LCoS Microdisplay Strategy

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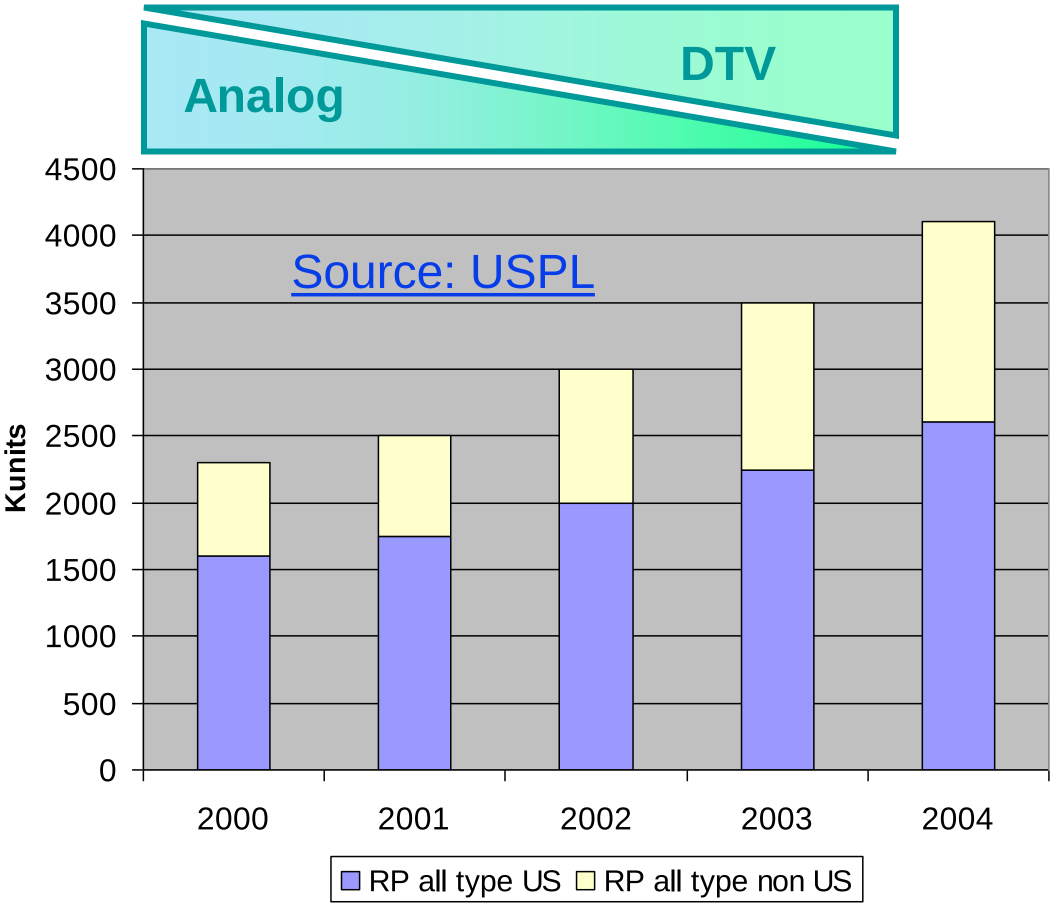
Microdisplay Strategy TV Video Market

- **Fundamental questions:**
  - **Can LCoS microdisplays compete in the future? (Performance - probably OK (some +, some -); Cost Evolution will be the key issue; Assumes quality/yield issues are soluble)**
  - **Who and what will be the competition? (DMD, 3x p-Si, other LCoS (Philips,JVC,?))**
  - **Who will be the customer base and what are their requirements?**
  - **What actions does Company X need to take to be successful?**

RP TV Market

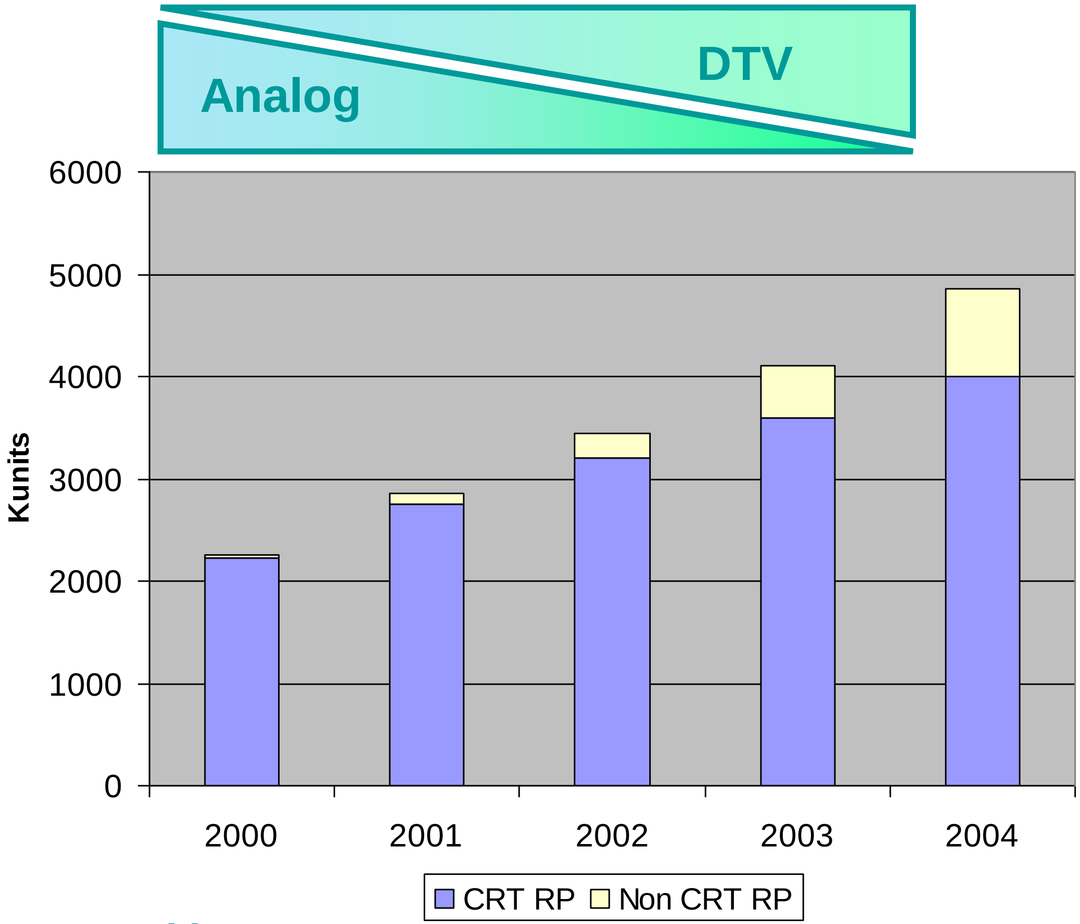
- RP TV is a healthy market
  - USPL: 4100 k in 2004
  - Stanford: 4100 k in 2006
- Non US countries in 2004
  - China 58%
  - Europe 13%
  - Rest of the world 29%



RP TV Market

- Source
  - Combination of
    - Adjusted CPL Forecast
    - Display Search
    - Stanford Resources
    - Semiconductor Industry Association (SIA)
    - SEMI
    - Dataquest
    - SEMATECH
- Non CRT RP in 2004:
  - 17% according to analysis above
  - FPD 2001. Optimistic: 50%
  - FPD 2001. Pessimistic: 5%

(Unfortunately not pessimistic enough)



Microdisplay Evolution

Projected microdisplay shipments and wafer consumption					
Segment	**2000**	**2001**	**2002**	**2003**	**2004**
		Microdisplay units (000)			
Front projection	1818	2180	2600	3086	3665
Rear projection	47	316	1926	6538	13,277
Embedded	9016	12,228	19,498	32,998	47,137
Headsets	727	1636	5316	9425	14,888
Total	**11,608**	**16,361**	**29,339**	**52,047**	**78,968**
Total wafers/month	**5915**	**8090**	**14,597**	**28,888**	**48,219**

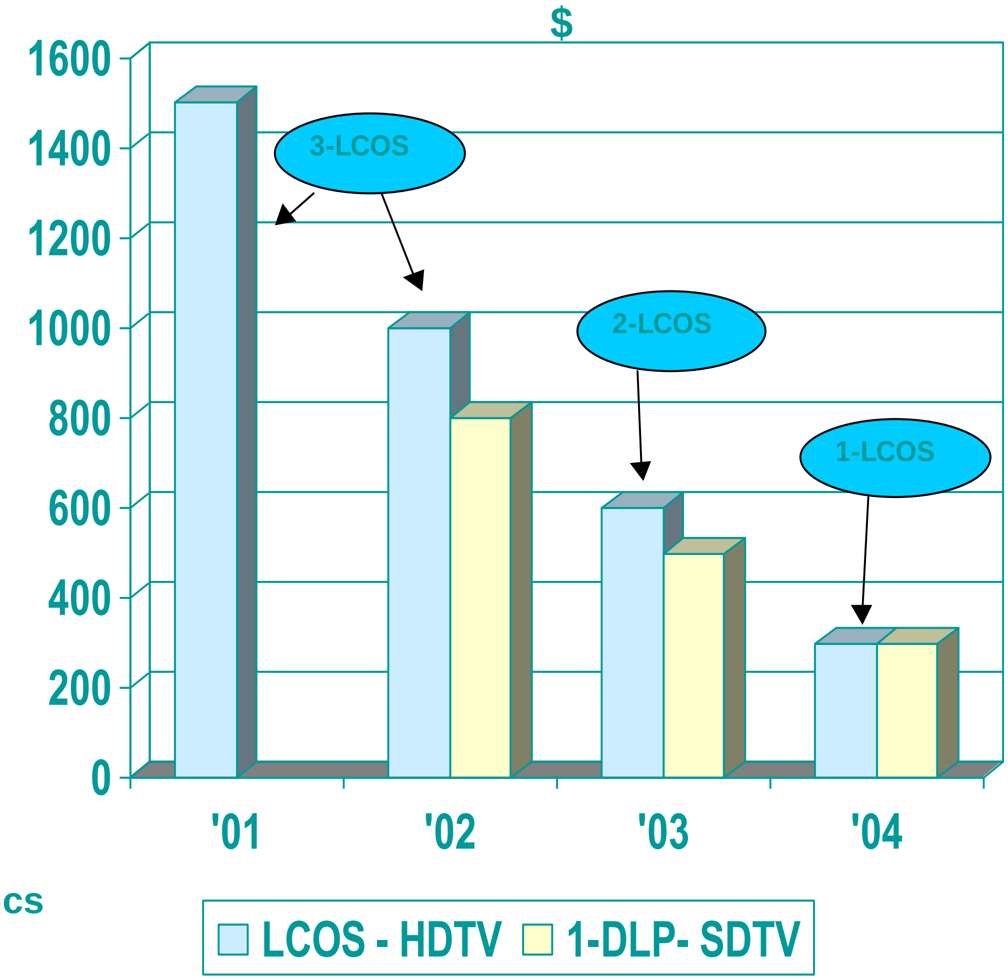
Source: MOG Consulting (www.mogweb.com)

13 Million microdisplays for RP application in 2004 => 4.5 million RP =>100% of the market **(see prior slide RP TV Market)**

Difficult to believe complete replacement of CRT based RP systems in this timeframe

Optical Engine Cost Evolution

- 3-LCOS OE
  - Complex Optics(tolerance issues make for difficult manufacturing)
  - Difficult to fine tune
  - LCOS +chip set
    - $450 in 2001
    - $300 in 2002
  - Good brightness potential
- Fewer imagers to reduce cost
  - Sequential color optics (DLP like)
  - 1st step: 2- LCOS
    Demonstrated by ColorLink
  - 2nd step: 1-LCOS
    Demonstrated by Philips
    BUT with large size imager (1.15")
  - Challenges
    - LC speed to be increased
    - To keep acceptable brightness and contrast vs 3-LCOS
  - Advantages
    - More compact and cheaper optics
    - Usable with front projection systems
    - Higher resolution than DLP solution and vs. p-Si at same imager cost

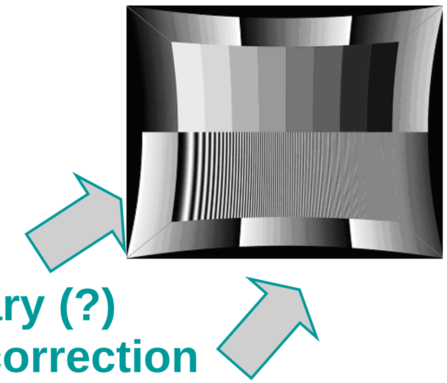


How to Achieve Cost Reduction

- **Optical Engine Architecture**
  - **3-LCOS =>**
    - **4 PBS cubes (Polarizing Beam Splitter)**
    - **3 LCOS: different LC material for R,G&B to optimize performance for each wavelength**
  - **2-LCOS =>**
    - **Only 1 PBS**
    - **Projection lens easier to design**
    - **1 LCOS for B/G; one for R (as Philips lamp delivers less Red), ? Wrt current status of TMM type engine (blue limiting??)**
    - **B/G LCOS sequentially addressed => 2x faster LC material & electronics needed ?**
    - **B/G LCOS has to manage a light spectrum covering blue & green wavelengths**
  - **1-LCOS**
    - **Same optical architecture than 2-LCOS + 1 color wheel**
    - **R/G/B LCOS sequentially addressed => 3x faster LC material & electronics needed ?**
    - **As only 1 LCOS is used, its spectral bandwidth has to cover Red, Green and Blue wavelength (some thruput/contrast loss)**
    - **1-LCOS solution is a challenge. Is Intermediary step with 2-LCOS necessary?**

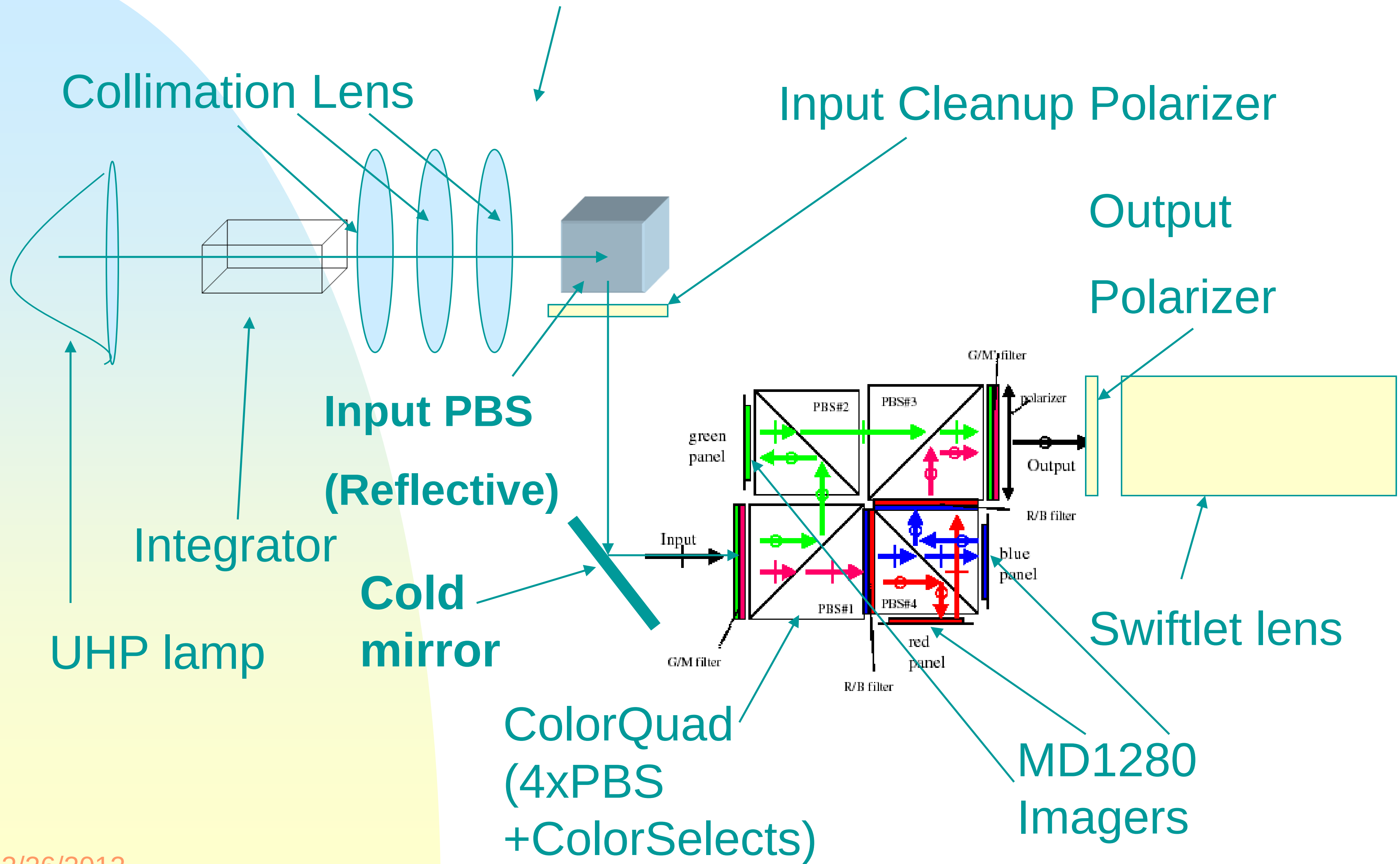
How to Achieve Cost Reduction

- LCOS backplane.

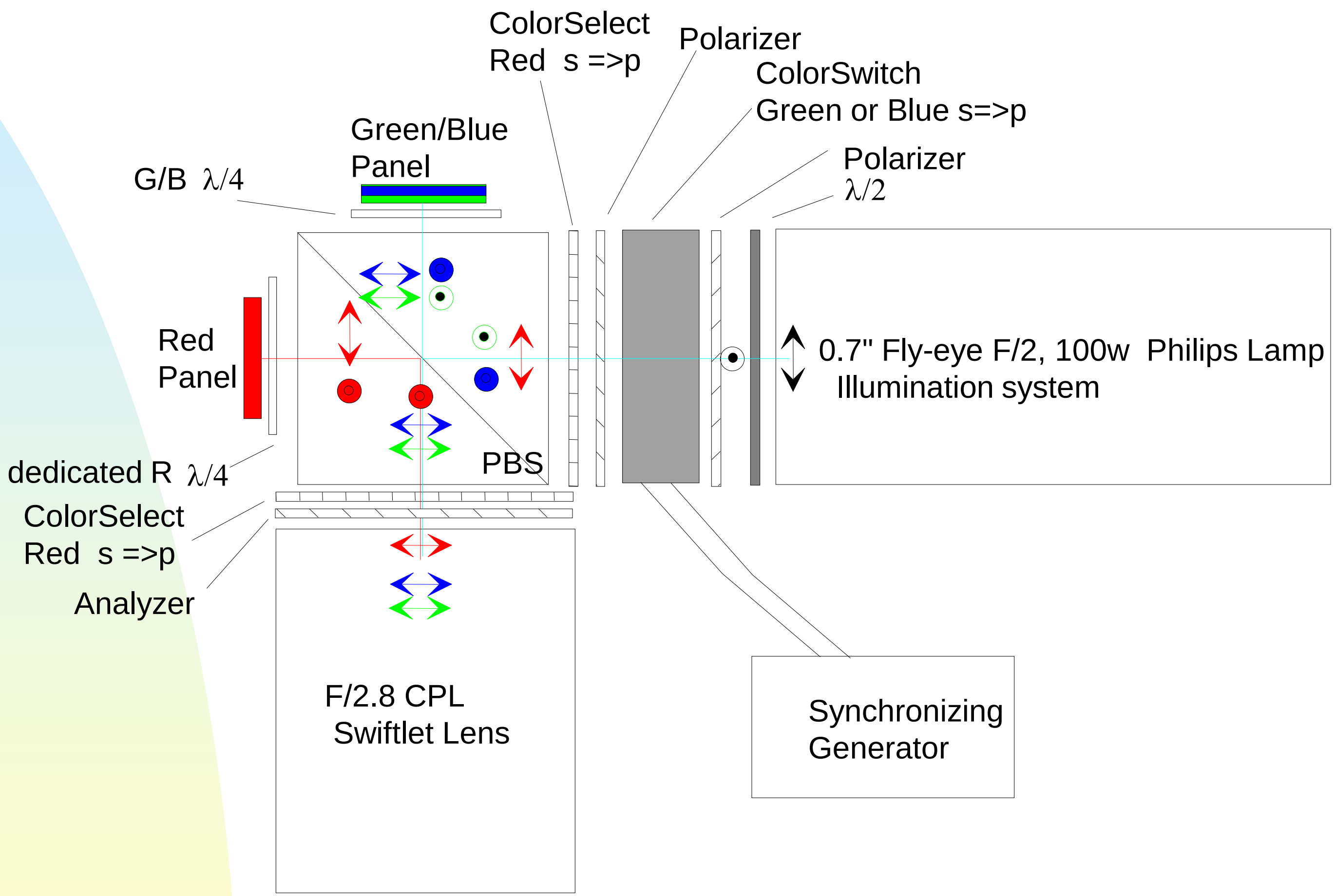


- Reduce silicon size (ex. to 0.5 ")
  - + More chips per wafer
  - ? Pitch 5.8µ for 1920x1080 will be a challenge
  - + Optics components will have a reduced size as well
  - - Higher MTF of the projection lens likely to be necessary (?)
  - - More distortion and lateral chromatism / Electronics correction mandatory (?)
  - - Less brightness. Difficult to concentrate high light flux on small areas => Lens aperture to be increased (ex. from F/3 to F/2.2)
  - Target: 0.5 " 1920 x 1080 or 1280 x 720 ????
- Keep standard size
  - - Fewer chips per wafer
  - + More thruput (brightness)
  - + Possibility to use depreciated machinery (1µ process fab) lower cost per wafer processed? At least for a while?
  - + Possibility to have electronics correction of low cost projection lenses
  - Ex: 0.83 " 1920 x 1080 9.6µ pitch
- Universal Desire
  - To integrate as much electronics as possible inside the imager
  - However, question is "What makes sense??"

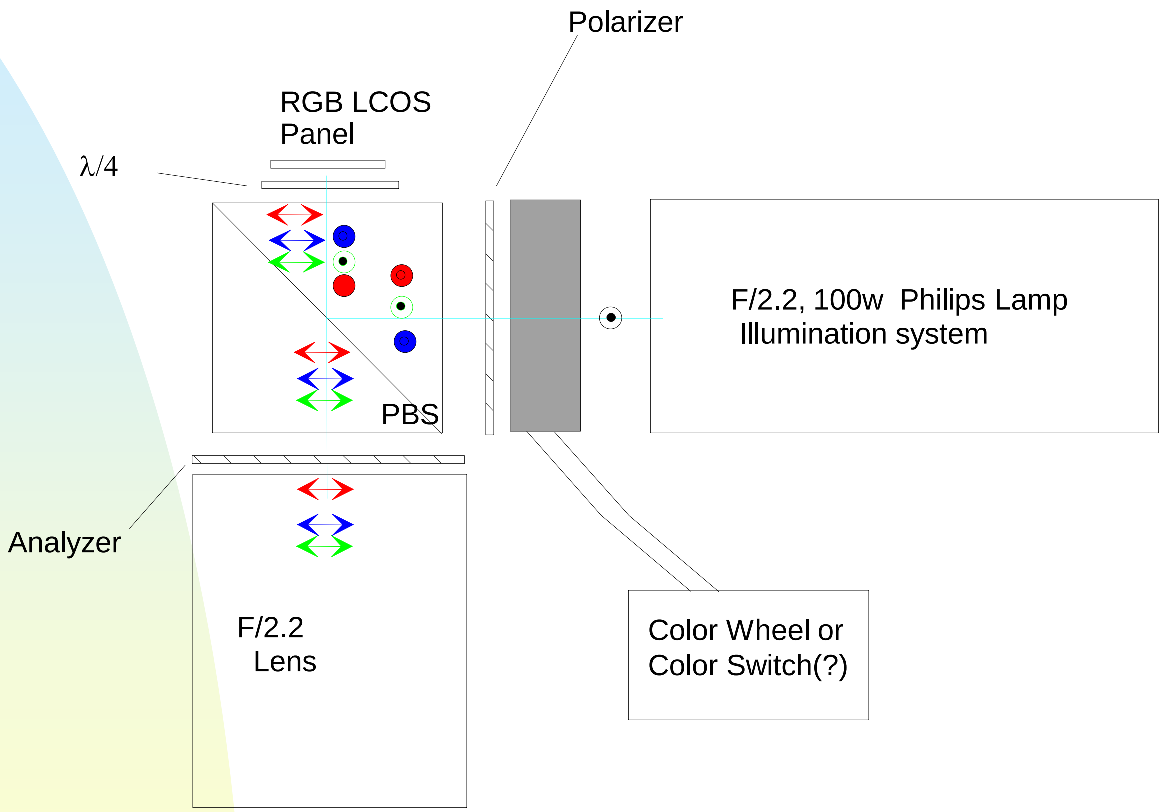
3-LCOS Concept



2-LCOS Concept



1-LCOS Concept



Architecture Issues

- Key questions are
  - What is a good estimate of the cost evolution for given architectures?
  - What are the performance challenges for each of the candidate architectures?
  - Are there different market segment requirements that may call for different architectural(or technology platforms)?
  - What are the resource, partnership and timing to execute the strategy?

Is another path than 3LV LCoS going to be needed in the "short" or "mid" term??

