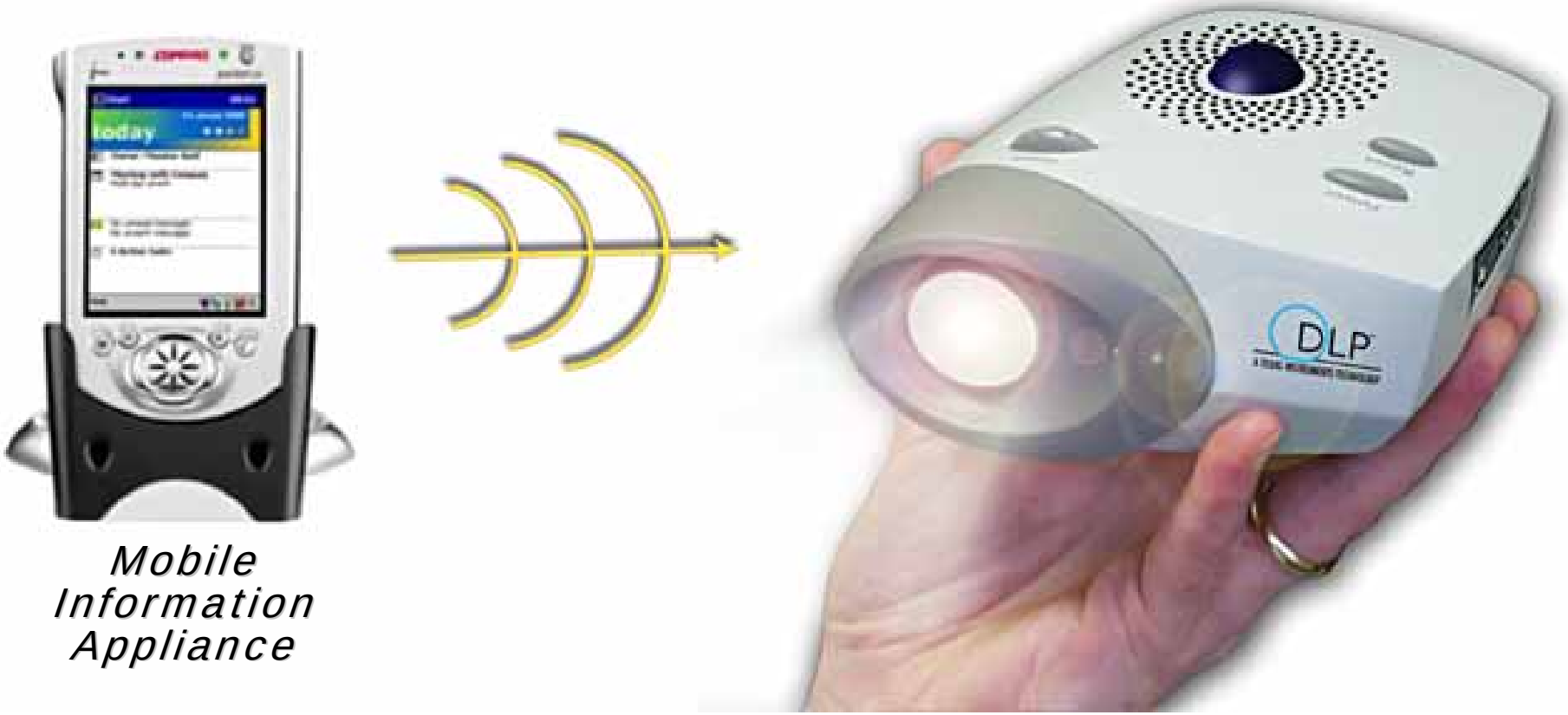


DLP Cinema™

Source: Texus Instrument Inc.

Application 3: Lighter, Brighter, and Wireless

Source: Texus Instrument Inc.

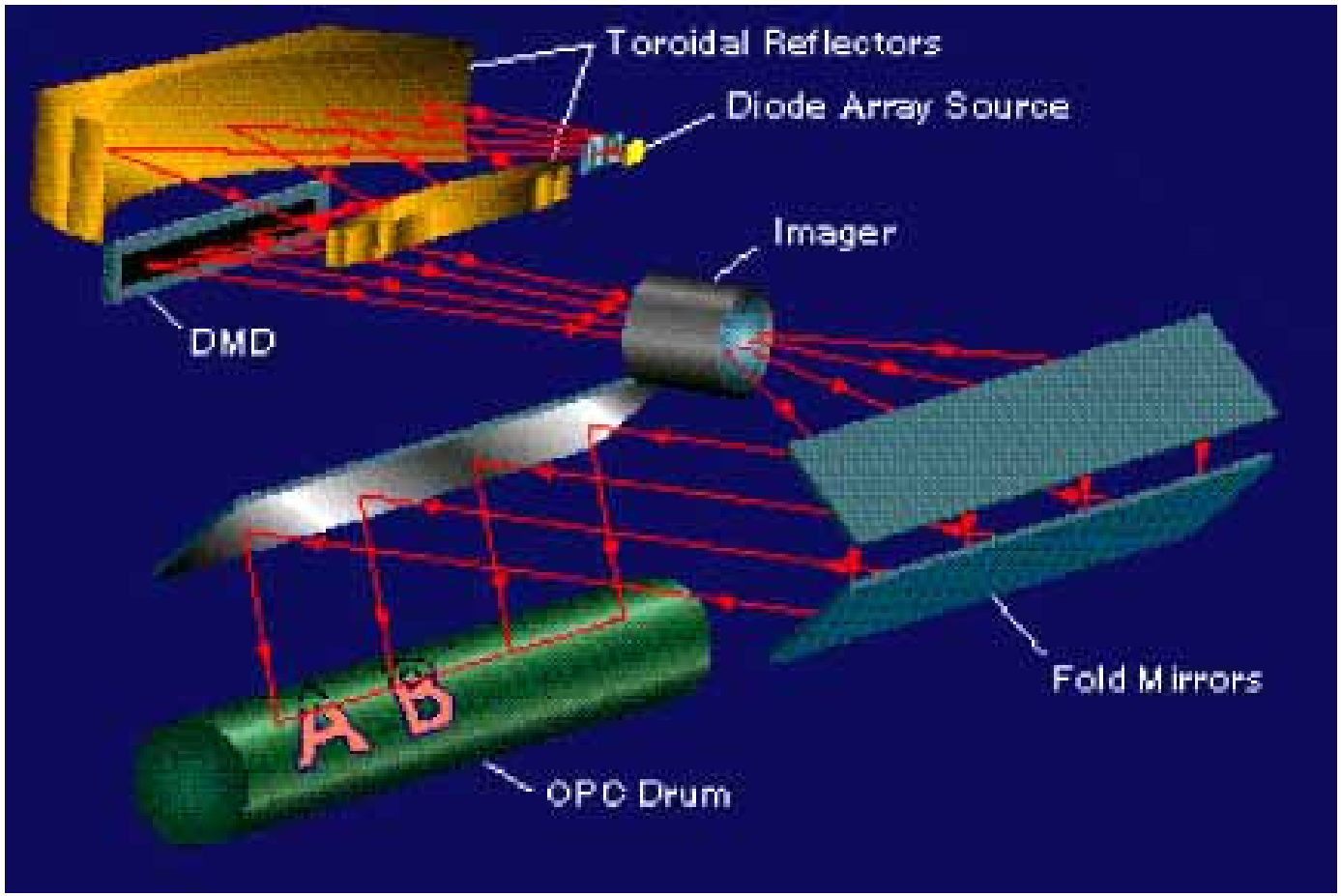


電池、LED光源，具有瞬間開機、體積小又輕巧的特色，
三菱產品的重量只有400公克、零售價在500至700美元

Application 4: Projection TV

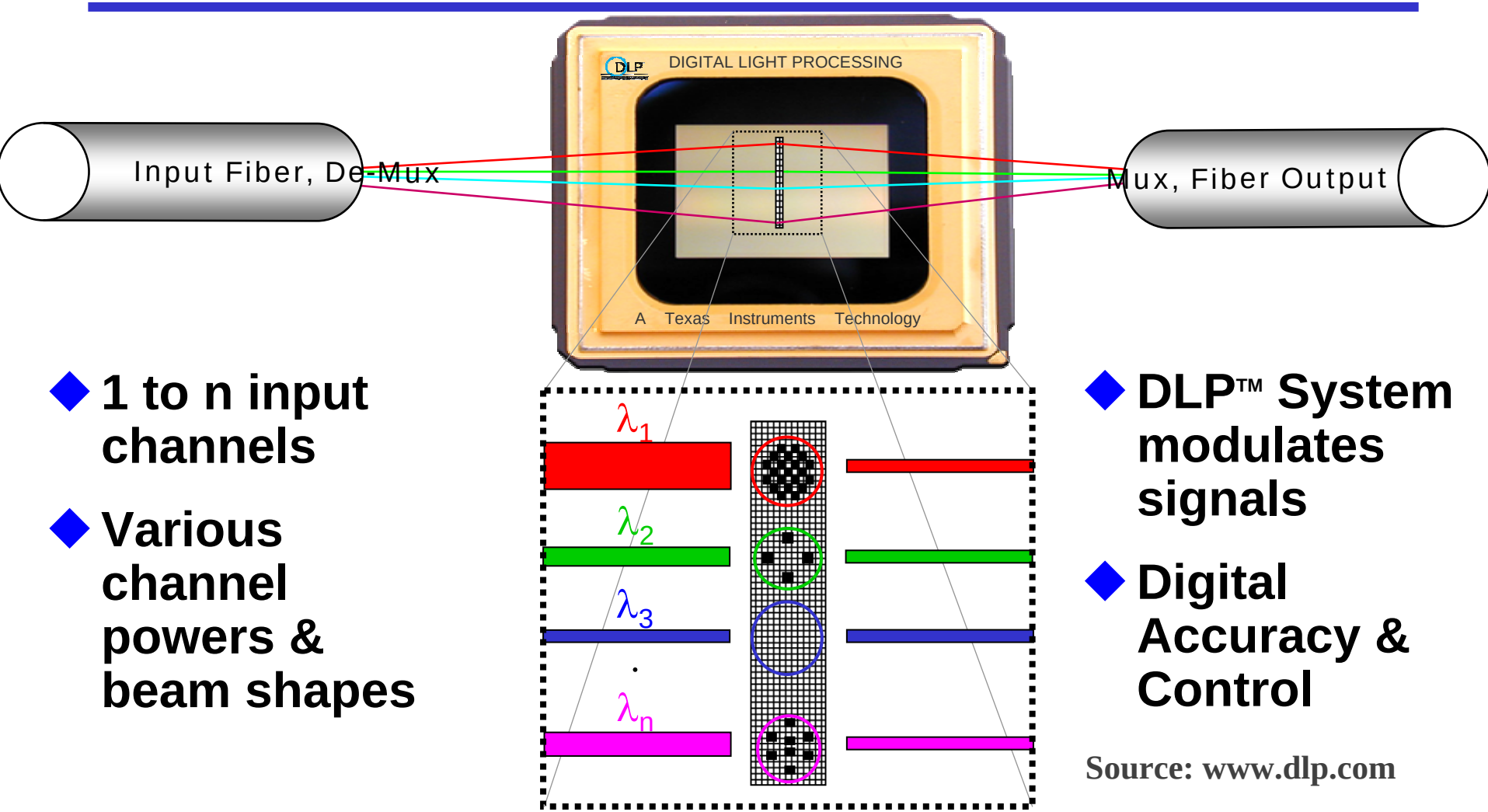
Source: www.dlp.com

Application 5: Printing



Source: www.dlp.com

Application 6: DLP™ Digital Channel Modulation
with hundreds of Switches per Channel!



- 1 to n input channels
- Various channel powers & beam shapes

- DLP™ System modulates signals
- Digital Accuracy & Control

Source: www.dlp.com

DLP™ Dynamic Filter Module

Potential Features

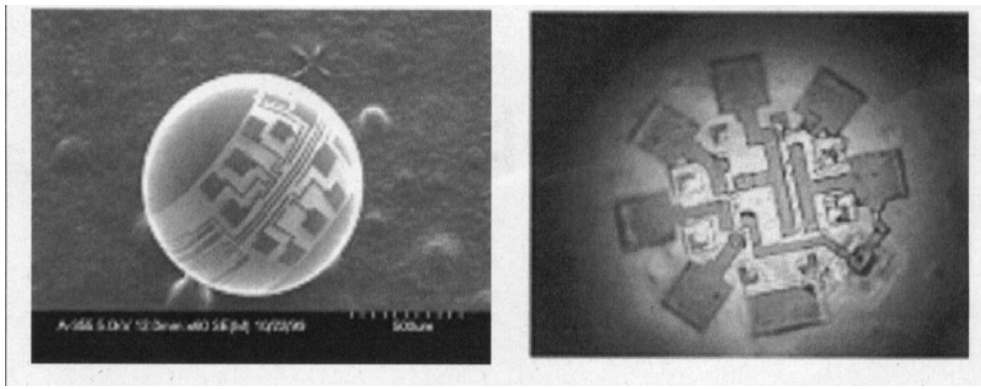
- <$10,000 Module
- Insertion Loss: 4-6 dB
- Dynamic Band or Channel Control
  - 40 – 160 Channels
  - 10 – 30 dB Attenuation
- Resolution : 0.1dB @ 100GHz
- PDL: 0.2 dB
- PMD: 2 ps
- C-band, L-Band Compatible
- Control: RS232 & High Speed I/F

*TI Prototype 40-channel DLP™ Dynamic Filter

***Note: TI does not intend to "productize" this prototype. We will use it for learning. OEMs will build their own DLP DGE modules.**

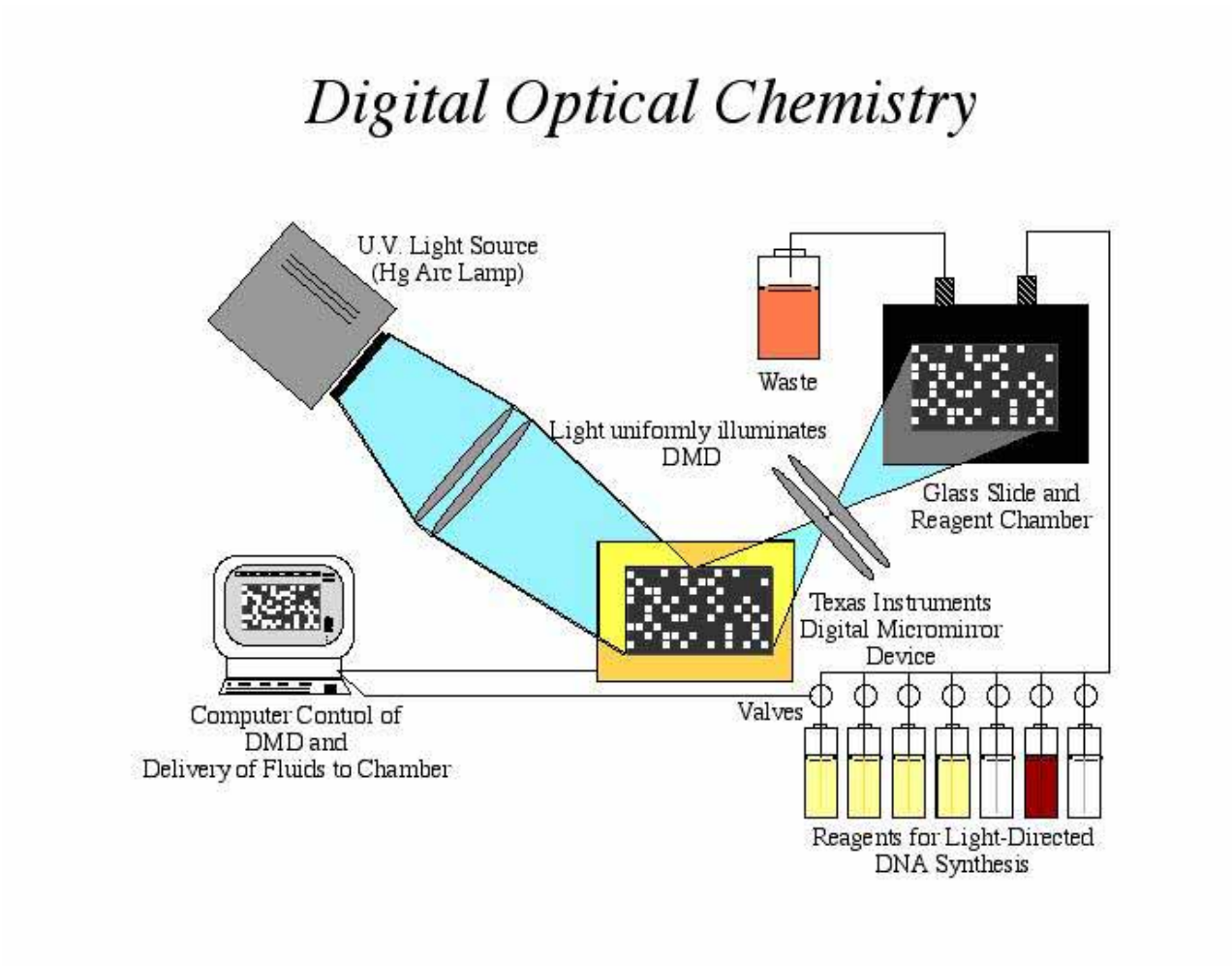
Source: www.dlp.com

Application 7: Maskless Exposure



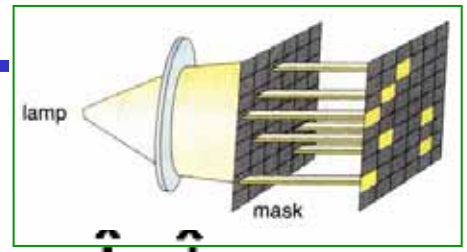
Source: Ball Inc.

Application 8 : Light-directed peptide synthesis :



Application 8 : Light-directed peptide synthesis :

(photolithography)

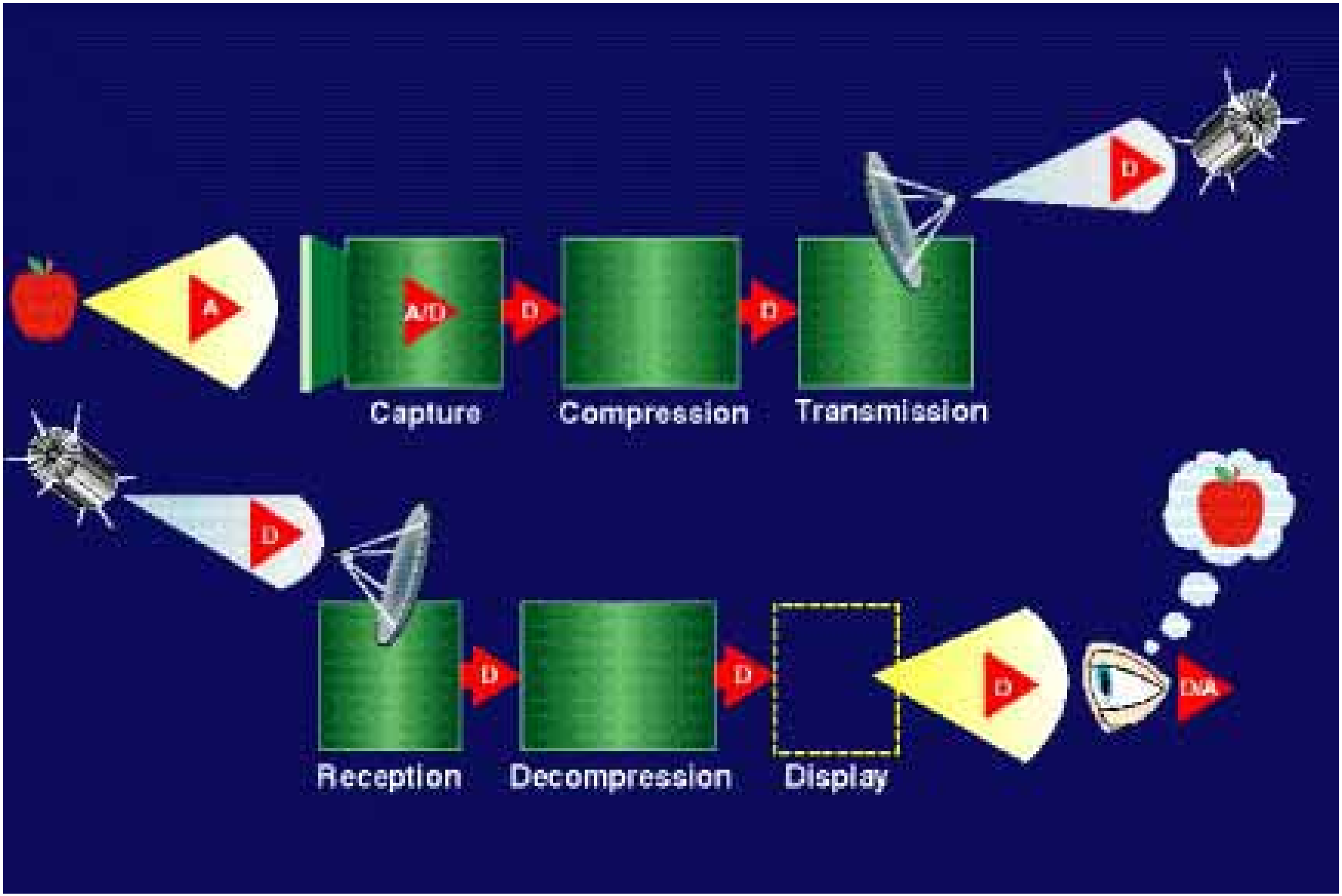


x-A: NVOC-(NH-CHR-COOH)
x-G:
x-F:
.....

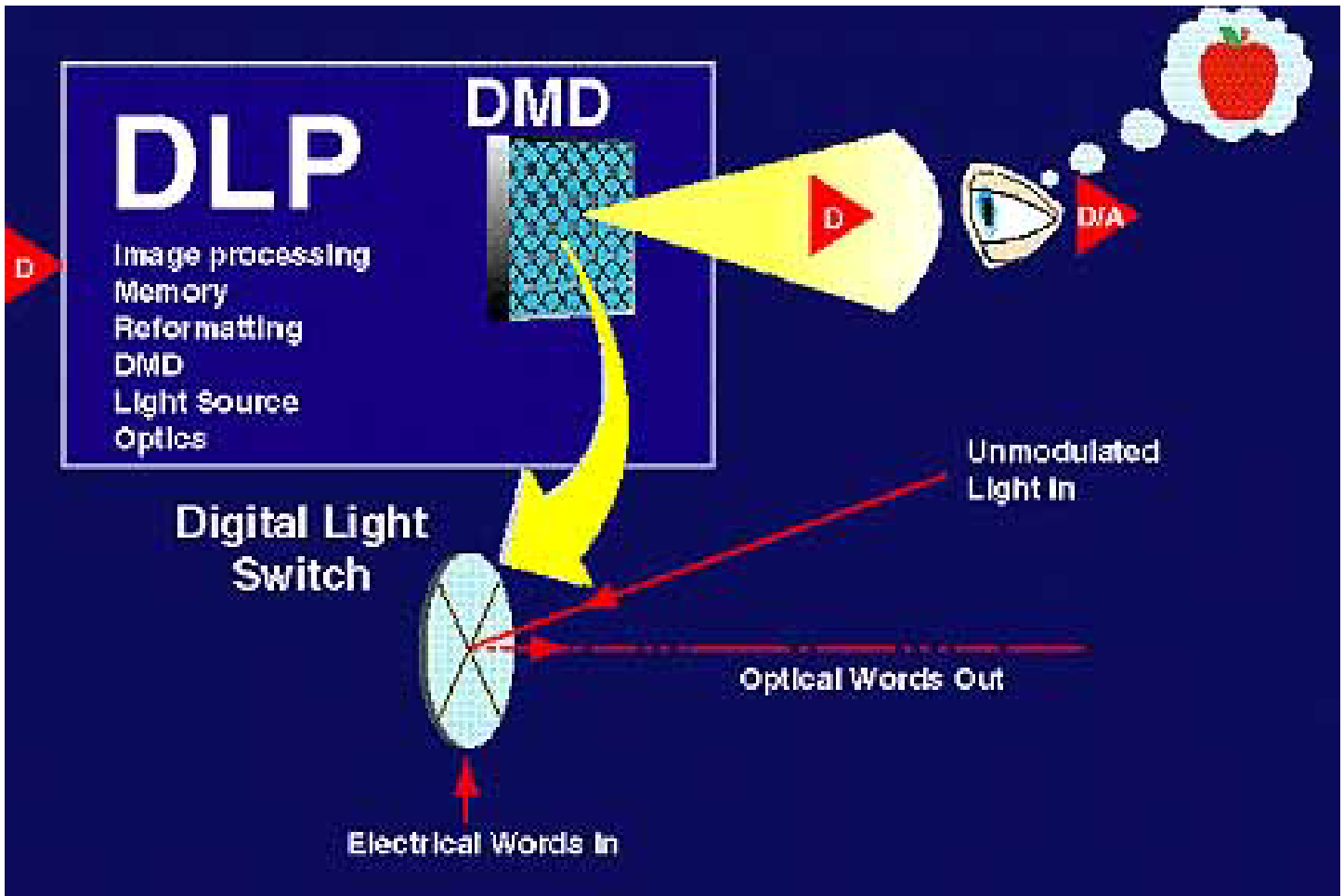
x : photolabile protecting group
NVOC (nitrovertryloxycarbonyl)

A,G,F,R,N,L : amino acids

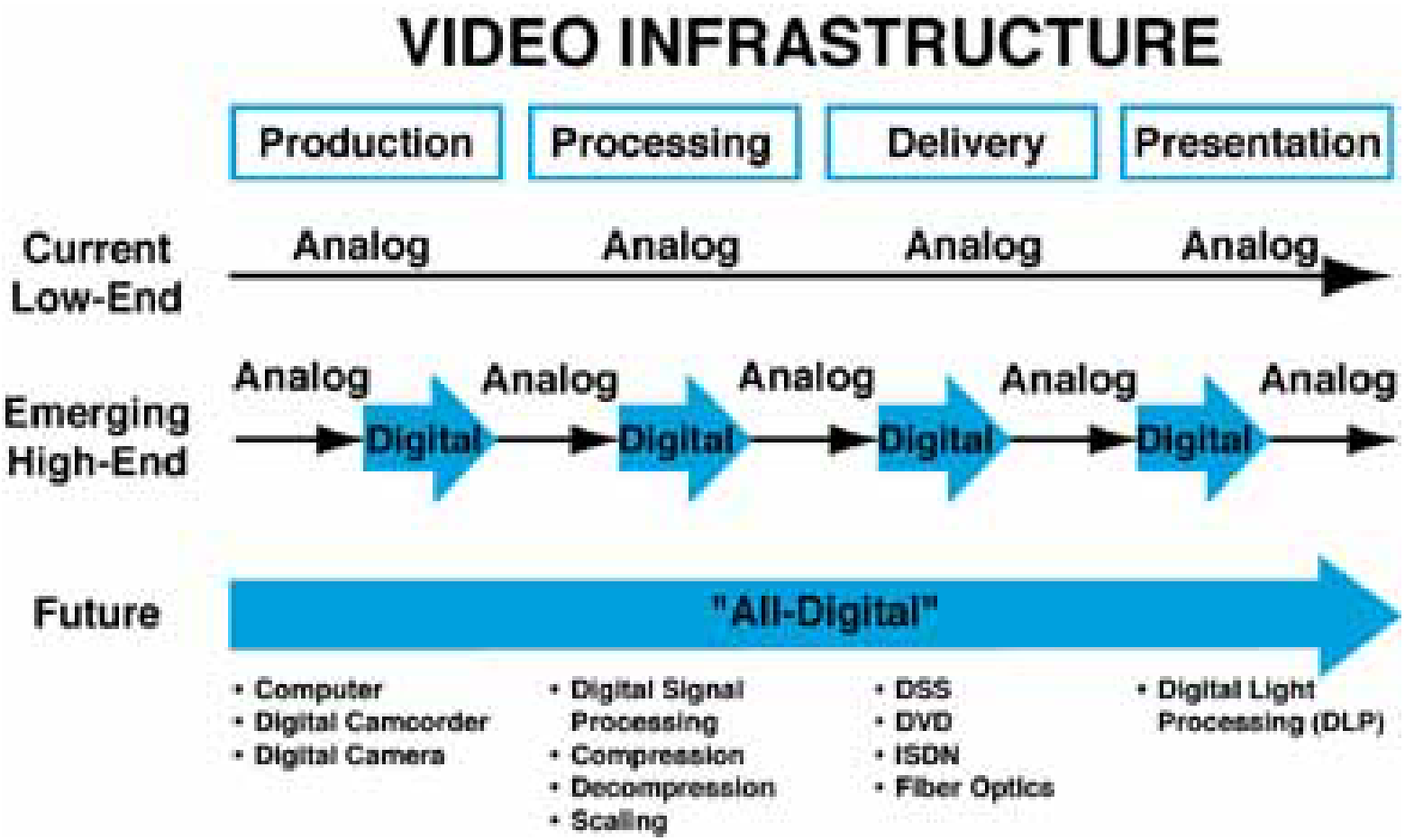
Signal Delivery


A
A/D
D
D
D
Capture
Compression
Transmission
D
D
D
D
D
D/A
Reception
Decompression
Display

