

Ultra-miniature projector: *A high resolution, battery powered laser display*

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MOTOROLA

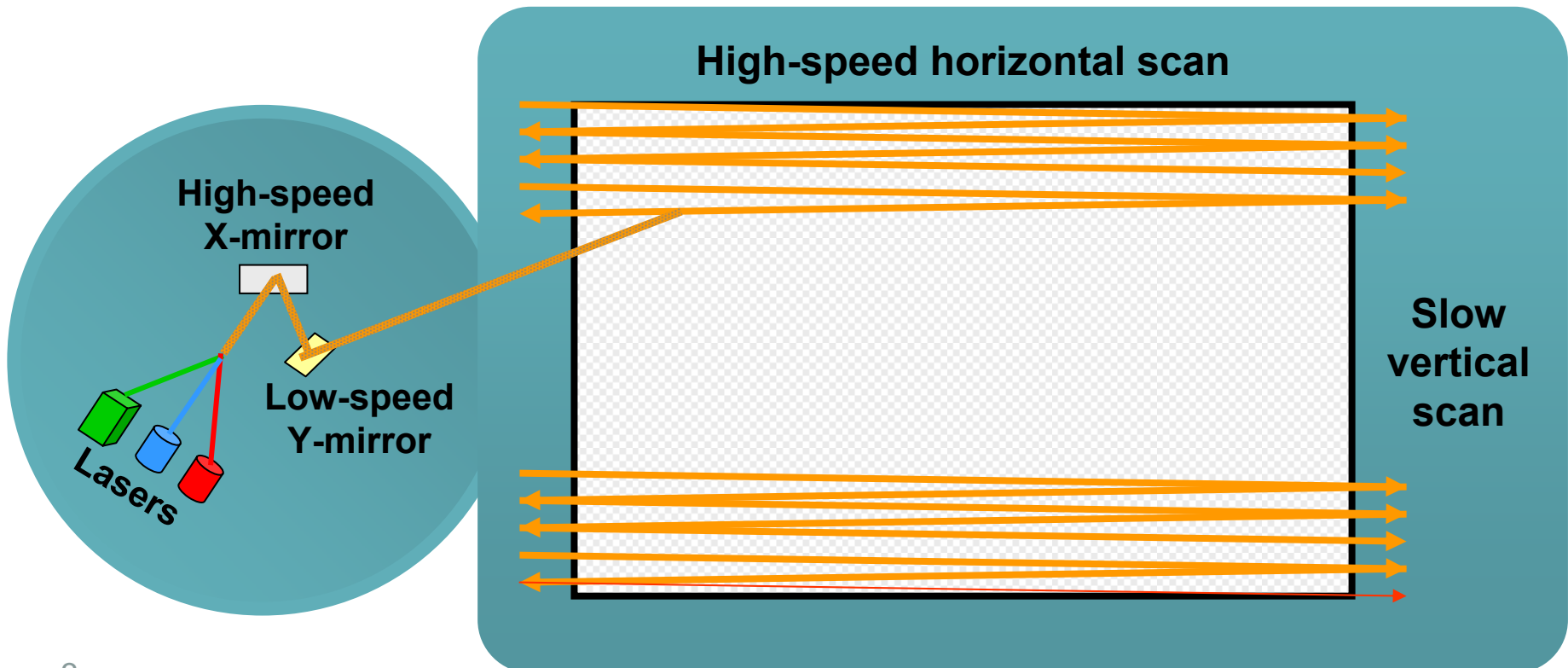
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- **Introduction**
- **Benefits of LPD**
- **LPD Technology**
- **Product Concepts**
- **Future Improvements**
- **Conclusion**



What is LPD?