How to Achieve Cost Reduction

- Improve Manufacturing Yields and Thruput
  - Screen Defects (bright spots,dark or “magenta” spots)
    - Spacers => spacerless (easy to say)
    - Reduce/eliminate ITO pinholes (thru cleaning steps in middle of multilayer deposition)-vendor issue
    - Reduce or eliminate polyimide damage and debris from rubbing process (by using one of the non-contact Pi alignment methods-photo,e beam or ion beam patterning), in meantime continue continuous improvement (CI) efforts with existing process/materials
  - Spacerless may (will) bring other problems in maintenance of cell gap control and resulting uniformity
    - Examine design options for
      - increased thickness of glass to reduce deflection under surface tension of LC, may need to be coupled with optics (lens) redesign
      - use of electronic adjustment by pixel or blocks of pixels to compensation of systematic differences, may also allow for cost reduction thru longer term reduction of optics/assembly costs by loosening materials requirements and assembly tolerances

How to Achieve Cost Reduction

- **Improve Manufacturing Yields and Thruput**
  - **Defect and criteria understanding**
    - system level target is likely to be a real necessity in TV market
    - need to understand situation with transmissive p-Si imagers (differences ? and if so why--size ratios of defect to pixel area??)
    - need to correlate observed defect levels at test or microsope evaluation to operating product environment
    - need to get good root cause failure analysis of a number of defects to both verify or refute anticipated causes and paretos as well as provide data based clues for best corrective actions
  - **Reduce or Eliminate Testing**
    - current ATE testing for spot defects much too long (15-18 minutes) due to high sampling ratio in vision system setup to obtain discrimination for subpixel scale defects
    - since criteria requirement will probably not go away this means that TFS must solve the problem as a process/materials/design issue to allow this to become a sampling check rather than a 100% GO-NO GO test

Final System Manufacturers Viewpoint

- **What is important to them?**
  - **Product performance requirements**
  - **Product quality level**
  - **Product reliability**
  - **Serviceability and Maintainability**
  - **Product Cost Trends**
  - **Supply Chain Considerations**
  - **Value Chain Considerations**
  - **Ability to control or strongly influence their destiny**
  - **IP Considerations**

Supply Chain Considerations

- Second source and multiple suppliers (for security, for capacity flexibility in response to market demand, for pricing leverage)
- Ability to minimize working capital (by nature of material flow, due to nature of design concepts, due to commercial relationships)
- Ease of manufacturing (cycle time in plants, manufacturing direct cost, level of capital investment required for assembly facilities)
- Ease of design integration (ability to be flexible with respect to sourcing , product changes, changing customer-market needs,etc.)

Competitive Positioning

- Incumbent product and technology in respective market segments
- Existing supply base for incumbent products (strength, degree of commitment, capacity to move into other technologies
- Alternate technologies in each respective market segment
- Alternate producers in proposed (target/subject) replacement technology

Need to review a SWOT analysis by market segment

Standardization

- Mechanically
- Optically
- Electrically

]Functional
]Interface Specifications
]Needed

- System Level
- Subassembly/subsystem Level
- Component Level
- Key Material Level

Standardization

- Issue of PC community and TV community at system level, display manufacturers, and video/graphics processing IC designers
  - What is the “best” overall product solution?
  - What are the potential resulting business value chain concerns?
  - How to get agreement on a direction?

Standardization

- Appendix A contains some suggestions for a Strawman of electrical system function partitioning between the TV or Monitor system and the Display driving system that could be a basis for starting discussions.
- Technical rationale for the partitioning is fairly sound. However, other business concerns, desire for IP control and history will be factors that make achieving an industry consensus difficult.
- For this reason, some flexibility (and potential duplication) in the functions will likely be necessary.

Standardization

- **Optical/mechanical interfaces and standards will be problematic in an environment of many suppliers at many points in the value chain.**
- **This is one reason why the Kernel concept can be a facilitating approach by simplifying those interfaces, and the associated engineering and design efforts required to support the specification of interfaces in a more complex assembly or supply chain management task situation.**

LCOS Kernel Concept

Value Chain Integration Approach

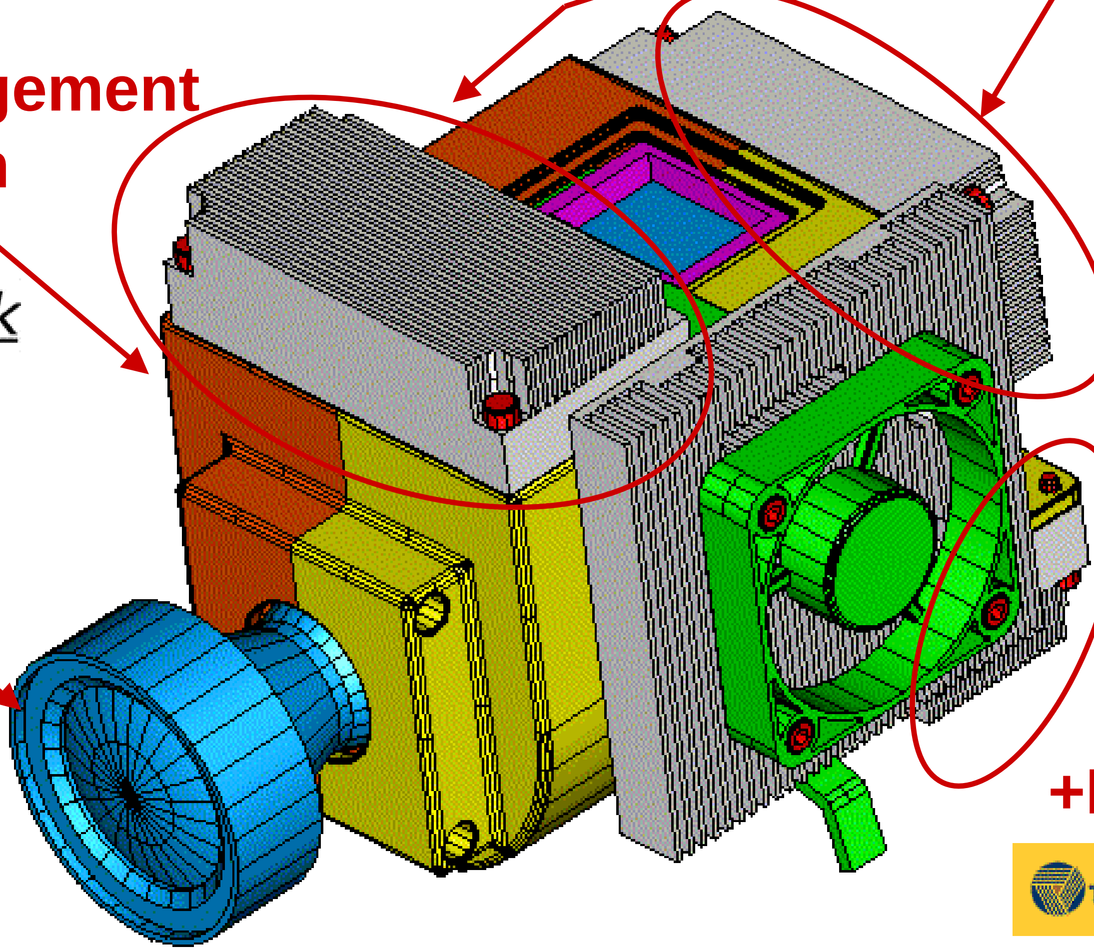
Imagers

THREE-FIVE SYSTEMS, INC.®

Color Management Prism

ColorLink

Projection and or Input Optics(?)



+Drive ASIC(s)

THREE-FIVE SYSTEMS, INC.®

Increased Value Chain Integration

- Advantages
  - Optimize system performance
  - Establish cleaner interfaces (mechanical and electrical)
  - Facilitates assembly at system manufacturer
  - Reduce MD variants (allows Company X to get learning curve benefits faster)
  - Reduce total system cost (BOM + Mfg)
- Disadvantages
  - Ties to the selected Color Mgt technology
  - Investment $ (internal development or acquire externally)
  - Resources to execute

Value Chain Integration

- Manufacturing
  - Company X has a sound high volume manufacturing capability with experience in
    - LCD fabrication and processing
    - Display packaging
    - Automated Testing (including machine vision inspection systems)
    - Electronics assembly
    - More limited experience in small systems assembly

Value Chain Integration

- **Manufacturing**
  - **Manufacturing of the LCoS Kernel concept (either directly or through selected contractors) should not be any fundamental problem, assuming an arrangement is made to obtain the necessary access to IP and technical assistance (whether done thru acquisition, joint venture or other less formal business partnership)**
  - **A more difficult question will be should that integration extend to the point of adding the optics and mechanical mounting structure and making (having made) a full turnkey light engine**

Value Chain Integration

- **Manufacturing**
  - **The full light engine assembly will require careful analysis and preparation since it will be of a bulk that Company X manufacturing is not used to handling. This can present many more problems than immediately obvious if not managed with care. However, fundamentally I again see no issue in engaging in that business either directly or indirectly.**
  - **From the supply chain perspective of the final system maker it will be much more analogous to the assembly of a direct view CRT TV or monitor if a complete ,aligned, plug and play light engine can be provided.**

Some Next Steps

- Fix yield/quality problems,drastically reduce test frequency or test time
- Decide on a cost reduction path
- Decide if value chain expansion helps both Company X revenue and margin growth and facilitates customer market success
- Decide if “standardization” drive is worth overcoming the resistance or if other approaches are needed.

Comments

- **Kernel concept makes sense to me at this stage:**
  - **Interaction of optical components (including imager) that deal with polarized light manipulation is critical to system performance (brightness, contrast ratio, colorimetry tracking, color uniformity,color gamut, thermal and temporal stability, major potential sources of reliability issues other than lamp)**
  - **There would appear to be a real technical synergy from working these items together in some well defined matter.**
  - **Coincidentally, optics and systems skills acquired could be synergistic with NTE market if Company X decides to participate there more actively.**

Comments

- **Working the imagers and color management system together appears positive with respect to**
  - **optimization of system performance from a design perspective (not just optically, but also from the perspective of using the imager drive electronics system to compensate for specific system deficiencies that could then allow for improved performance or reduced cost)**
  - **optimization of system performance from a manufacturing assembly and alignment perspective**
  - **reducing required imager type proliferation to fine tune to every customers optical system**
  - **providing customers with options for and easier to assemble/easier to manage product due to reduced interfaces, alignments, and suppliers to manage.**

Comments

- This last feature can facilitate the market entry of less established and dominant firms in the marketplace.
  - This may create a market opportunity that otherwise does not exist
  - In the case of a firm like Philips or SONY they will likely continue with their own in house solutions and are unlikely to be customers, although tactically they might engage if they sense a competitive problem for either performance or cost-price until they can address it within their own house.

Comments

- In the case of a firm like Thomson, the apparent change to a different, DELL like, business model would be consistent with a Kernel type approach in many respects.
- However, for THOMSON as for some of the other newer and or smaller entrants, the best solution is a total light engine so that TV or Monitor assembly is as close to the Direct View CRT assembly model as possible, alleviating the need for significant changes in factories and supply chain managment.

The Kernel may not be enough.

Comments

- Competitively,
  - TI is not selling a light engine per se, but they have reference designs available and a key component vendor list that they can use to facilitate entry by a system manufacturer. They would prefer to remain in the chip/module side of the business as they see getting into engine assembly as degrading their margins.
  - EPSON will certainly sell someone an imager module if that is what they want, but they would prefer to get into and are attempting to sell the light engine package.

Comments

- Philips is also trying to sell their light engine as a package, in their case selling their imager design without the unique color management system that goes with it would be problematic. They may very well want to get a contractor to do the wafer fab and LC assembly and packaging, but they will want design control to insure their system is optimized.
- The Philips solution may turn out to be a very good one for RP systems in the mid to large screen size range. However their scrolling prism system may not be as prone to miniaturization as a one or two panel LCOS for portable. This is a plus for the kernel as it may allow for a larger volume base and associated cost reduction potential

Comments

- **The kernel or light engine business approach is not without significant risk and challenges.**
  - **How to get the product know how?**
  - **How to get the associated manufacturing capability?**
  - **Potential turn off of customers who have some expertise and or IP in the engine design and/or color management space and want to add that value themselves?**
  - **Potential turn off of imager customers who see Company X as a competitor rather than a supplier.**
  - **Potential IP barriers in a space (system optics design and manufacture)that is not Company X core competence.**

Some Possible Next Steps

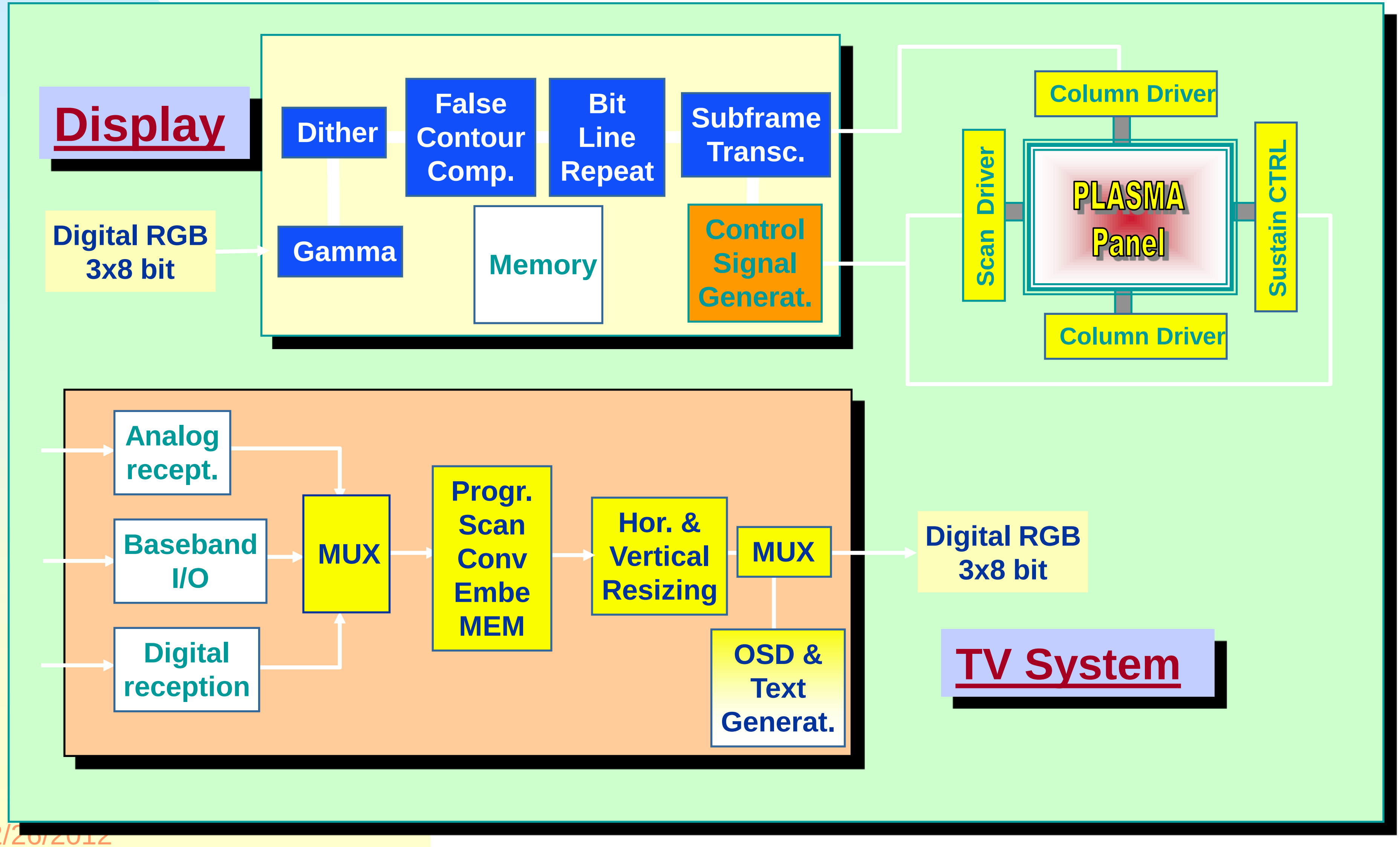
- Work on providing a better cost model basis for LCoS architecture direction.
- Work on providing deeper analysis and recommended direction on either a kernel and or light engine strategy.
- Work on defining direction of driver system functionality with respect to standardization and/or defining customer beneficial features.

Appendix A

Display Interfaces

David F. Hakala

Concept of a *FPD TV (Ex. Plasma)*



Distribution of Tasks

Function	Front End (Box)	Front End (Integrated in Monitor)	Display Processor
Progressive scan conversion	yes	yes	no
Format control, resizing	yes	yes	no
Letter box detection	yes	yes	no
PIP, POP engine(s)	yes	yes	no
PC signal formatting and scaling	yes	yes	no
OSD insertion	yes (high resolution graphics)	yes(high resolution graphics)	yes(5bits-control)
Video control (Contrast, brightness, saturation, hue)	no	no	yes
YUV / RGB matrix	yes	yes	no
Peaking	yes	yes	no
Gamma correction	no	no	yes
Dithering	no	no	yes
Subframe encoding	no	no	yes

Suggestion for Partitioning of Functions Between System and Display

Architecture Alternatives

- Some of the features that might be added to the basic architecture of the Front End:
  - noise reduction
  - edge replacement
  - programmable built-in gamma function (3x10 bit RGB output)
    - plasma gamma function
    - LCD gamma function
  - video control
    - luminance
    - contrast
    - saturation

Addition of these last two features, or not, to the system or the display is more a function of how the value chain and control gets split up … <u>not</u> upon which makes the most sense technically