Application 4: Projection TV



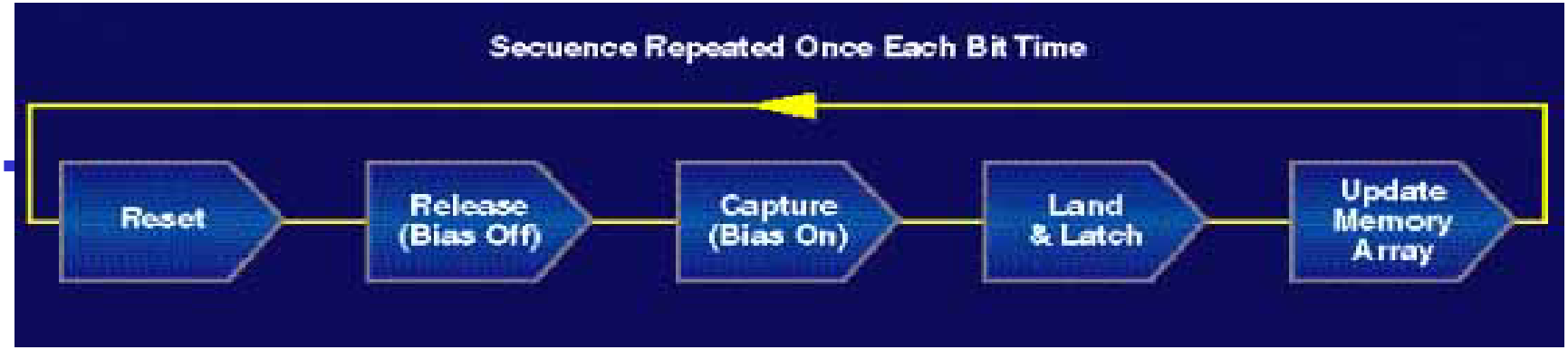
Source: www.dlp.com


VIDEO INFRASTRUCTURE
Production
Processing
Delivery
Presentation
Current Low-End
Analog
Analog
Analog
Analog
Emerging High-End
Analog
Digital
Analog
Digital
Analog
Digital
Analog
Digital
Analog
Future
"All-Digital"
• Computer
• Digital Camcorder
• Digital Camera
• Digital Signal Processing
• Compression
• Decompression
• Scaling
• DSS
• DVD
• ISDN
• Fiber Optics
• Digital Light Processing (DLP)

《黑客帝国3》全球零时差同步上映（组图）

中国日报网站消息：《黑客帝国》第三部《革命》于格林威治时间昨天下午两点，在全球100多个国家和地区同步上映。 为了取得最大的票房成功，《黑客帝国》3采取了全球零时差同步上映的方式，这给《黑客帝国》的这部总结篇造就了巨大的宣传攻势。

2003-11-07



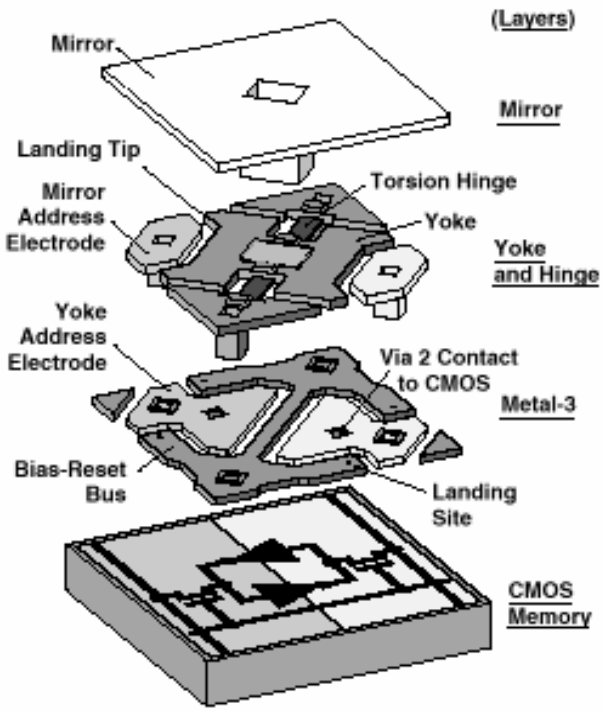
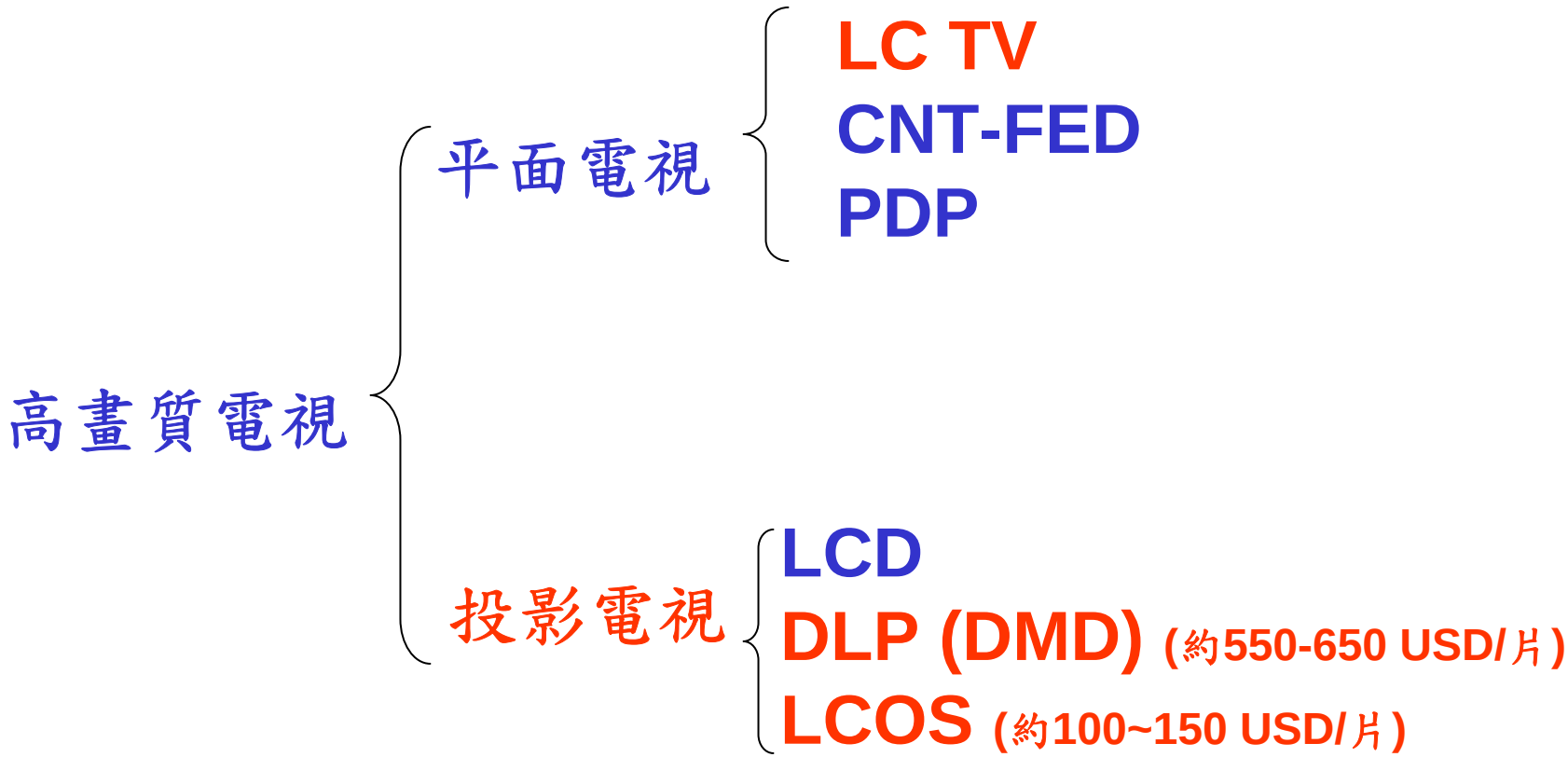


Figure 8. DMD pixel exploded view

Projection Display

高畫質電視

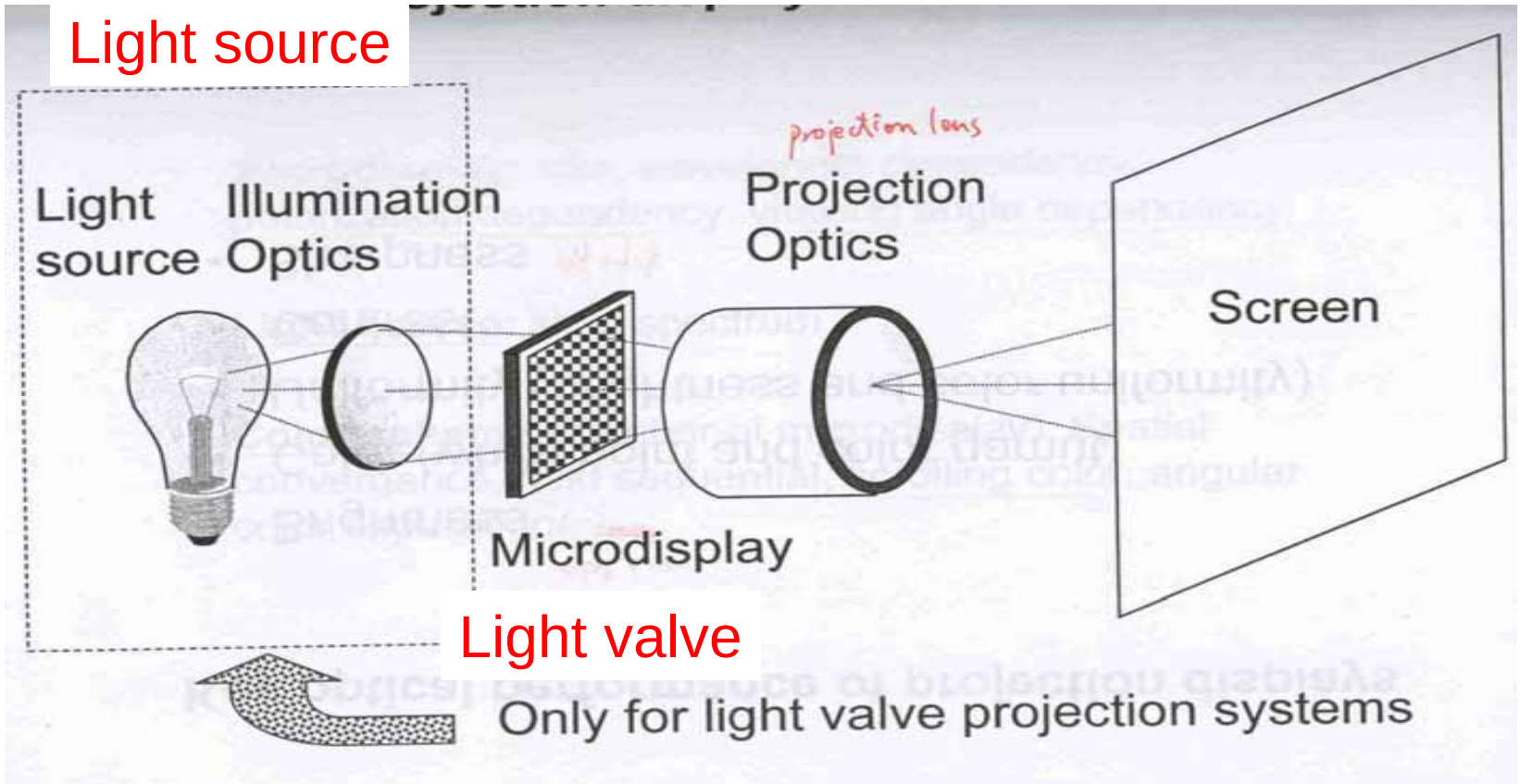

高畫質電視
平面電視
LC TV
CNT-FED
PDP
投影電視
LCD
DLP (DMD) (約550-650 USD/片)
LCOS (約100~150 USD/片)

Key issues of projection display

- brightness
- color
- uniformity
- contrast and sharpness

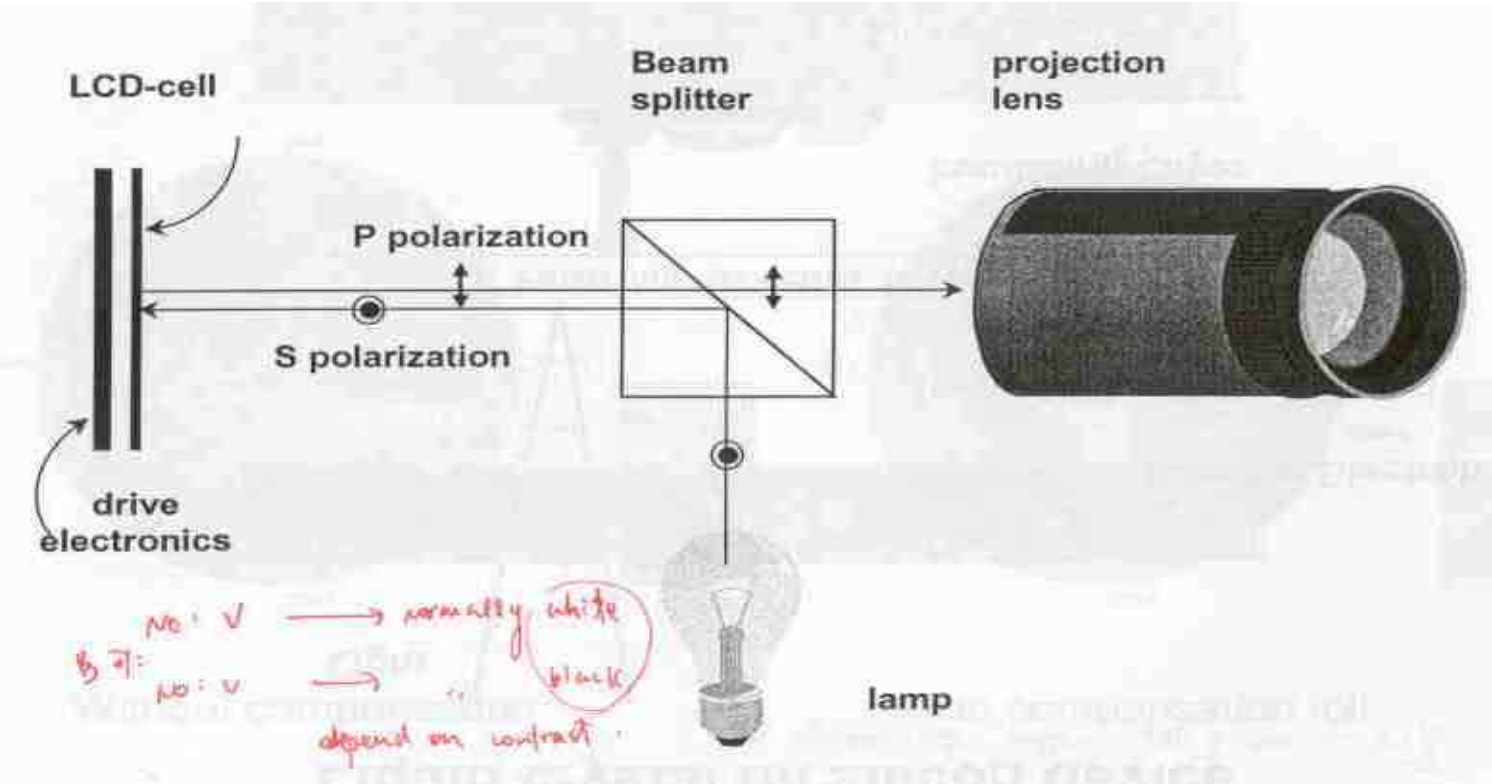
Source: 陳政寰 台科大電子工程系

Projection displays schematics



Source: 陳政寰 台科大電子工程系

Reflective Scheme of Projection



Source: 陳政寰 台科大電子工程系

ＤＬＰ投影機市佔衝至47％

DLP投影機晶片獨家供應商德州儀器（TI）宣布，去年全年DLP投影機在商用和家用市場勇奪四七％市佔率，由於德儀先前曾表示，市佔率將突破四成，因此，此數字已遠超過市場預期，顯示TI在朝更高解析技術邁進中，成熟產品的降價策略奏效，提拔代工廠與品牌廠同步成長。

德儀表示，去年整年DLP成長強勁，也因此超過愛普生（EPSON）、新力（SONY）等投影機面板供應商，成為全球最大面板子系統供應商，DLP投影機商用及家用全球市佔率一舉突破四十七％，領先LCD投影機和LCoS系統，稱霸投影機領域。

2005.03.01　工商時報

大尺吋平面電視 大打價格戰

大尺吋平面電視價格大戰愈演愈烈，繼42吋電漿電視降至4.99萬元，三星與燦坤3C今（20）日將聯手，推出10.9萬元的50吋背投式電視（DLP），降幅高達4 萬元。

通路業者指出，DLP及LCOS電視以50吋的大尺寸為主力戰區，過去進口產品價格在14.9萬元至20萬元間，難以提振買氣，三星一口氣降至10.9萬元，價格非常有誘因，加上DLP電視的畫質上急起直追，具有「俗擱大碗」的優勢，全球市場以美國及大陸為主。

2005/01/20 經濟日報

德儀 力保DLP電視晶片一哥

德州儀器（TI）DLP產品總監白瑞克表示，今年50吋以上的背投電視將以解析度達1080p的高畫質電視（HDTV）為主流，TI這款1080p的DLP晶片已經進入量產，將可鞏固TI在背投電視晶片的霸主地位。

TI自1996以來總出貨的DLP晶片達500萬片，其中，花了五年的出貨量才達到100萬台，經過二年再增加200萬台，但最近的八個月出貨量就達200萬片，白瑞克指出，由此顯見TI的DLP晶片成長快速。

他指出，今年新興的DLP產品還有掌上型投影機、多功能即時劇院，例如由三菱電機、三星採用TI的DLP晶片，新開發出的掌上型投影機，使用電池、LED光源，具有瞬間開機、體積小又輕巧的特色，三菱產品的重量只有400公克、零售價在500至700美元。這種易於攜帶、價格低的新產品，將可替DLP產品增溫。

2005/01/27 經濟日報

台積電明年將推出MEMS平台

一直以來，生產製程難以標準化是MEMS市場發展的最大障礙。經過三年的研發，晶圓代工廠商台積電(TSMC)表示，把IC製程技術與微電機系統(MEMS)相結合將可在2006年開始有所成效。受到德州儀器(TI)數位光處理(DLP)技術所取得的成功之鼓舞，台積電認爲MEMS領域的機會增加了。據市調公司In-Stat的資料，2009年MEMS市場將從今年的80億美元左右成長到140億美元。「盡管DLP產品的出貨量與其它(MEMS)產品相較仍低，但銷售額卻非常突出。因此許多人對該領域非常感興趣。」台積電的主流技術行銷經理Claire Chen表示。「一旦IC代工廠商進入這個領域，將使MEMS設計廠商更有利可圖，並能提供更有吸引力的產品功能。」

2005.09.23　電子工程專輯

台積電明年將推出MEMS平台

MEMS市場一直由惠普(HP)和意法半導體(STMicroelectronics)等廠商所壟斷，他們爲噴墨印表機生產微流體元件(microfluidic device)。該市場中的主要廠商還有感應器廠商Bosch。根據市調公司Yole Developpement的資料，去年上述三家廠商的MEMS銷售額總計略高於10億美元。然而，2004年德州儀器異軍突起，以9億美元的DLP晶片銷售額成爲該市場的老大。

如果台積電明年推出一種設計製程，對於MEMS設計廠商來說將會是相當重要的進展。這些設計商主要依賴由擁有自主製程技術的小型晶圓代工廠商組成的分散網路。

台積電的豐富資源不僅能改善規模經濟，而且會帶來標準的基礎設備。這可能有助於縮短產品投入市場的時間。目前典型的產品推出時間爲5~10年。

2005.09.23　電子工程專輯

最薄50吋背投電視 中光電志紅開發完成(1/2)

- 中強光電 (5371)與轉投資之志紅科技，共同宣佈成功開發全球第一台最薄的50吋背投電視，以及第一台採用最新數位光學 (DLP)之65吋高畫質數位電視，將於近日開始出貨，並將在美國消費性電子大展 (CES)中展出。 中光電表示，與轉投資志紅科技 (Optoma)所開發之高畫質寬螢幕數位電視RD50與RD65，分別創下全球最薄 (37.5公分)的50吋背投電視，與第一台65吋DLP HD2高畫質數位電視的領先紀錄。中光電與志紅科技的RD50與RD65在設計上，均採用德州儀器的DLP HD2數位光學投影技術。 中光電董事長張威儀表示，此二台高畫質數位電視結合中光電多年在數位投影的技術經驗，及轉投資志紅科技在數位影像技術的經驗，其定價更比市面上國外進口的電漿電視價格便宜 50%，預計 RD50 與 RD65 的市場訂價分別是 18.5 萬元及 29.5 萬元。
- 張威儀指出，DLP背投影電視較舊CRT背投技術，解析度較高、畫質較為精細，且DLP技術較LCD技術擁有更佳亮度與對比，對黑階的處理較好，DLP背投式電視沒有顯示螢幕衰退(Degrading)的問題，產品耐久性可達八、九年甚至十年以上，遠優於一般電漿電視二、三年的壽命。
- 張威儀表示，大尺寸平面顯示器未來將是背投影電視的天下，目前已開發完成的兩款背投影電視，將在近日內出貨。

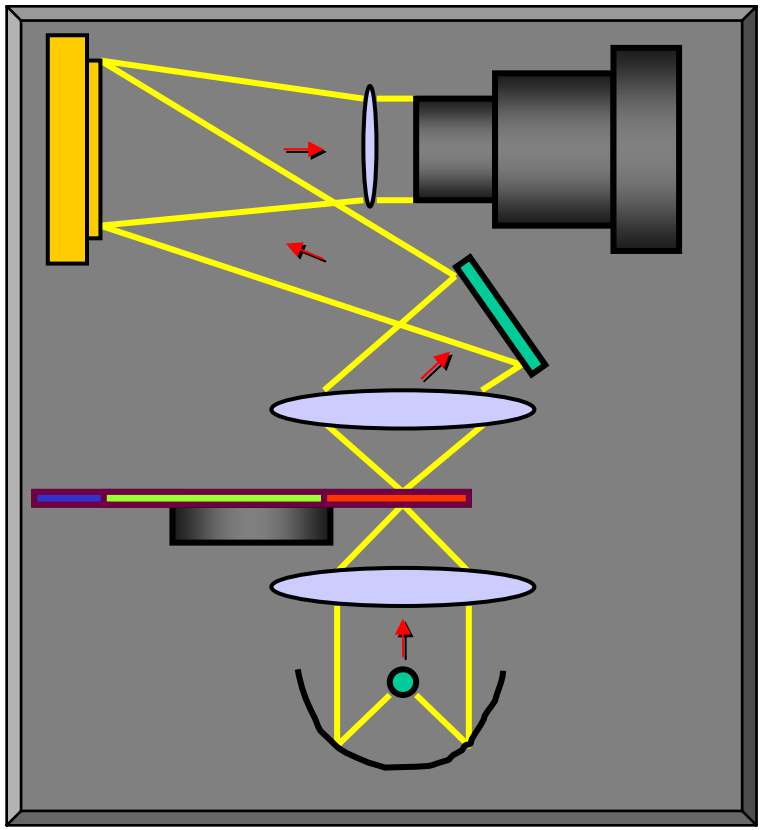
2003/01/07 經濟日報

65吋背投影式高畫質數位電視 亮相(1/2)

- 以「Optoma」品牌聞名全球的投影機製造商志紅科技，正式跨入高畫質電視，昨天宣佈運用德州儀器的DLP(DigitalLightProcessing)技術，研發全球第一部65吋的背投影式高畫質數位電視，並將於8日起在台北世貿展覽館舉辦的「音響影視大展」中，正式對外展出。
- 志紅科技董事長莊謙信表示，志紅並將這次展覽中，推動一項千人試用活動，甄選1,000名發燒友和視覺的貴族，加入10~14天的免費鑑賞試用。
- 由於不少製造電漿電視的業者，都在最近降價促銷，志紅這次推出65吋高畫質電視165,000元，希望提供消費者另一項選擇，詳情可洽詢0800-880-876或者www.optoma.com.tw。
- 莊謙信表示，在與目前的內投影和電漿電視比較後，DLP技術的數位電視解析度達1280x720、而且比ＬＣＤ技術擁有更高對比，達到1800:1，另外在價格上，比起電漿電視也要便宜50%左右，同時也沒有輻射危害之虞。
- 他說，按照志紅的估算，由於國內視聽發燒友不少，每年至少有1~2萬台的市場，志紅希望能夠在這一波展覽中，打出名號。