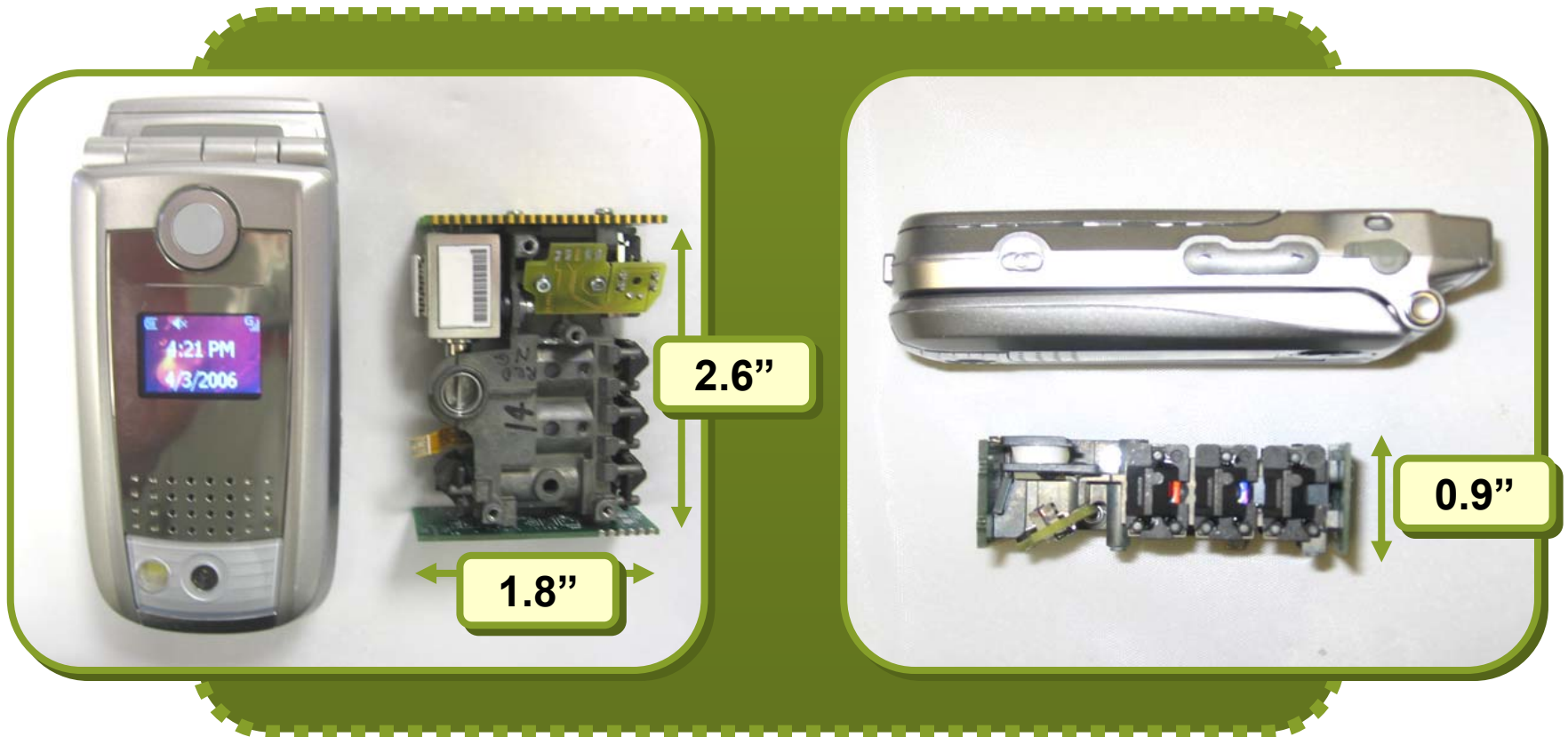
LPD is a projection display technology that uses 3 lasers coupled with scanning mirrors to produce full color, high resolution images



Advantages of Lasers vs. Other Light Sources

Lasers	Other Light Sources (e.g. LEDs, UHP lamps)
Diffraction limited Maximum brightness	Non-diffraction limited Low brightness
Emitted light can be efficiently concentrated into narrow beam	Emitted light cannot be efficiently concentrated into narrow beam
Simultaneously can achieve <ul style="list-style-type: none">▪ Small size▪ Low power consumption▪ Infinite depth of focus	Trades-off between following features <ul style="list-style-type: none">▪ Large collection optics▪ High power consumption▪ Limited depth of focus

- At a volume of 4.3 cubic inches, the LPD engine can be integrated into small mobile devices



LPD Benefits: Always in Focus

LPD images are always in focus at any distance...