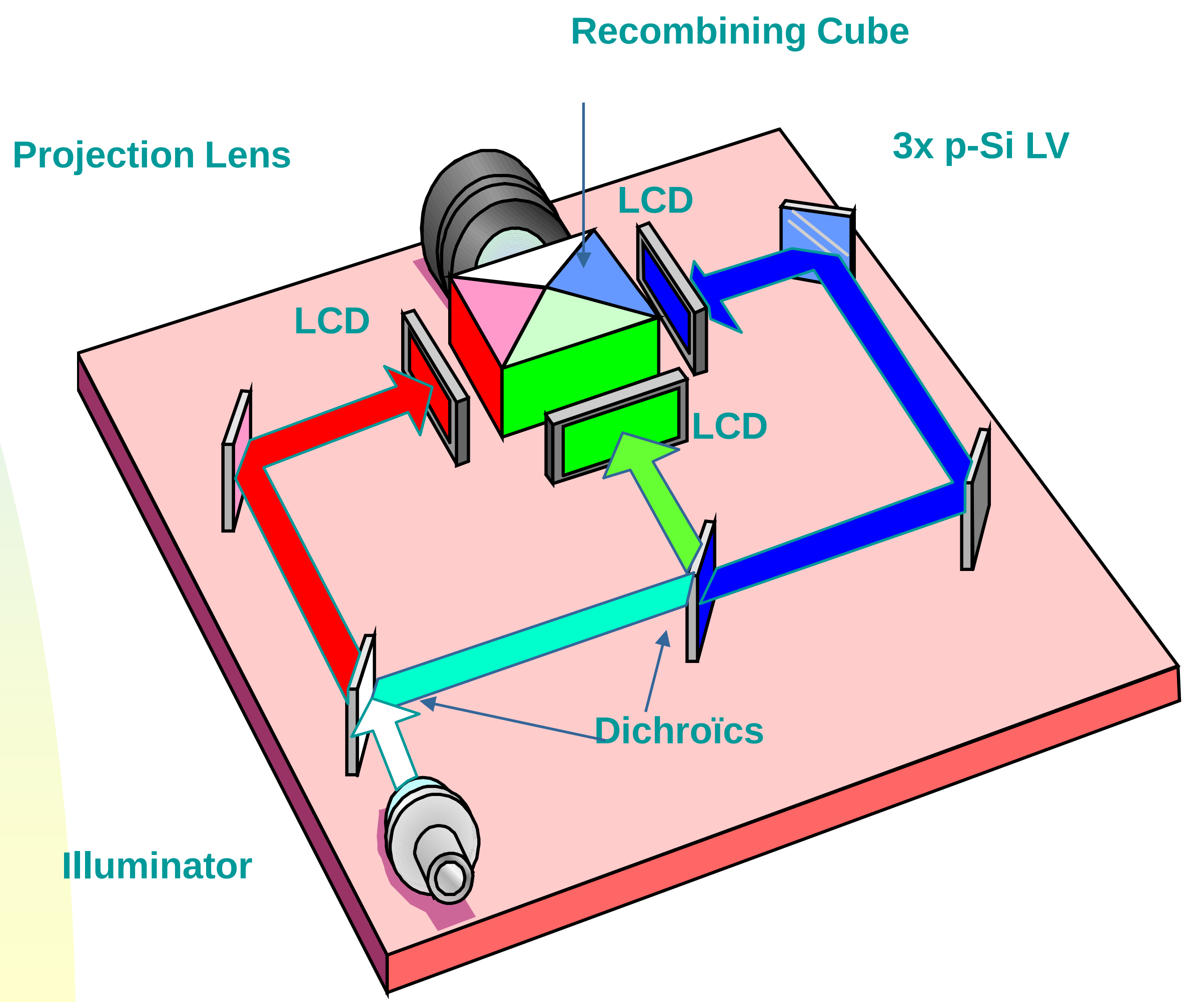
Appendix B

Off Axis LCOS Projector (NOVA Engine) Overview

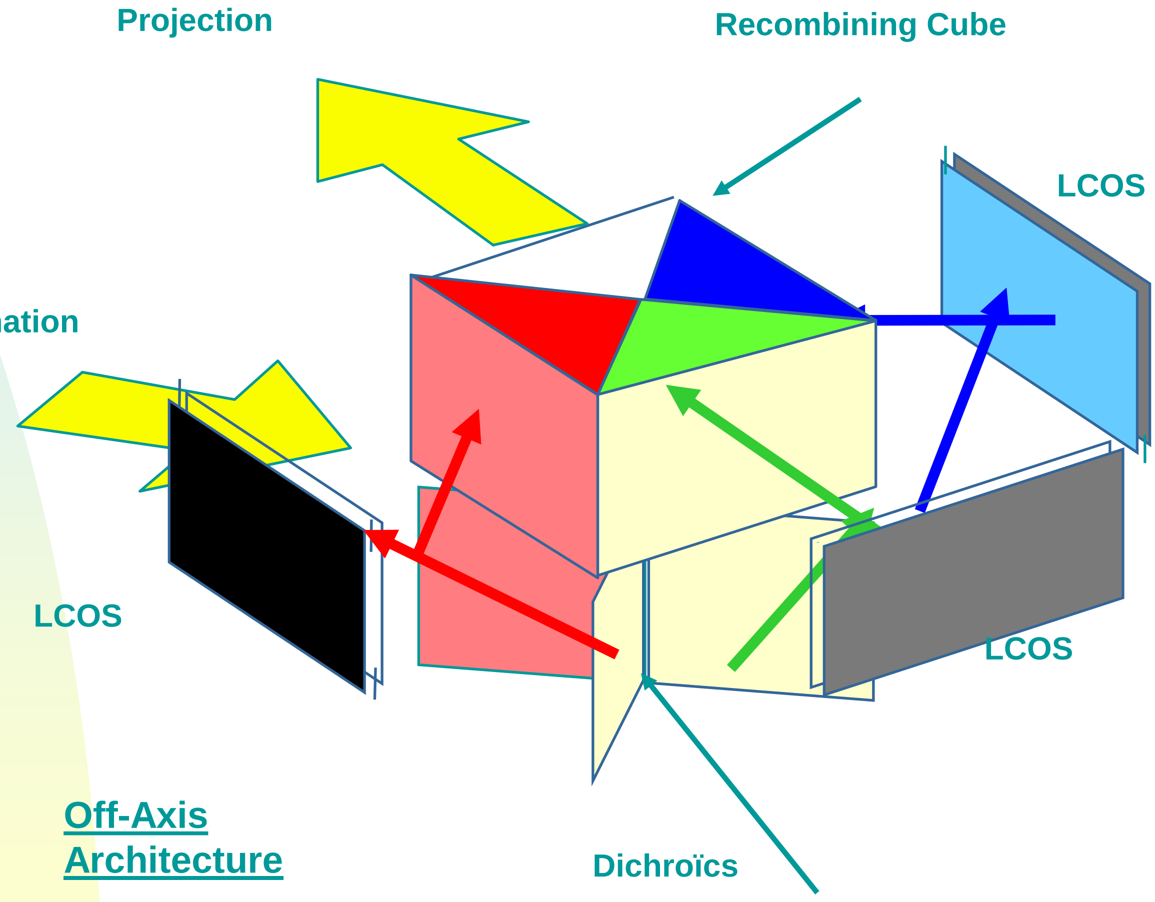
Dr. David F. Hakala

October 31,2001

Main Stream Front ProjectorTechnology

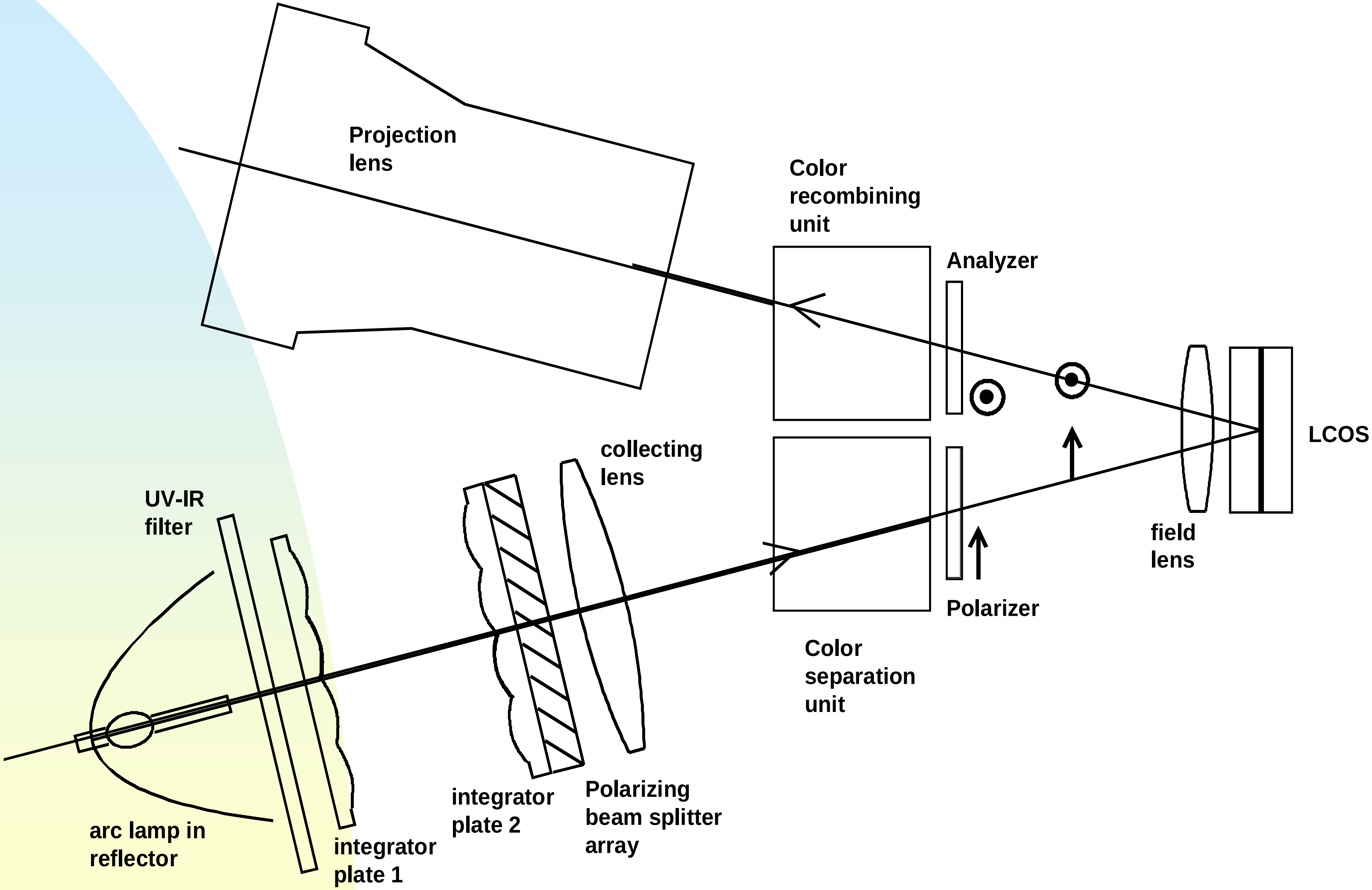


Off-Axis Architecture



Off-Axis Architecture

Off-Axis Architecture



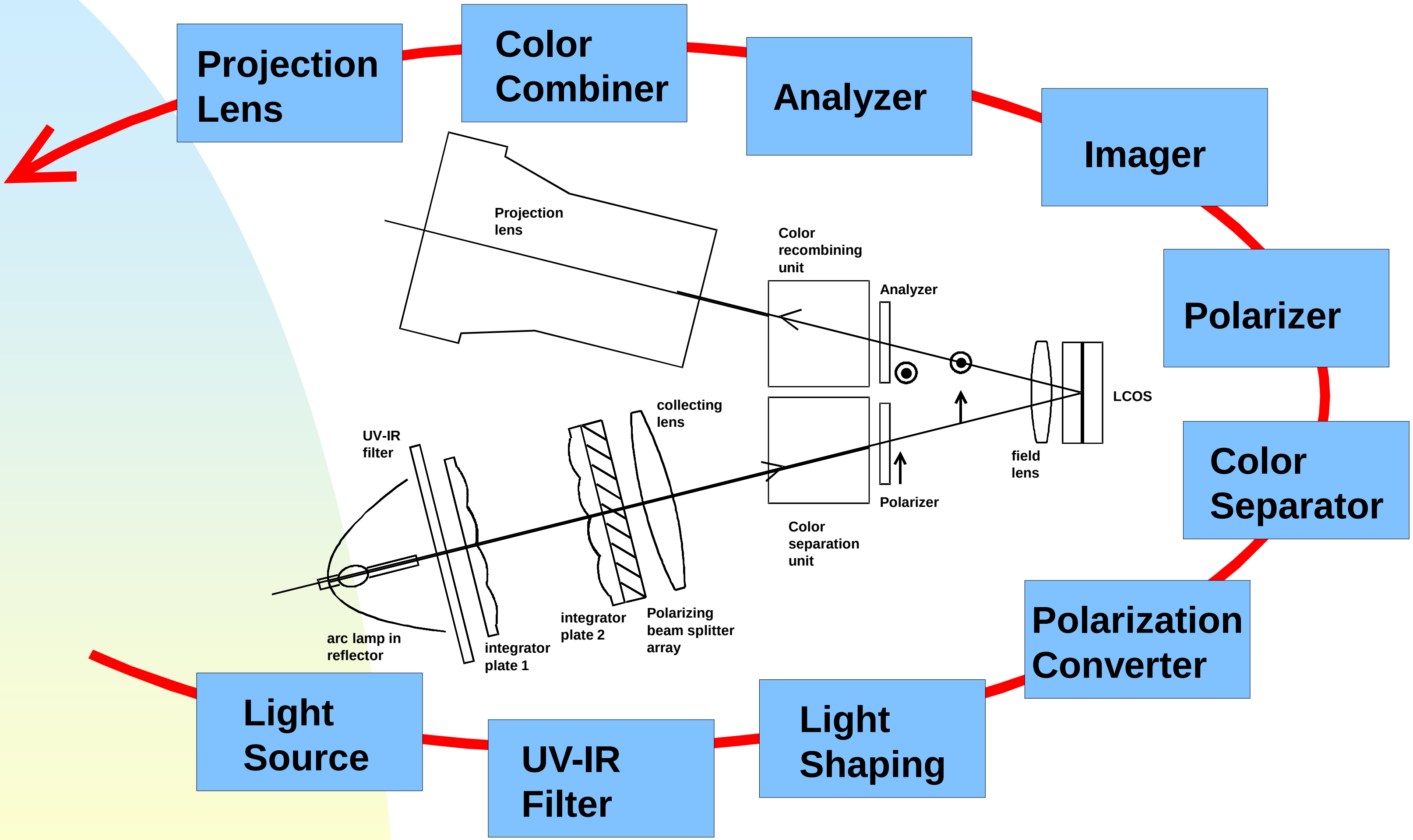
Off-Axis Architecture Pros

- TN 45° - very good LC Contrast Angle
  - 400:1 Demonstrated Nova + 0.97'' S-Vision Imager
- Possibility to modify the Angle with a Compensation Film
- Mechanical Limitation of f / #
  - ~ f/3 on Nova and 4x3
  - Consistent with the Contrast Target
  - Improved Trade-Off possible with 16x9
- No Thick Glass Part between Polarizers
  - Smaller Risk of Contrast Degradation due to Glass Stress Birefringence than systems with PBS interior to Polarizers
- 500 lm through 190 mm^2 Imager ($50 Cost Target / Imager ???)
- Cost, Availability:
  - Components similar to the Main Stream Technology
  - Available from several Sources
- Off-Axis License not an issue for Company X

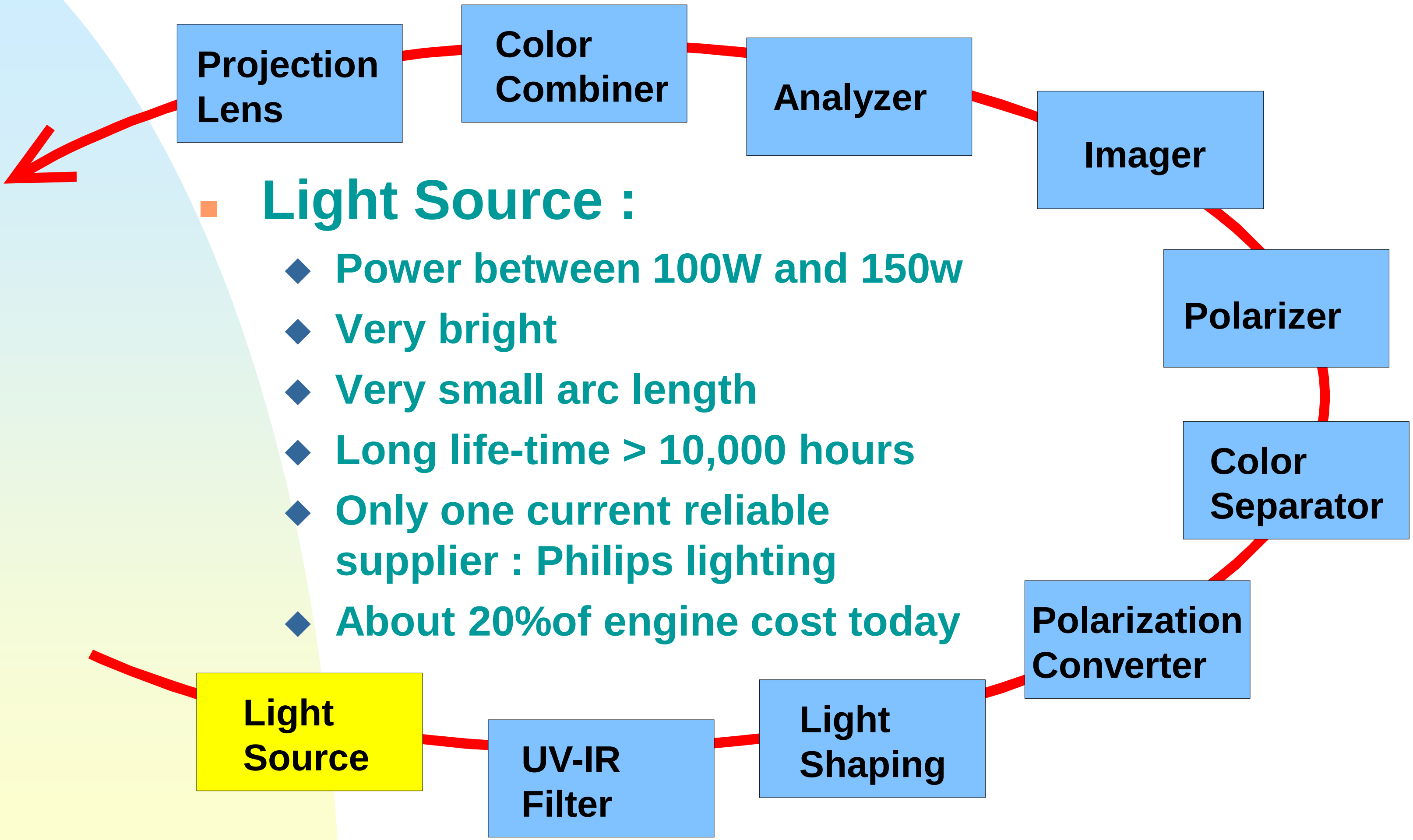
Off-Axis Architecture Cons

- Color Shift
  - Beam under an Angle at the Cube
- Long Back Focal Length
  - Unclear Lens Design Status
  - Analysis doesn't show strong Link to Costing directly, but design task is challenging and it is expected to impact cost
  - F/3 Limitation

Projector Architecture

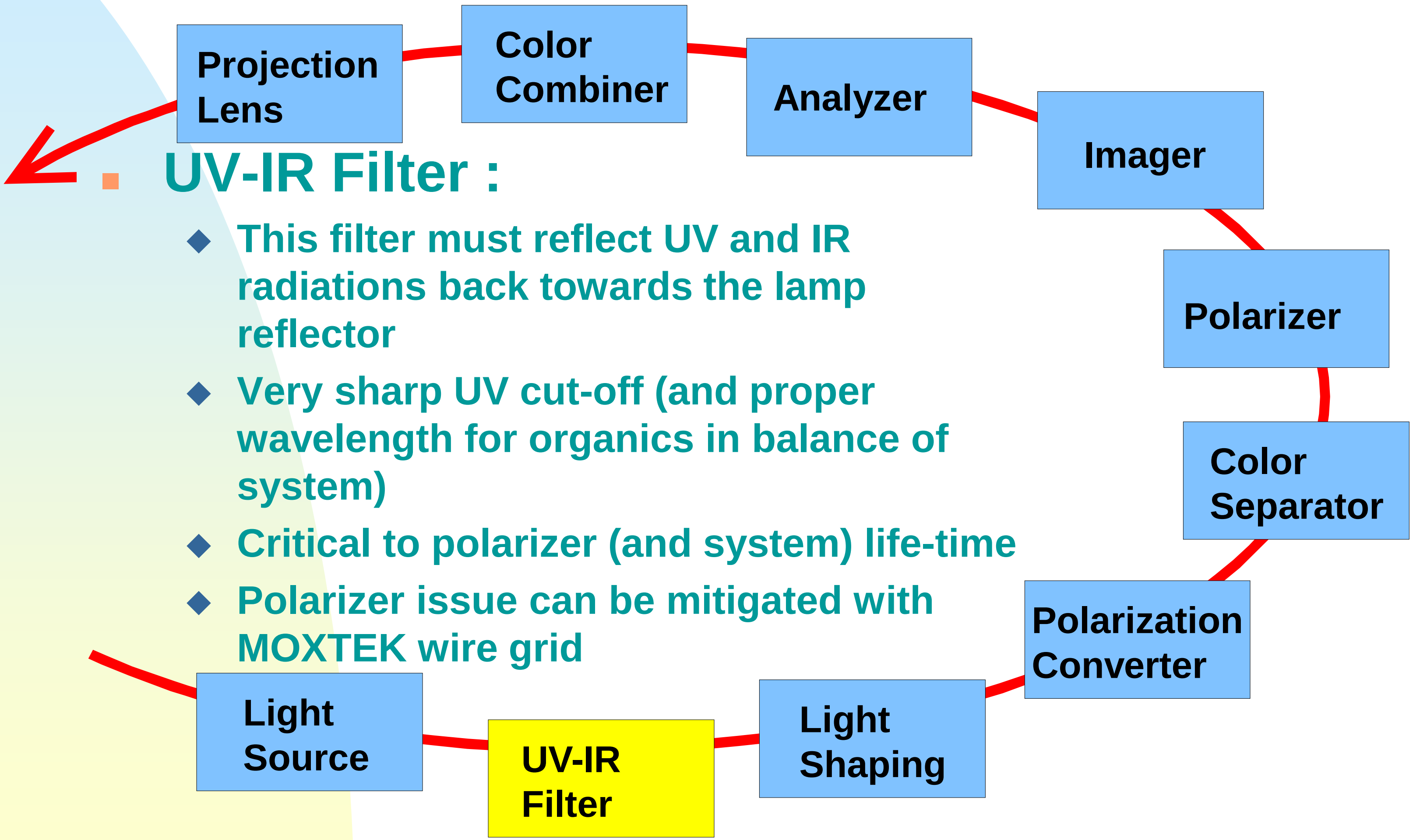


Projector Architecture



- **Light Source :**
  - Power between 100W and 150w
  - Very bright
  - Very small arc length
  - Long life-time > 10,000 hours
  - Only one current reliable supplier : Philips lighting
  - About 20%of engine cost today

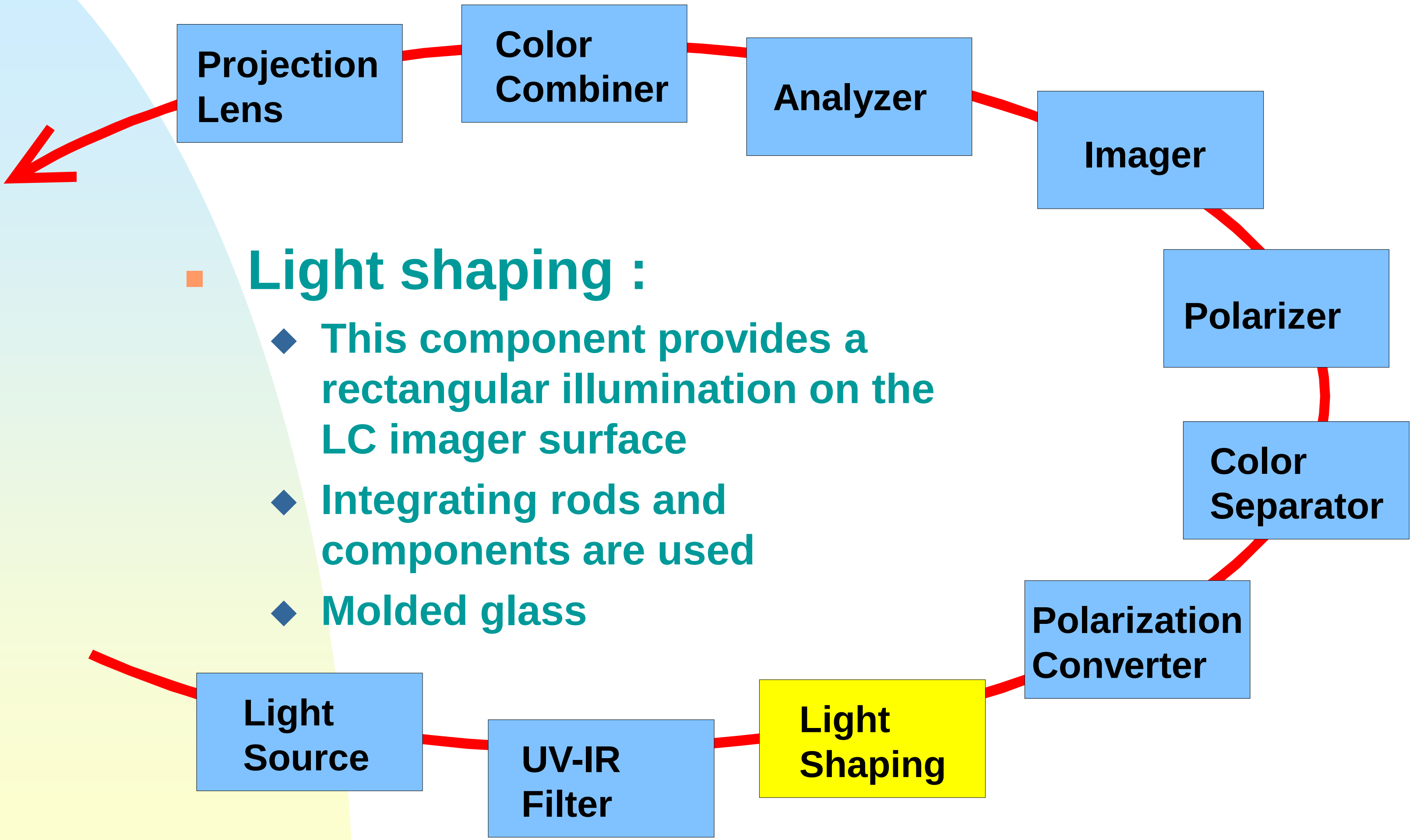
Projector Architecture



- **UV-IR Filter :**
  - This filter must reflect UV and IR radiations back towards the lamp reflector
  - Very sharp UV cut-off (and proper wavelength for organics in balance of system)
  - Critical to polarizer (and system) life-time
  - Polarizer issue can be mitigated with MOXTEK wire grid

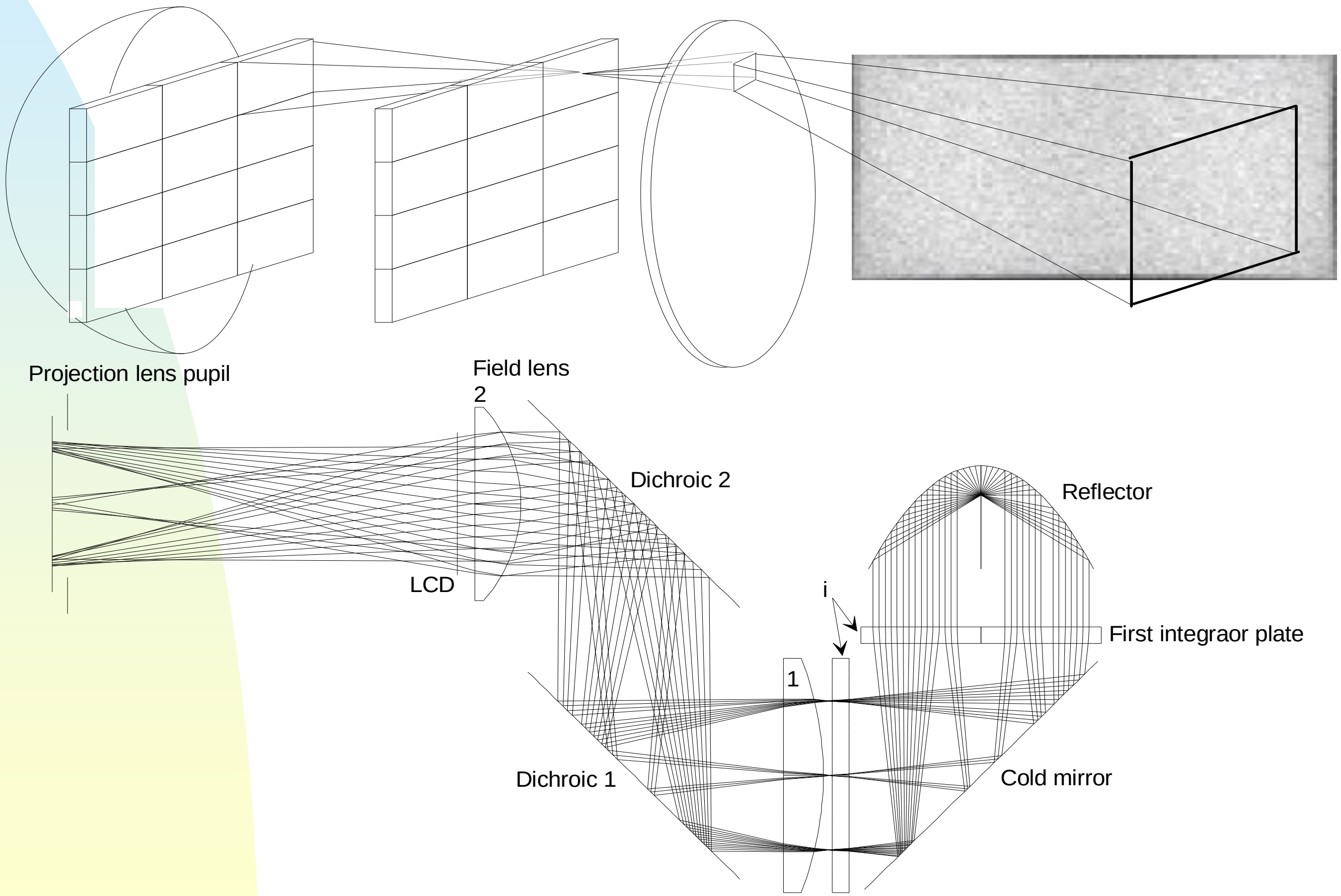
Projector Architecture

- **Light shaping :**
  - This component provides a rectangular illumination on the LC imager surface
  - Integrating rods and components are used
  - Molded glass

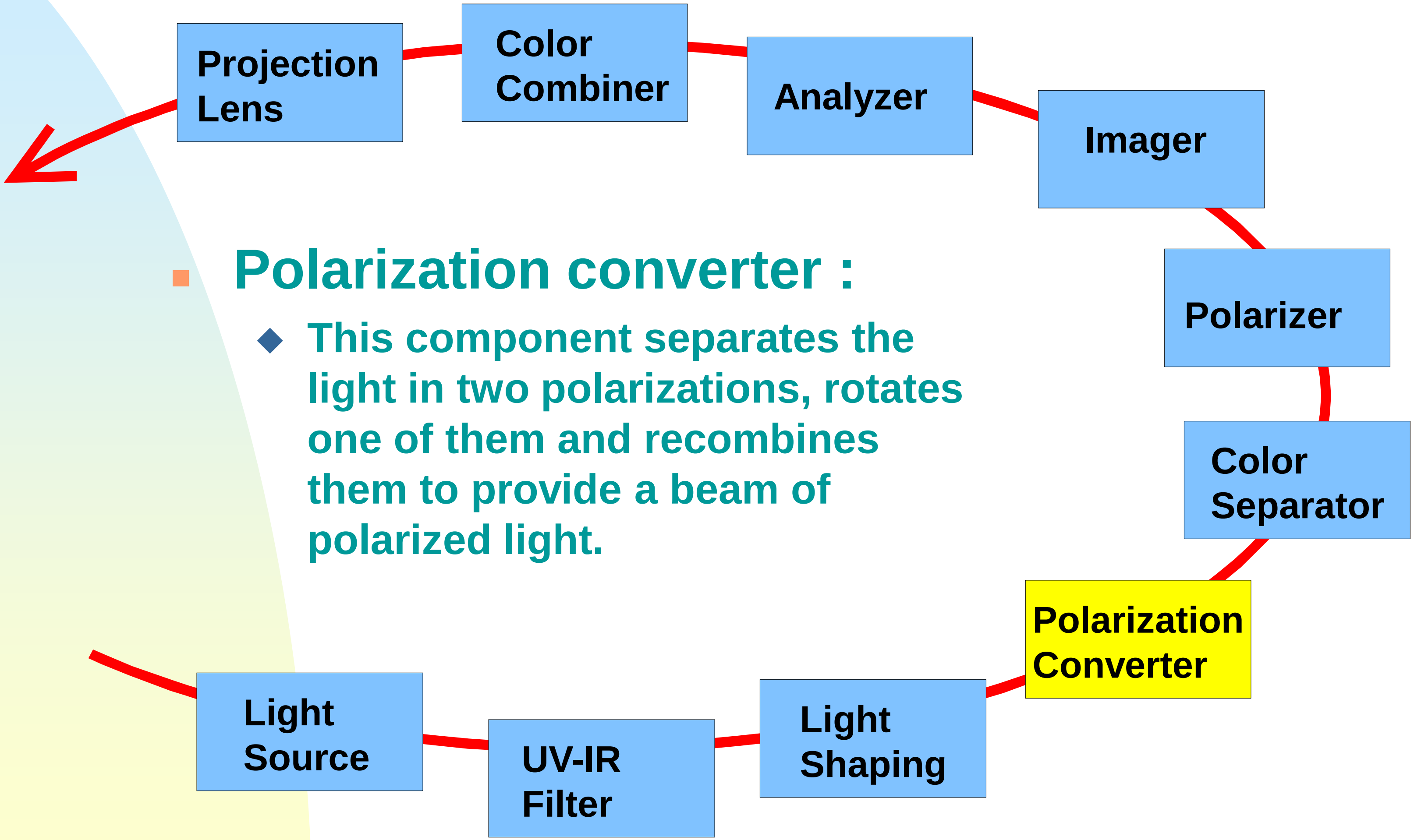


Projector Architecture

- Light shaping : Integrator



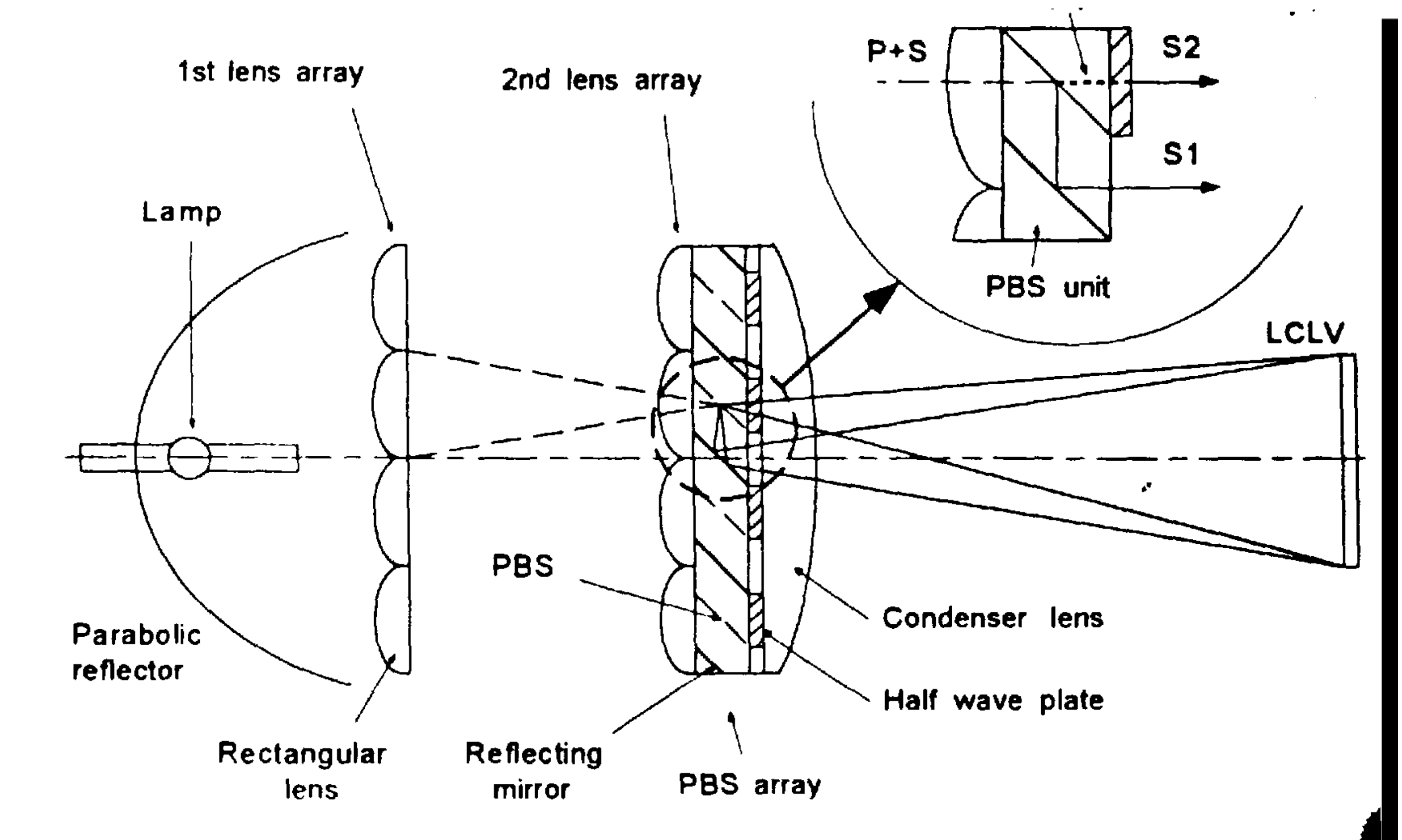
Projector Architecture



- **Polarization converter :**
  - **This component separates the light in two polarizations, rotates one of them and recombines them to provide a beam of polarized light.**