2003/01/07 經濟日報

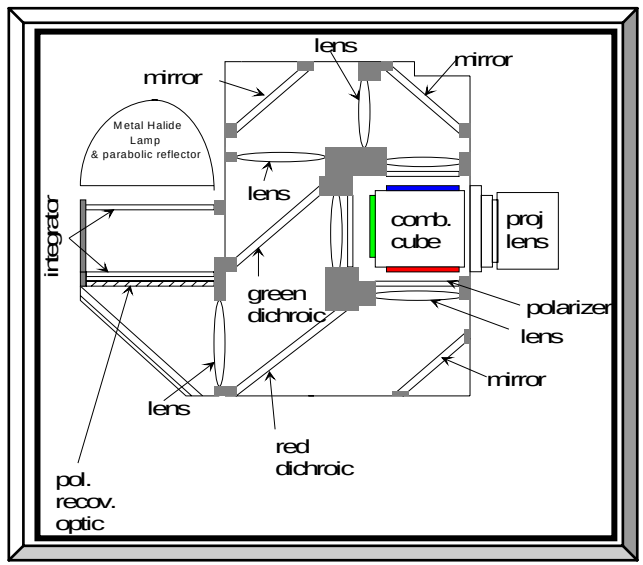
Lightest/Brightest



DLP™ = simple optical system

- **Single ‘panel’ = simpler optics**
- **Reflective = greater efficiency**

LCD = complex optical system



Reflective DMD for Projection

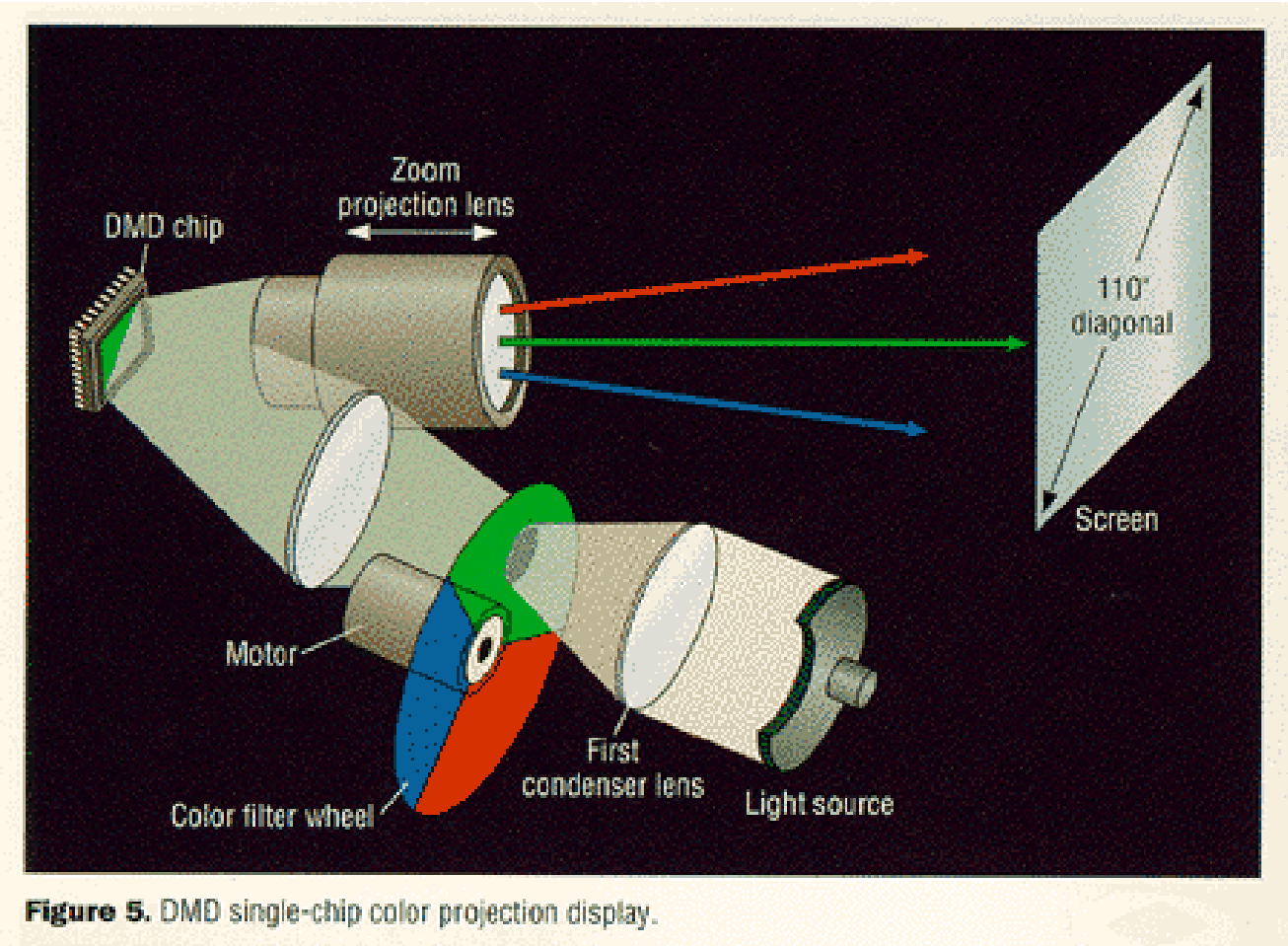
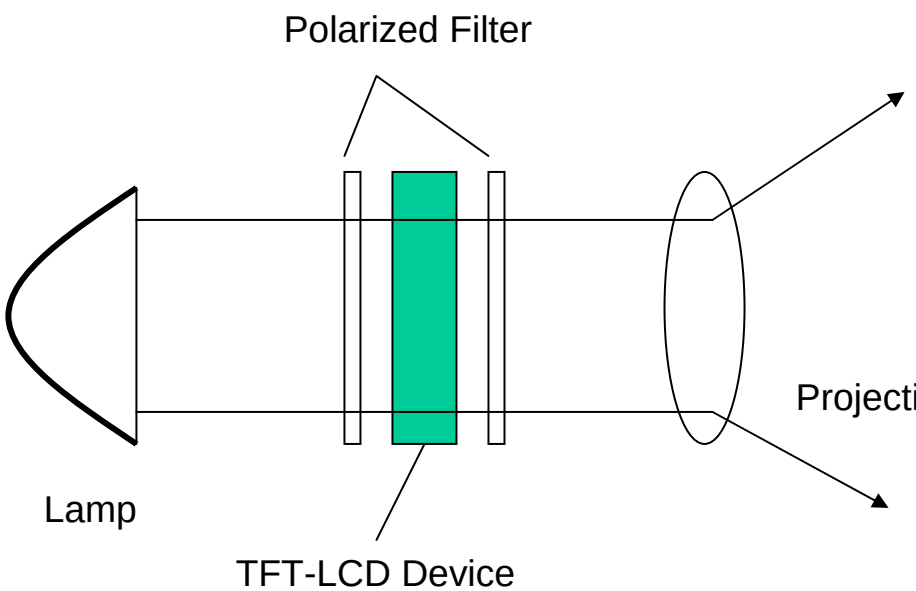
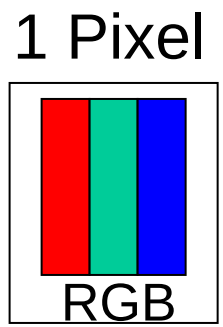


Figure 5. DMD single-chip color projection display.

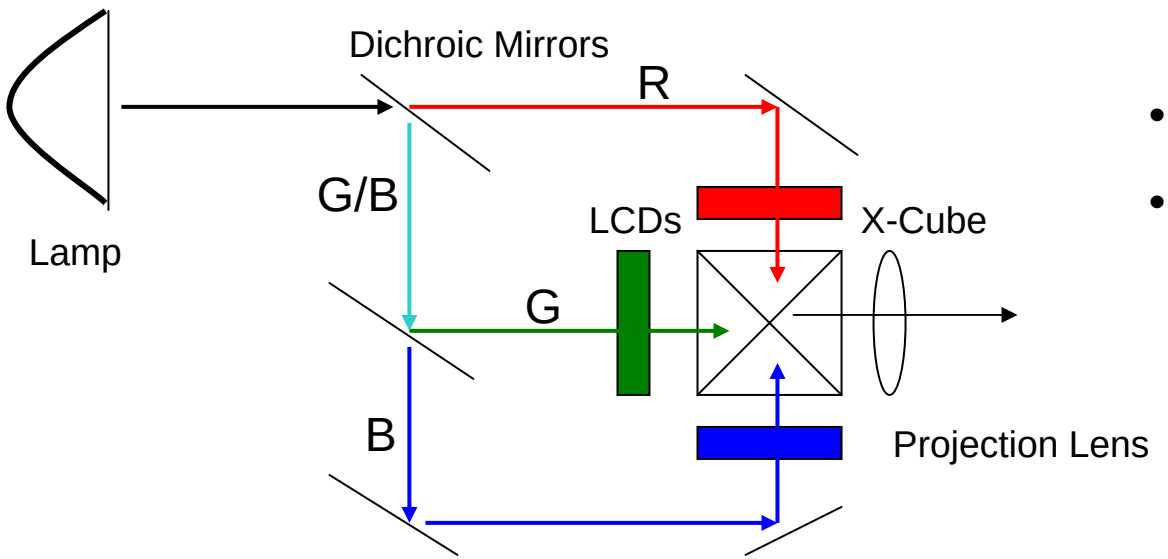
1 Panel Transmissive Type Projector





1 pixel contains 3 sub-pixels

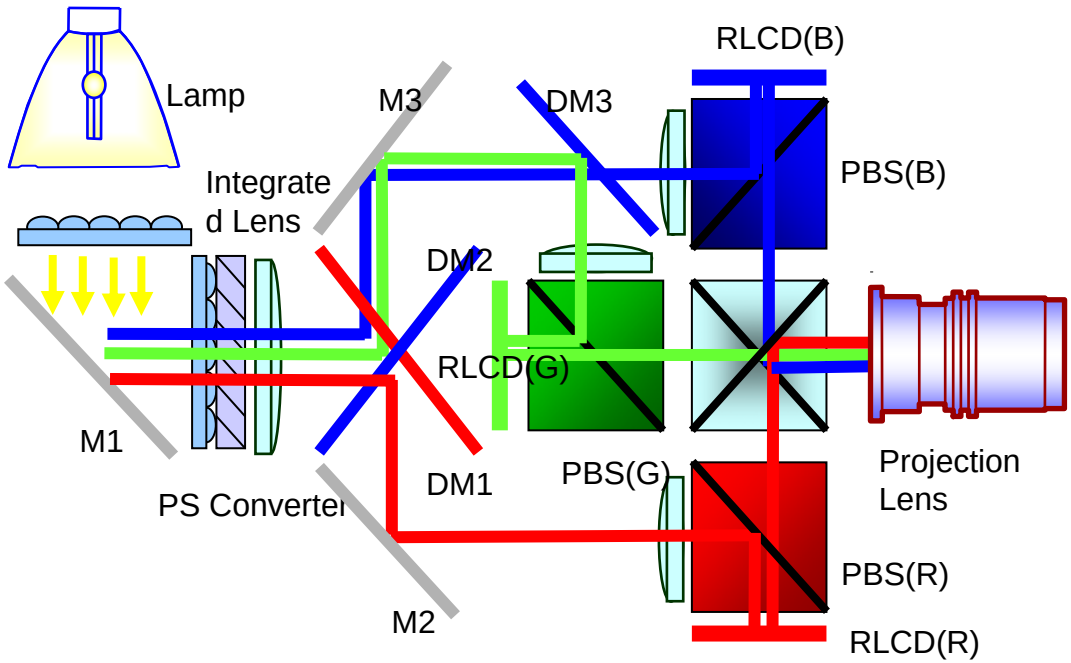
3 Panels Transmissive Type Projector



- 3 panels are needed
- 1 pixel contains

  no sub-pixel

3 Panels Reflective Type Projector



1 panel projector is similar to that of DLP's

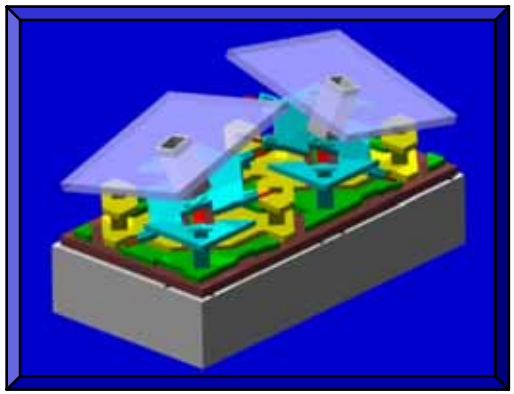
Resolution: 1280 ×1024

Pixels: 1280 ×1024

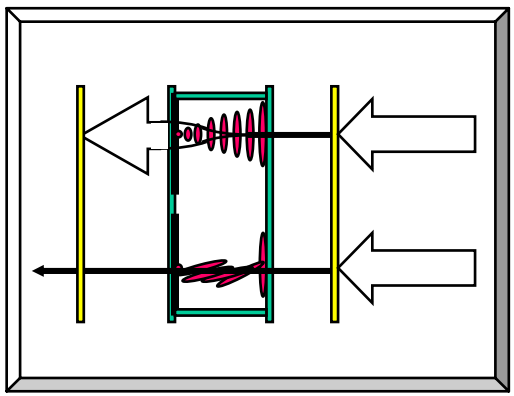
LCoS panel × 3

Source: Dr.徐正池 (ITRI/ERSAO)

Better Image Motion



DMD™ = fast switching



LCD = slow switching

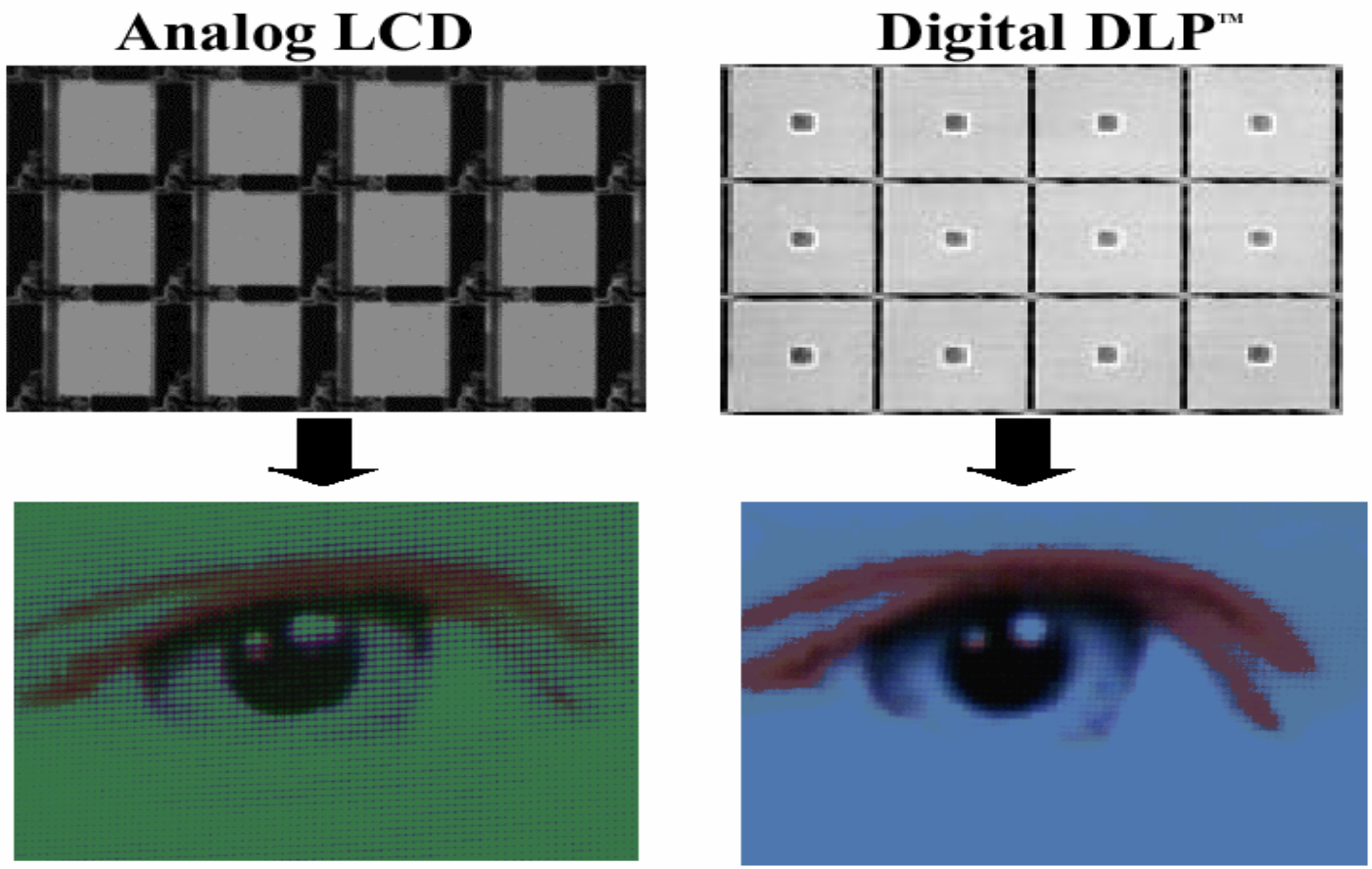
- DMD™ switching is fast with minimal ‘lag’ (few microseconds)
- **LCD switching is slow with significant ‘lag’ (tens of milliseconds)**
- **Result is ‘smearing’ in LCD projection of fast moving video**
- **DLP™ is much better at reproducing full-motion video**

LCD V.S *DLP* projector performance

	三片式LCD投影機	單片式DLP投影機
• 解析度	VGA-XGA	**SVGA-XGA**
• 亮度	高	較低
• 影像精細度	差	**較佳**
• 對比度	佳	較差
• 體積	大	**較小**
• 重量	重	**較輕**
• 系統組裝	複雜	**較簡單**
• 產品價格	較低	**較高**

sourse: www.pida.com.tw

See the digital difference



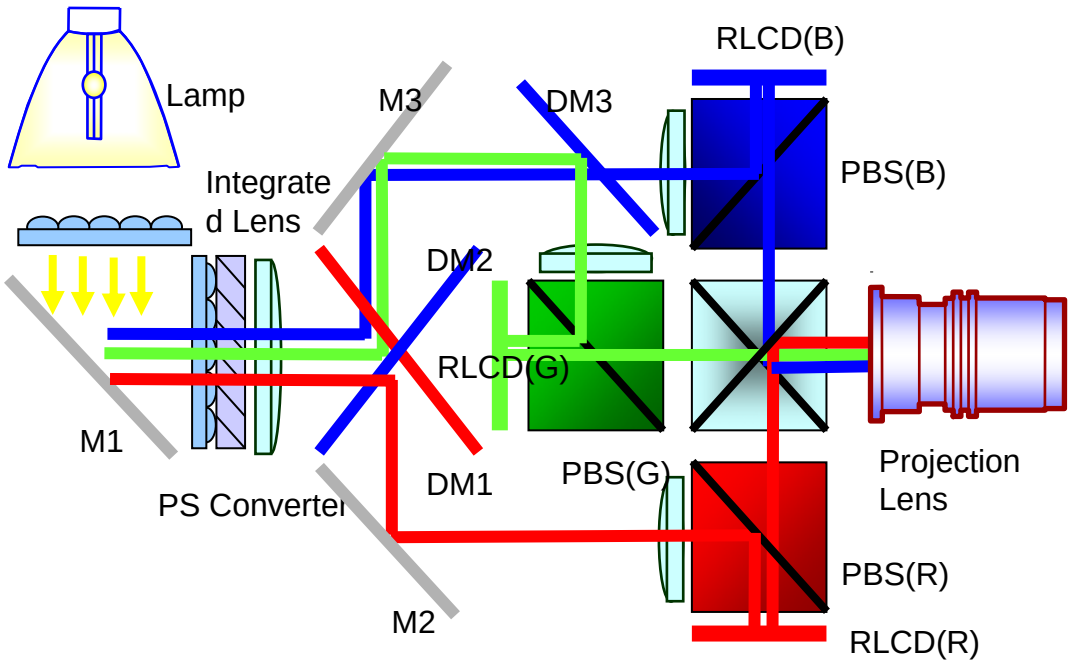
sourse: www.ti.com

重 量 分 類

Ultra-Ultra Portable	超輕可攜帶型	< 5 磅
Ultra Portable	超可攜帶型	5-10 磅
Portable	可攜帶型	10-20磅
Fixed	定置型	> 20 磅

資料來源：PIDA 整理

3 Panels Reflective Type Projector



1 panel projector is similar to that of DLP's

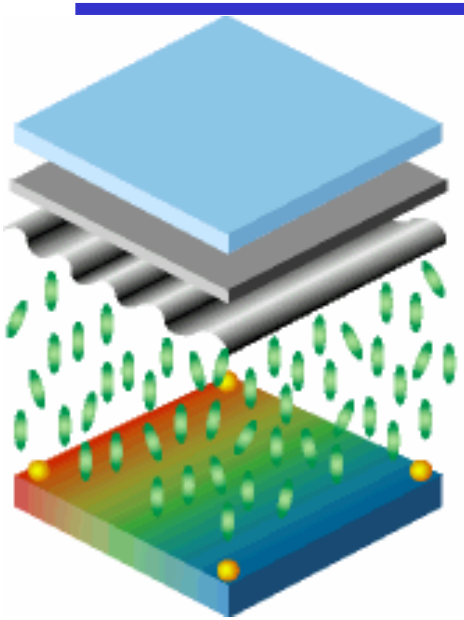
Resolution: 1280 ×1024

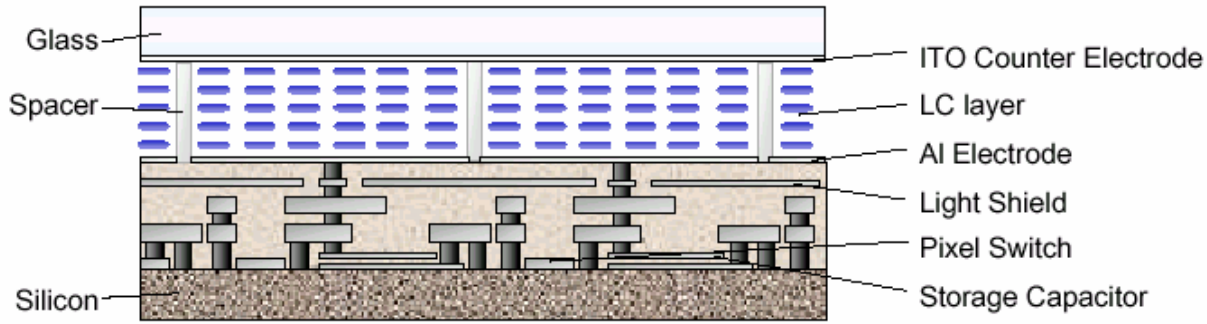
Pixels: 1280 ×1024

LCoS panel × 3

Source: Dr.徐正池 (ITRI/ERSAO)

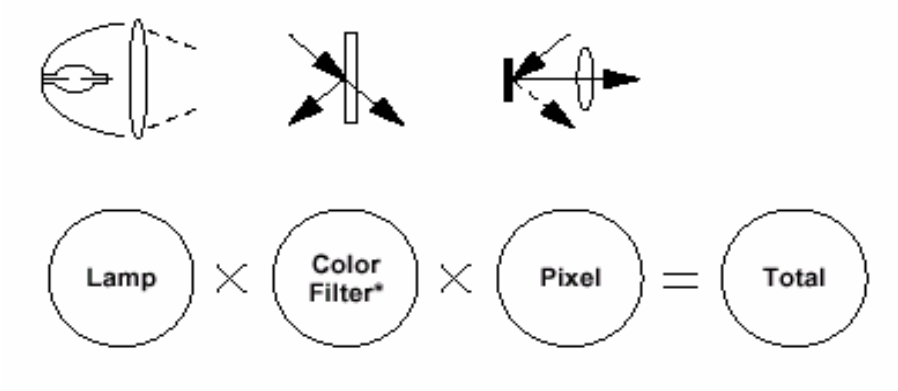
Reflective LCOS for Projection



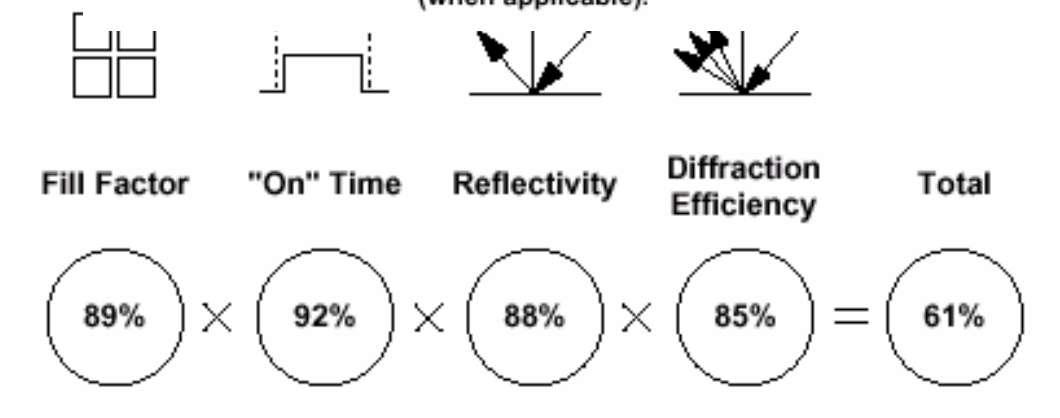


Source: http://www.optivu.com/home.htm

Display Performance



Optical efficiency of DLP projection system



Optical efficiency of DMD pixel

Ref.: J. M. Florence, R. Miller, and T. A. Bartlett, “Contrast ratio in DMD-based projection systems,” in *Proc. SID ’97*, Boston,MA, May 1997, pp. 920–922.