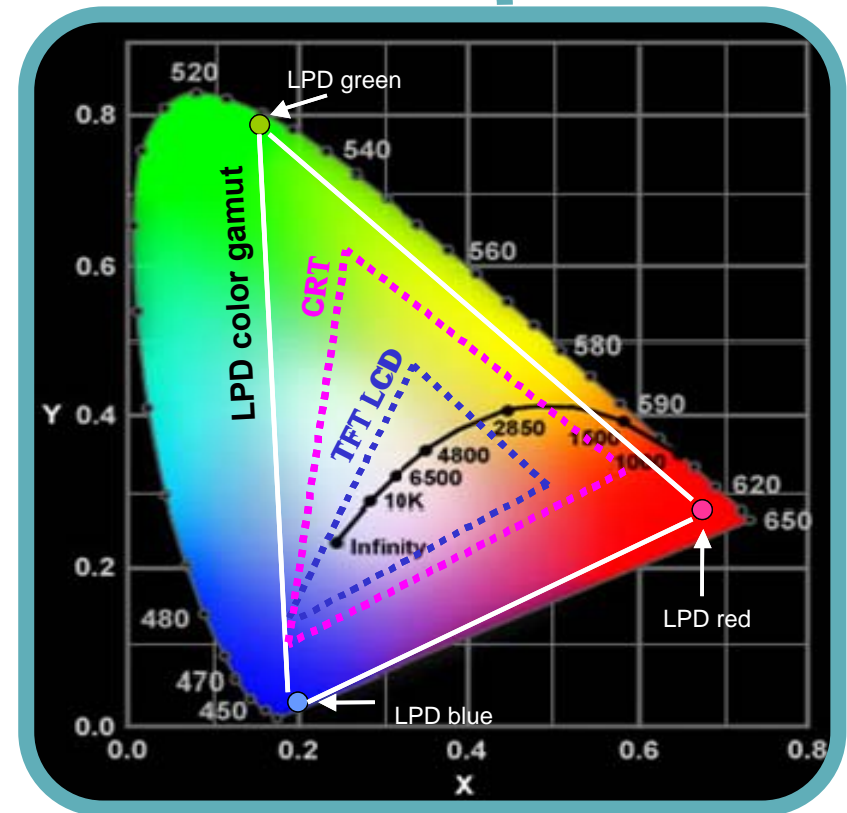
...even on curved screens or uneven surfaces



- **The average power consumption of the LPD engine is ~4 watts**
- **The light output of the LPD engine is 10 lumens**
- **In ambient lighting conditions, LPD produces a viewable image of:**
 - 8" diagonal image on any surface
 - 20" diagonal image with ambient light reducing screen
- **In a darkened room, LPD produces a viewable image of:**
 - 30" – 50" diagonal image on any surface