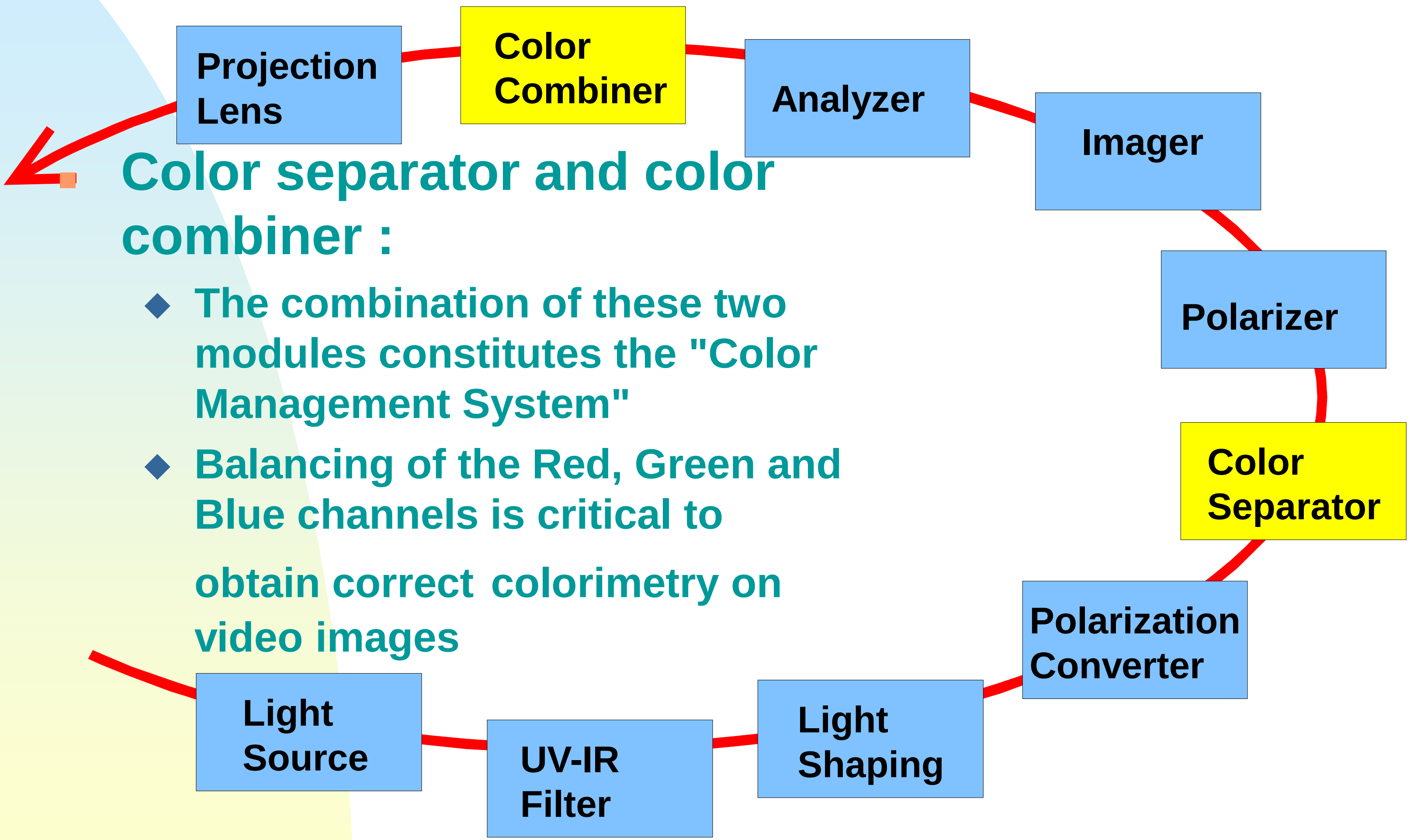
Projector Architecture

- Polarization converter :



Optical layout of the polarized light illuminating system

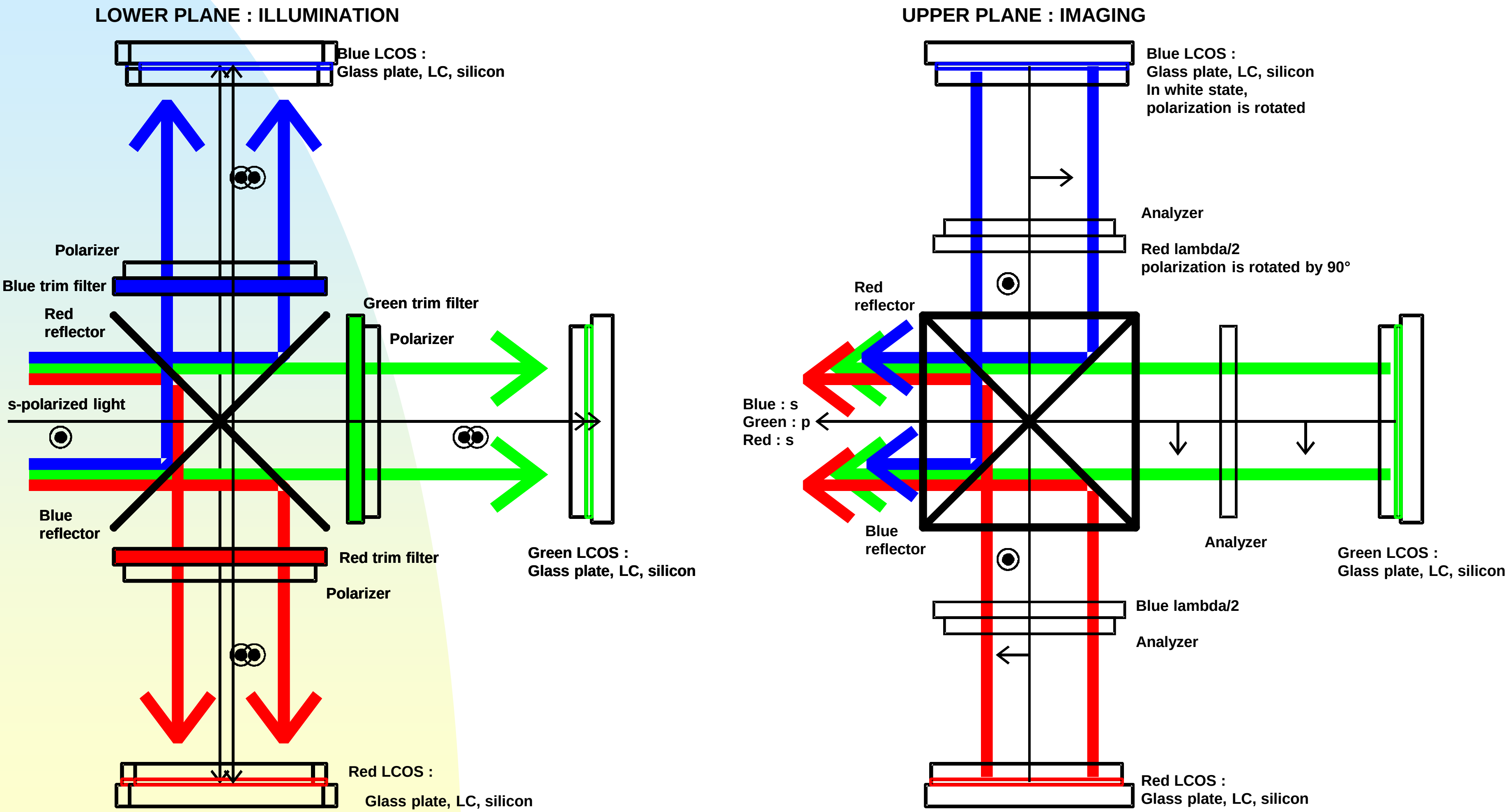
Projector Architecture



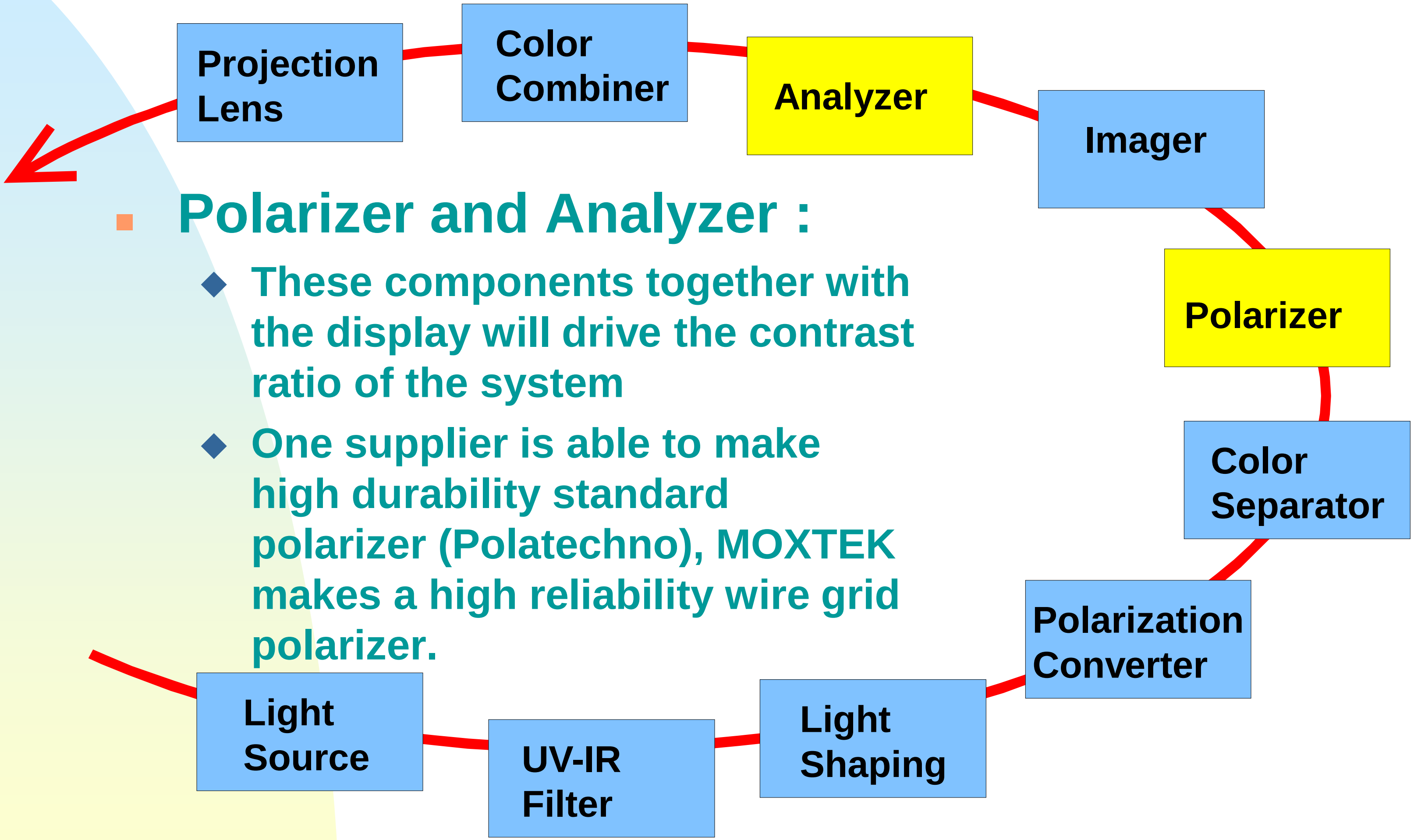
- **Color separator and color combiner :**
  - **The combination of these two modules constitutes the "Color Management System"**
  - **Balancing of the Red, Green and Blue channels is critical to obtain correct colorimetry on video images**

Off Axis Projector Architecture

COLOR MANAGEMENT IN OFF-AXIS ARCHITECTURE

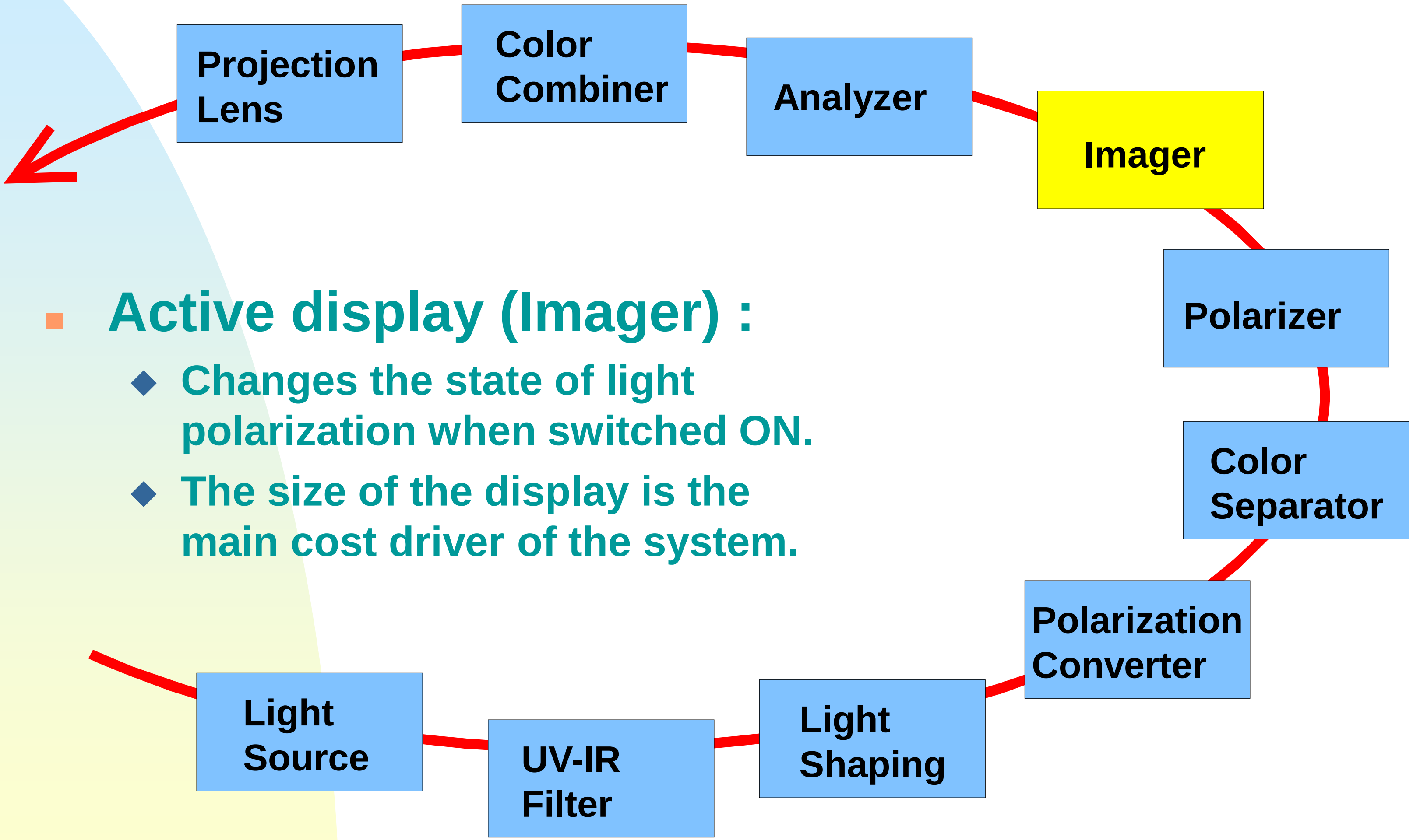


Projector Architecture



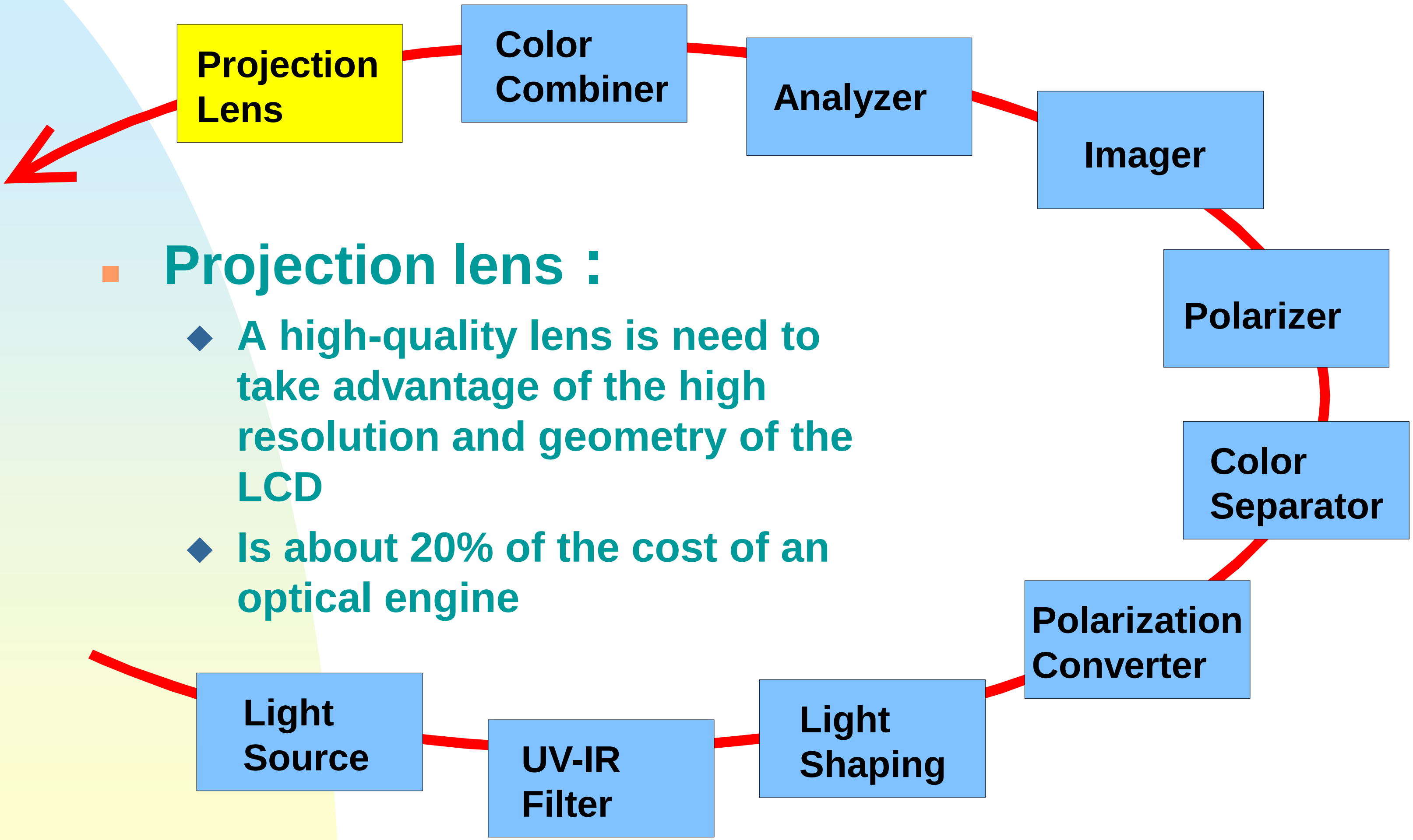
- **Polarizer and Analyzer :**
  - These components together with the display will drive the contrast ratio of the system
  - One supplier is able to make high durability standard polarizer (Polatechno), MOXTEK makes a high reliability wire grid polarizer.

Projector Architecture



- **Active display (Imager) :**
  - Changes the state of light polarization when switched ON.
  - The size of the display is the main cost driver of the system.

Projector Architecture

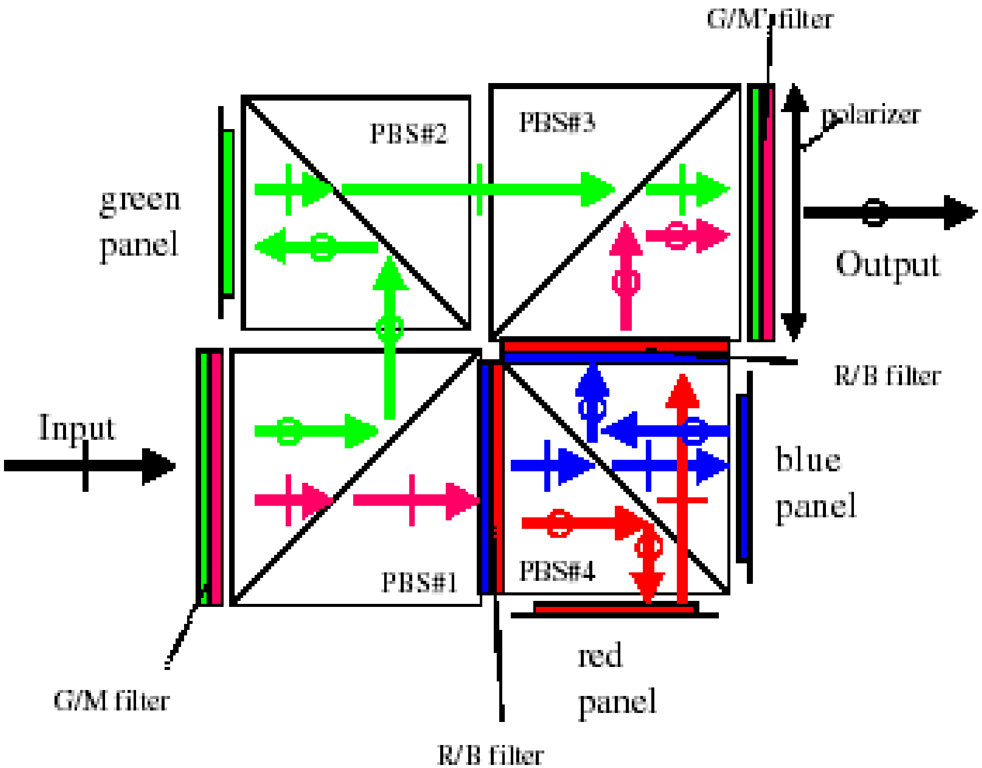


- **Projection lens :**
  - A high-quality lens is need to take advantage of the high resolution and geometry of the LCD
  - Is about 20% of the cost of an optical engine

Appendix C

Color Management Systems

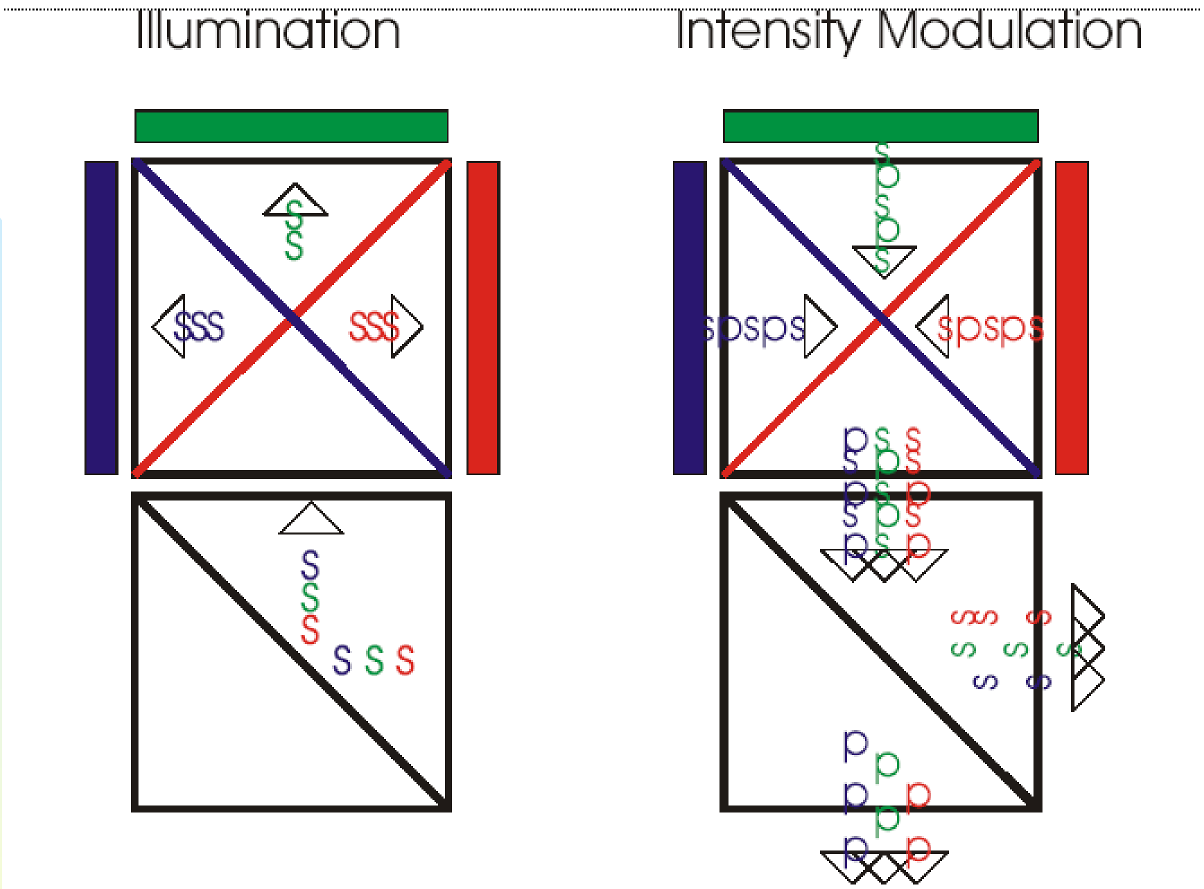
Color Management Systems



ColorQuad™ architecture showing beam paths and their associated polarizations for the R,G,B channels. The panels are assumed to be turned on corresponding to a white state.