Comparison of key components

- DMD for projection
- LCOS for projection

Color expression and Gray Scale

Color Generation

- 3-Channel Color
- Color Sequential

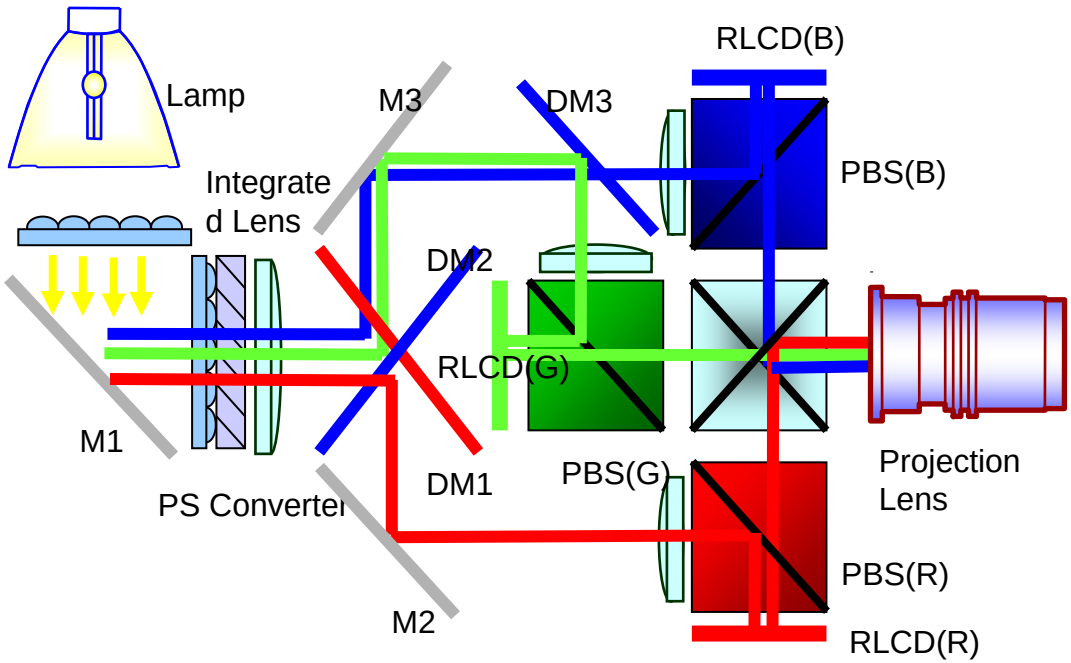
Source: Dr.徐正池 (ITRI/ERSAO)

3-Channel Color

1 Frame

Source: Dr.徐正池 (ITRI/ERSAO)

3 Panels Reflective Type Projector



1 panel projector is similar to that of DLP's

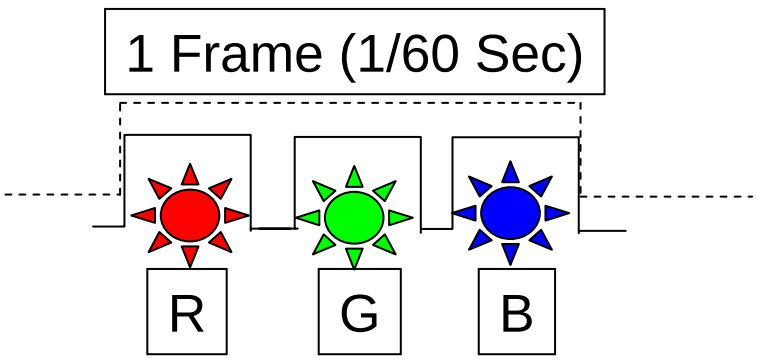
Resolution: 1280 ×1024

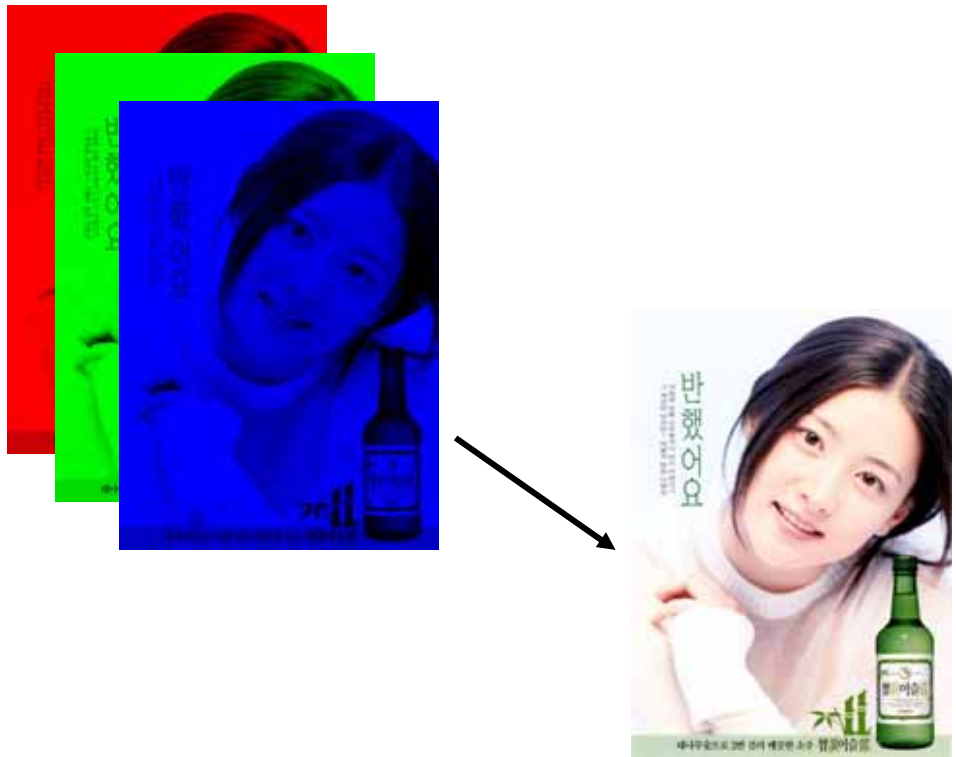
Pixels: 1280 ×1024

LCoS panel × 3

Source: Dr.徐正池 (ITRI/ERSAO)

Color Sequential





Drawback：

Frame rate: 180Hz

→ f_{CLOCK} 變3倍

Source: Dr.徐正池 (ITRI/ERSAO)

Reflective Scheme of DMD

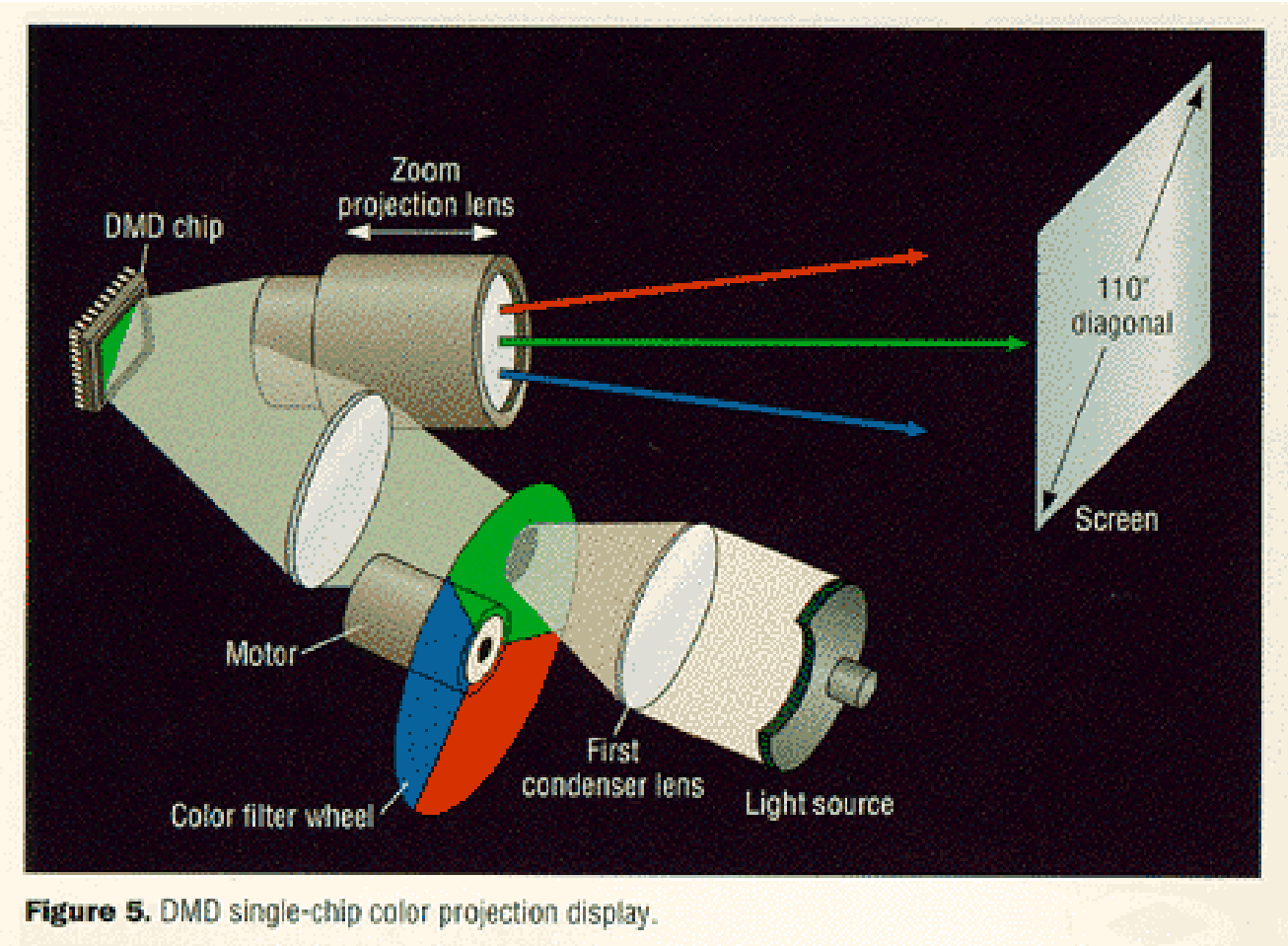
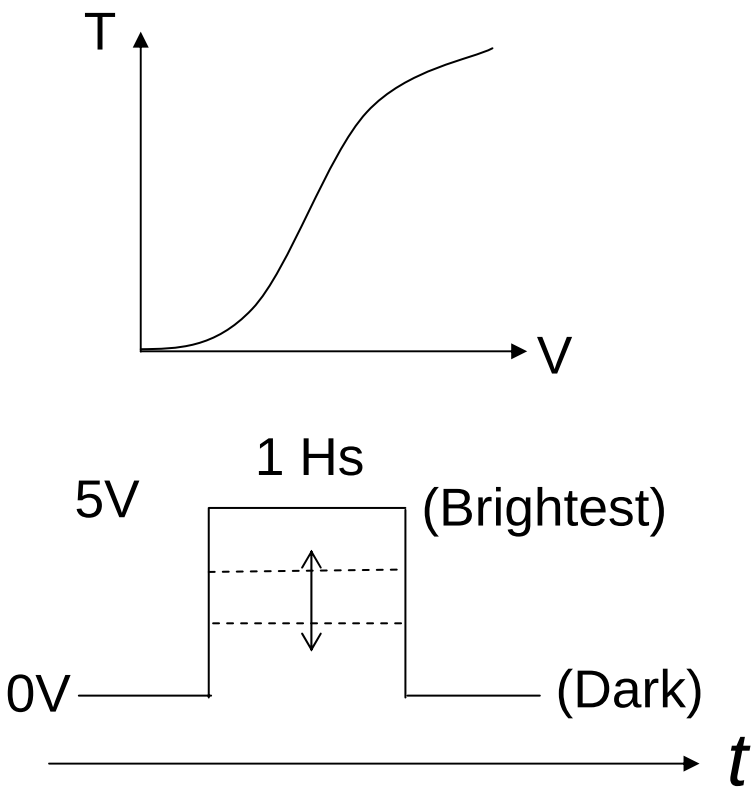
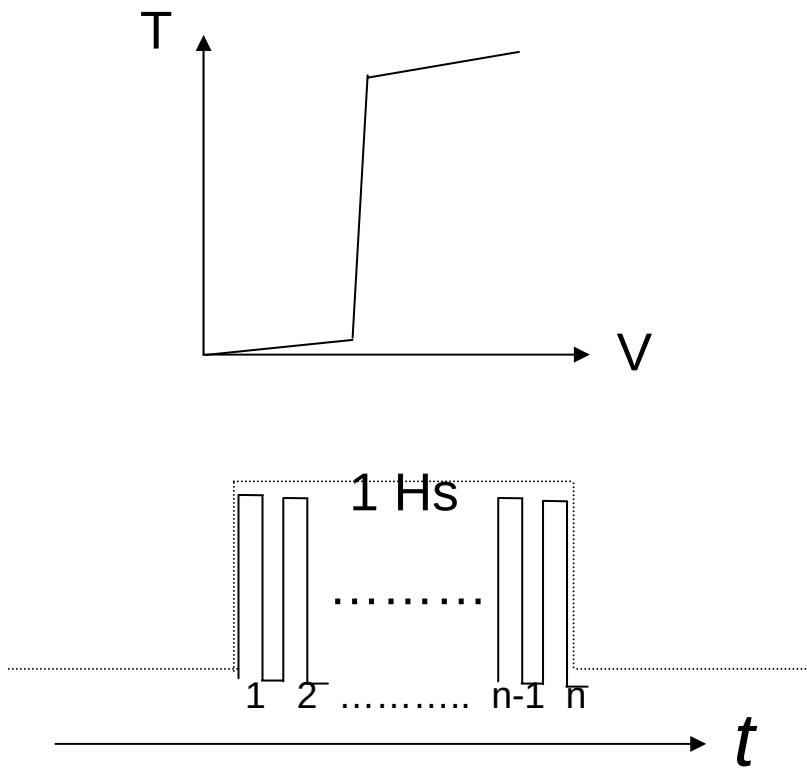


Figure 5. DMD single-chip color projection display.

Gray Scale Method



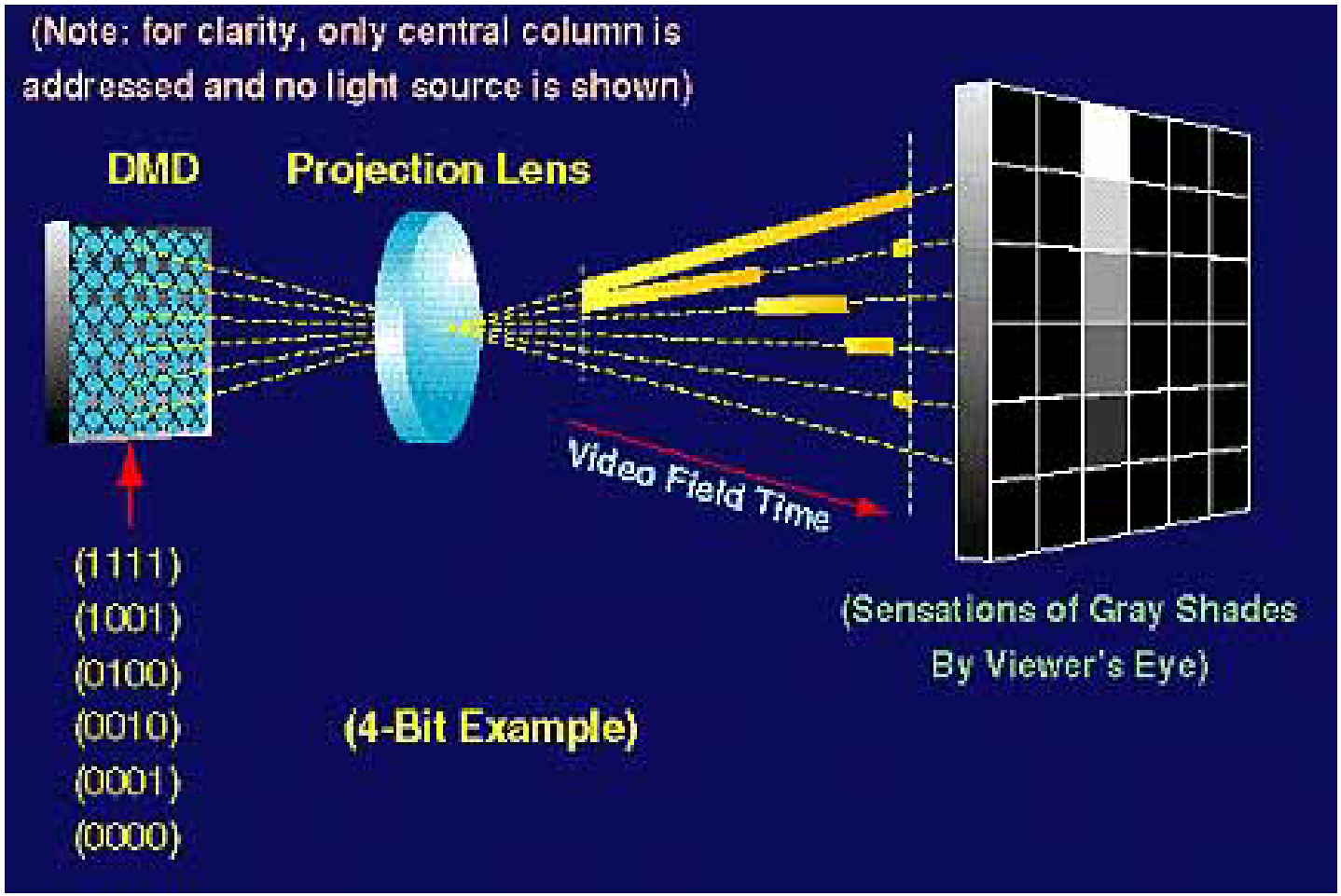
Voltage modulation



Pulse width modulation

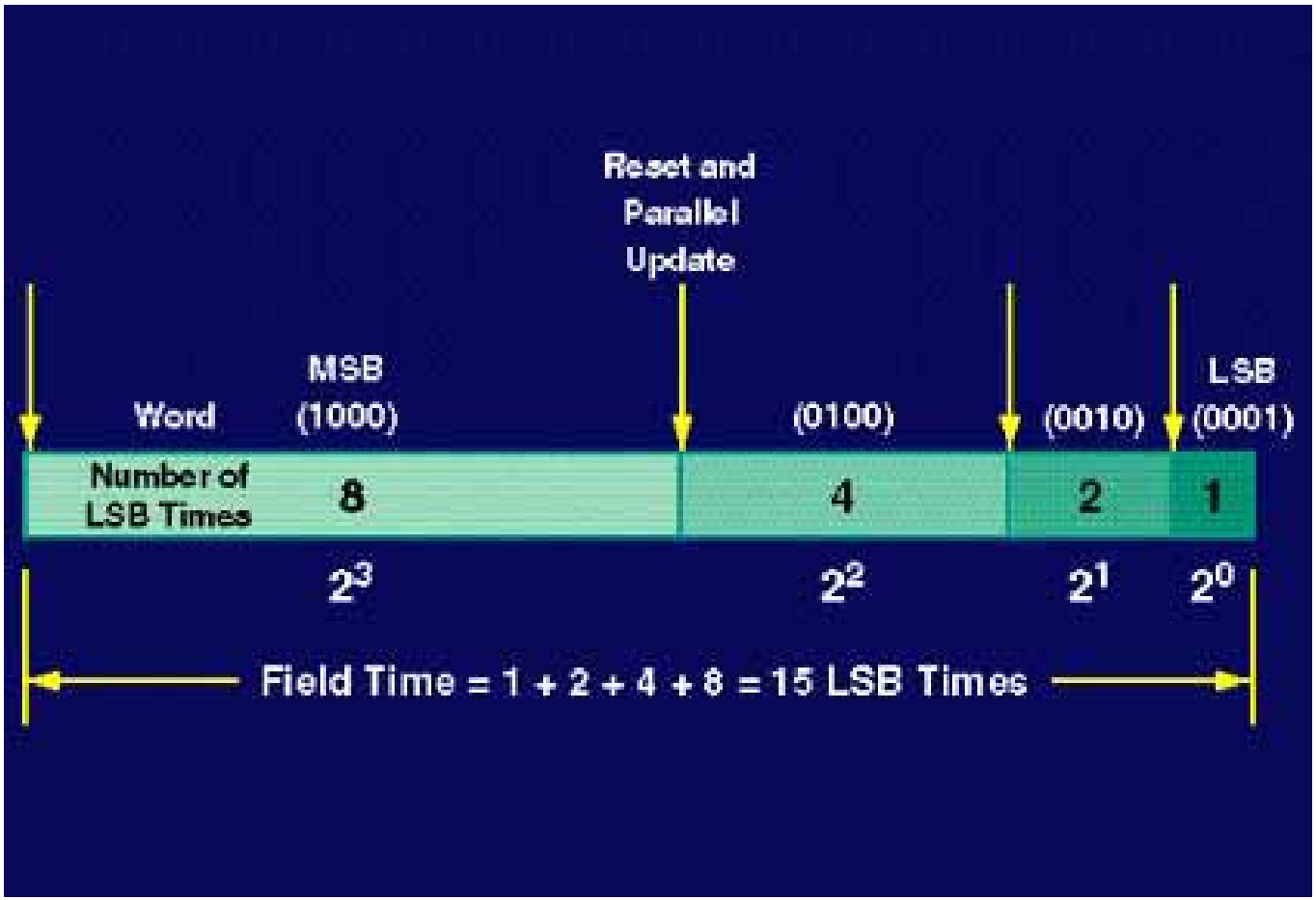
Source: Dr.徐正池 (ITRI/ERSAO)

Application 4: Projection TV



Source: www.dlp.com

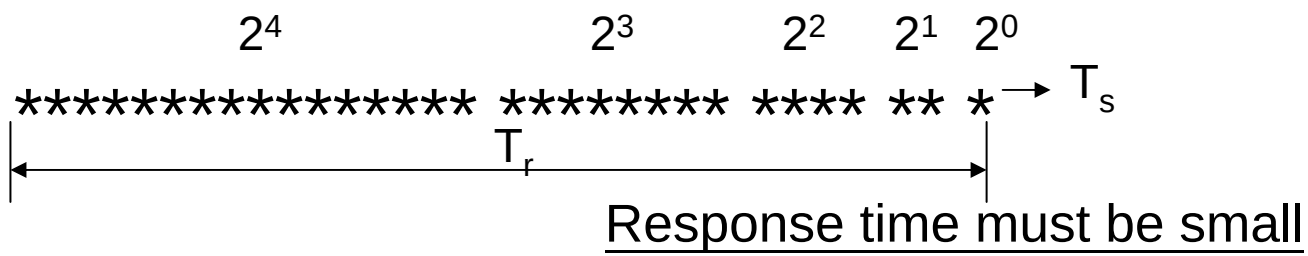
Application 4: Projection TV



Source: www.dlp.com

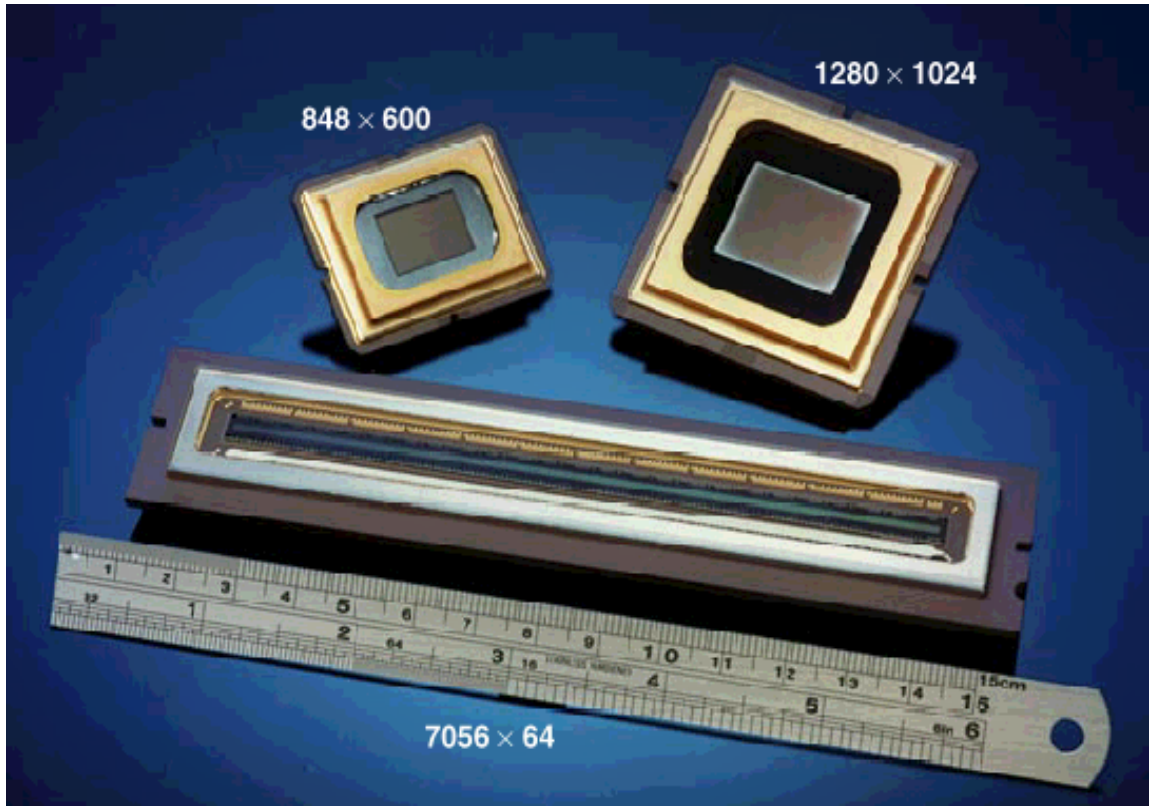
Pulse Width Modulation

- Color depth = m bits
- Gray scale G = 2^m - 1
- Row time $T_r = T_f / N$
- Slot time $t_s = T_r / G$



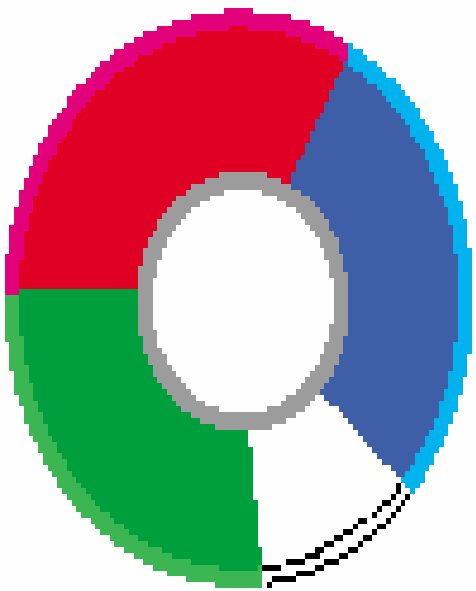
Source: Dr.徐正池 (ITRI/ERSAO)

DMD Configuration

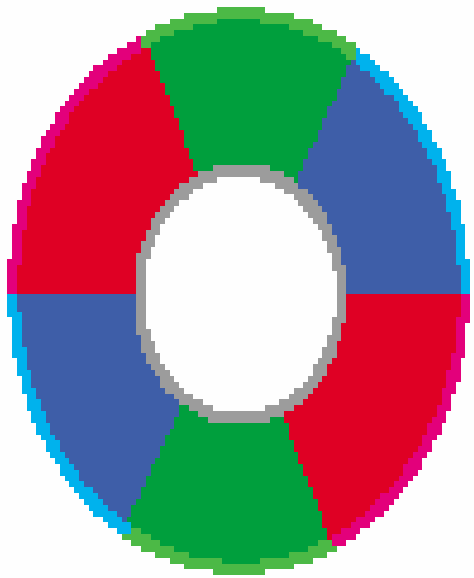


Source:
www.ti.com/dlp

FS color wheel



4-Segment Color Wheel

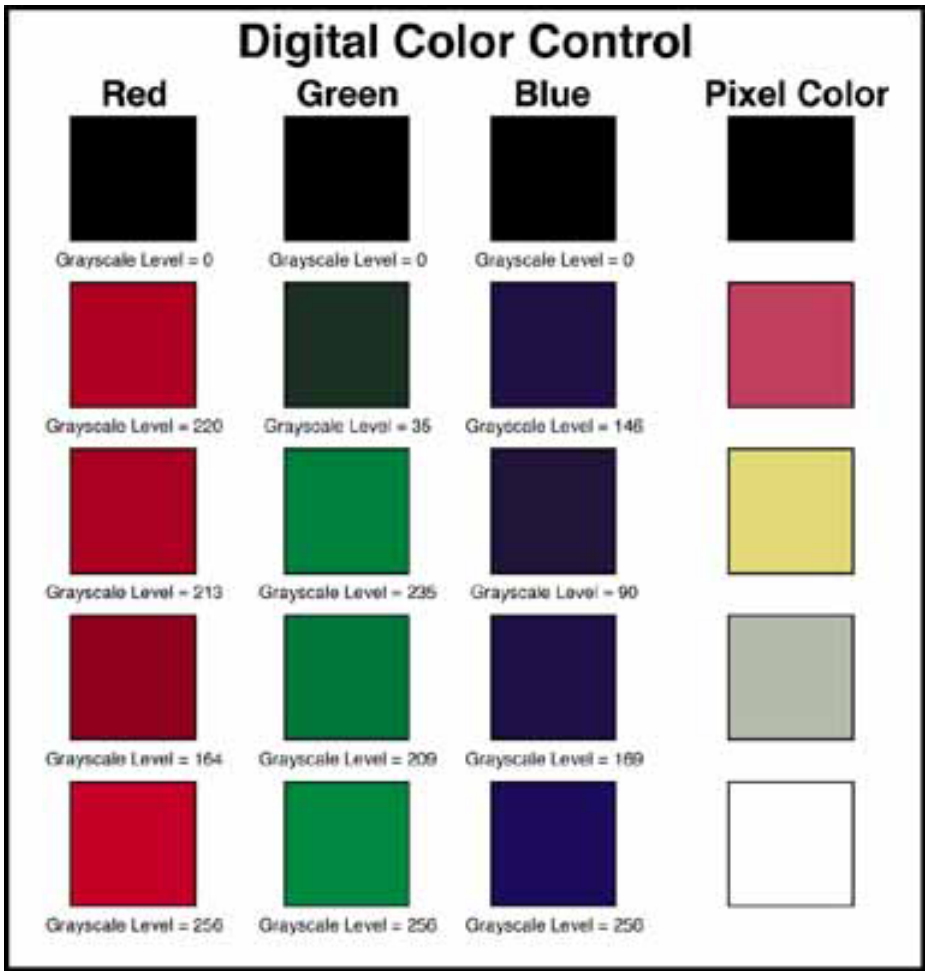


6-Segment Color Wheel

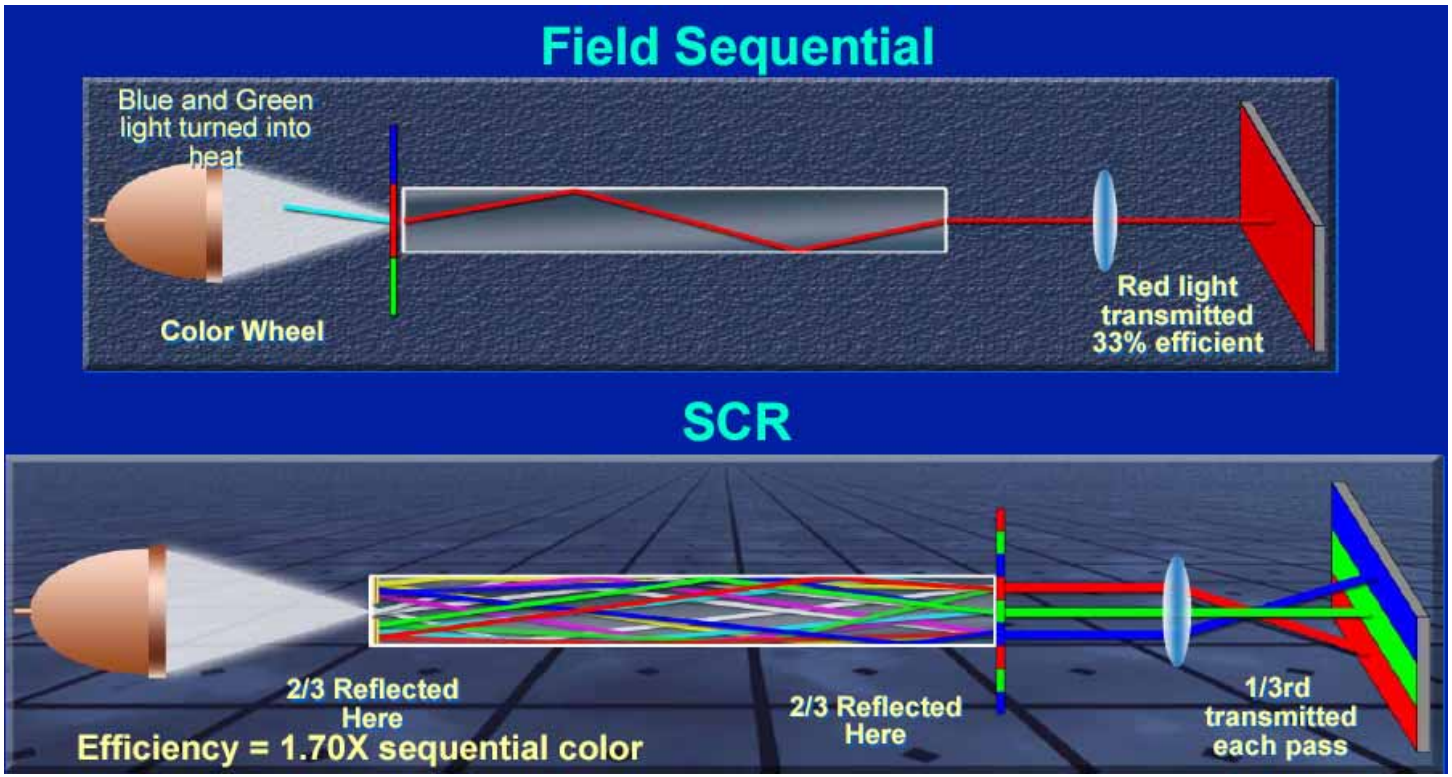
FS and SCR color wheel

- Field Sequential
  （FS color wheel）

- Sequential color recapture
  （SCR color wheel）


Digital Color Control
Red
Green
Blue
Pixel Color
Grayscale Level = 0
Grayscale Level = 0
Grayscale Level = 0
Grayscale Level = 220
Grayscale Level = 35
Grayscale Level = 146
Grayscale Level = 213
Grayscale Level = 235
Grayscale Level = 90
Grayscale Level = 164
Grayscale Level = 209
Grayscale Level = 189
Grayscale Level = 256
Grayscale Level = 256
Grayscale Level = 256