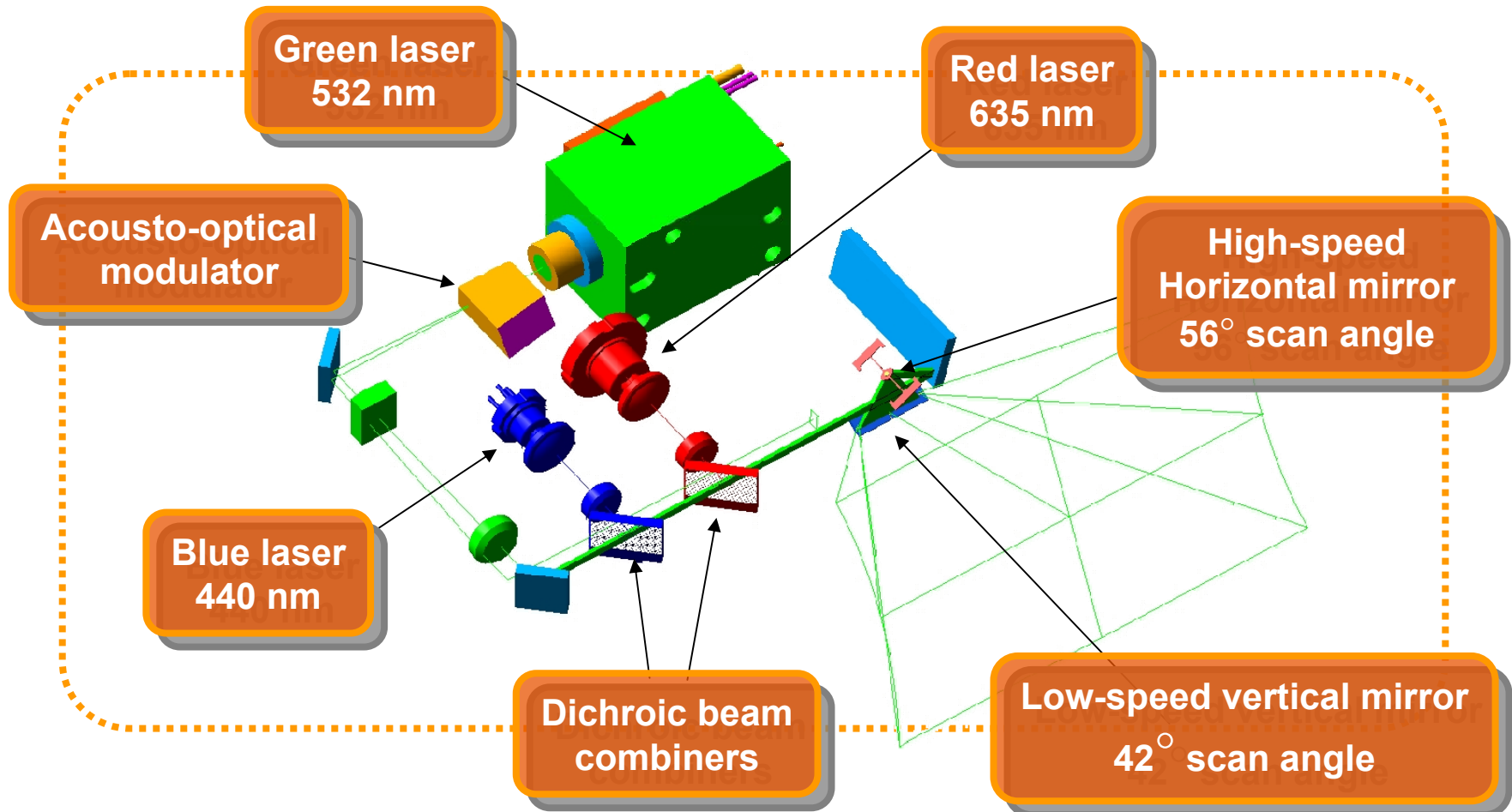
LPD Benefits: High Resolution and Unmatched Color Richness

- **XGA resolution text (1024 x 768 pixels) at any distance**
- **720p HDTV video (1280 x 720 pixels)**
- **Flexibility to display lower resolutions (e.g. VGA)**
- **Extremely wide color gamut**
 - Red = 635 nm
 - Green = 532 nm
 - Blue = 440 nm
- **16 million colors (8 bits per color)**



- **Rugged: withstands 1500 g shock**
- **Meets IEC Class 2 laser safety standards**
- **Video interface is compatible with common LCD interface**
 - **Meets VESA timing specifications**
- **USB 1.1, UART and I²C control interfaces**
- **0° – 40°C temperature range**

Symbol's holistic system design approach resulted in a high-performance, manufacturable product