ColorLink ColorQuad Architecture

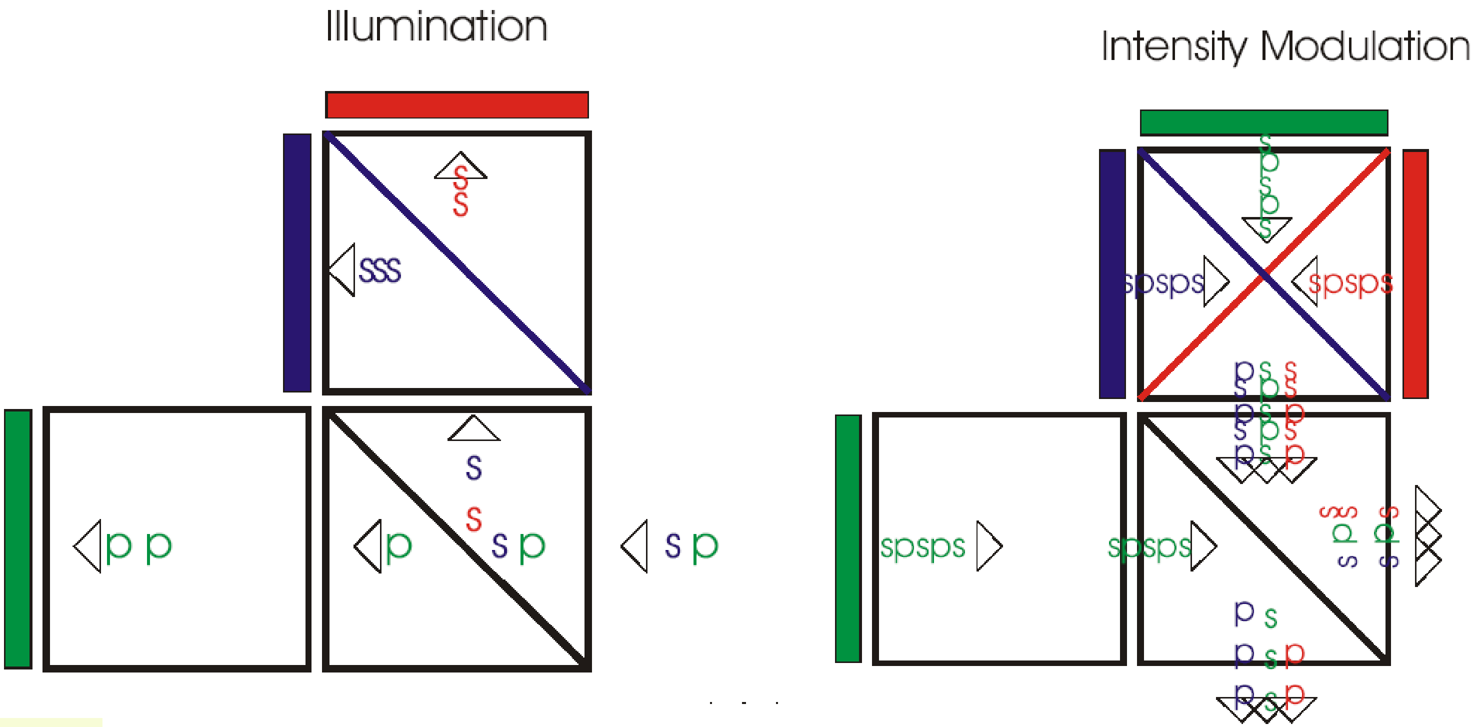
Color Management Systems



In the colorcube system the light used for illumination is uniformly linear polarized. The light reflected from the reflective LCD-panels is polarization modulated The PBS transfers this polarization modulation into intensity modulation.

Alternate Color Management System(Balzers)

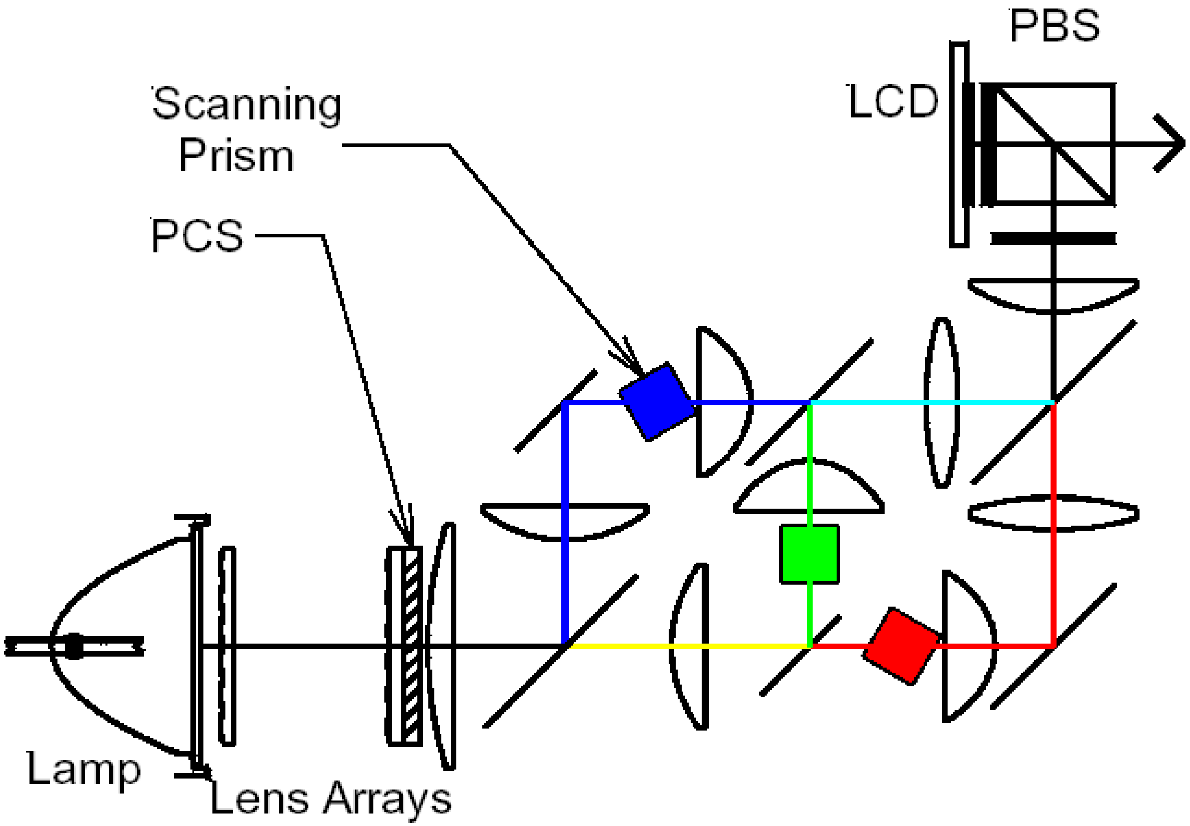
Color Management Systems



Illumination and intensity modulation within the colorcorner.

ColorCorner Configuration (Balzers)

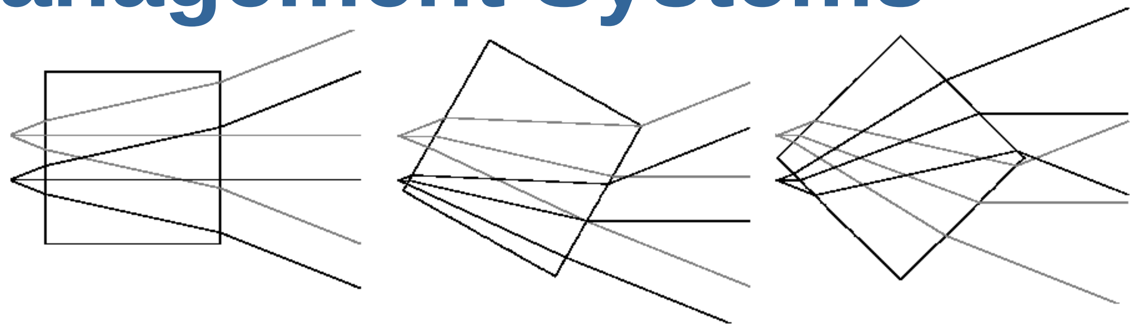
Color Management Systems



Lightpath schematic of the three prism single panel optical system.

Philips Scrolling Prism-Physical Architecture

Color Management Systems



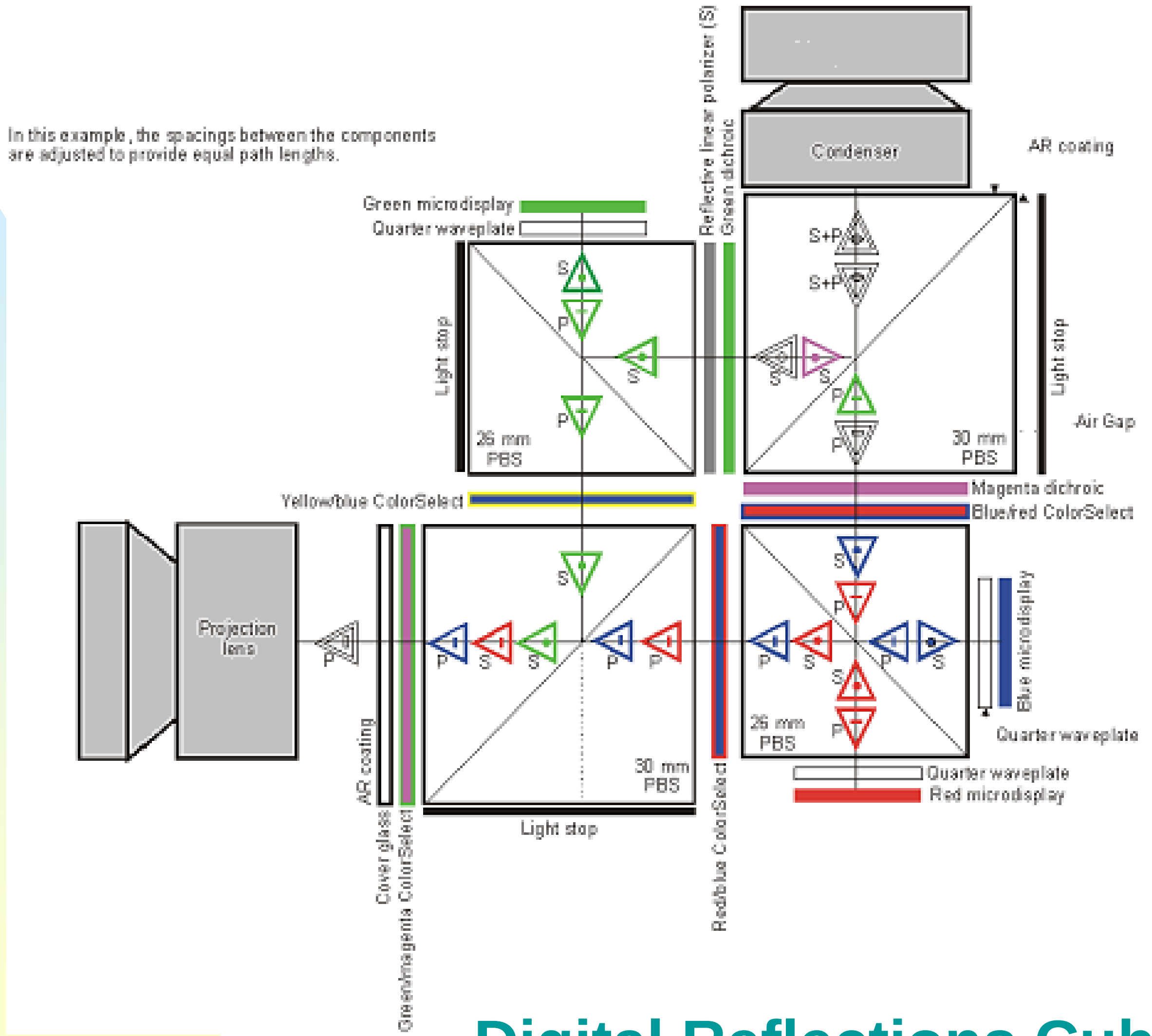
(a) (b) (c)

Scanning of a stripe by a rotating prism at three rotation positions.

Illumination pattern and addressing points at the LCD panel.

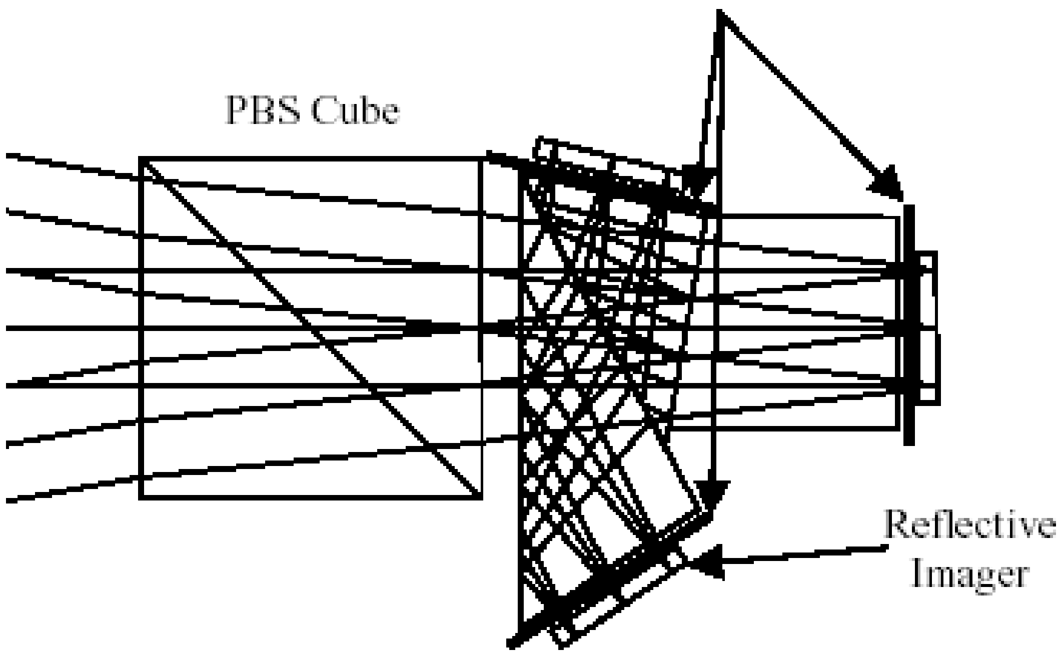
Philips Scrolling Prism-Method of Operation

Color Management Systems



Digital Reflections Cube

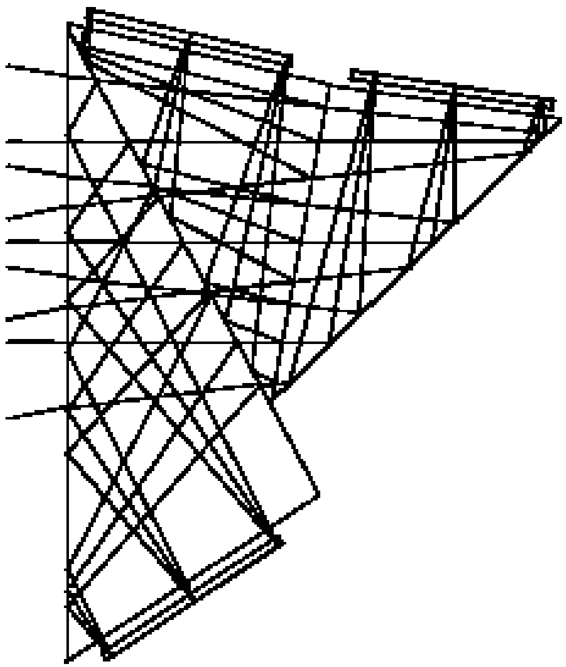
Color Management Systems



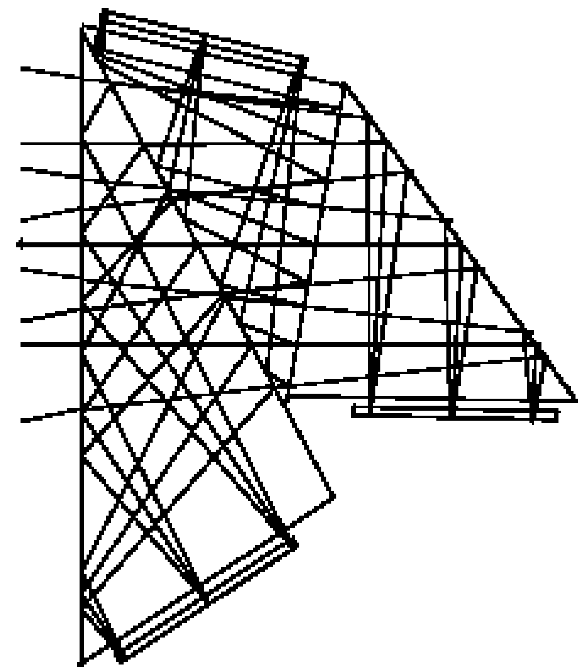
Philips Prism Used with Reflective Imager and Image Plane Compensators for Contrast Enhancement

Philips Prism

Color Management Systems



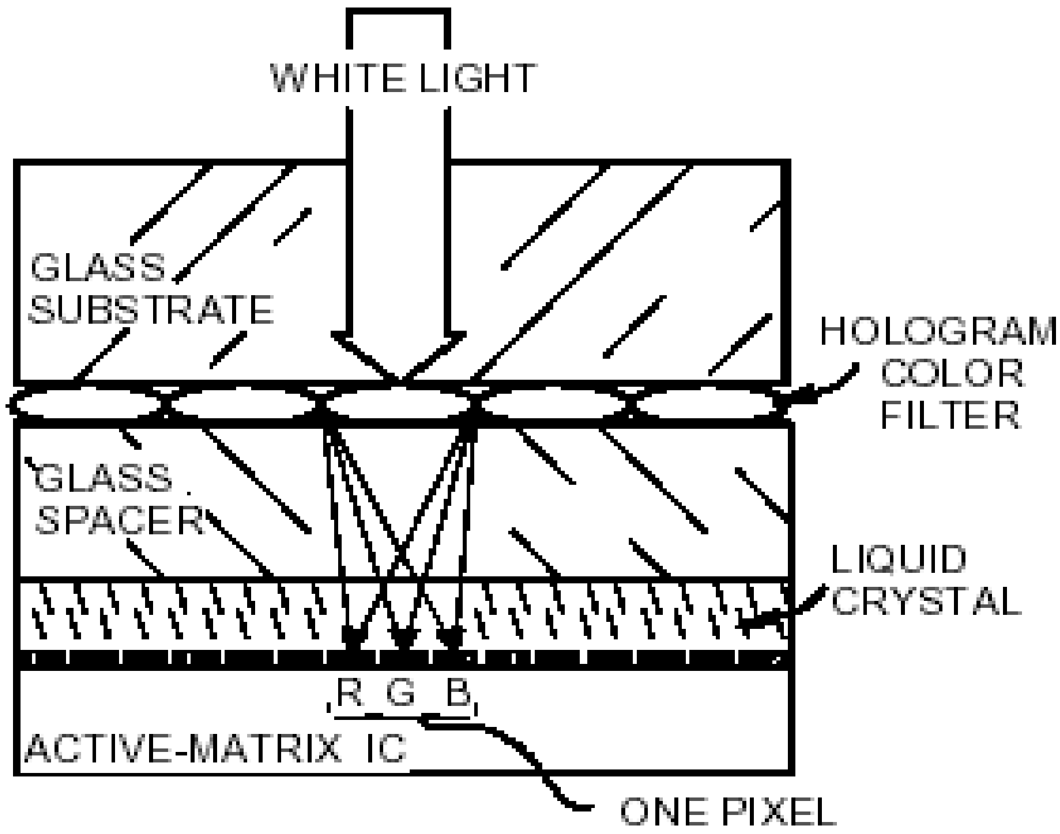
Modified Philips Prism Concept



Alternate Modified Philips Prism Concept

OCLI Modified Philips Prisms

Color Management Systems



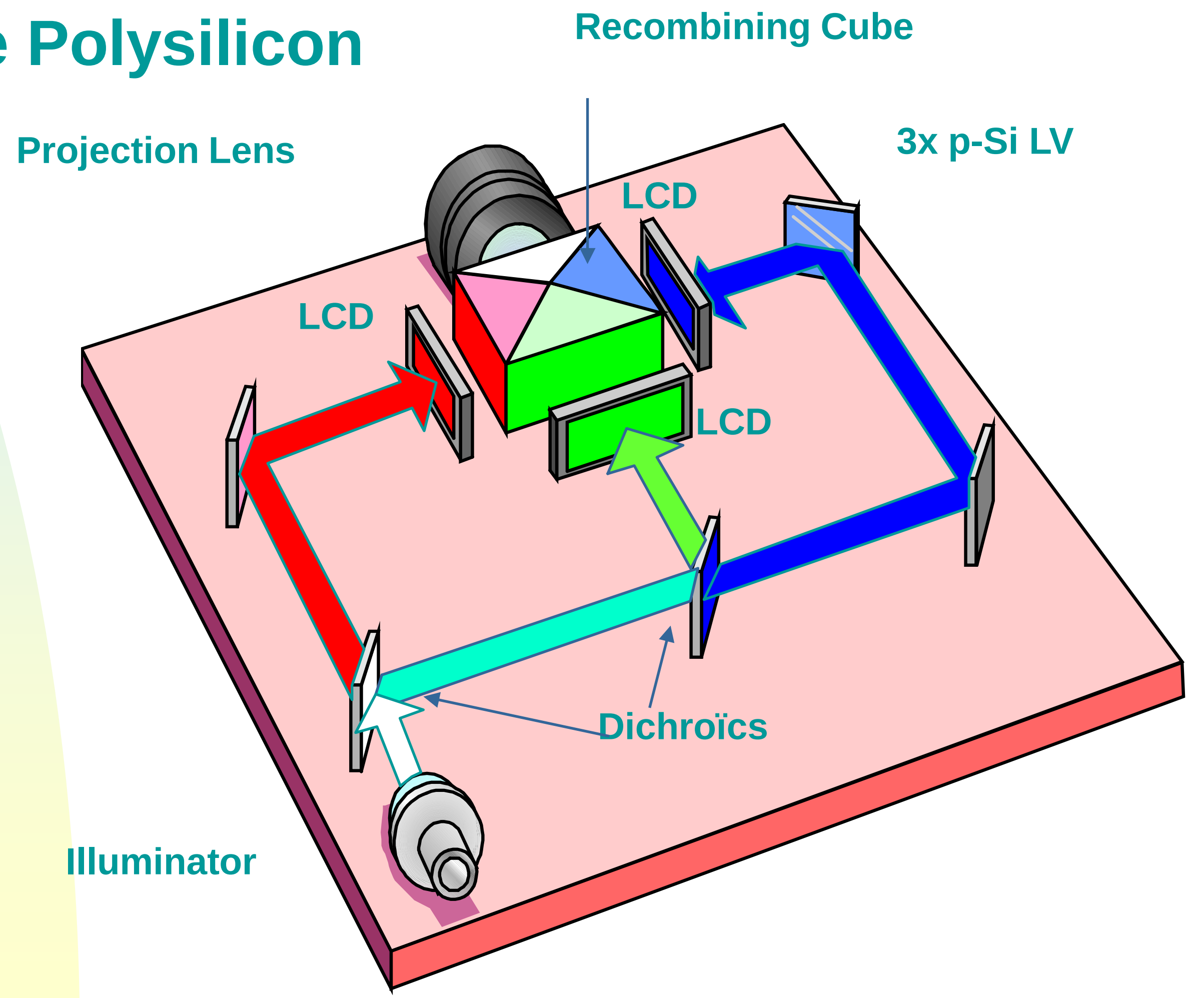
Cross Section of SD-ILA Showing Optical Function of Holographic Color Filter