Recycling process



- 含有 recycling process

$$\frac{1}{3}\left[1+\left(\frac{2}{3}\right)^{2}+\left(\frac{2}{3}\right)^{4}+....\right]=\frac{1}{3}[1.8]$$

Key structures and process

Features of Digital Micromirror Devices

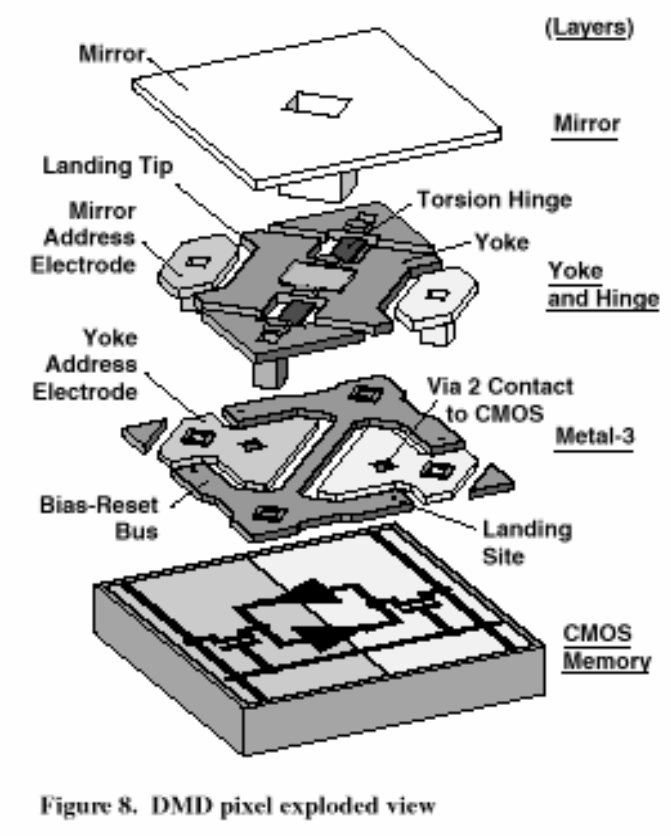
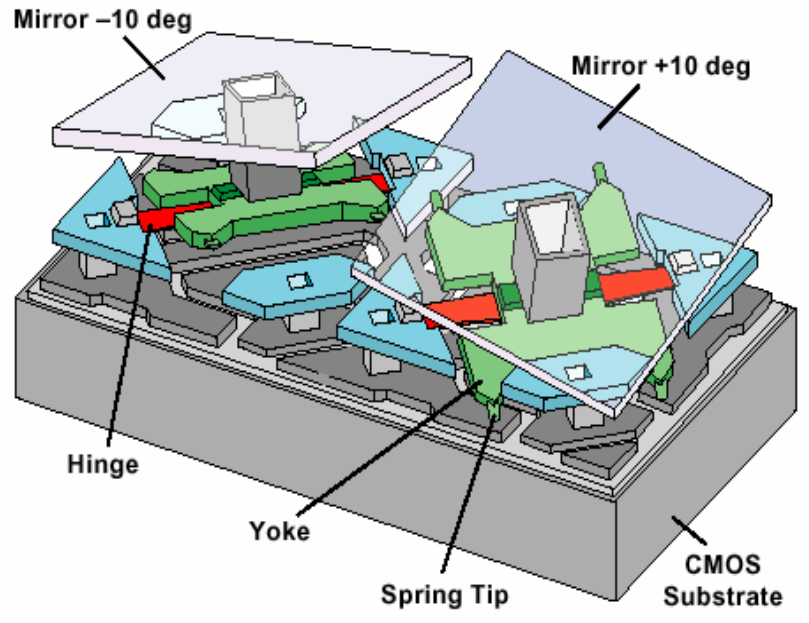


Figure 8. DMD pixel exploded view

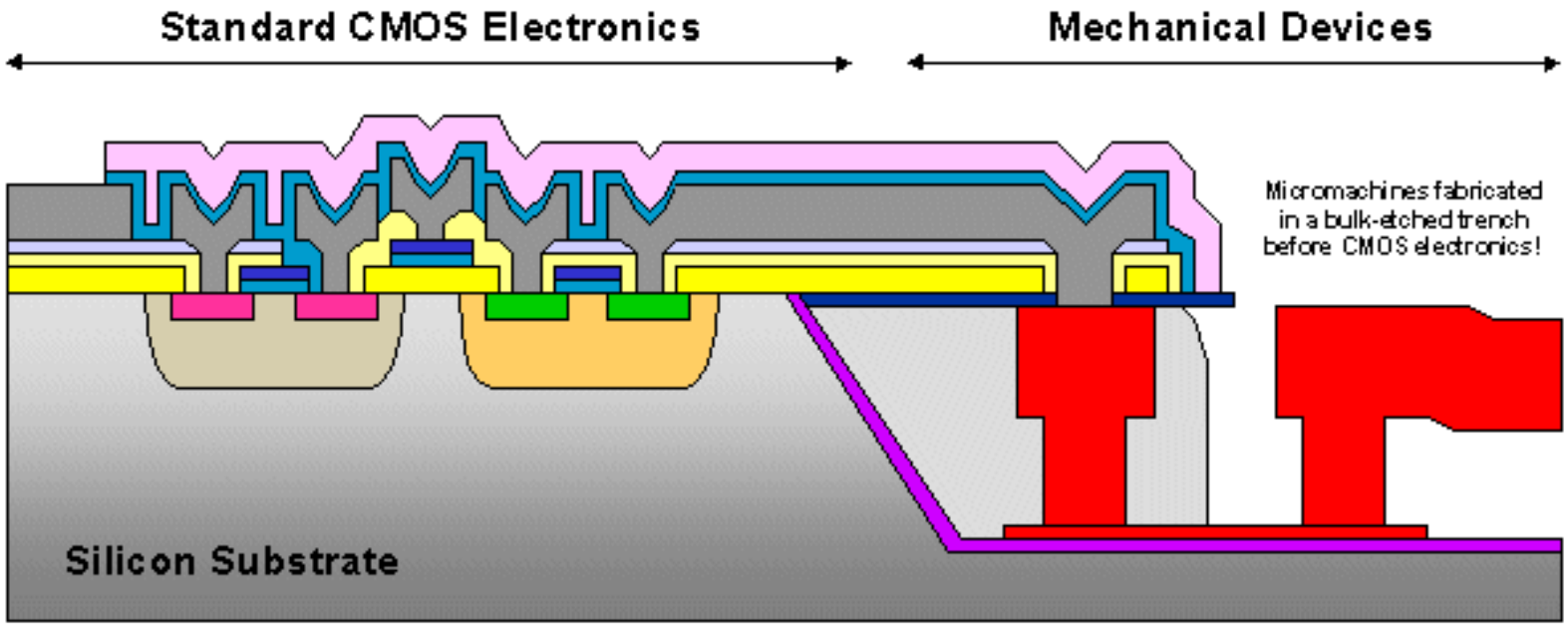


To improve the contrast ratio of projection displays,the mechanical structure was hidden under the mirror

Source: www.ti.com

Integrated Microsystems

Integrated Microelectromechanical Systems (IMEMS) Technology:

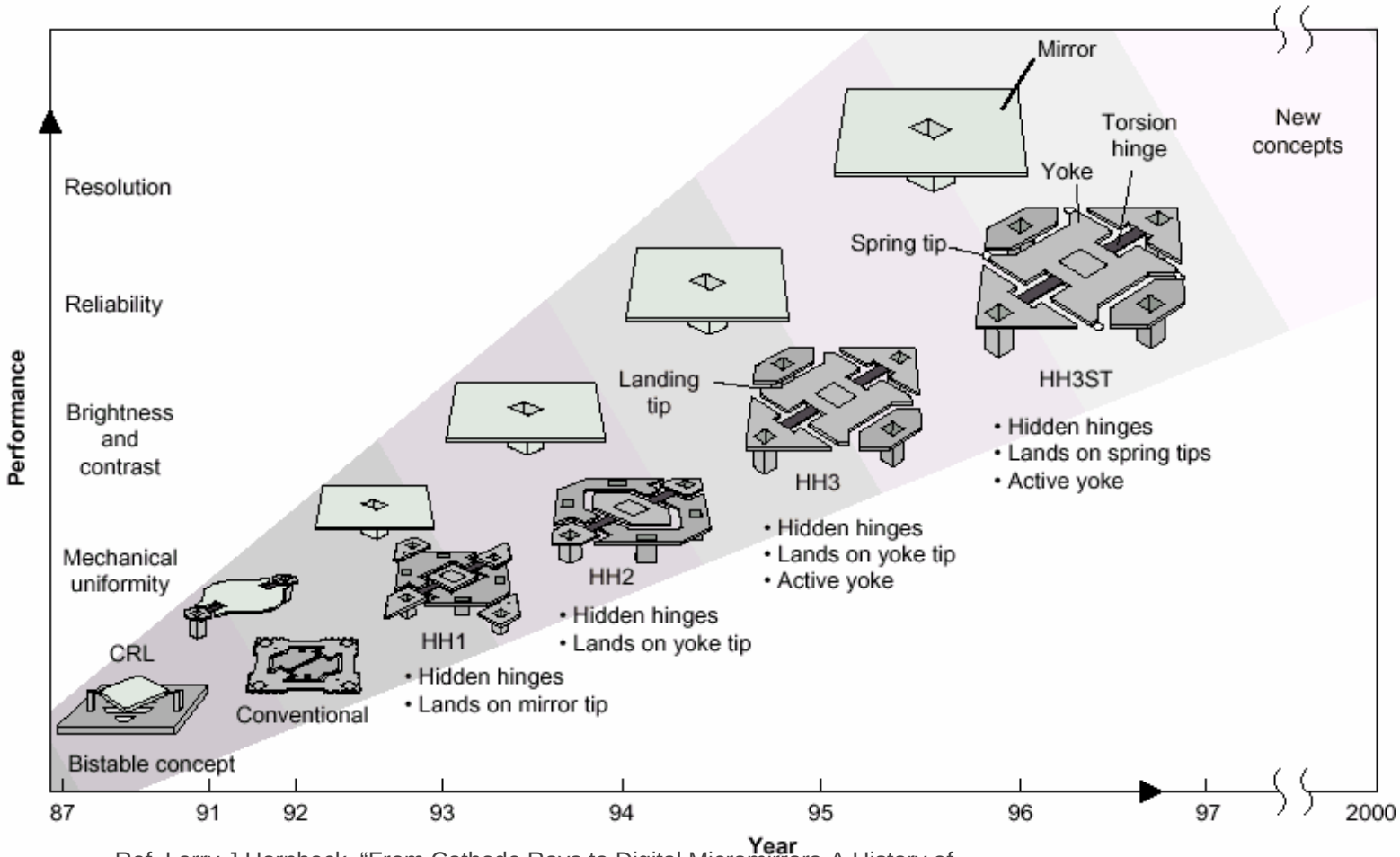


After Sandia National Laboratories, http://www.mdl.sandia.gov/micromachine

Benefits of Trench Integration:

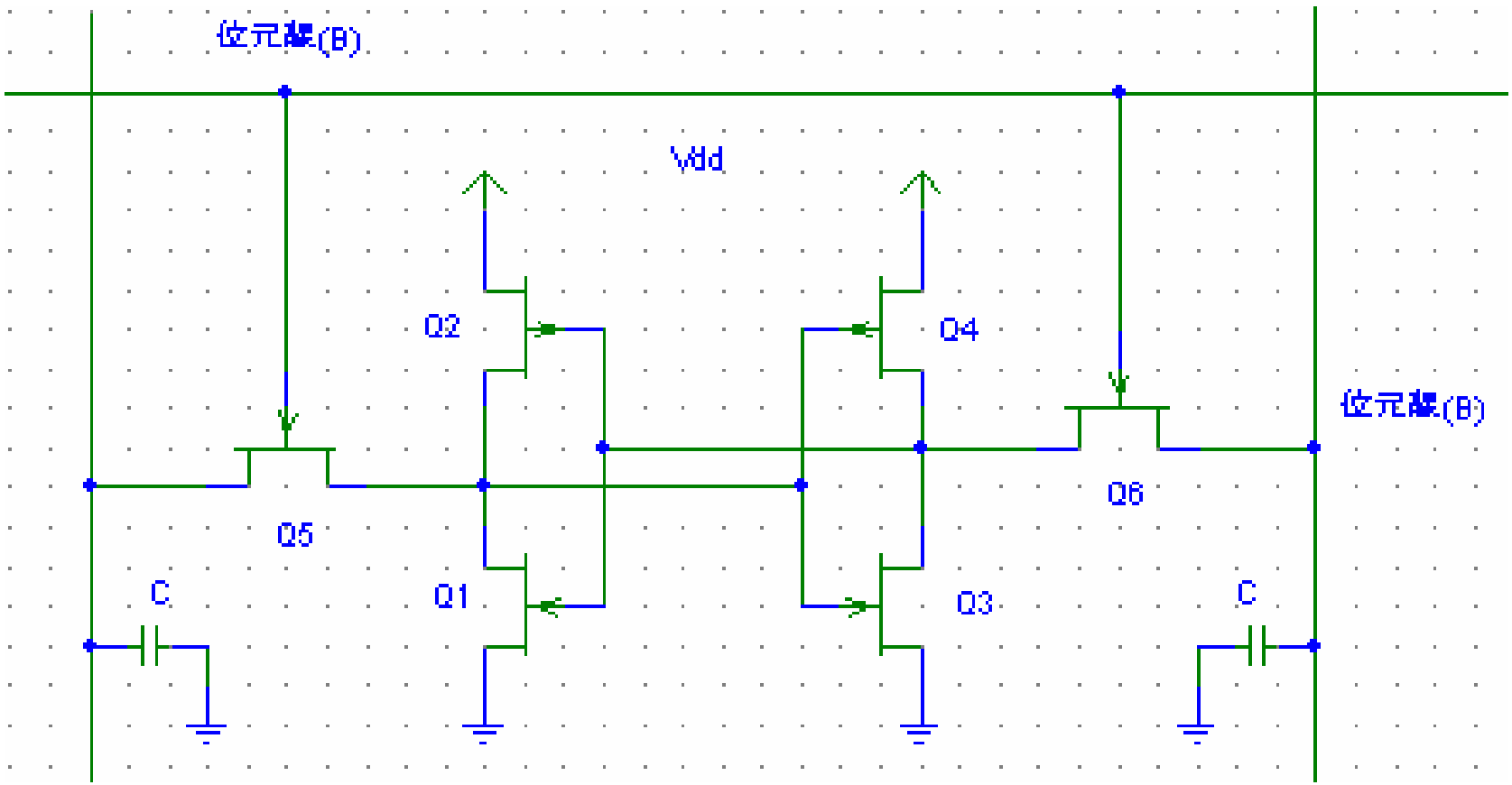
- Smaller, Faster, Less Costly, Lower Power, and Higher Sensitivity Integrated Systems
- High Levels of Compatibility: Overcomes Limitations of Traditional Integration Strategies

Evolution of DMD pixel architecture



Ref. Larry J.Hornbeck, “From Cathode Rays to Digital Micromirrors-A History of Electronic Projection Display Technology,” TI Technical Journal, July-September 1998

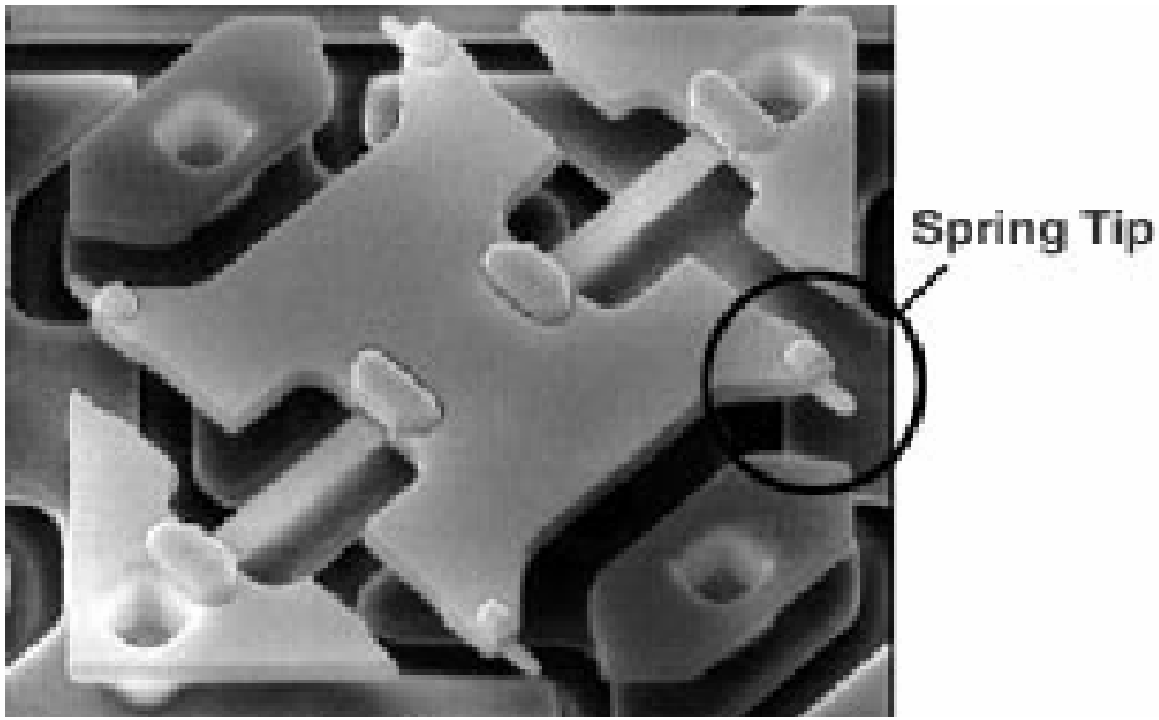
SRAM記憶單元



Microelectronic Circuits

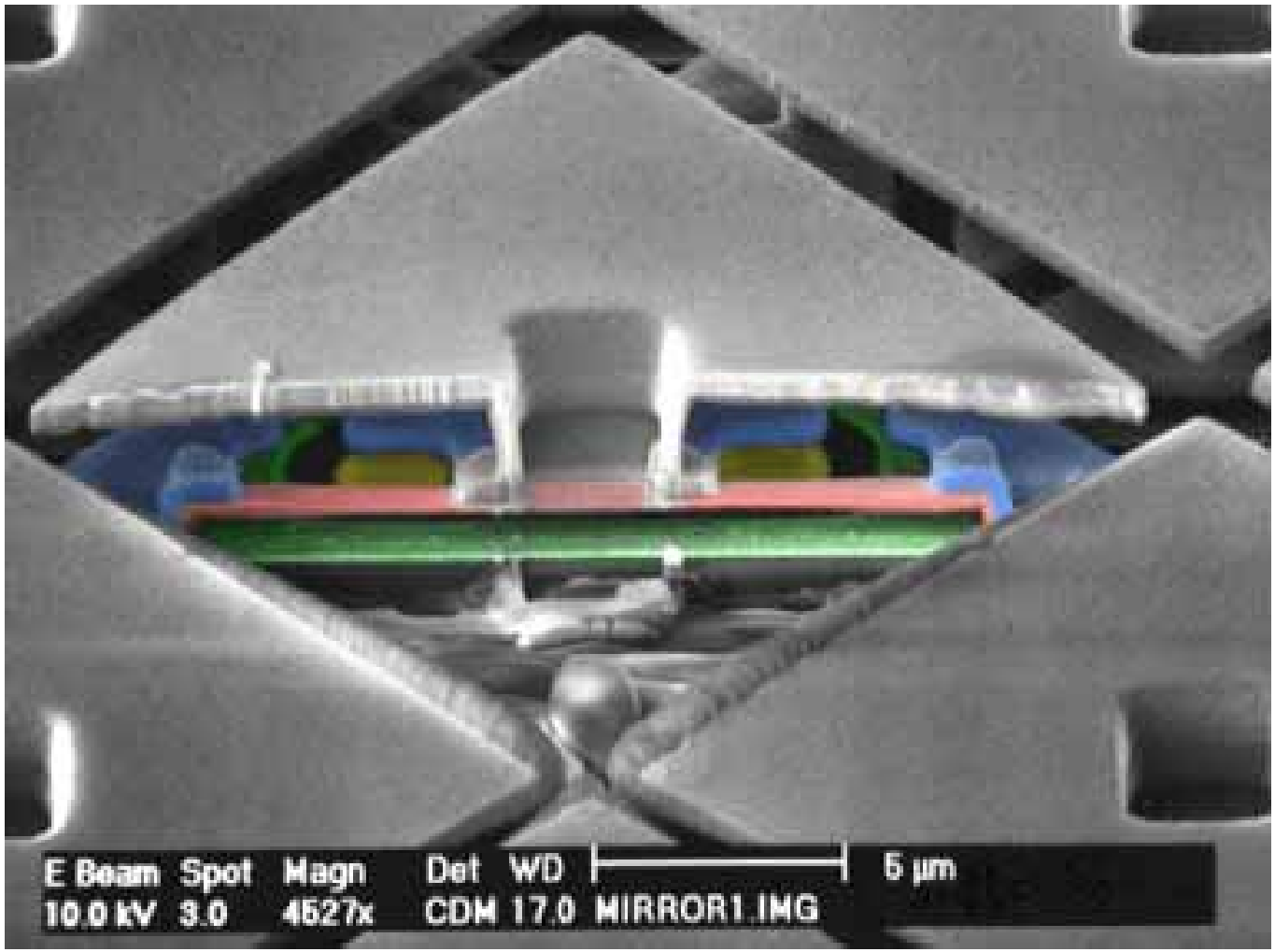
Adel S. Sedra, Kenneth C. Smith

SEM photomicrograph of yoke and spring tips (mirror removed)



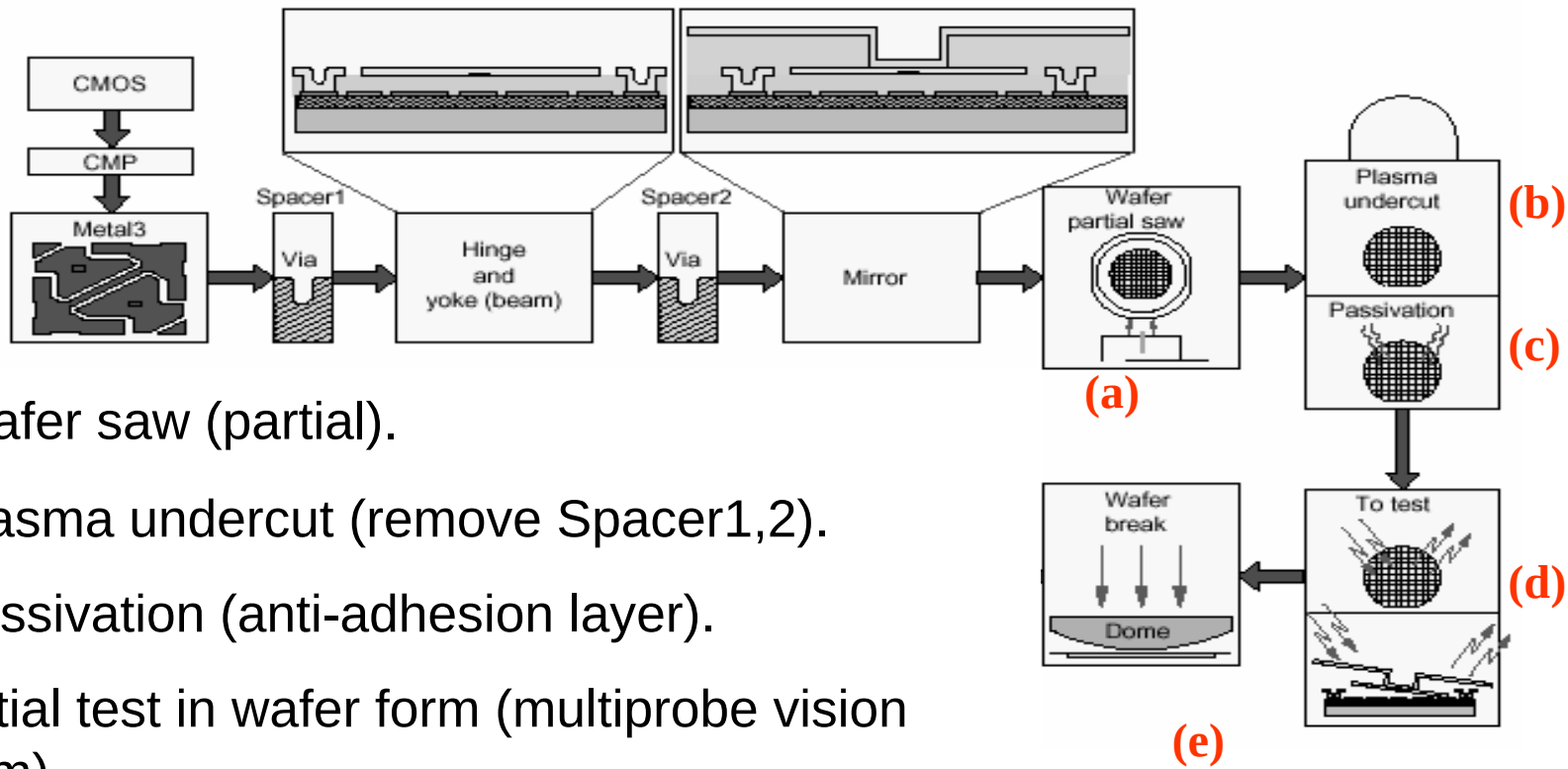
•The spring not only absorbs energy during landing but stores energy for more efficient mirror release.