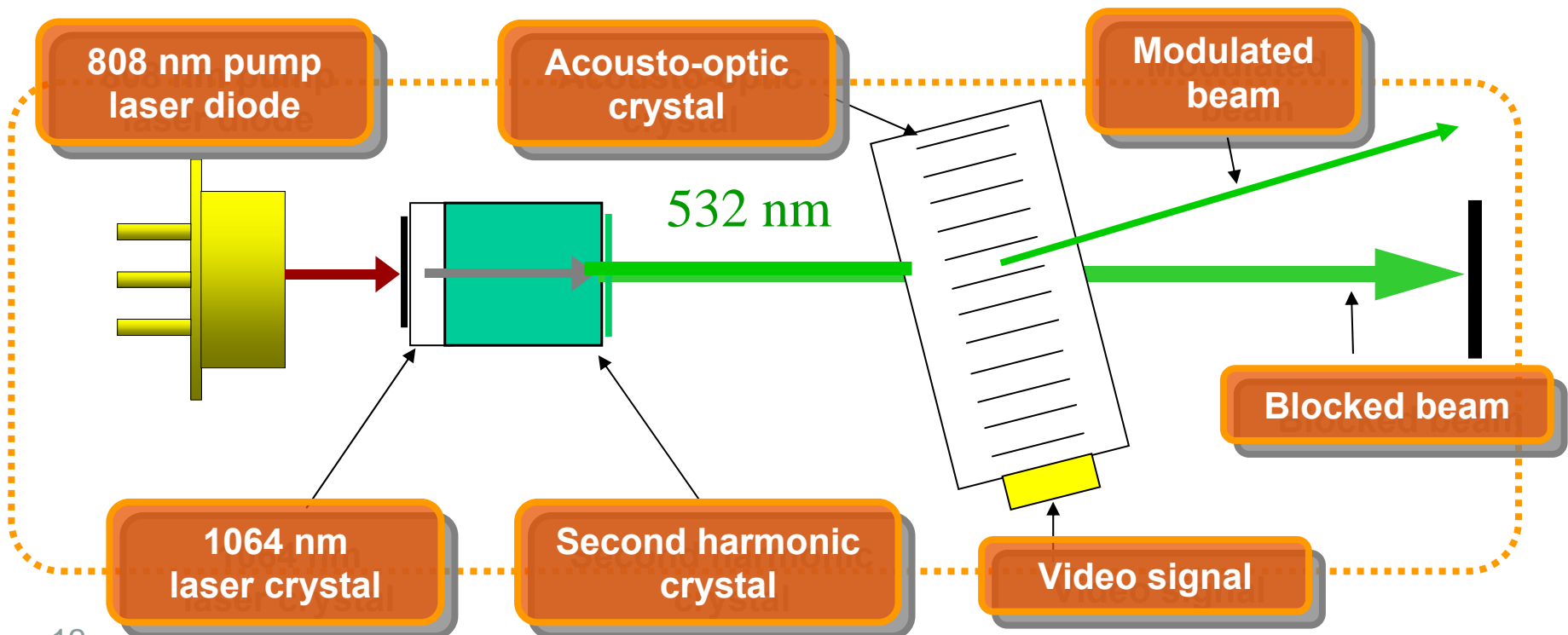
Semiconductor laser diodes

- Directly modulated
- Low power consumption
- Low heat output
- Compact size



LPD Technology: Green Laser System

- Diode pumped solid state (DPSS) infrared laser (1064 nm)
- Frequency doubled to obtain 532 nm green light
- External acousto-optic crystal is needed for high-speed modulation
- High power consumption



1. Scan angle

- Larger scan angle accommodates higher resolution

2. Mirror size

- Larger mirror accommodates larger beam in the scanner
- In turn, larger beam can be focused into smaller spot at the image plane due to diffraction

3. Horizontal mirror speed

- $60 \text{ frames/sec} \times 768 \text{ lines/frame} \times \frac{1}{2} \text{ cycle/line} = 23,000 \text{ cycles/sec}$

4. Modulation speed of lasers

- $1,024 \text{ pixels/line} \times 2 \text{ lines/cycle} \times 23,000 \text{ cycles/sec} = 47 \text{ MHz}$