JVC D-ILA Holographic Color Separator/Recombiner

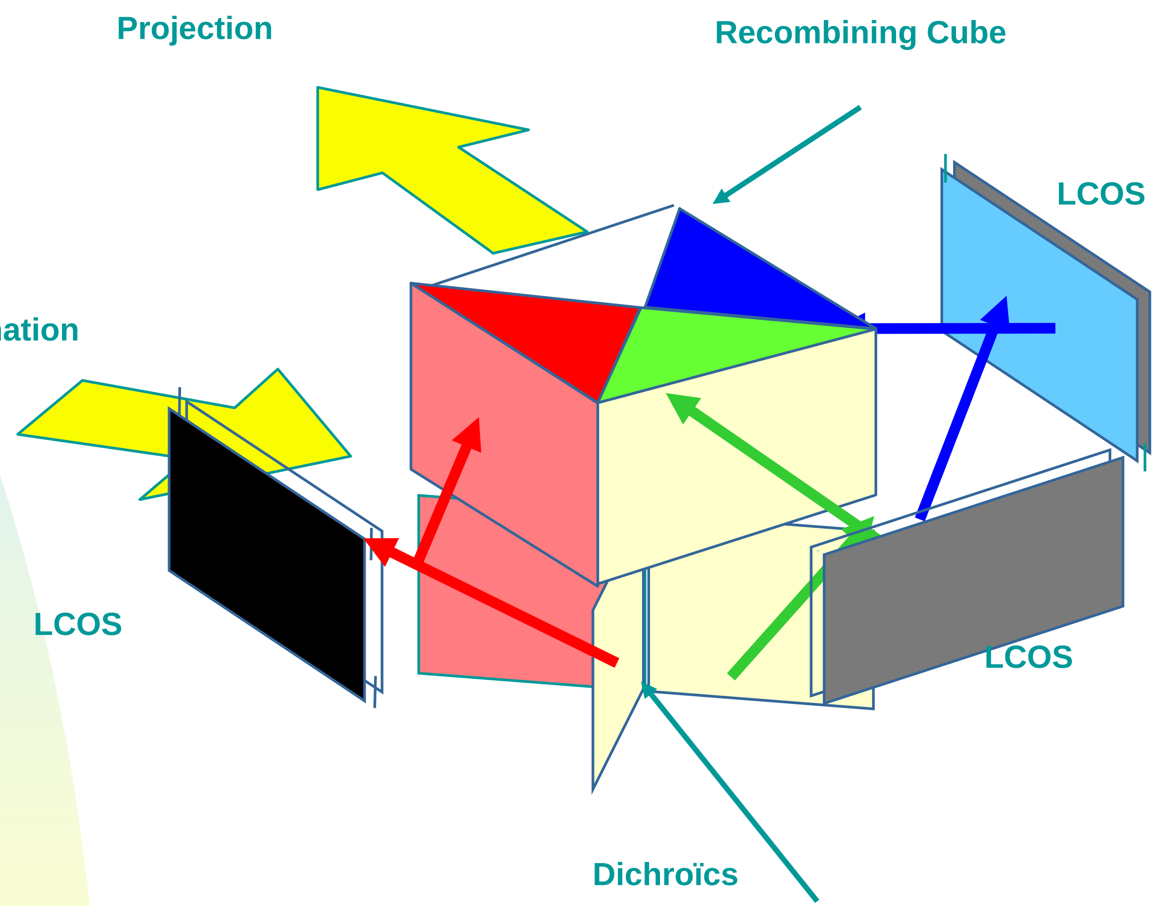
Color Management Systems

Main Stream Front ProjectorTechnology

Transmissive Polysilicon



Color Management Systems



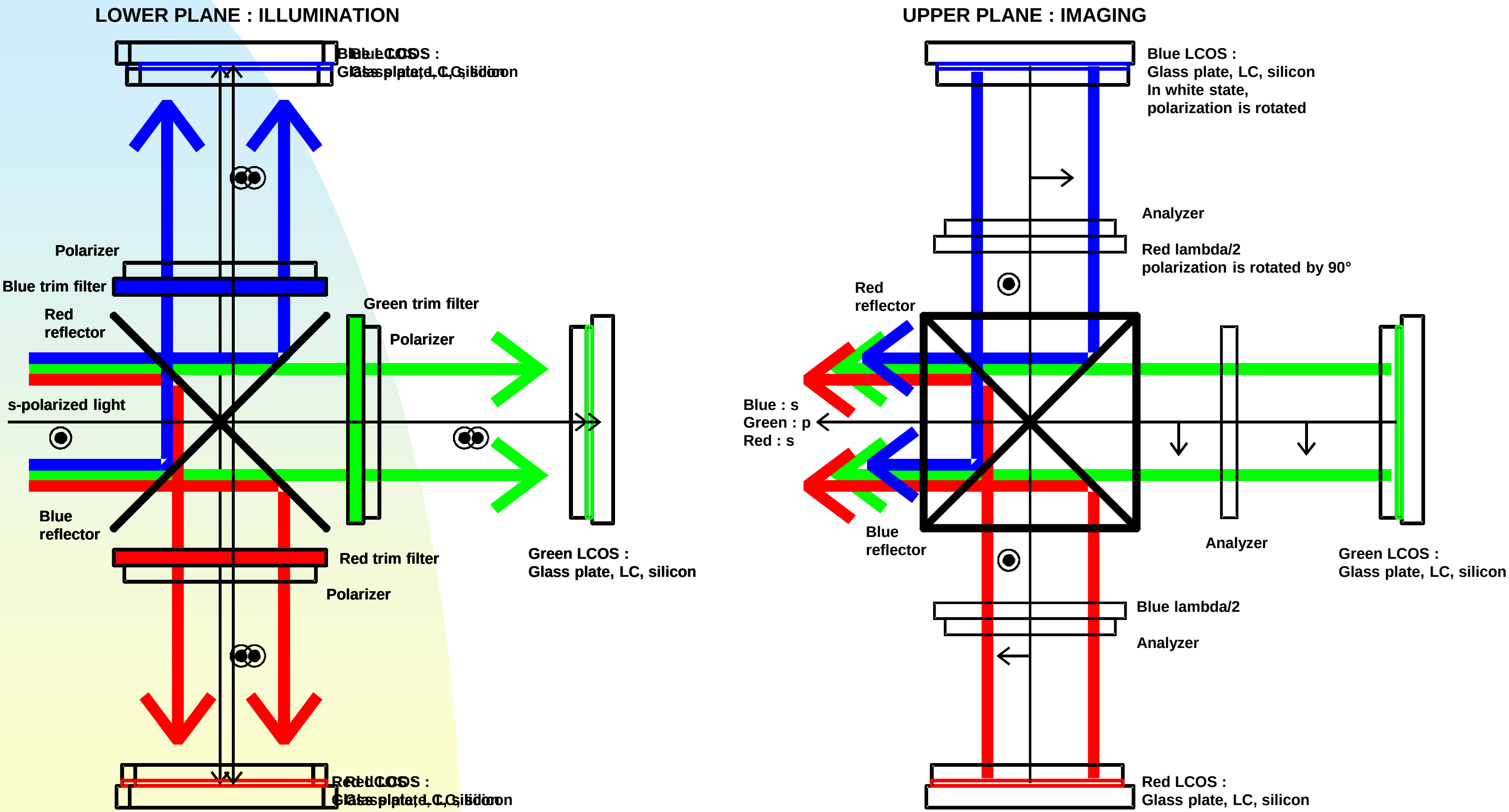
Off-Axis Architecture (NOVA)

See Appendix B for more detail

Color Management Systems

Off Axis Projector Architecture

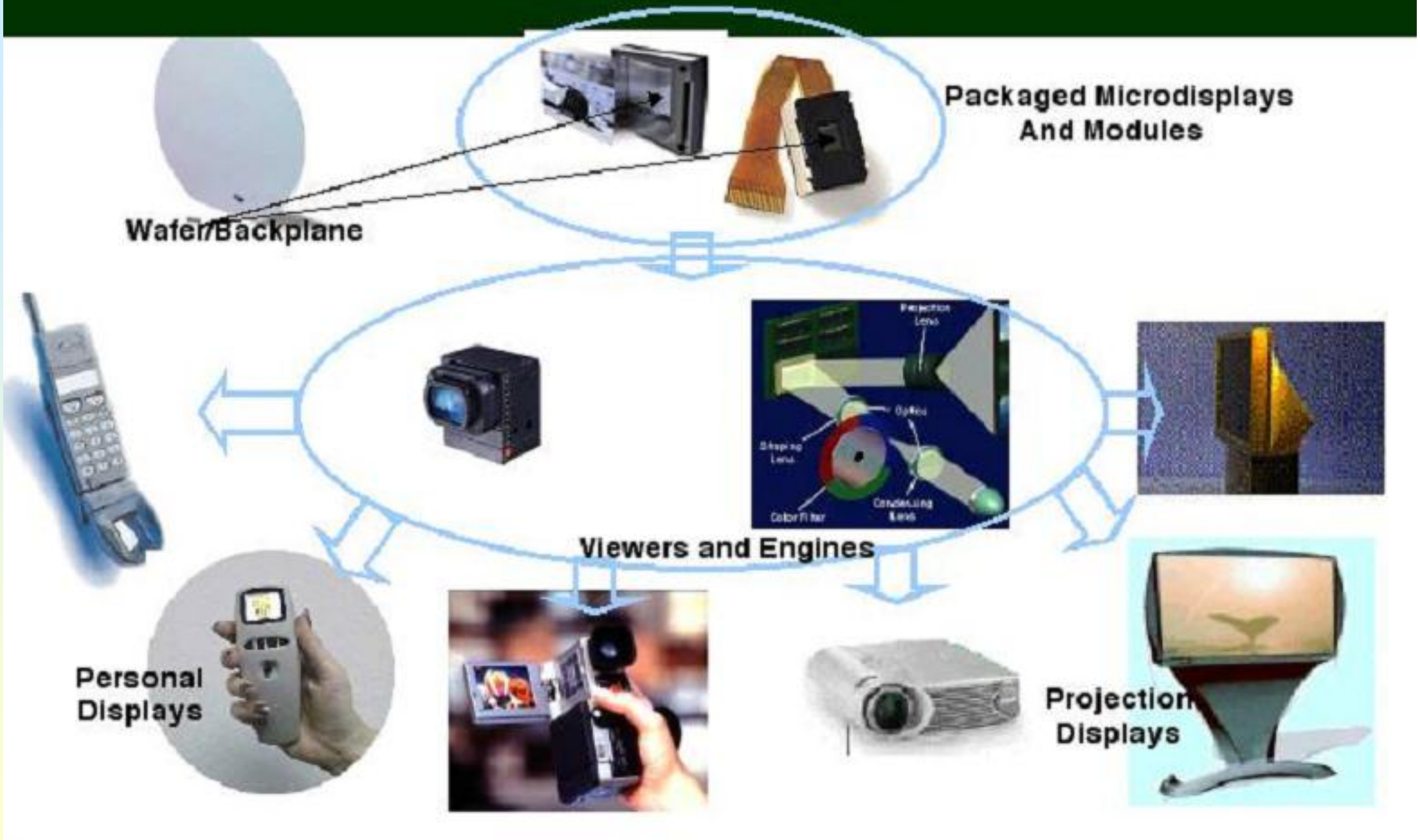
COLOR MANAGEMENT IN OFF-AXIS ARCHITECTURE



Appendix D

Market Data

Microdisplay Supply Chain

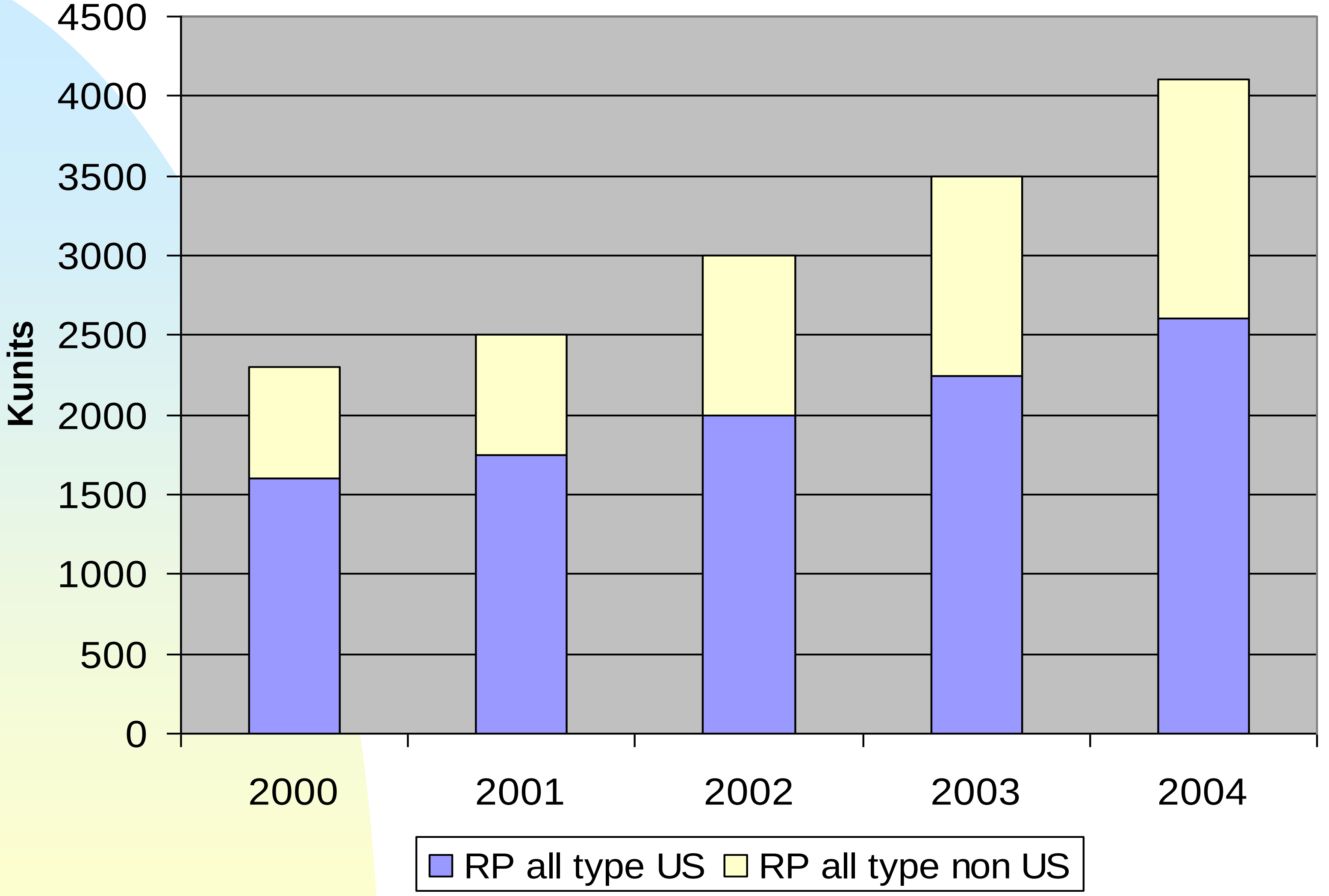


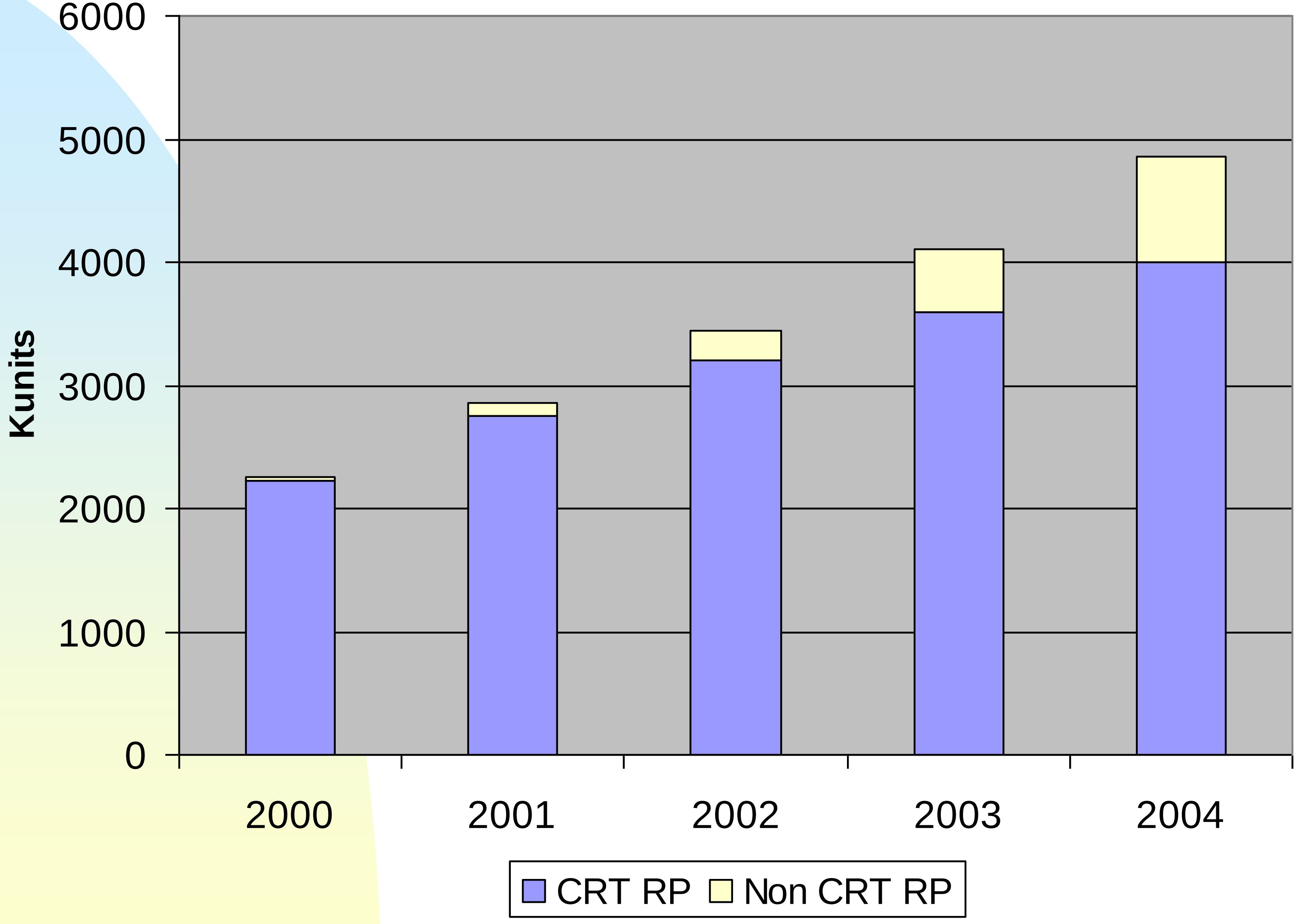
Value Chain

Terminology	Projection	Personal Display
Engine or Viewer	Imaging Module + Color separation/wheel Polarization Recovery Other optics (optional) Optical Chassis	Microdisplay Module + RGB LED lamps Magnifier Optical frame
Imaging Module	**1 to 3 Microdisplays Interface ASIC (if required) Frame Buffer (if required)**	**1 Microdisplay Interface ASIC (if required) Frame Buffer (if required)**
Microdisplay Device	Microdisplay Packaged and tested Flex print (if required)	Microdisplay Packaged and tested Flex print (if required)

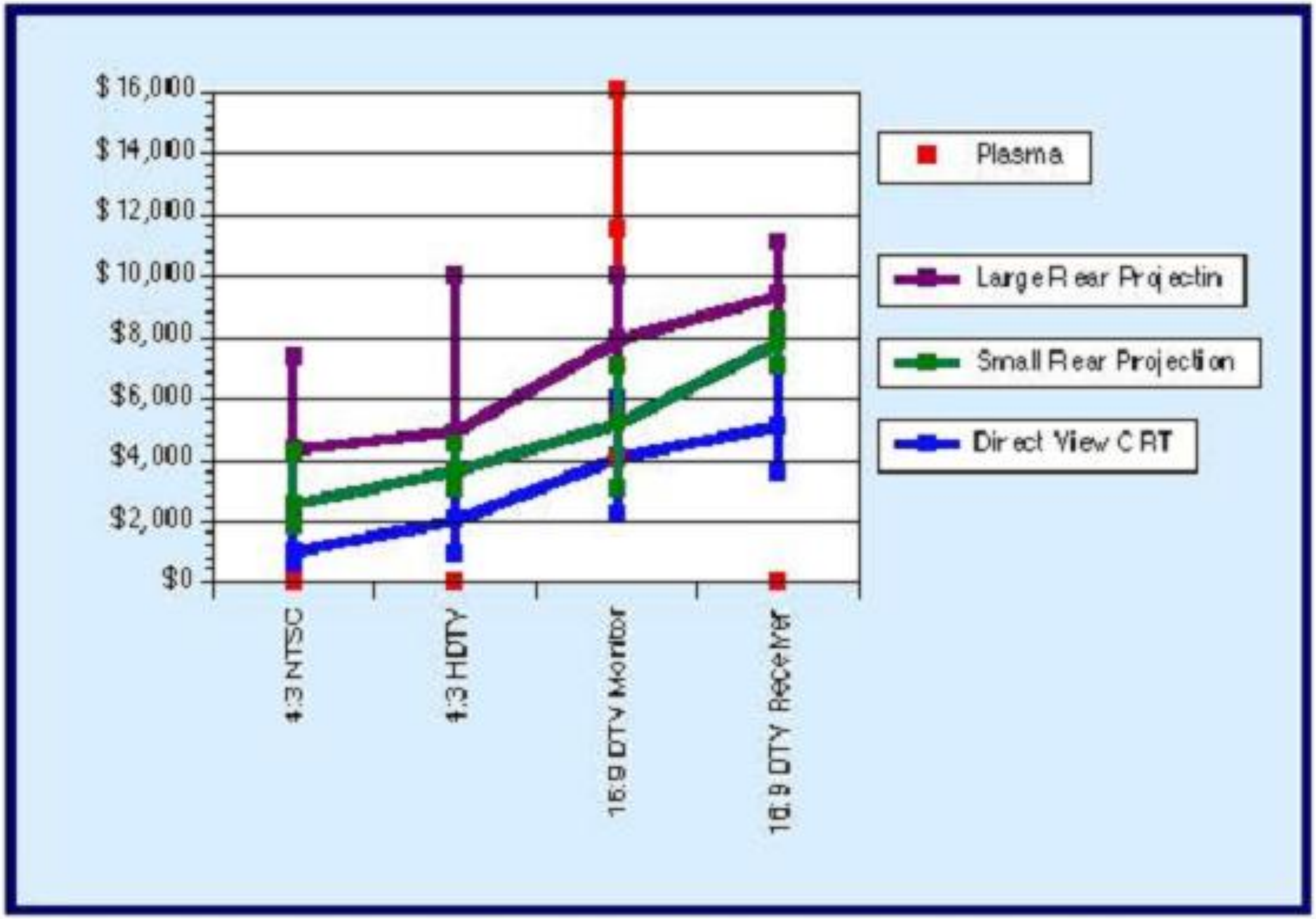
Overview of Rear Projection Opportunities

	Big Screen TV	Performance TV	Performance PC Monitor	Electronic Desk
Incumbent	RP CRT	DV CRT≥32"	DV CRT≥21"	New Market
Leading Challenger	Plasma	AMLCD	AMLCD≥17"	na
2005 Market Size (million units)	6.0	12.0	25.0	unknown
2005 Revenue (billion)	$15.2	$11.2	$25.0	na
Target Microdisplay System Performance				
Definition/Size	HDTV 720 60 Inch	HDTV 720 36 Inch	UXGA/HDTV 20 Inch	3600 x 2400 20-30 Inch
Lumens	>1000	500	200	400
Other	16:9	16:9	16:9;	3:2
System Price	$3,000	$1,450	$1,500	$5,000
Module Price	$500	$300	$400	$550
Features	Brightness Viewing angle Price Thin/light	Price Thin/light	Price Thin/light	150-200 dpi Bright Pixel Count

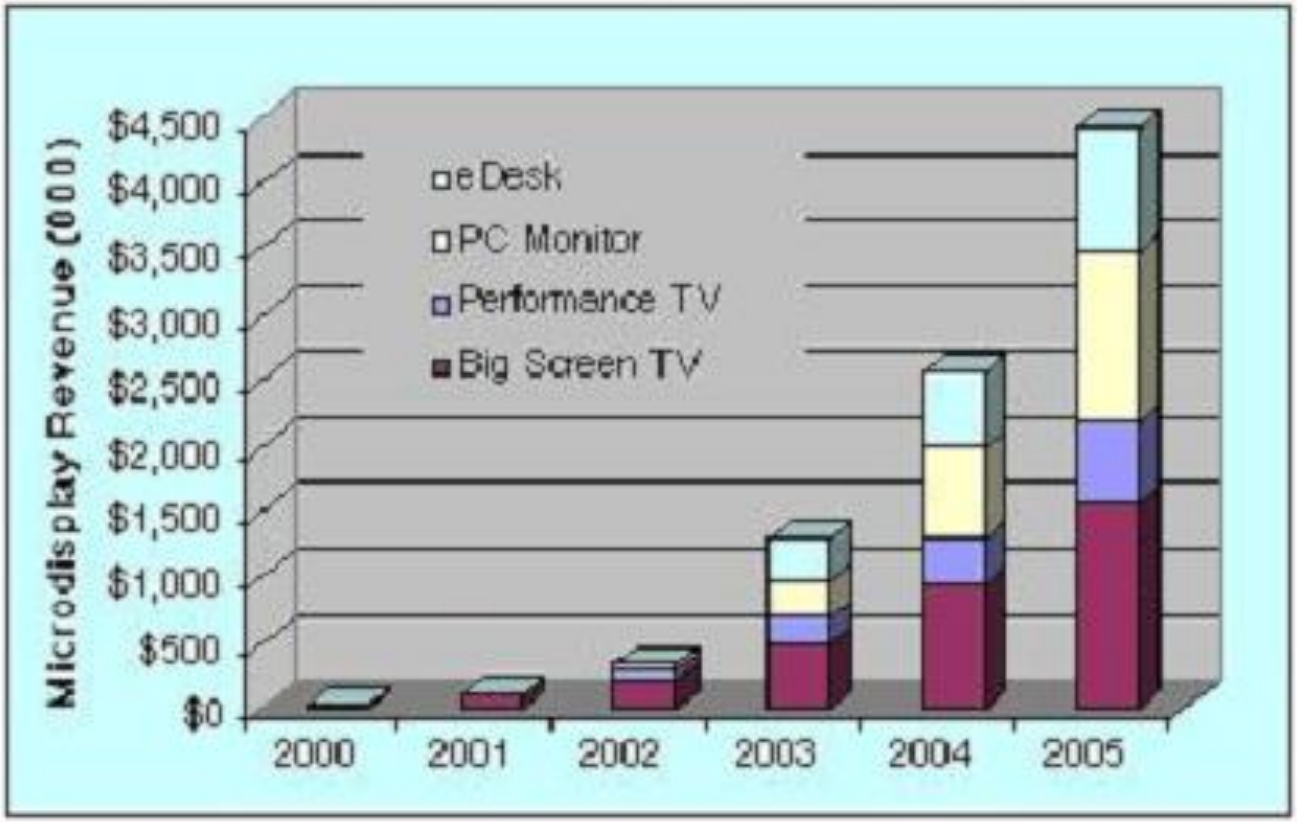

Kunits
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2000
2001
2002
2003
2004
RP all type US
RP all type non US