Exploded View



Source: www.dlp.com

DMD Packaging process flow



a. Wafer saw (partial).

b. Plasma undercut (remove Spacer1,2).

c. Passivation (anti-adhesion layer).

d. Initial test in wafer form (multiprobe vision system).

e. Wafer break (break into individual chips).

sourse: www.ti.com

DMD Packaging process flow

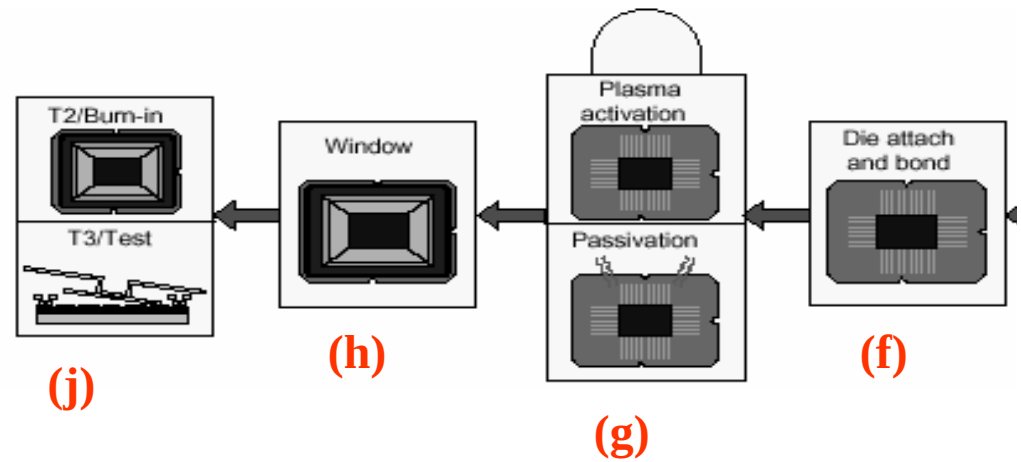
f. Chip attachment to ceramic package and wire bond.

g. Plasma activation (clean) and repassivation.

h. Getter strip attachment to window.

i. Hermetic window attachment (weld glass-to-metal fused window assembly to metal seal ring of package).

j. Burn in and final test.



sourse: www.ti.com

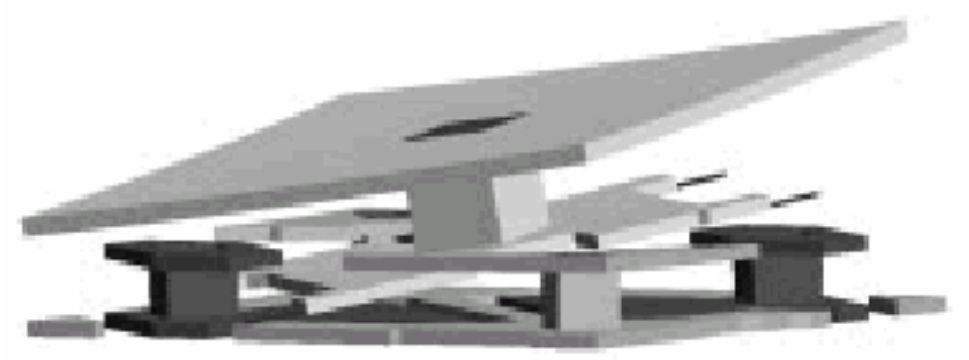
Actuation

Digital Micromirror Device Dynamical Analysis

- The electrostatic torque (T_e) (ignoring fringing fields) is given by:

$$T_e = \int x\,(dF/dA)dA$$

- dF/dA：the electrostatic force per unit area exerted on an elemental area dA of the yoke or mirror.
- X：a distance from the torsion axis to the yoke or mirror.



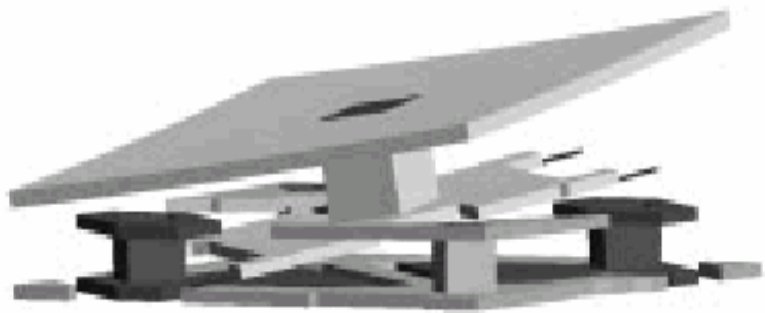
Source: P. Van Kessel, L. Hornbeck, R. Meier and M. Douglass, “A MEMS-based Projection Display,” *IEEE Proceedings*, submitted for summer 1998 publication.

Digital Micromirror Device Dynamical Analysis

$$T_e = \int x\,(dF/dA)dA$$

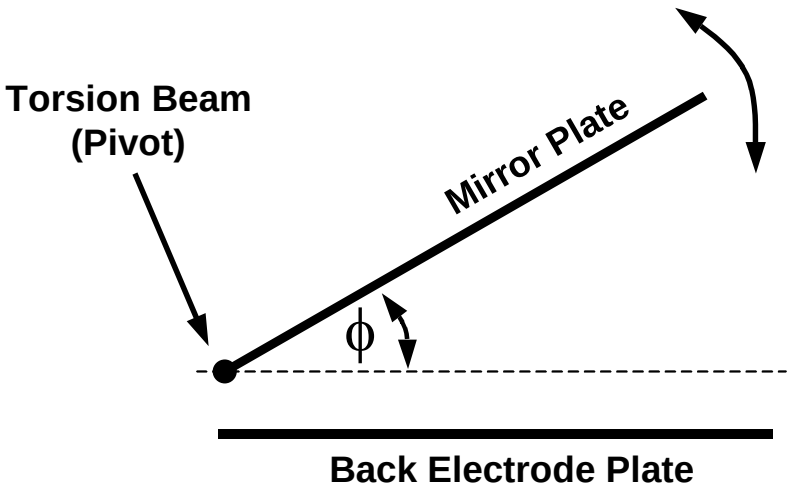
$$dF/dA = (1/2)\,\varepsilon_o(\Delta V/\Delta Z)^2$$

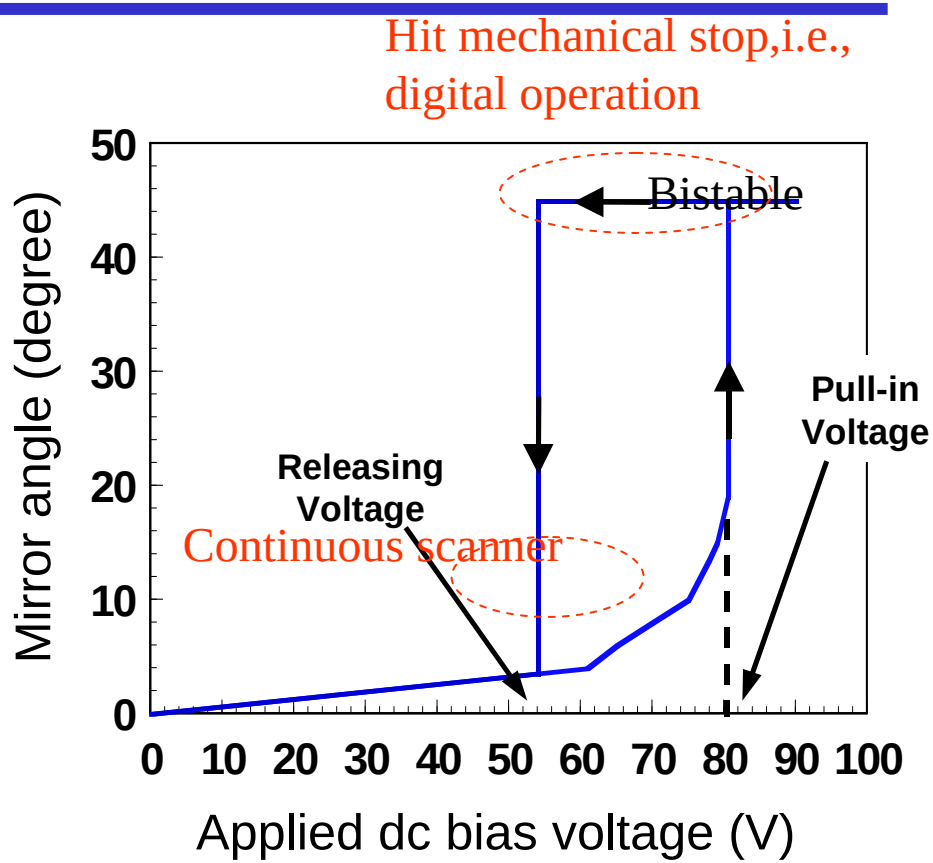
- ΔV：the potential difference across the air gap, measured between the mirror/yoke and address electrodes.
- ΔZ：the size of the air gap at a given elemental area dA location.



Source: P. Van Kessel, L. Hornbeck, R. Meier and M. Douglass, “A MEMS-based Projection Display,” *IEEE Proceedings*, submitted for summer 1998 publication.

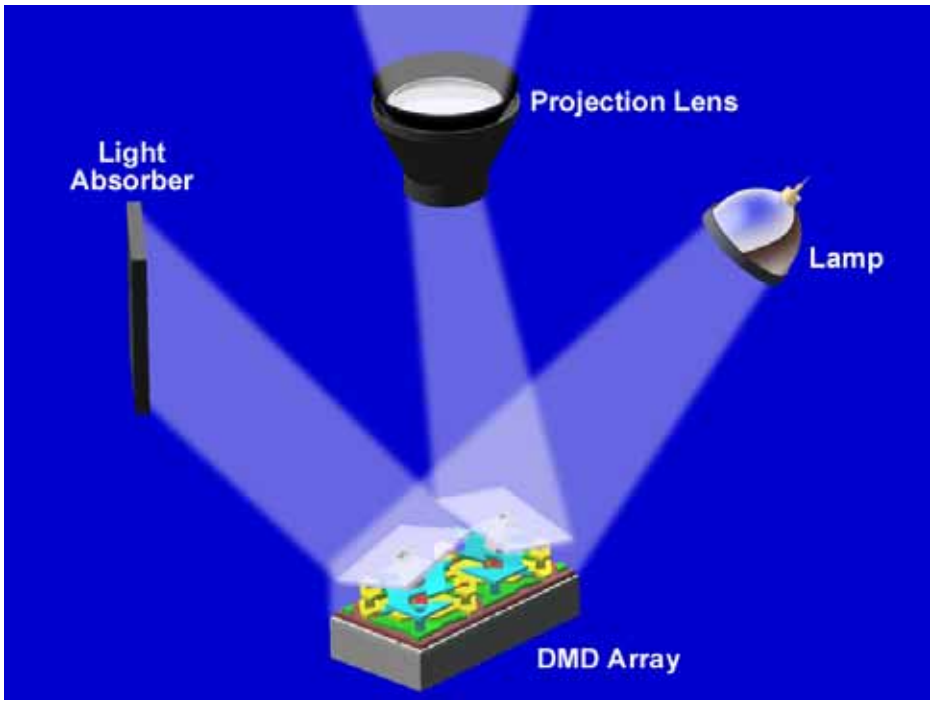
Ex: Torsion Mirror

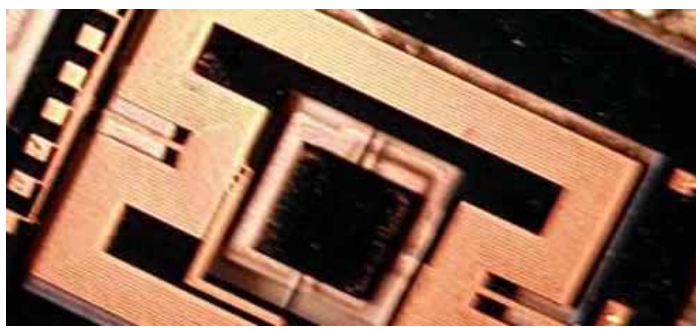




S.S Lee, UCLA thesis, 1998

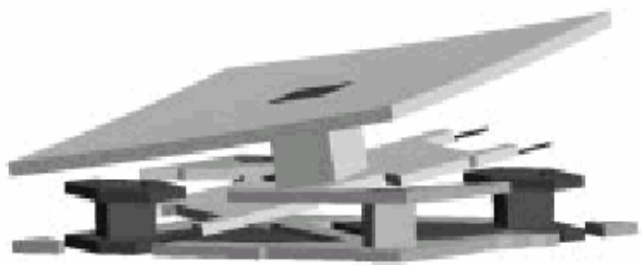
DMD vs. μ-scanner





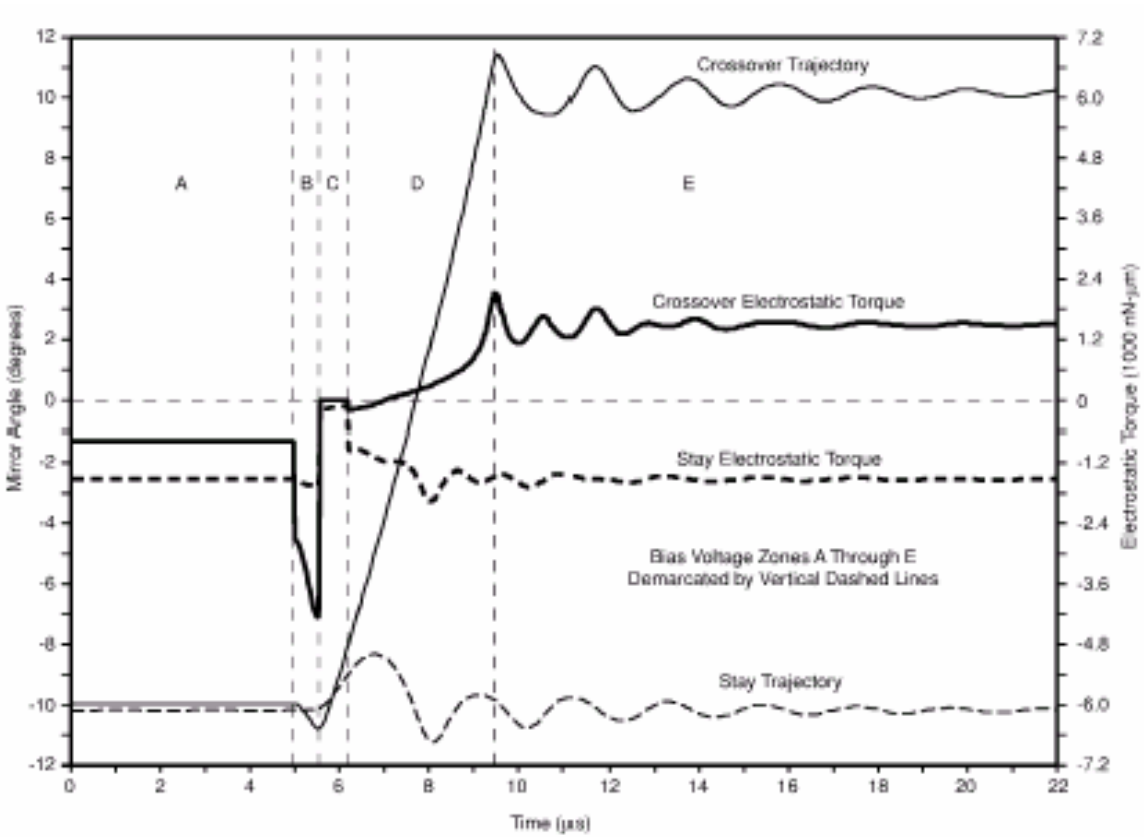
Digital Micromirror Device Dynamical Analysis

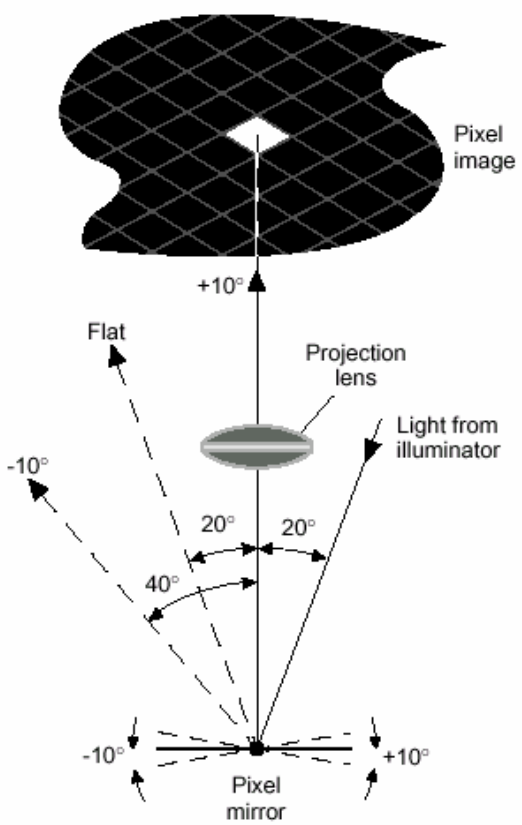
- The electrostatic torque (T_e) is proportional to the square of the voltage difference across the air gap and inversely proportional to the square of the air gap size.
- Key to achieving these optimization goals is effective drive voltage waveform design, which aims to elicit desired dynamic angular responses from the mirror through the application of time-varying electrostatic torque.



Source: P. Van Kessel, L. Hornbeck, R. Meier and M. Douglass, "A MEMS-based Projection Display," *IEEE Proceedings*, submitted for summer 1998 publication.

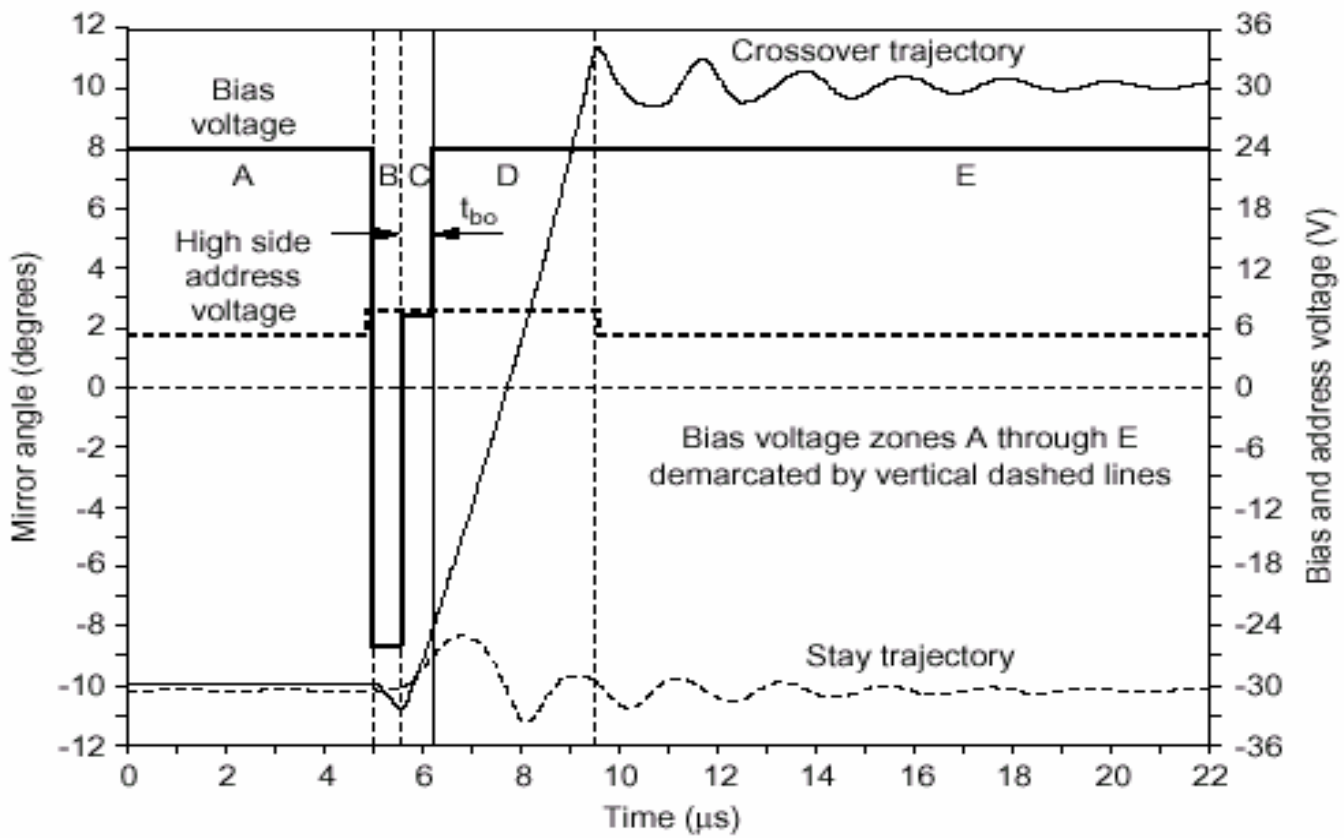
Optical Switching Time





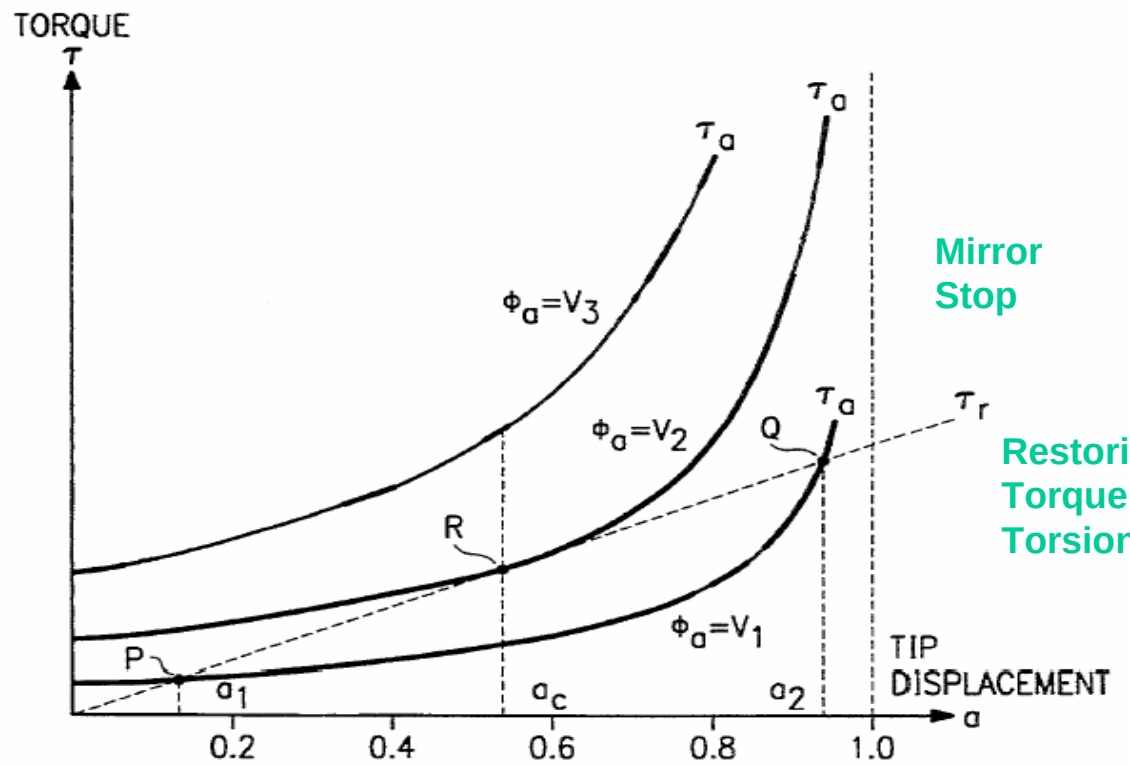
Ref. PETER F. VAN KESSEL, LARRY J. HORNBECK, “A MEMS-Based Projection Display,” 1704 PROCEEDINGS OF THE IEEE, VOL. 86, NO. 8, AUGUST 1998

Digital Micromirror Device Dynamical Analysis



Source: P. Van Kessel, L. Hornbeck, R. Meier and M. Douglass, "A MEMS-based Projection Display," *IEEE Proceedings*, submitted for summer 1998 publication.

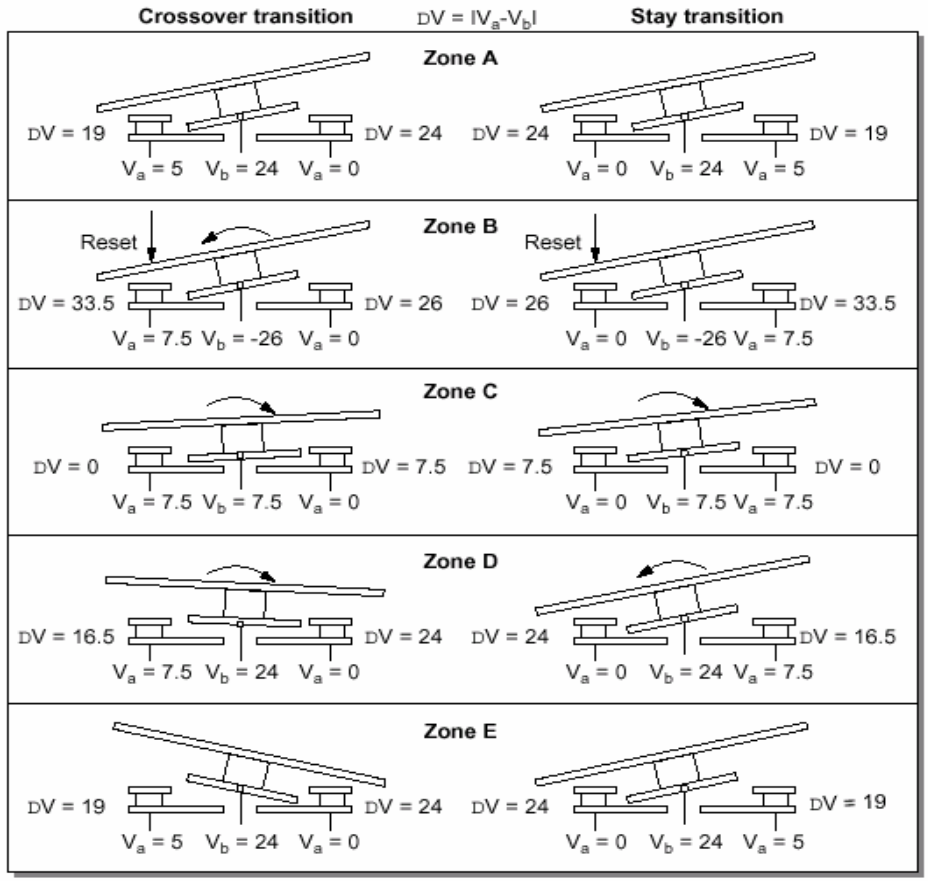
Mirror Displacement V.S Torque for Three Address Voltages Applied to The DMD



Source:Gale; Richard O, “Optimized electronic operation of digital

micromirror devices” U.S.P No.544566, Aug22, 1995

Applied voltages and potential differences for each zone

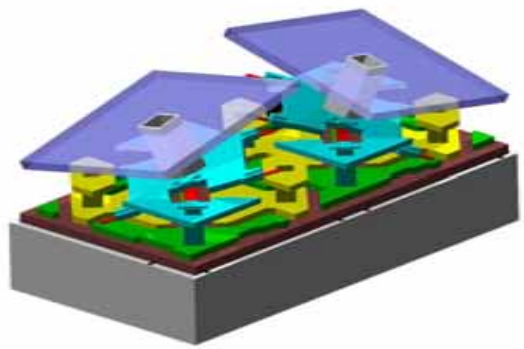


Source: P. Van Kessel, L. Hornbeck, R. Meier and M. Douglass, "A MEMS-based Projection Display," *IEEE Proceedings*, submitted for summer 1998 publication.