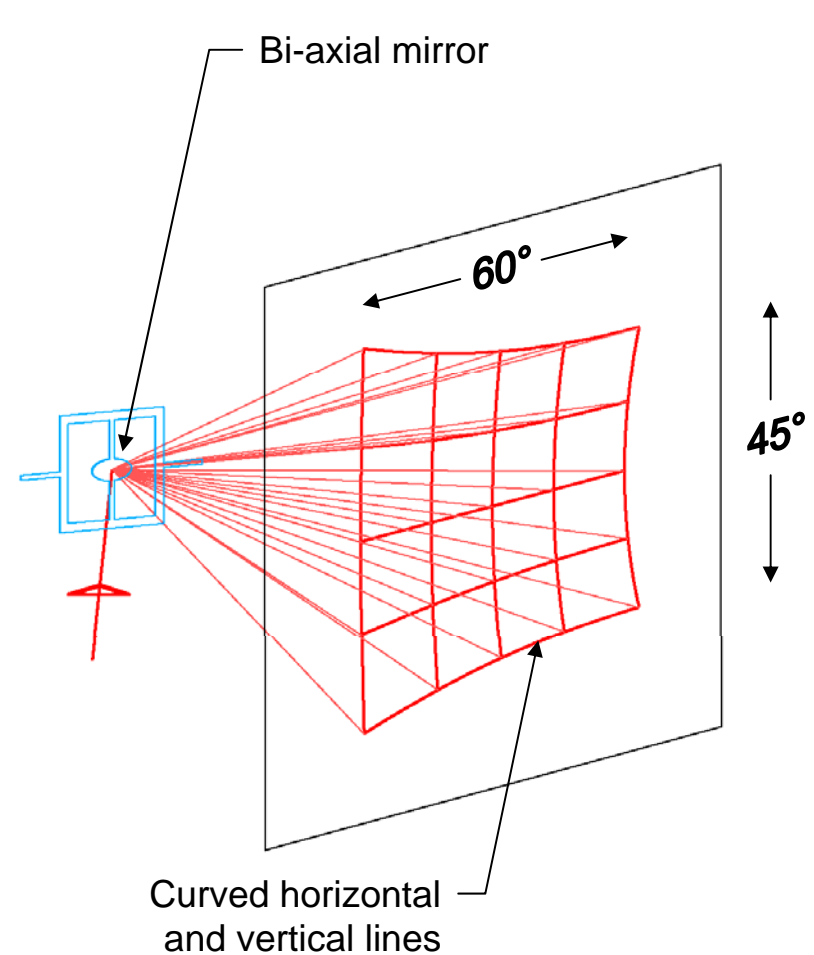
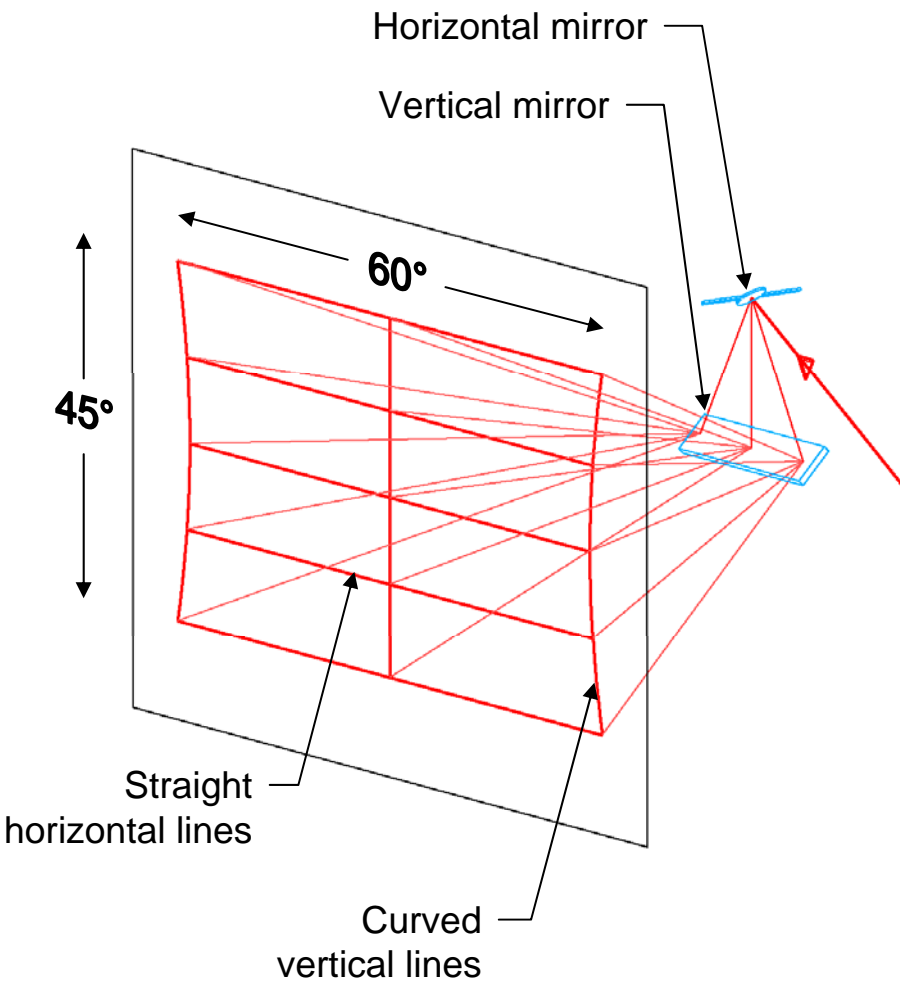
High-speed horizontal mirror