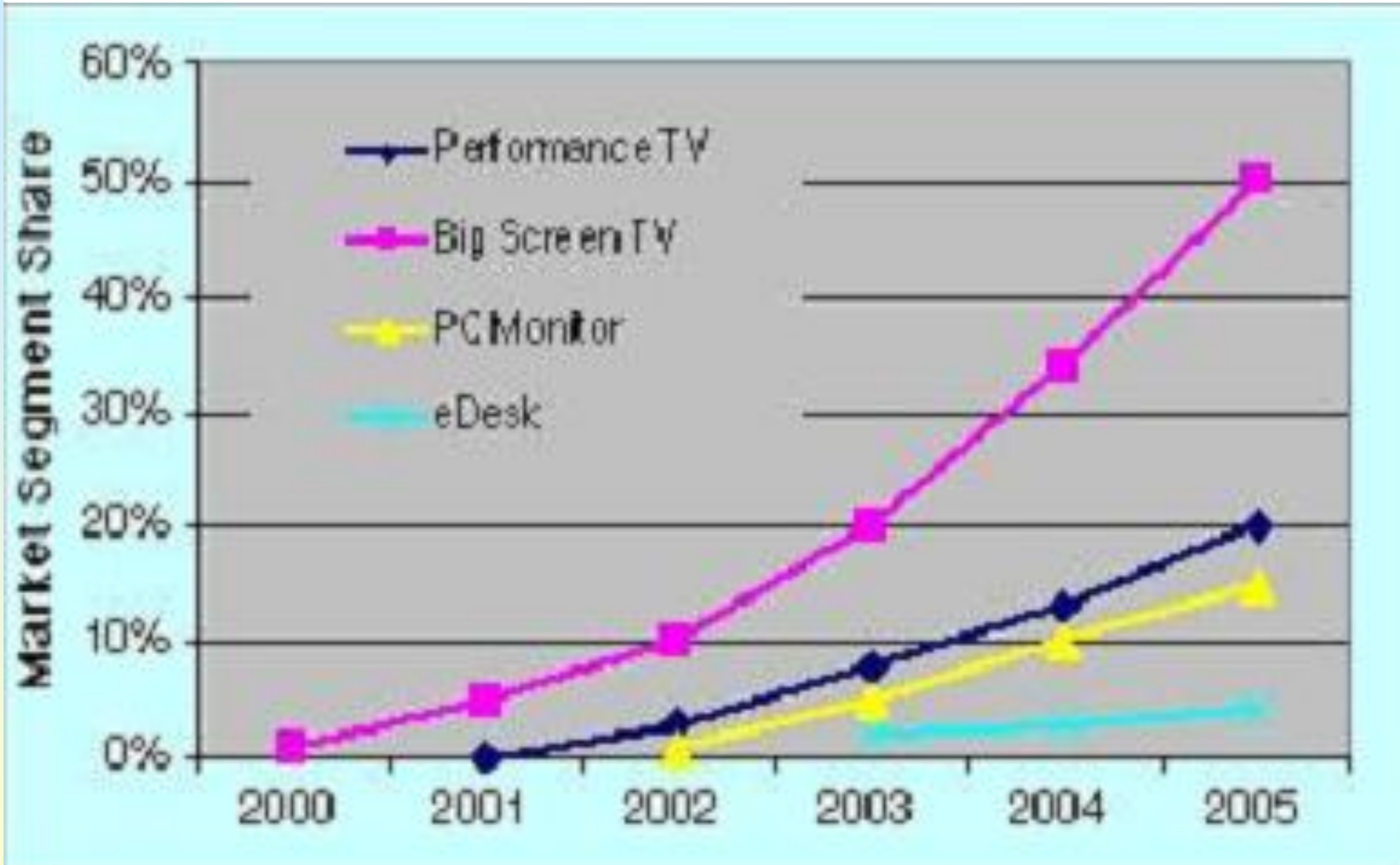

6000
5000
4000
3000
2000
1000
0
Kunits
2000
2001
2002
2003
2004
CRT RP
Non CRT RP

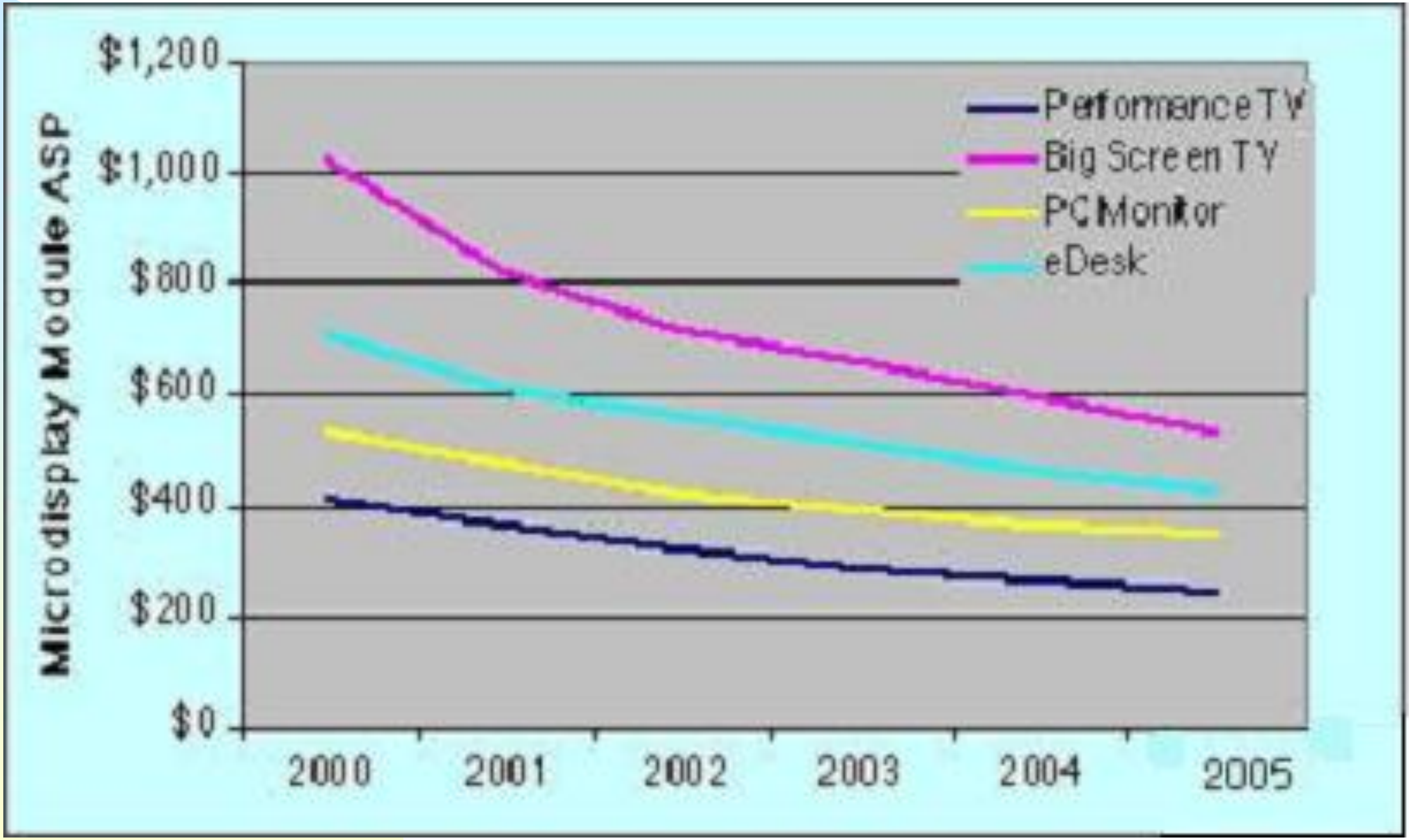
Current DTV Prices



Microdisplay Forecast Rear Projection Displays

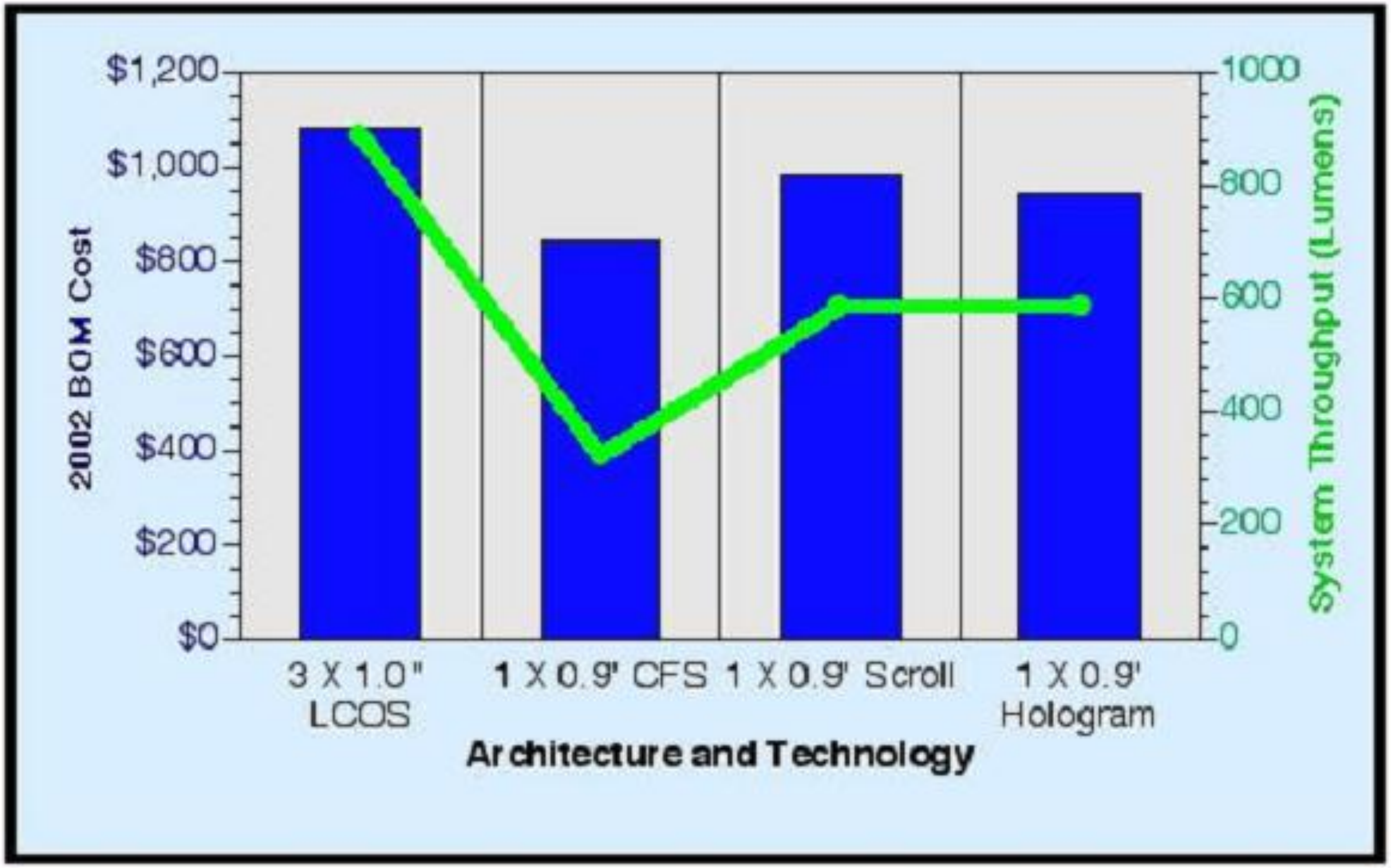



Market Segment Share
60%
50%
40%
30%
20%
10%
0%
Performance TV
Big Screen TV
PC Monitor
eDesk
2000
2001
2002
2003
2004
2005



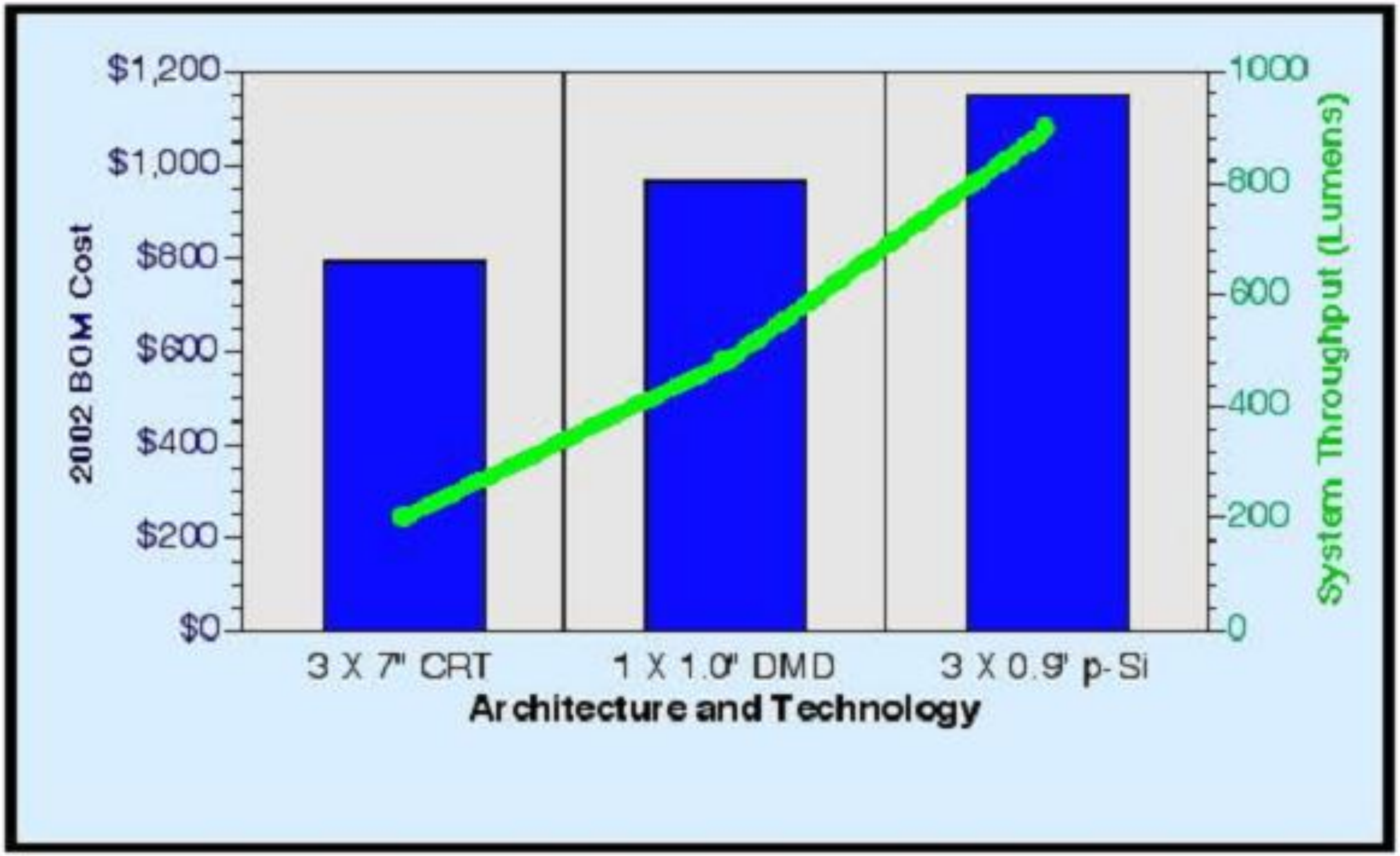
Microdisplay Module ASP
$1,200
$1,000
$800
$600
$400
$200
$0
2000
2001
2002
2003
2004
2005
Performance TV
Big Screen TV
PC Monitor
eDesk

Comparison of LCOS Architectures



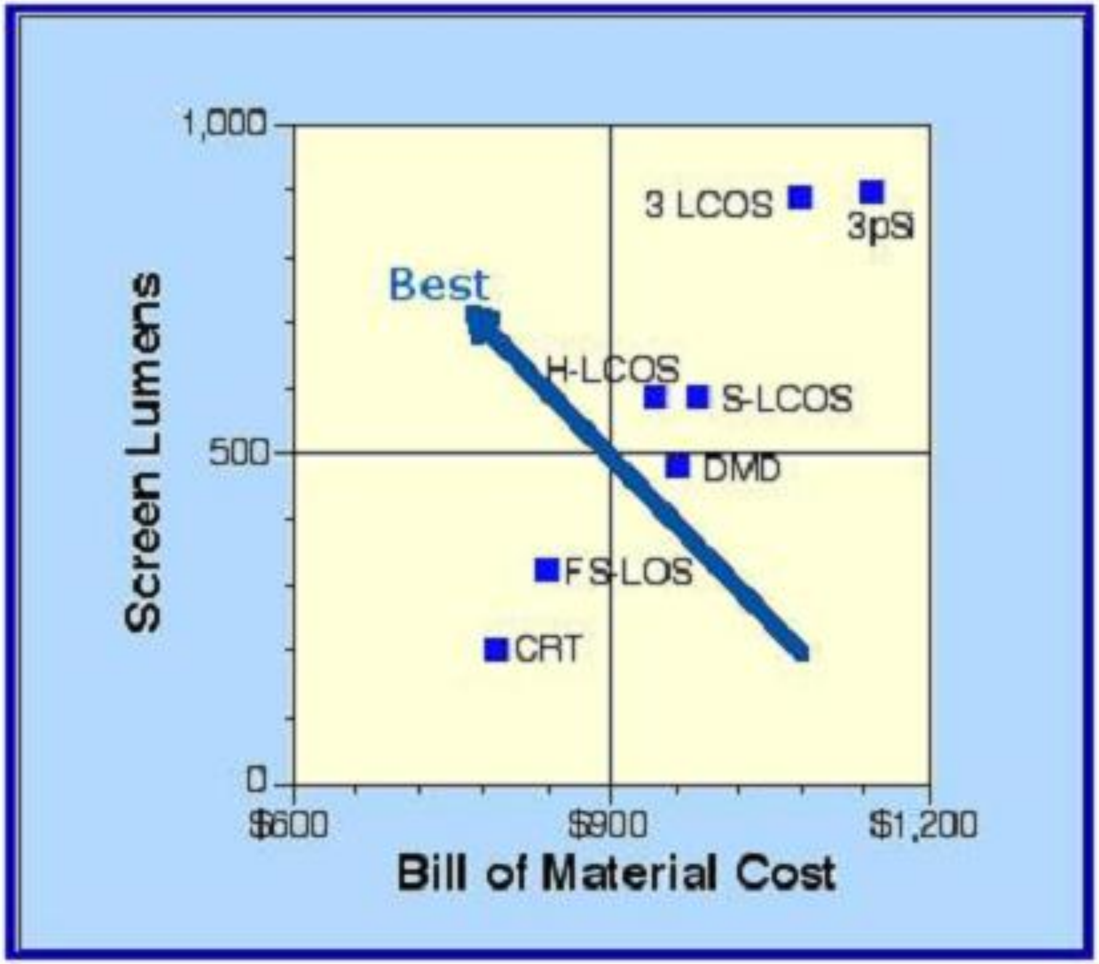
Basis: 120W HPM lamp, 2002 projected costs, 10K units/month