DMD hinge Characteristic V.S Voltage Required

- The voltages required to deflect a mirror depend on the architecture of the device and the materials used in its construction.
- The hinge physical parameters such as length, width, and thickness, as well as the hinge material, control the hinge compliance which determines how much force is required to deflect the mirror.

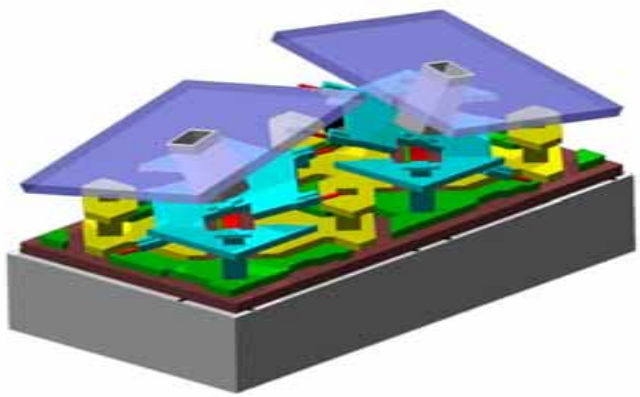
Source: 1.Source: Gale; RichardO,
"Optimized electronic
operation of digital
micromirror devices",
U.S.P No.544566, Aug22, 1995
2.http://www.ti.com/dlp



Mirror Dynamic Characteristic

- Often, the mirror tip is stuck to the landing electrode and will not reset on its own.
- A reset sequence is required to break the mirror free from the landing electrodes.
- The propose of the reset pulses is to store mechanical energy in the mirror in order to spring the mirror away from the landing electrodes.

Source: 1.Gale; Richard O, “Optimized electronic operation of digital micromirror devices”, U.S.P No.544566, Aug22, 1995
2.http://www.ti.com/dlp



Conclusion

- R&D has proceeded in three phases:

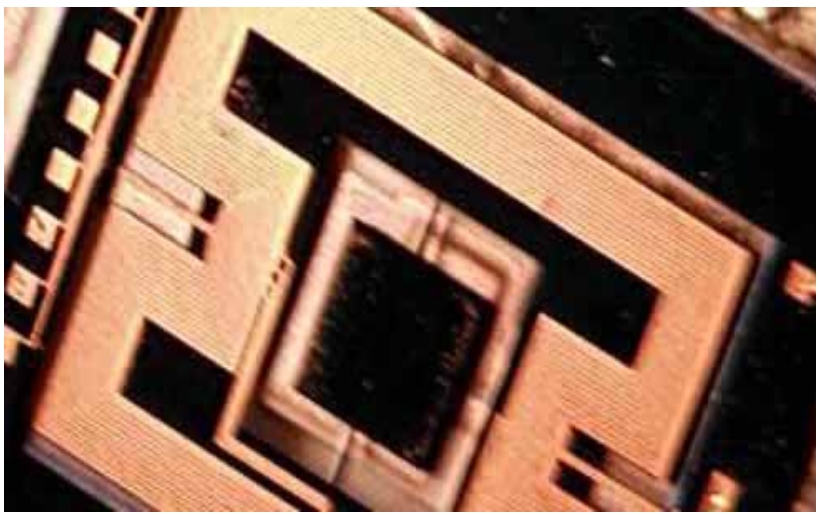
- Anti-adhesion & electronic drive improvement.
- Architectural improvements for better performance as well as basic reliability improvements.
- Lowering the cost & continually improving image quality.

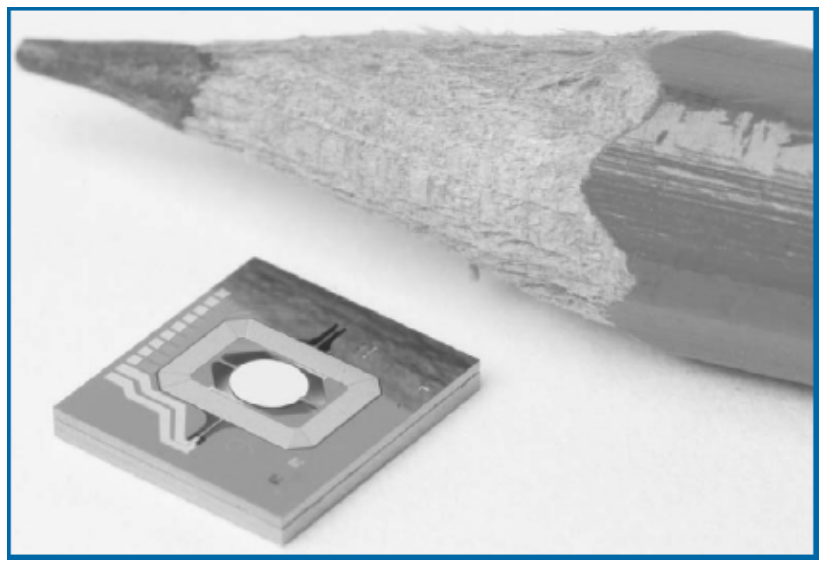
Microvision Display
- Scanning

Applications

Applications

Micro Display





1.5 x 1.6 mm MEMS-based scanner

Micro Display

MEMS-based scanner

Micro Display-Vedio

MEMS-based scanner

Press Release vs. Field Trial

Microvision Reports Third Quarter 2005 Revenue of $3.3 Million and Year to Date Revenue of $12.0 Million, up 27% and 62% (Microvision Only) over 2004

Automotive Repair: American Honda Motor Company Training Center, Torrance, CA.

Results: Average Productivity Gain = 38%

Heavy Truck Repair: Volvo Trucks North America's North American Institute, Greensboro, NC.
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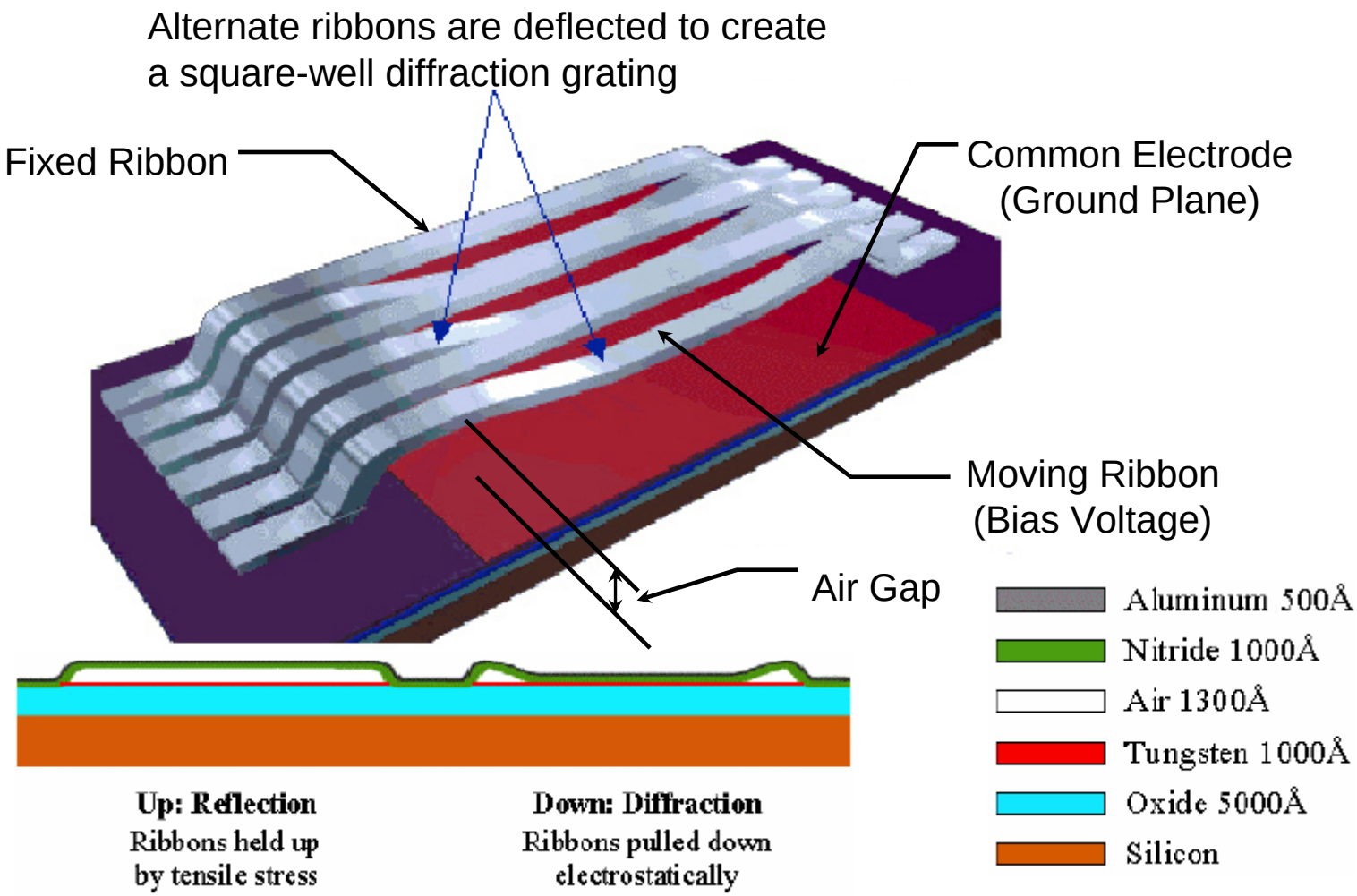
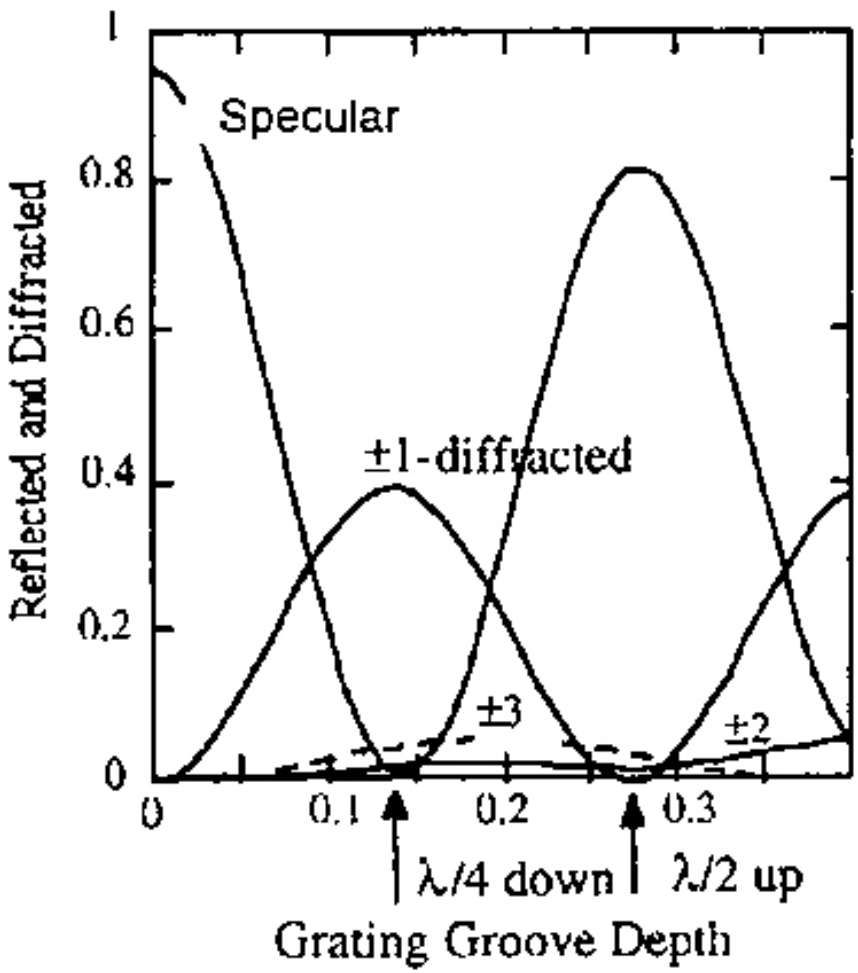
Grating Light Valve Display
- Diffraction

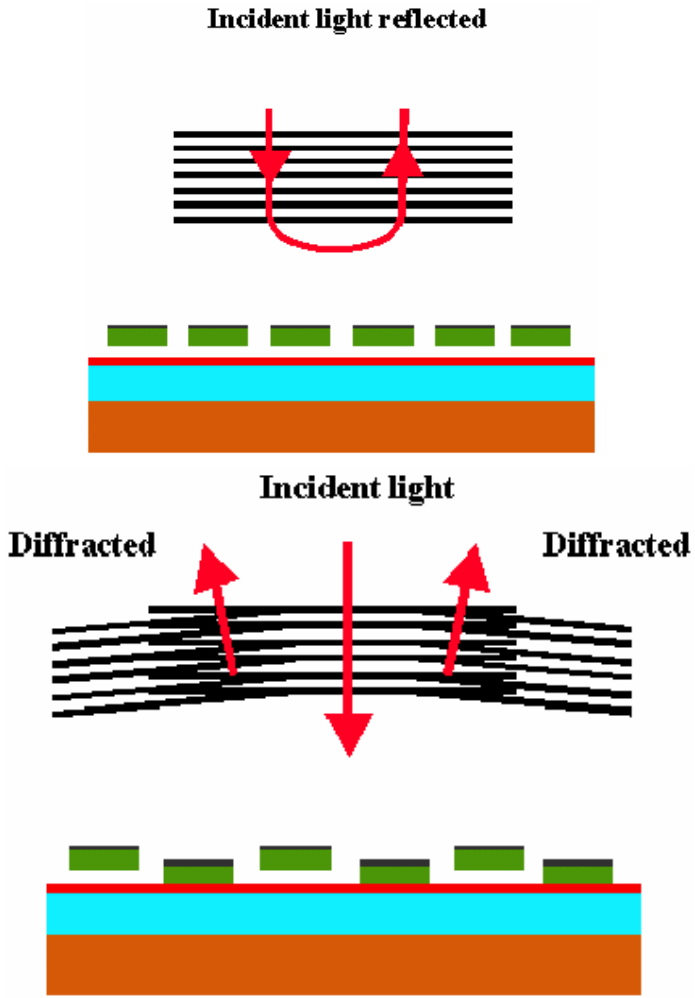
Grating Light Valve Configuration



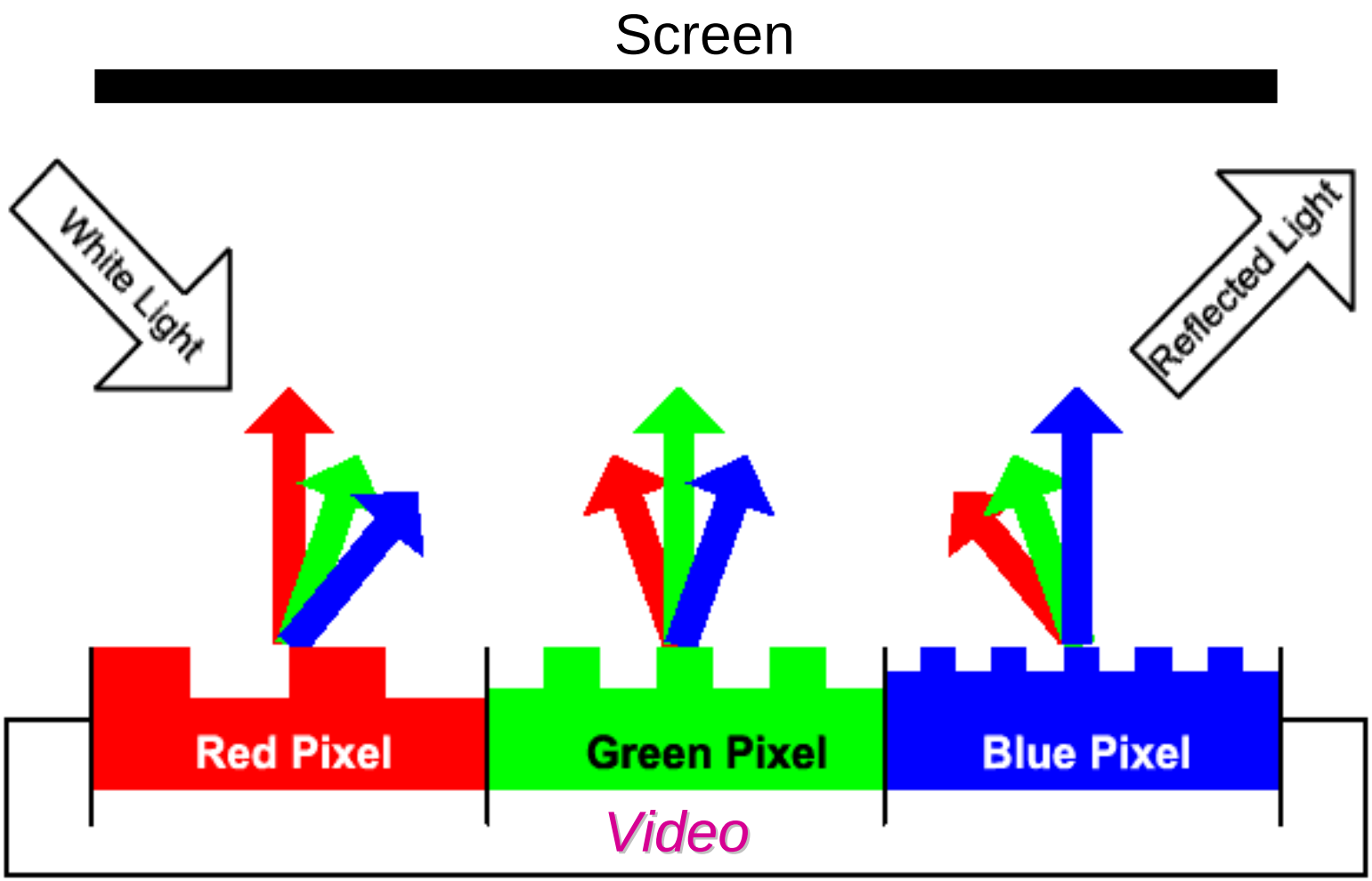
Source: www.siliconlight.com

Grating Light Valve Diffraction Efficiency



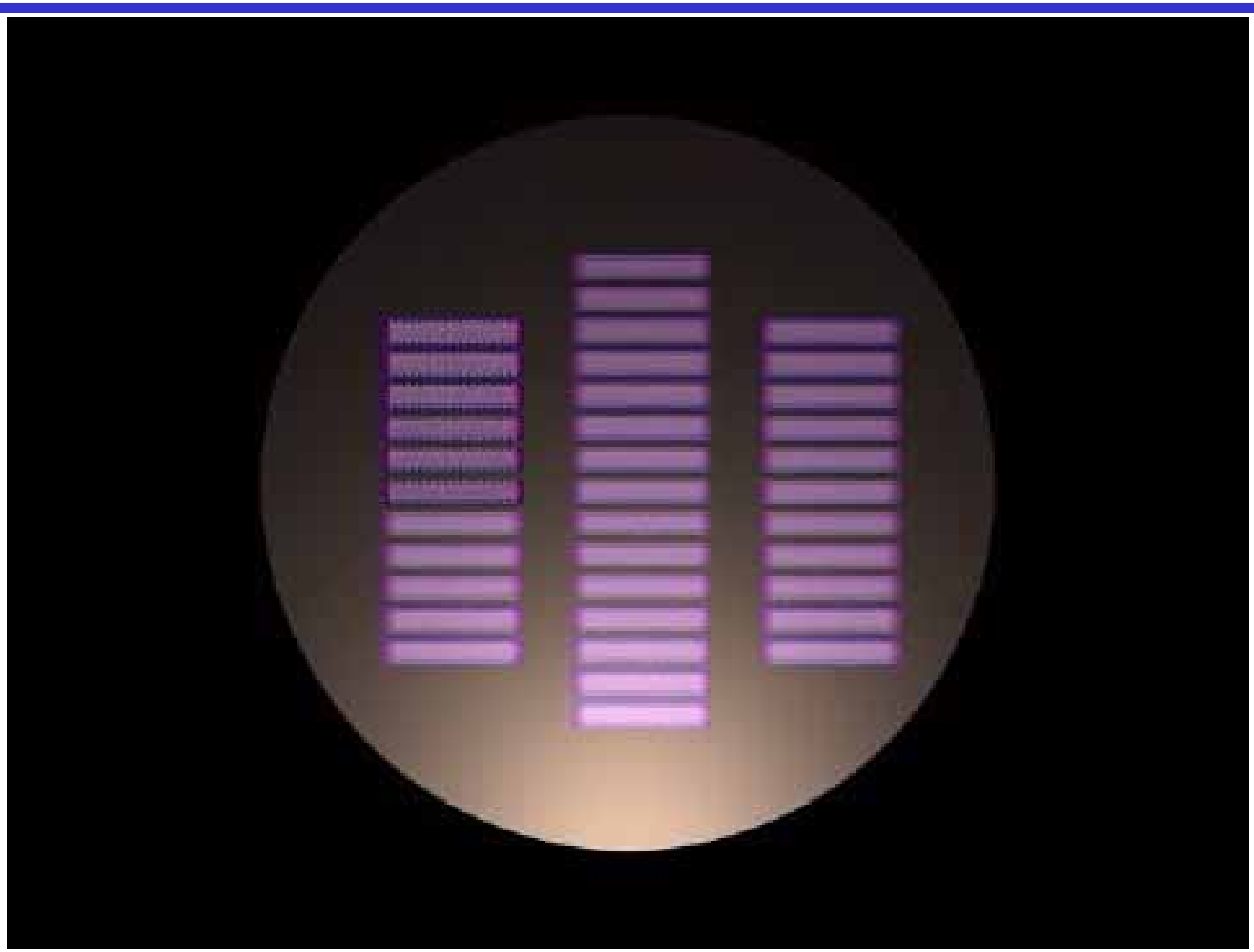


Grating Light Valve Scattering Principle



Source: www.siliconlight.com

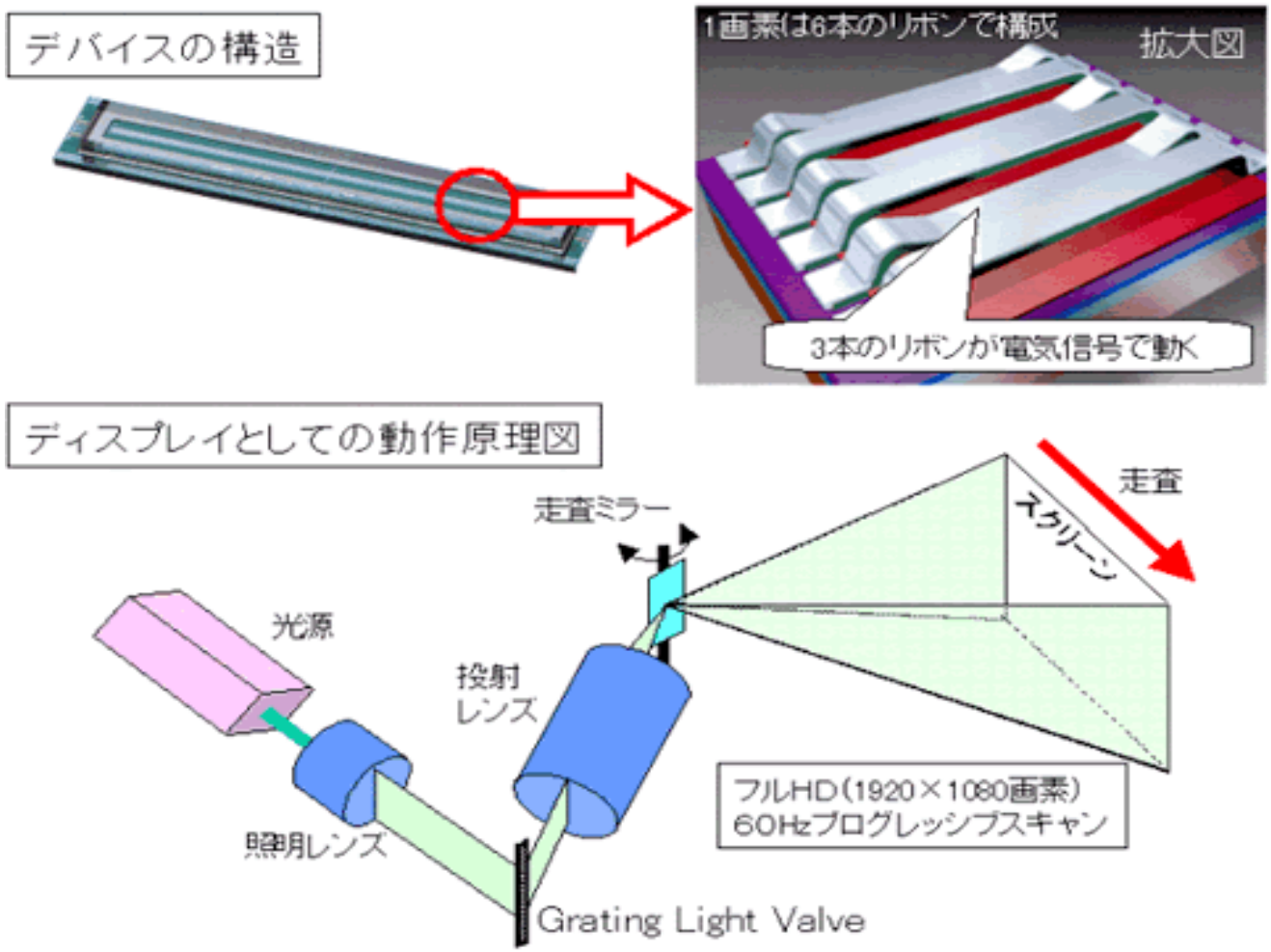
Grating Light Valve Scattering Principle