- MEMS device
- Piezo-electric drive
- Magnetic feedback
- Low power consumption
- $\lambda/10$ flatness

Low-speed vertical mirror

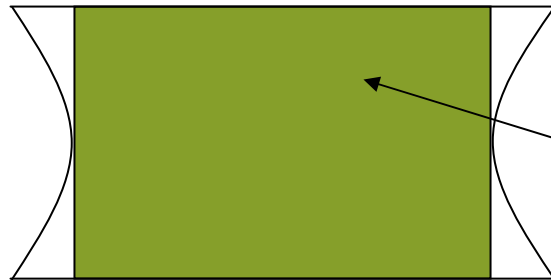
- Magnetic drive and feedback
- Low power consumption
- $\lambda/10$ flatness

Two scan mirrors vs. one bi-axial mirror



In LPD, the two 1-axes mirrors are arranged so that the horizontal axis is straight

The vertical pincushion effect is corrected by using a smaller part of the display area



- Usable display area
- Displays full XGA resolution image

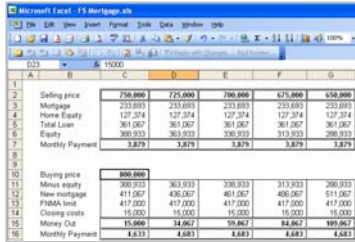
- **Note that there is not a linear correspondence between clock time and pixels in the horizontal direction.**
- **Beam velocity is sinusoidal since mirror is scanning at resonance**
- **Laser is turned on longer near end of scan to maintain uniform pixel size**
- **Laser intensity is reduced in proportion to maintain uniform brightness**

- **Laptop / PDA**
- **Cellphone**
- **Micro projector**
- **MP4 player / TV**
- **Games / Toys**
- **Automotive**
- **Signage**
- **Many possibilities**



LPD Product Concepts

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	A	B	C	D	E	F	G
1							
2	Selling price	750,000	725,000	700,000	675,000	650,000	
3	Mortgage	233,093	233,093	233,093	233,093	233,093	
4	Home Equity	127,914	127,914	127,914	127,914	127,914	
5	Total Loan	361,067	361,067	361,067	361,067	361,067	
6	Equity	388,933	388,933	388,933	388,933	388,933	
7	Monthly Payment	3,879	3,879	3,879	3,879	3,879	
8							
9							
10	Buying price	800,000					
11	Move equity	388,933	388,933	388,933	388,933	388,933	
12	New mortgage	411,067	411,067	411,067	411,067	411,067	
13	PMMA local	417,000	417,000	417,000	417,000	417,000	
14	Closing costs	15,000	15,000	15,000	15,000	15,000	
15	Money Out	15,000	34,067	59,067	84,067	109,067	
16	Monthly Payment	4,833	4,833	4,833	4,833	4,833	



PDA's

- PowerPoint
- Spreadsheets
- Full motion video



Cell Phones

- Streaming video
- High res photos
- Live sports



Video iPods

- Full length movies
- Live TV
- Home videos



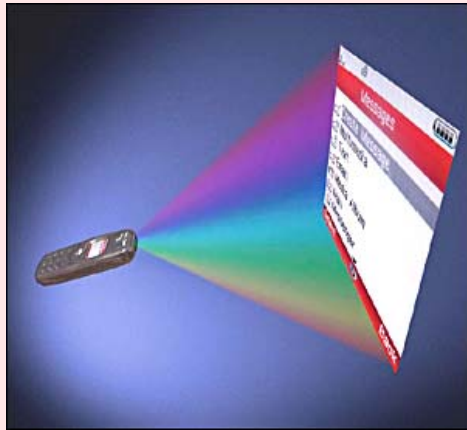
Gaming Devices

- Full screen action
- High resolution
- Panoramic images

Project Images from a Device Anywhere, Anytime!