Costs and Throughput



Basis: 120W HPM lamp, 2002 projected costs, 10K units/month

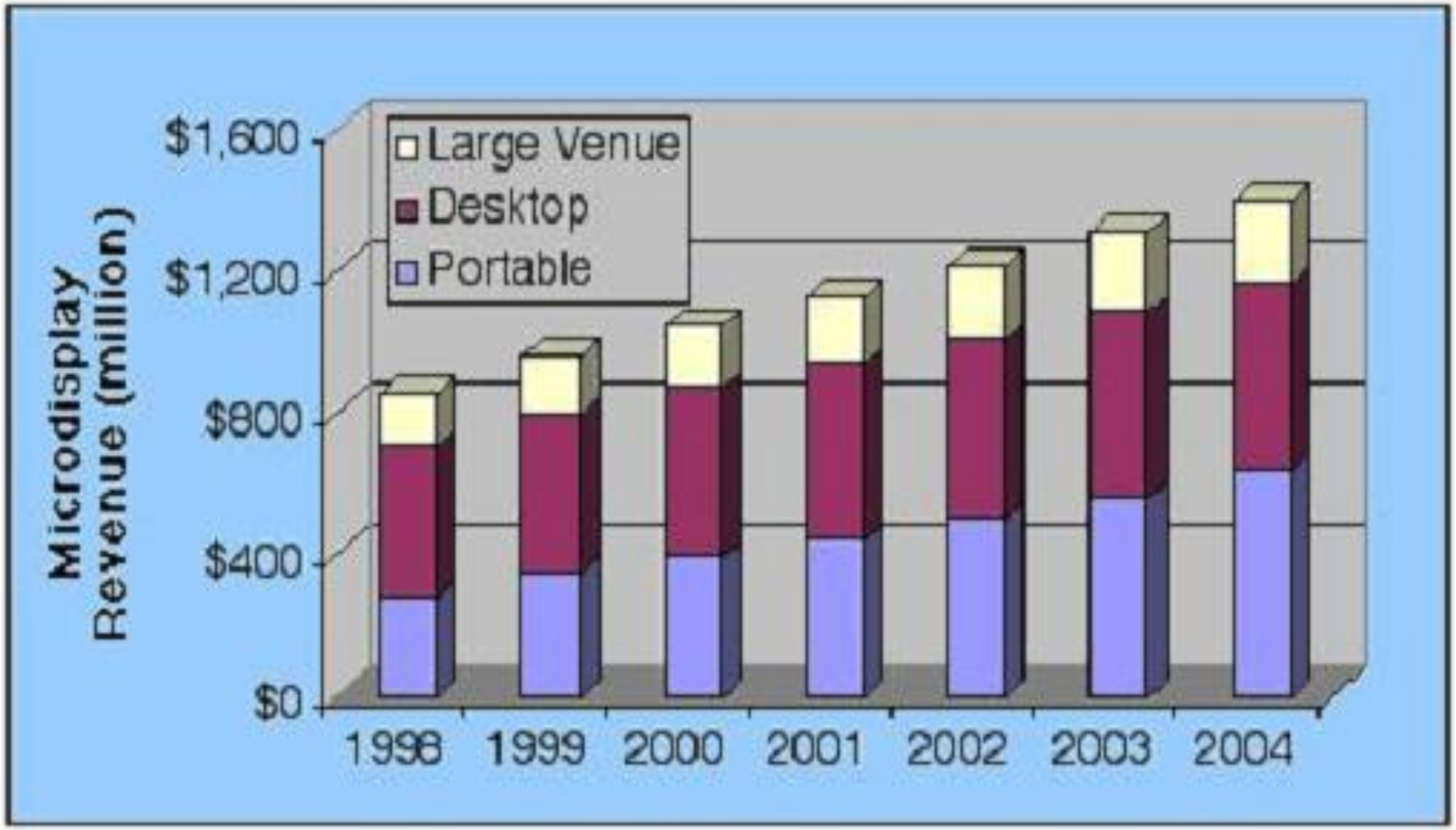
Comparison of Technologies

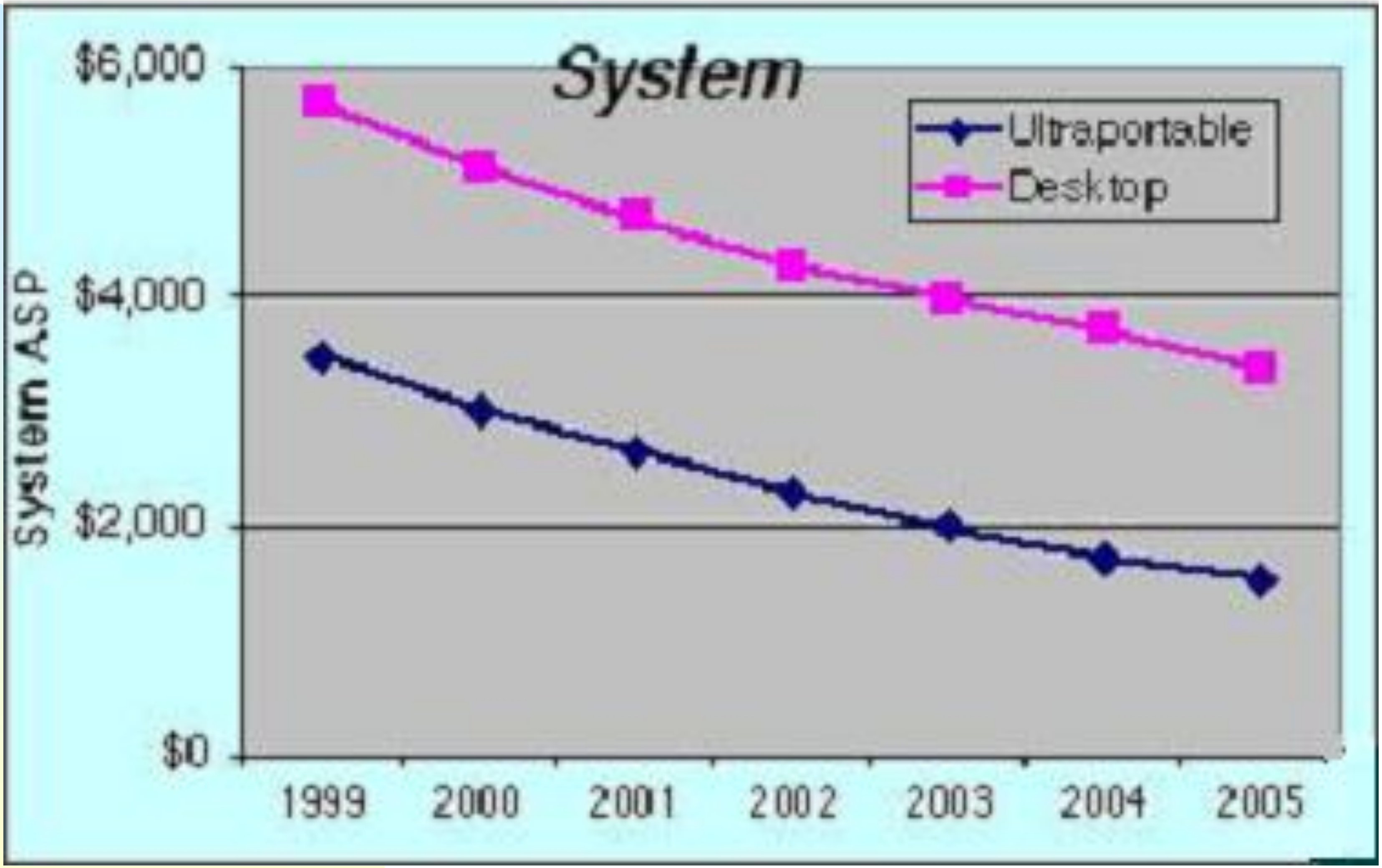


Presentation Market Progress

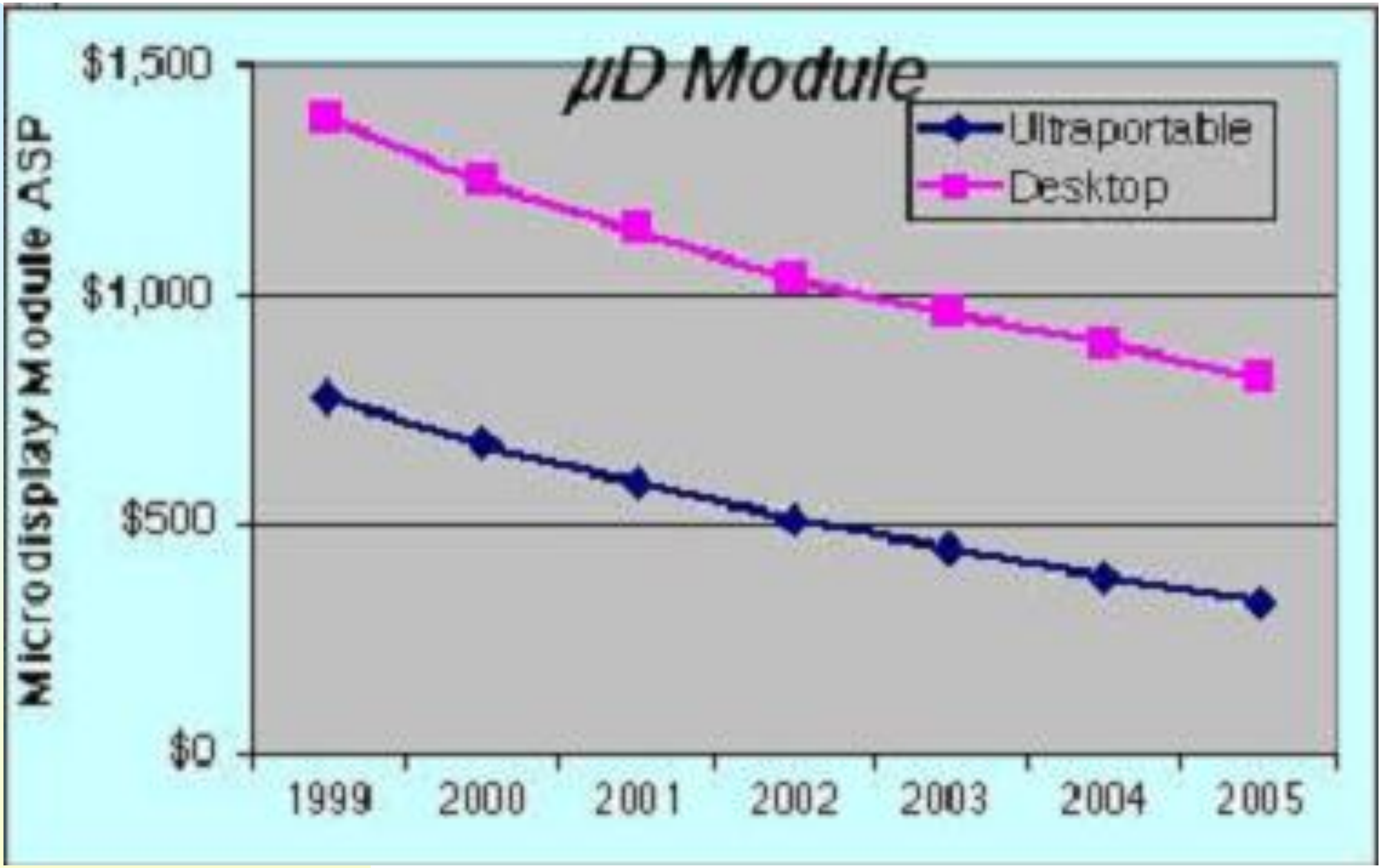
	1990	1995	2000
Value System Specifications			
Definition/Size	VGA	VGA	SVGA
Lumens	200	400	800
Other	<20 pounds	<15 pounds	<4 lbs
Incumbent	AMLCD Flat Panel/ OHP	3 x 1.3 p-Si	1 x DMD 3 x 0.7 p-Si
System Street Price	$5,000	$4,000	$3,000
Imaging Module Price	$2000	$1000	$700
System Shipments	40,000	200,000	1,000,000

Front Projection Module Revenue

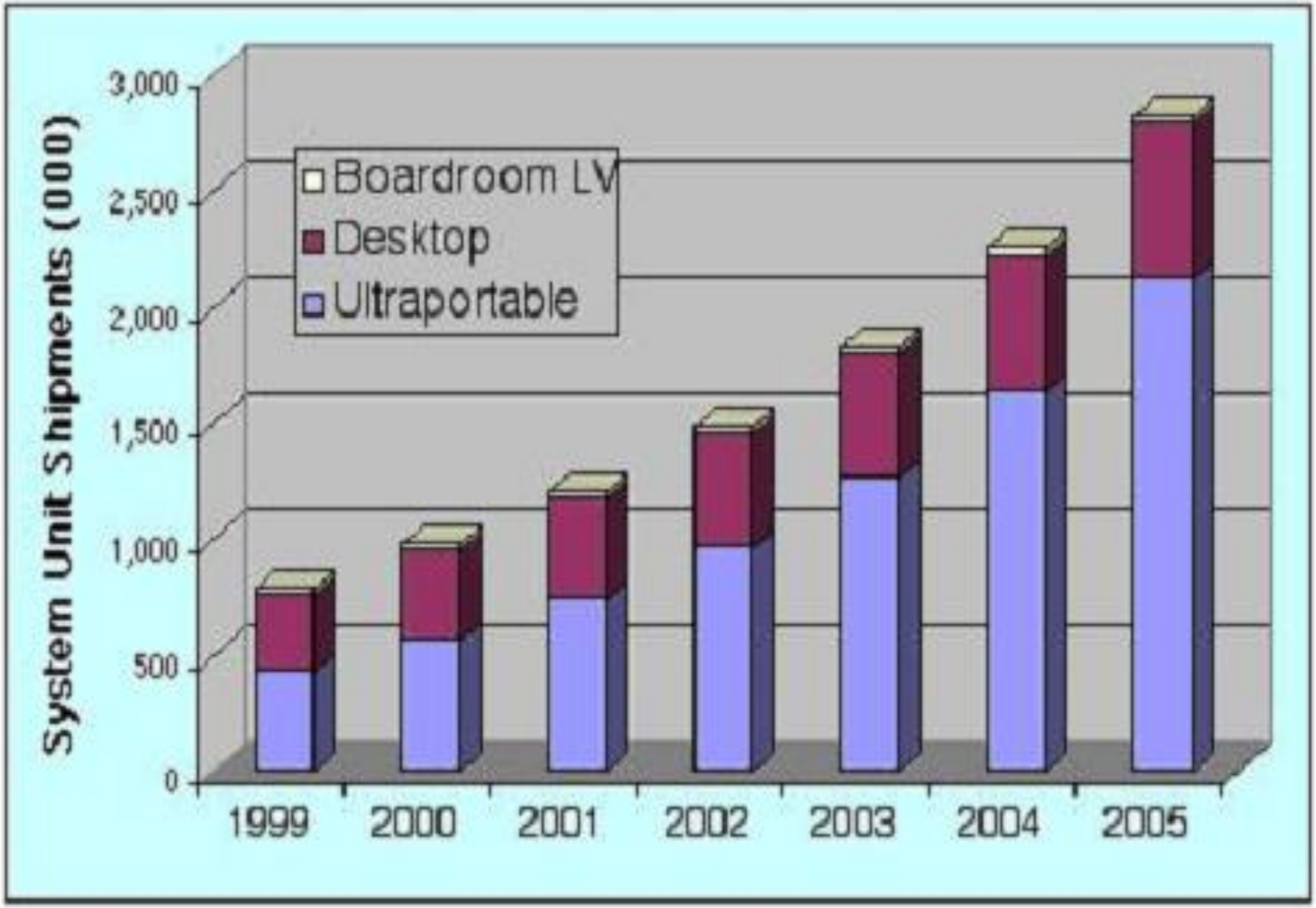




System
System ASP
$6,000
$4,000
$2,000
$0
1999
2000
2001
2002
2003
2004
2005
Ultraportable
Desktop



μD Module
Microdisplay Module ASP
$1,500
$1,000
$500
$0
Ultraportable
Desktop
1999
2000
2001
2002
2003
2004
2005


Boardroom LV
Desktop
Ultraportable
System Unit Shipments (000)
3,000
2,500
2,000
1,500
1,000
500
0
1999
2000
2001
2002
2003
2004
2005

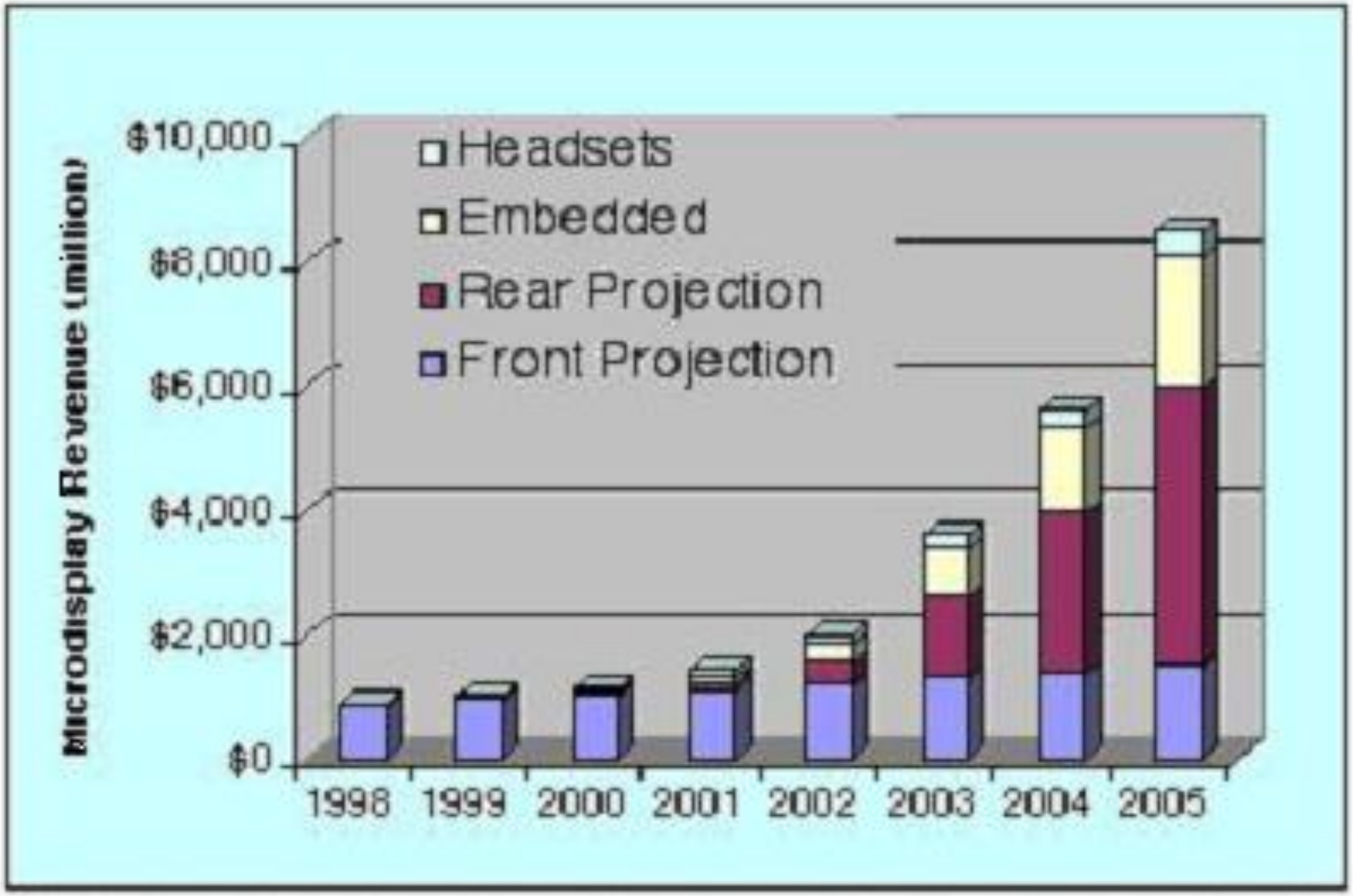
Viewfinder Market Progress

	1990	1995	2000
Value System Specifications			
Definition/Size	220 line NTSC	Q-NTSC	QVGA
Color	Monochrome	Color	Monochrome
Incumbent	1 inch CRT	0.4 inch poly-silicon	1 x poly-silicon 1 x LCOS
Imaging Module Price	$20.00	$25.00	$12.00
Camcorder Shipments	7 million	9 million	11 million
Microdisplay Penetration	nil	15%	40%
Digicam Shipments	nil	1 million	9.4 million
Microdisplay Penetration		nil	5%

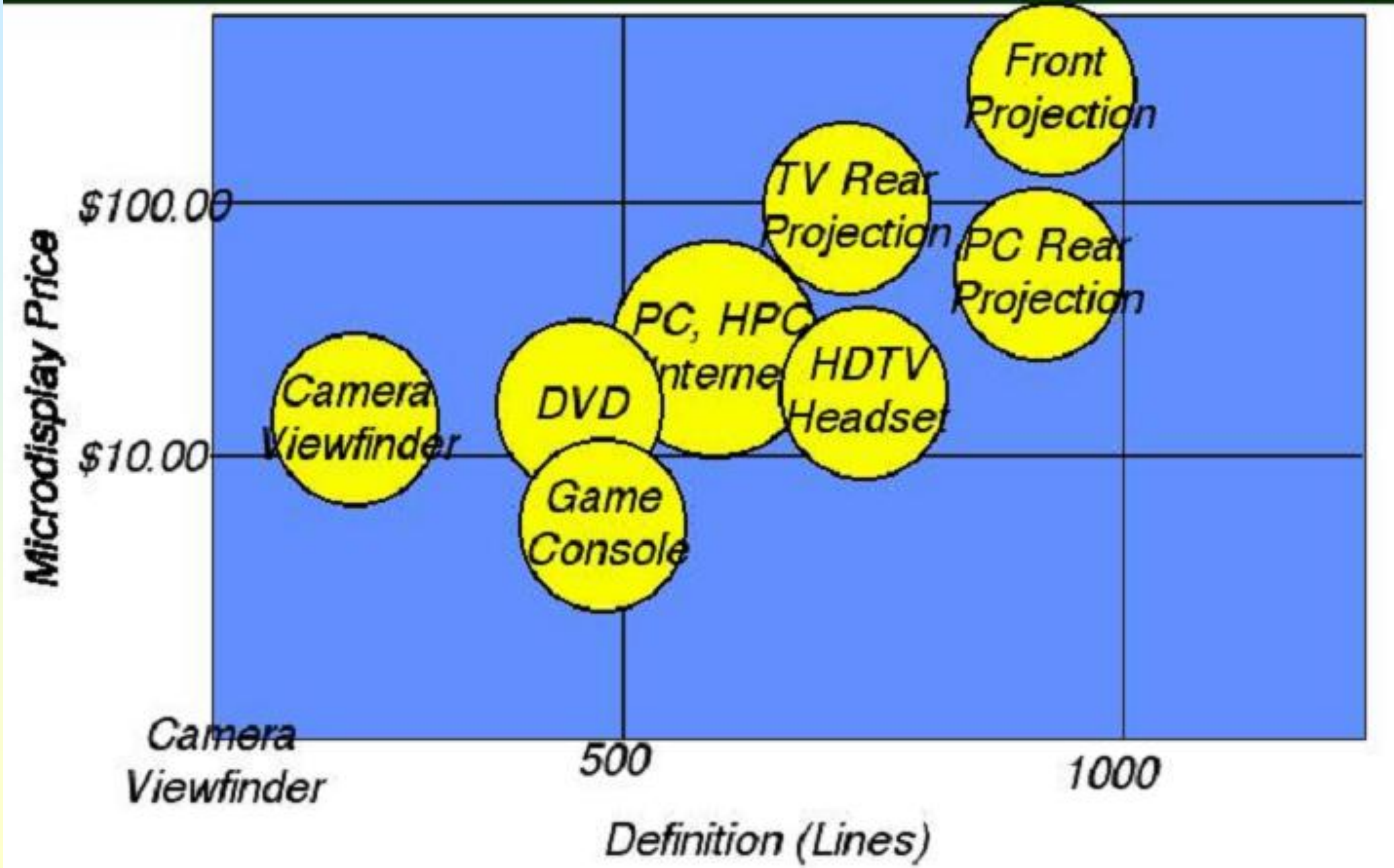
Overview of Near Eye Opportunities

	Cellphone/ Internet Appliance	PC, HPC, Vertical Markets	Portable DVD Game Consoles	HDTV Headsets
Target Performance				
Definition	VGA-XGA	SVGA-XGA	SDTV	HDTV 720
Color Bits	3	3-6	3-6	6
Power	<<100mW	Tethered	<<100mW	Tethered
Headset Street Price	na	$300	$150	$400
Target Microdisplay Price	$25	$20	$15	$40
2005 TAM				
Potential Units (million)	50 to 100	1 to 3	5 to 10	1 to 2
Potential microdisplay Revenue (million)	>$1,000	>$100	>$100	$100

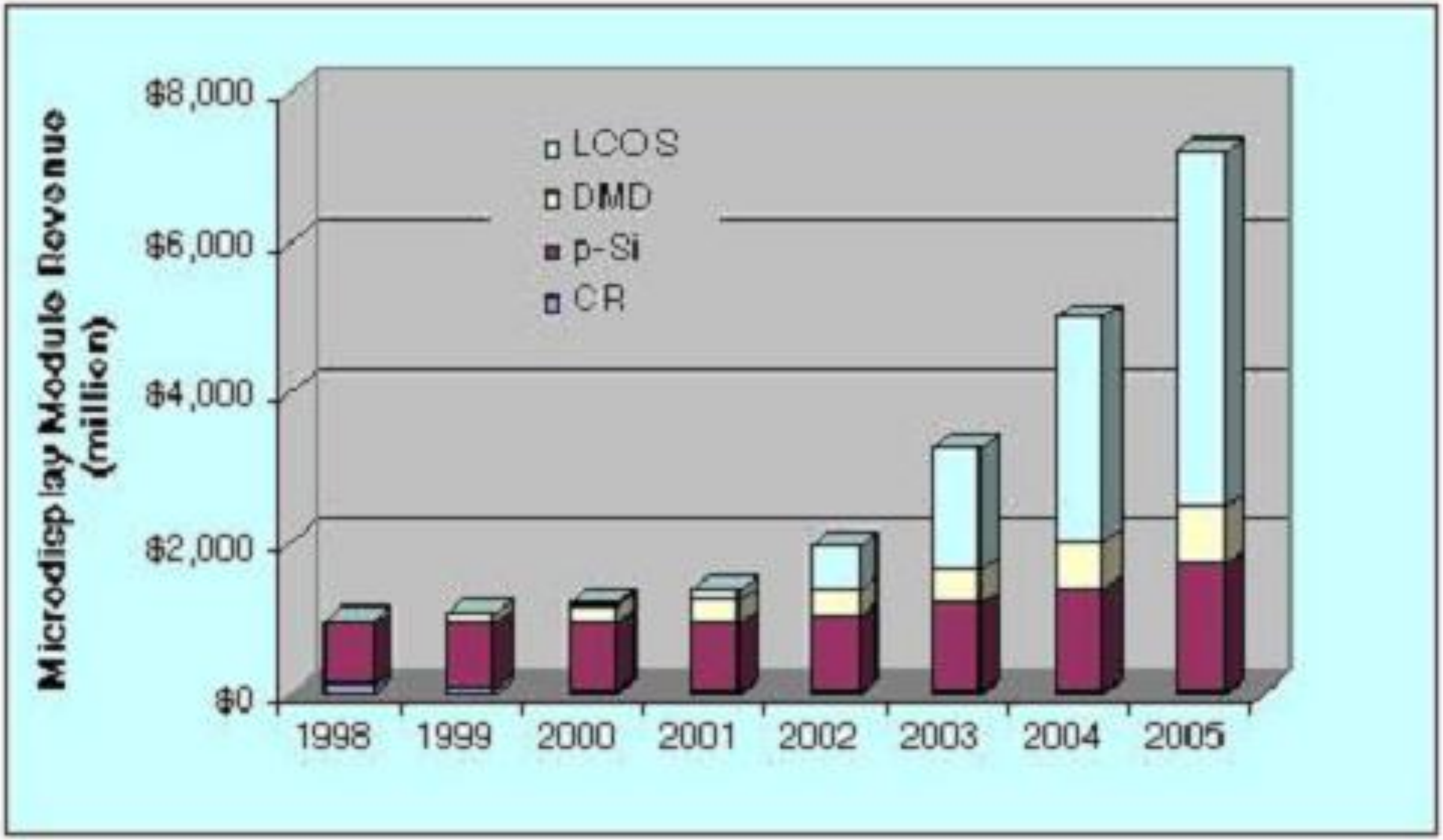
Total Available Market



Microdisplay Pricing Space



Revenue by Technology



Projected microdisplay shipments and wafer consumption

Segment	2000	2001	2002	2003	2004
	Microdisplay units (000)				
Front projection	1818	2180	2600	3086	3665
Rear projection	47	316	1926	6538	13,277
Embedded	9016	12,228	19,498	32,998	47,137
Headsets	727	1636	5316	9425	14,888
Total	**11,608**	**16,361**	**29,339**	**52,047**	**78,968**
Total wafers/month	**5915**	**8090**	**14,597**	**28,888**	**48,219**

Source: MCG Consulting (www.mcgweb.com)

Appendix E

TV
Display Performance Expectations

Display Performance Expectations

Light output

For the purposes of comparison, a 50W (16:9) screen size is used. Light output should be measured using a narrow angle (1 degree) luminance probe. The light output should be measured in the center of the screen, at maximum of the viewing envelope. The standard screen to be used will be selected by System Mfg. It can be assumed to have a gain of 6 minimum, with a viewing envelope typical for current consumer products. The engine should be expected to produce 160 Ft-Lamberts under these conditions. This will require at least 600 ANSI lumens of illumination on the back of the screen (given specific assumptions about screen characteristics).

Display Performance Expectations

Contrast Ratio

The system contrast ratio (including the screen, mirrors and cabinet) should exceed 150:1. Ambient light will be below 10 nits. The contrast ratio is the ratio of the peak light output from a small (<1% of screen area) white block, divided by the average of the measured light from the four adjacent areas to the illuminated box. This should exceed 150:1.

Display Performance Expectations

Color Rendition

It is expected that 16 million colors (8 bits per color) will be required. It may be desirable to have more resolution than this in order to achieve good performance in near-black scenes. This will be determined by subjective picture evaluation.

Color Temperature

The target white color temperature should be 6500K or higher. For CRT-based systems the current specification is 7500K (CIE x=. 301, y=. 310), with a 'Cool' option of 9300K (CIE x=. 285, y=. 295).

Display Performance Expectations

White Uniformity

Brightness at the center of the screen is measured as in 1.1. Corner brightness measured in the same manner shall be not less than 30% of the center.

Color Purity

Using 50% amplitude full-field white signal, no area of the screen should be more than two Minimum Perceptible Color Differences (CIE system) from the center of the screen.

Display Performance Expectations

Geometric Distortion

Overall picture distortion shall not exceed 2%. This will include trapezoid, pincushion, and parallelogram distortions.

Convergence

A convergence alignment to within one pixel should be achieved. This should be maintained over the entire screen. This alignment should be maintained under normal shipping conditions per the NSTB conditions.

Display Performance Expectations

Pixel Defects

No pixel defect should exceed the size of one pixel. Allowable defects are dependent on location and color. The display area shall be divided in to two viewing zones.

Zone A is a rectangle that is half the viewable height by half the viewable width, centered in the screen. In this area a maximum of one defect in each color is allowed.

Zone B is the rest of the viewable display area. Red and Green are allowed a maximum of 2 defects, with no adjacent cells being off. Blue is allowed a maximum of 4 pixel defects, with no adjacent pixels being defective.

Gray is the preferred color for stuck pixels. Defects smaller than 0.1 pixels are ignored. The largest dimension of the defect is used to judge its size.