Source: www.siliconlight.com

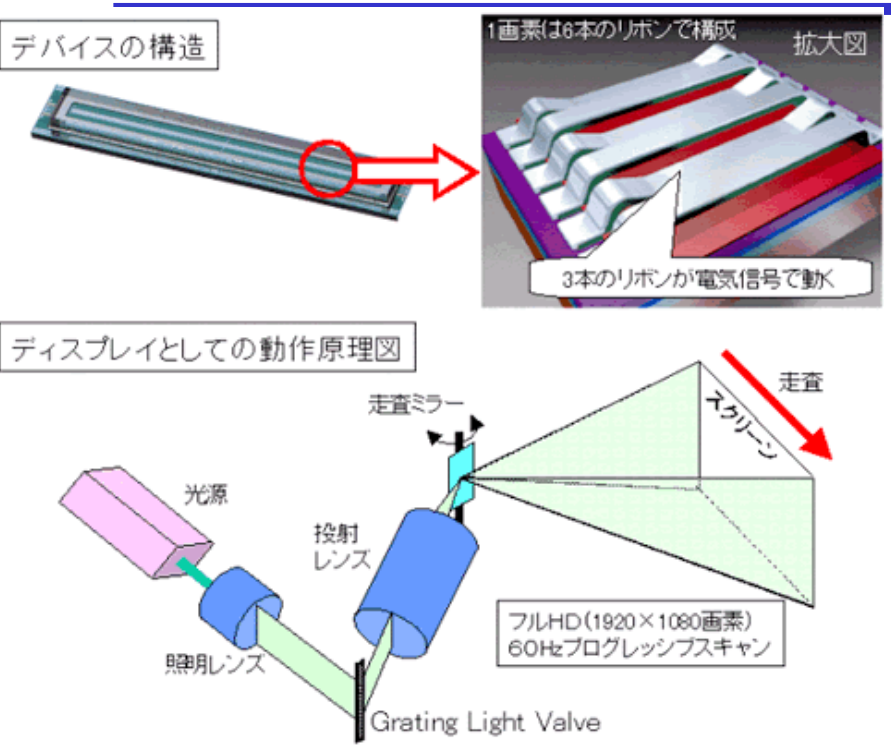
Video

The Scanned GLV Array Architecture



Source: www.siliconlight.com

The Scanned GLV Array Architecture



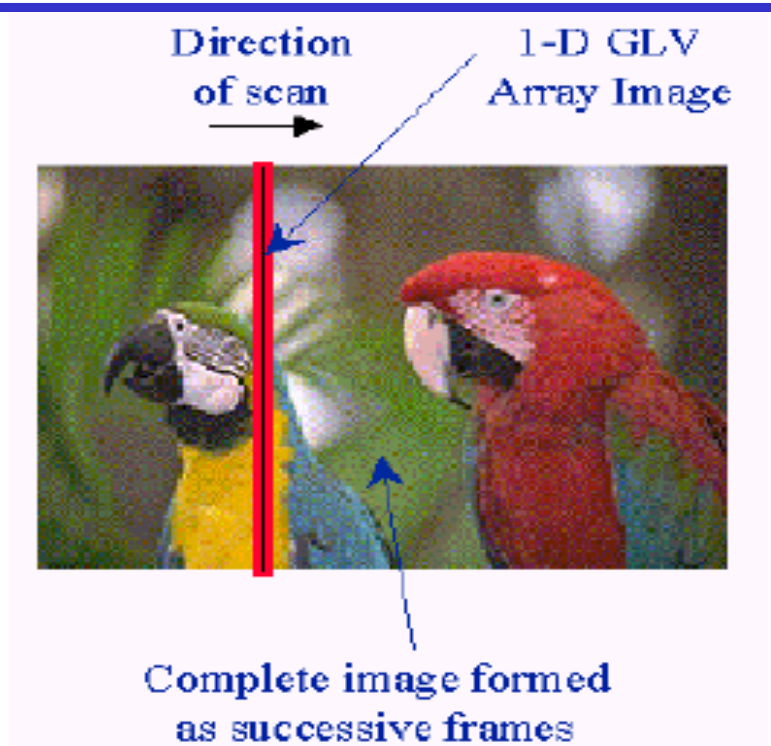
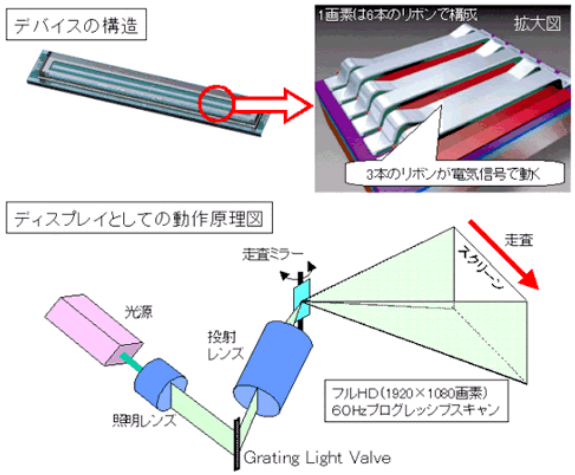


Diagram showing the scanned architecture of GLV technology: As the scan moves horizontally, the GLV pixels change to represent columns of video data, thereby forming one two-dimensional image per scan. The scanning rate is 60 frames per second.

Source: www.siliconlight.com

The Scanned GLV Array Architecture



Example of a projected image using GLV technology

Source: www.siliconlight.com

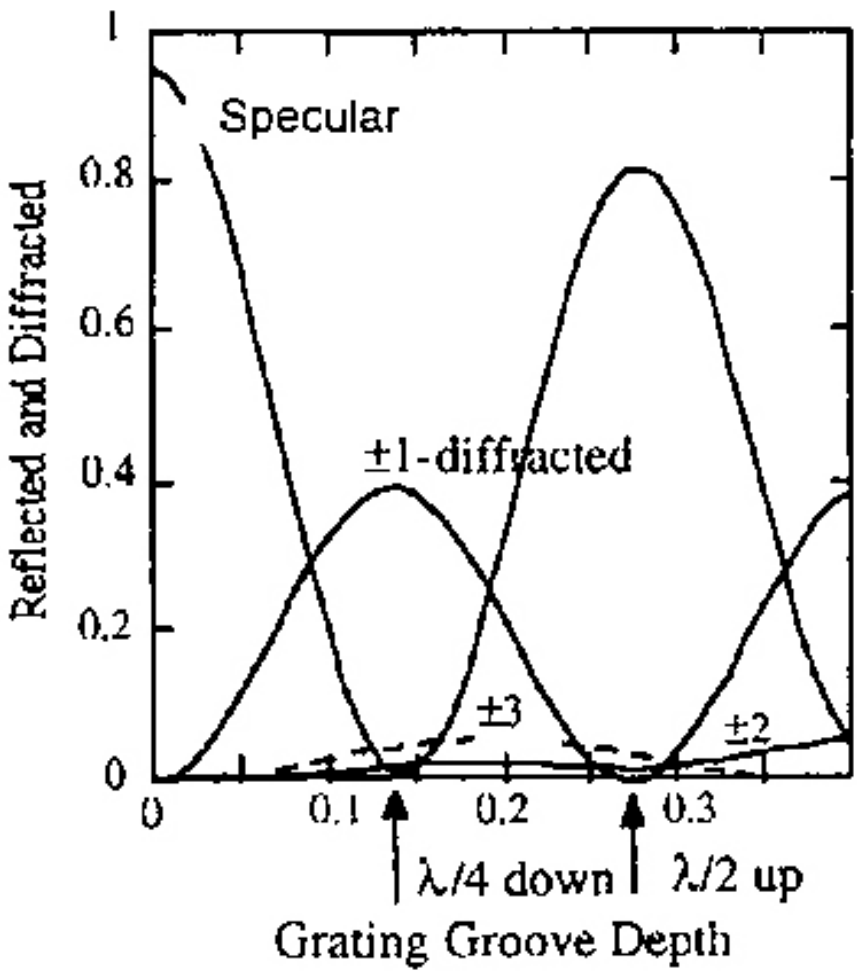
Display Performance DLP V.S GLV

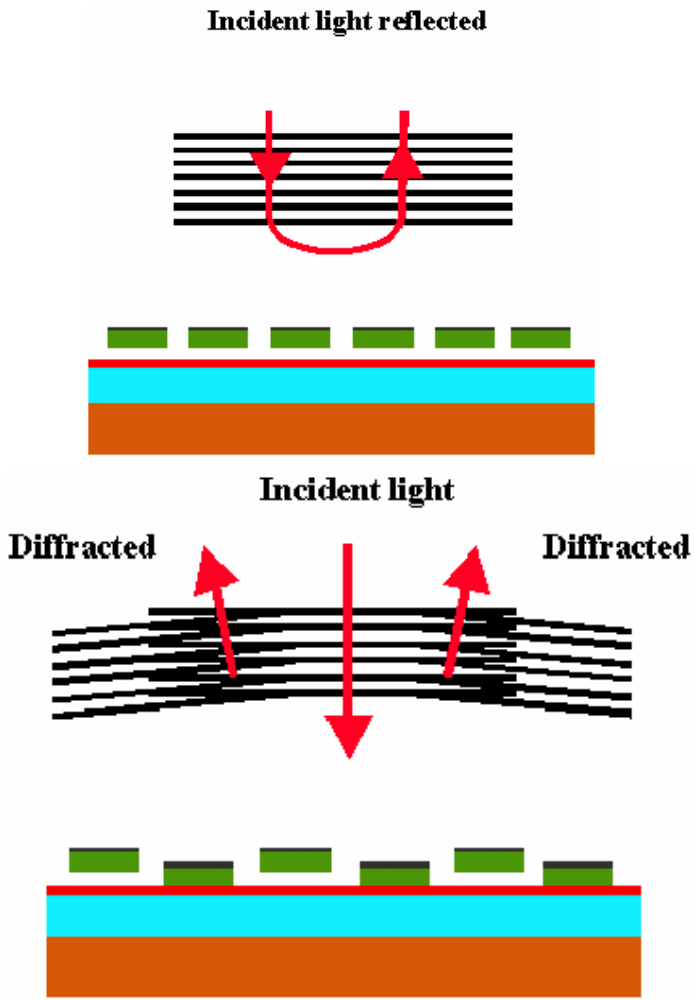
Single Chip DLP Projector		GLV
•Resolution	SVGA-XGA	SVGA-XGA ↑
•Brightness	Low	High
•Contrast	Poor	High
•Size	Small	Small
•Weight	Light	Light
•Assembly	Simple	Simple
•Price	High	Low
•Yield	Low	High
•Manufacturing	Complex	Simple

MEMS in Microdisplay

	DMD	GLV
•*Optics*	Reflection	Diffraction
•*Diffraction Efficiency*	X	41x2=82%
•*Color Filter*	Yes	No
•*Assembly*	Complex	Complex
•*Size*	Small	Small
•*Weight*	Light	Light
•*Manufacturing*	Complex	Simple
•*Price*	High	Low
•*Yield*	Low	High

Grating Light Valve Diffraction Efficiency





iMOD Display

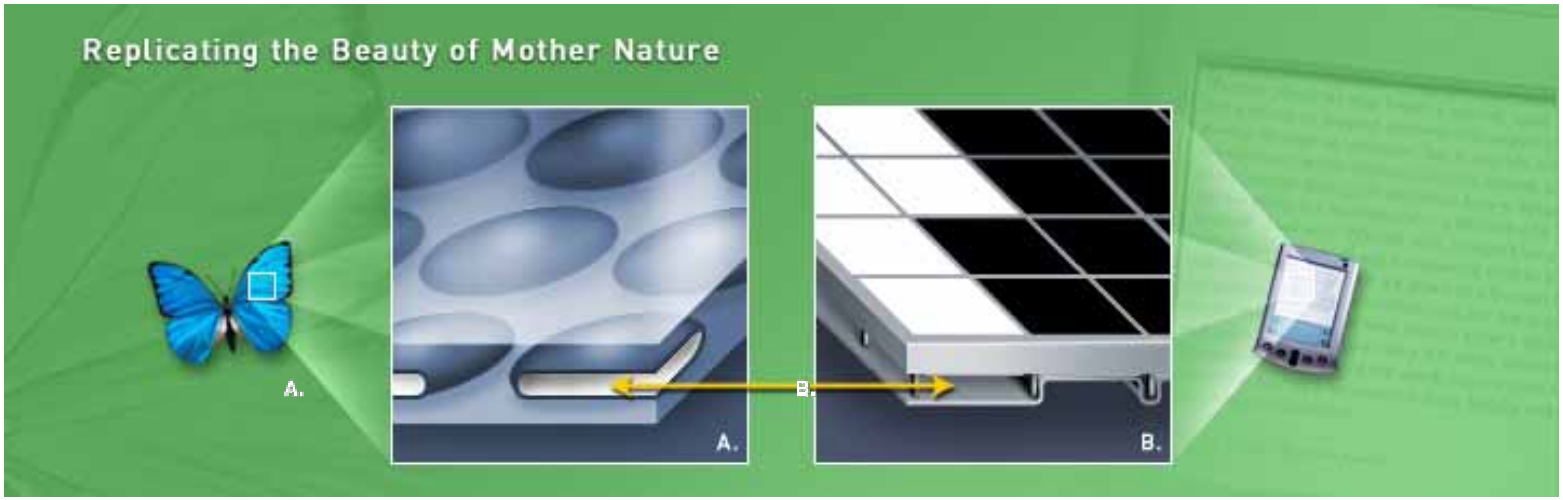
- Reflection & Interference

QUALCOMM to Acquire Display Technology Innovator Iridigm

- *Iridigm's Breakthrough iMoD Display Technology Delivers Significant Performance, Cost and Power Consumption Benefits* - SAN DIEGO - September 9, 2004 - QUALCOMM Incorporated (Nasdaq: QCOM), pioneer and world leader of Code Division Multiple Access (CDMA) digital wireless technology, today announced it has signed a definitive agreement to acquire Iridigm Display Corporation, a privately held display technology company, which will become a wholly owned subsidiary of QUALCOMM upon completion of the transaction. QUALCOMM will pay approximately $170 million in cash for the approximate 86 percent of Iridigm that it does not already own. Completion of the transaction is subject to regulatory approval and certain other closing conditions.

http://www.iridigm.com/tech_overview.htm

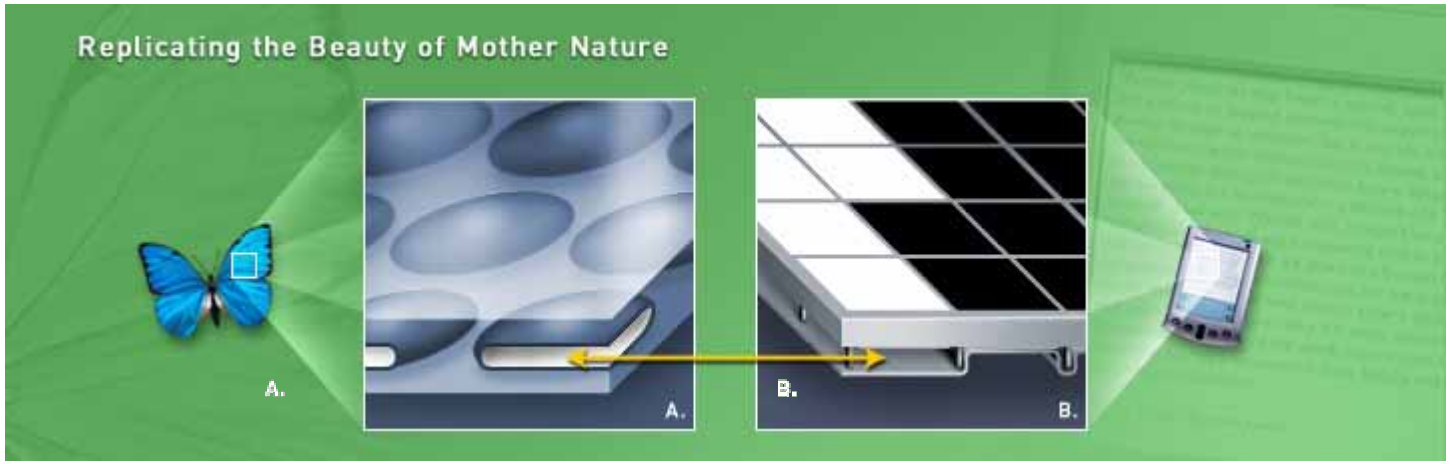
Concept from Butterflies



The power of Iridigm displays derives from the replication of some of Mother Nature's most beautiful creations: Butterflies. The iMoD element uses interference to create color in the same way that structural color works in nature. Microscopic structures on butterfly wings and peacock feathers cause light to interfere with itself, creating the shimmering iridescent colors that we see in these creatures

http://www.iridigm.com/tech_overview.htm

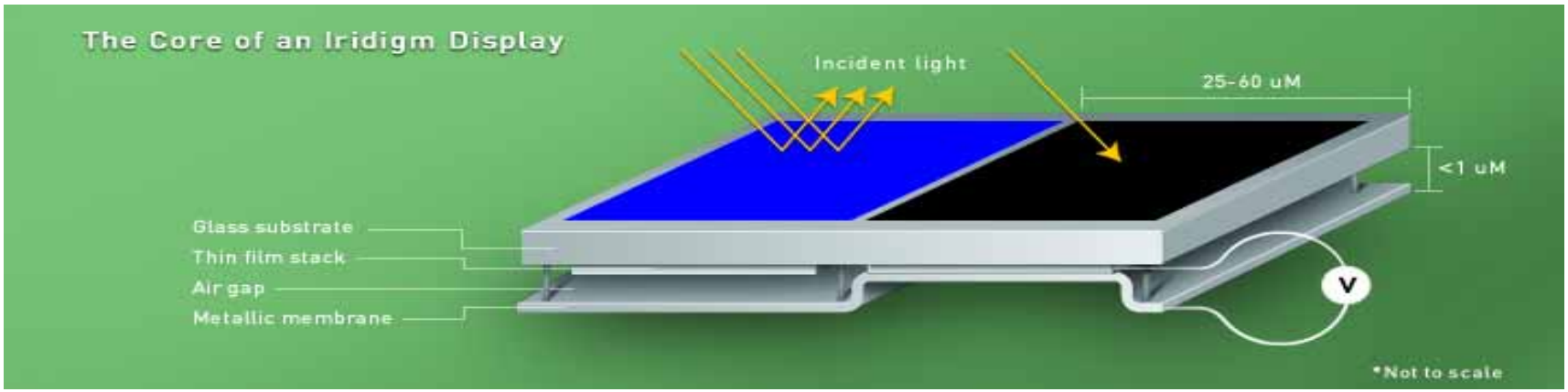
Interferometric Modulator (iMoD)



The iMoD elements in an Iridigm display work in the same way. Because interference is used to modulate the light, we call the device an Interferometric Modulator, or iMoD. **Since the iMoD contains no pigments, the color is inherently stable and cannot fade like inks or dyes when exposed to light.** At Iridigm, we are using natural iridescence to create a new paradigm for information display.

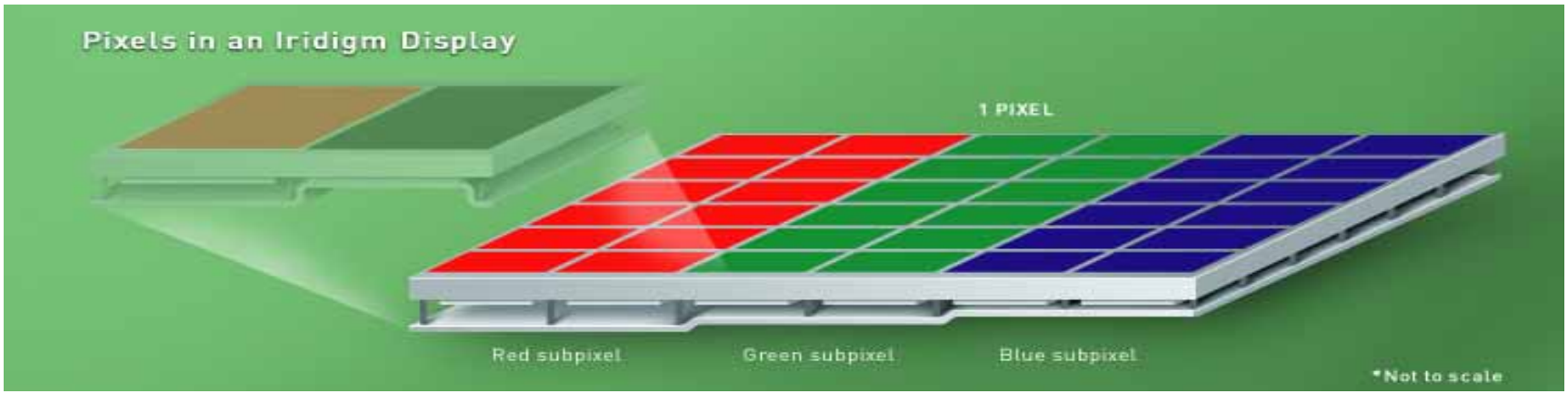
http://www.iridigm.com/tech_overview.htm

Device actuation with imaging on/off mechanism

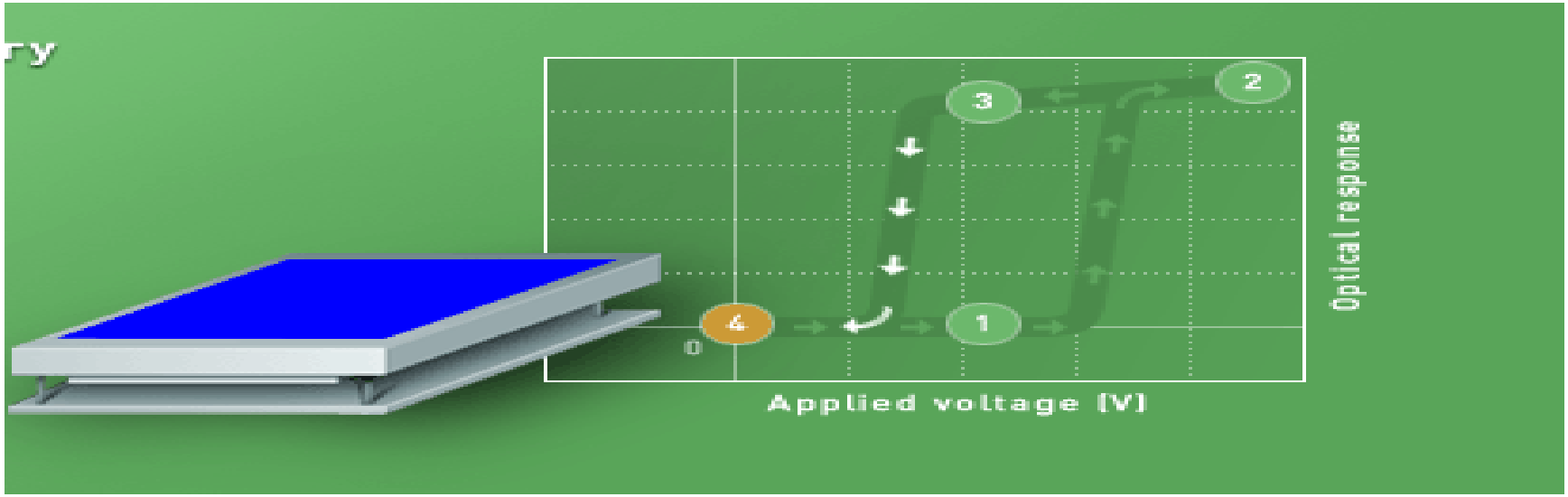


- iMoD element : a simple MEMS device (two conductive plates and air in between)
- One is a thin film stack on a glass substrate, the other is a metallic membrane suspended over it.
- The iMoD element has two stable states.
- No voltage: the plates are separated, and light hitting the substrate is reflected as shown above. When a small
- With voltage applied: the plates are pulled together by electrostatic attraction and the light is absorbed, turning the element black.

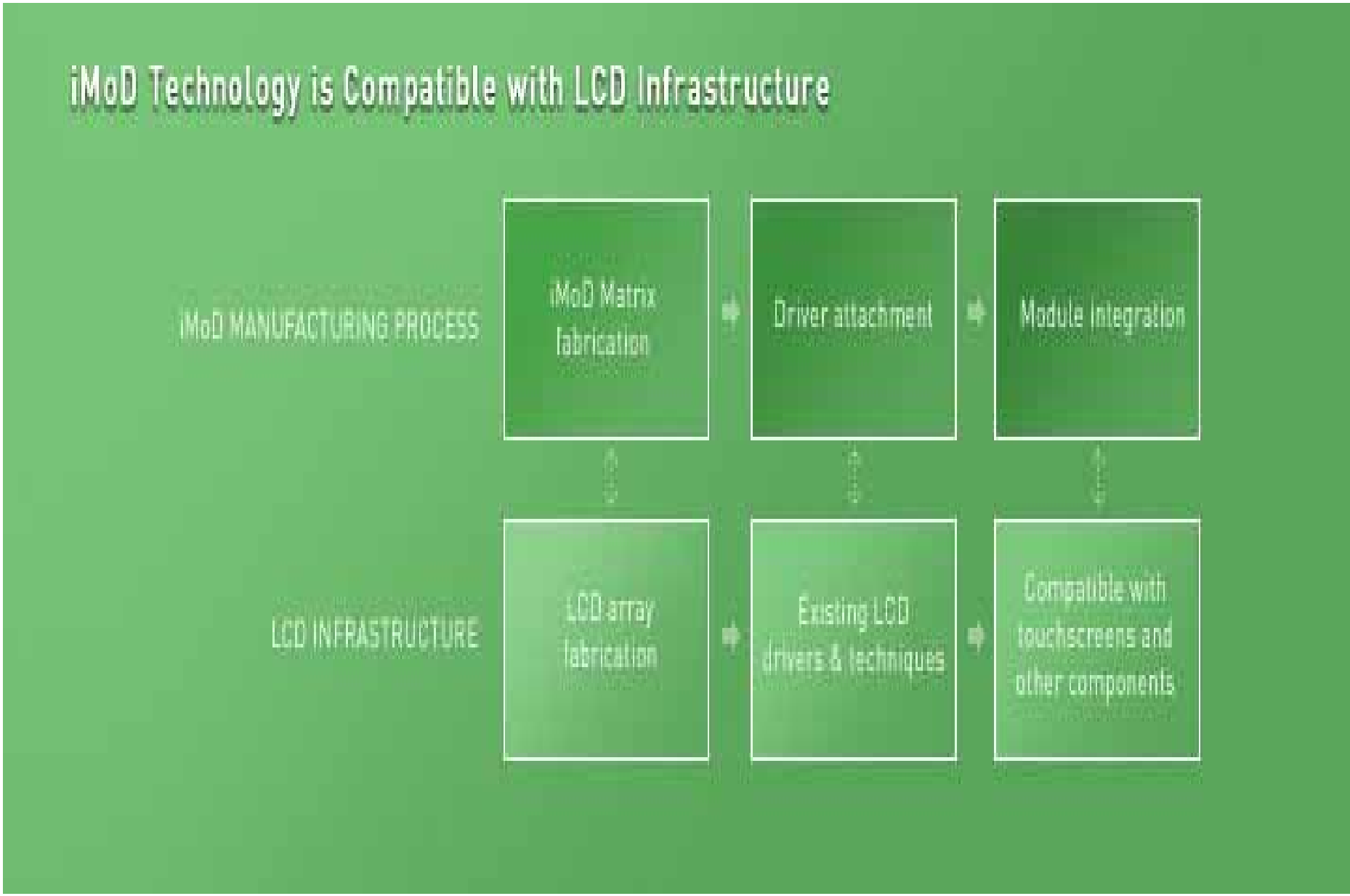
Pixel and color



- iMoD elements: 25-60 microns on a side (400-1,000 dots per inch).
- The color of the iMoD element is determined by the size of the gap between the plates.
- The blue iMoD has the smallest gap and the red has the largest.
- To create a flat panel display, a large array of iMoD elements are fabricated in the desired format (i.e. 5" full color VGA) and packaged. Finally, driver chips are attached at the edge to complete the display.



- Pixel memory is crucial to producing a high quality display. iMoD elements, which make up the iMoD pixels, possess electro-mechanical memory called hysteresis. The hysteresis effect shown in the diagram works somewhat like a pop-top on a bottle. Once the metallic membrane has been pulled down, it requires less energy to hold it than was exerted in pulling it down. This bi-stability not only allows the Iridigm display to replace the non-linearity of an active matrix device, it can also act as a real memory element.


iMoD Technology is Compatible with LCD Infrastructure
iMoD MANUFACTURING PROCESS
iMoD Matrix fabrication
Driver attachment
Module integration
LCD INFRASTRUCTURE
LCD array fabrication
Existing LCD drivers & techniques
Compatible with touchscreens and other components

DoCoMo Vision in 2010