LPD Applications are Endless

Cell Phone Projector



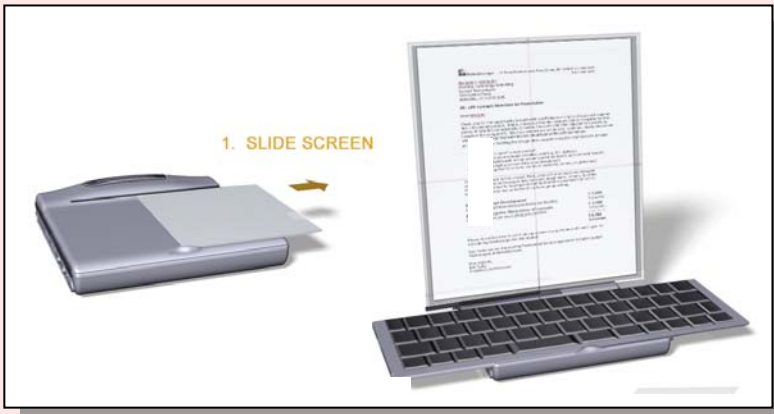
Peripheral Micro Projector



Automotive Dashboard



Folding Micro Laptop



Cylindrical Signage



PDA Docking Station



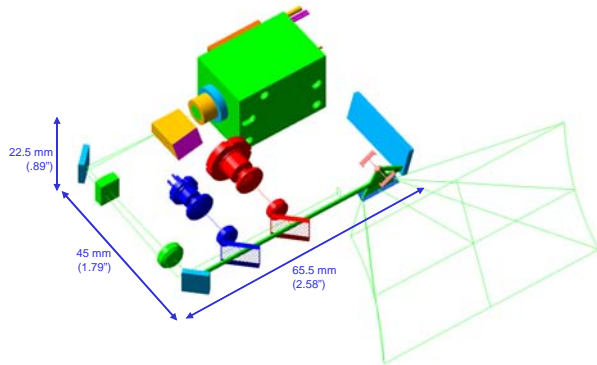
Improvement	Requirements
Further Miniaturization	<ul style="list-style-type: none">▪ Directly modulated green laser
Reduced Power Consumption	<ul style="list-style-type: none">▪ More efficient green laser (w/o temp. control)
Increased Brightness	<ul style="list-style-type: none">▪ Higher power lasers▪ Maintain IEC Class 2 laser safety
Increased Resolution	<ul style="list-style-type: none">▪ Improved scan mirrors



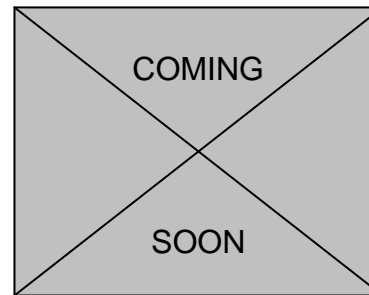
Future LPD Roadmap



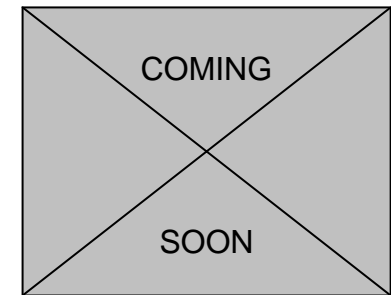
Gen 1 LPD



Gen 2 LPD



Gen 3 LPD



Specs

- 10 lumens
- 4.3 cubic inches
- 5 watts
- XGA

- 15 lumens
- <1.0 cubic inch
- 2.5 watts
- XGA or better

- 20 lumens
- 0.5 cubic inch
- 1.0 watt
- XGA or better

Product Enablement

Peripherals

- Micro projector
- Panoramic display
- PDA docking station

Integrated

- PDA
- Camcorder
- Laptop

Ubiquitous

- PDA
- Cell phone
- Laptop
- Video iPod
- Gameboy
- Automotive
- Camcorder
- DVD player

Conclusion

- LPD is a highly innovative technology with exciting market potential
- LPD has many advantages over competing technologies in mobile applications
- Symbol's holistic system design approach resulted in a high-performance, low-cost, manufacturable product

