

High-Capacity Optical Storage: Will blue laser or holographic storage be the solution?



***Optical Storage Symposium 2007
9/19/2007 ~ 2:00pm - 3:15pm***

Moderator: Michael Johnson ~ Director BusDev, CUC Broadcast

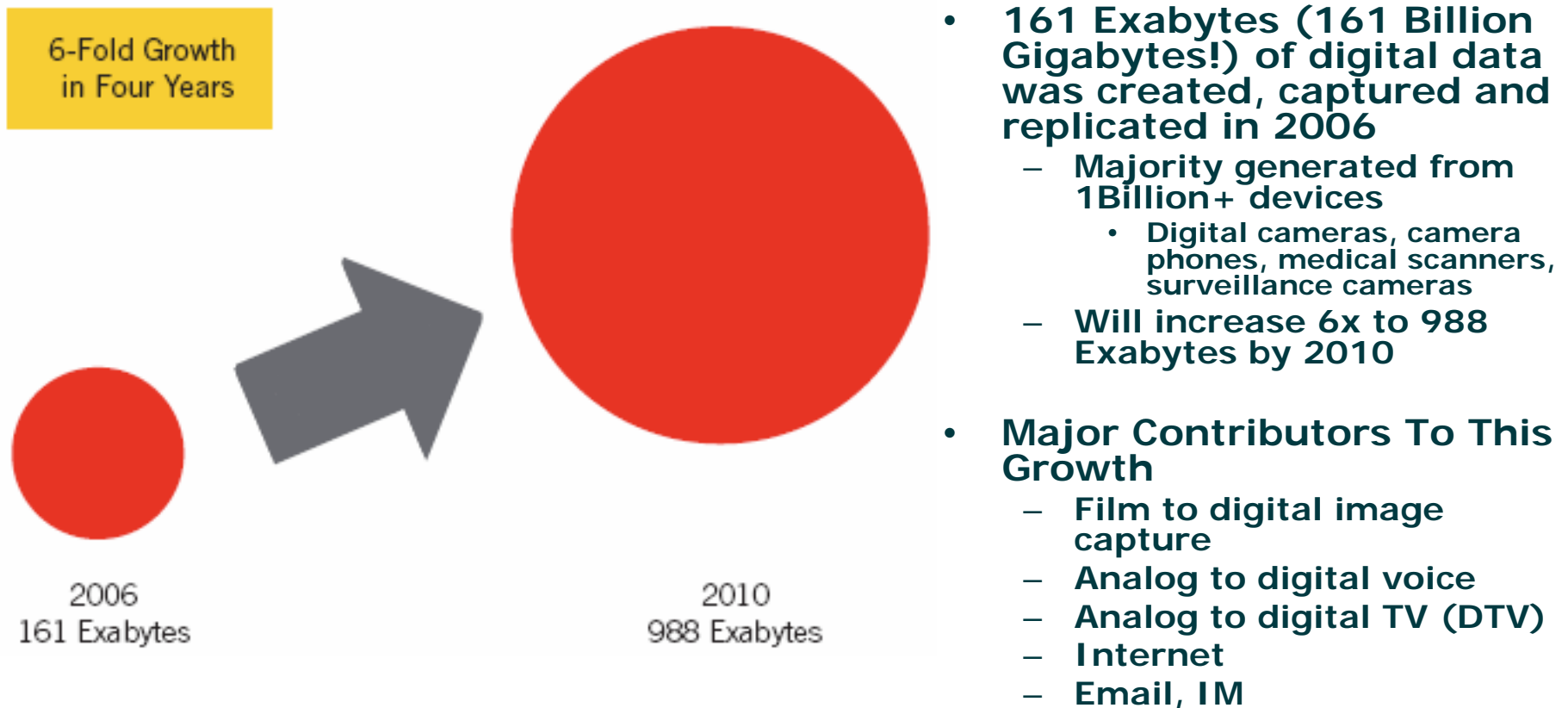
***Panel: Graham Irving, Director, K-PAR Archiving Software
Andy Richards, VP of BusDev, Plasmon Data
Horst Schellong, President, DISC Storage, LLC.***

High-Capacity Optical Storage

- **Market Drivers**
- **Market Review**
- **Technology Review**
- **Product Review**
- **Panel Review**
- **Q&A**

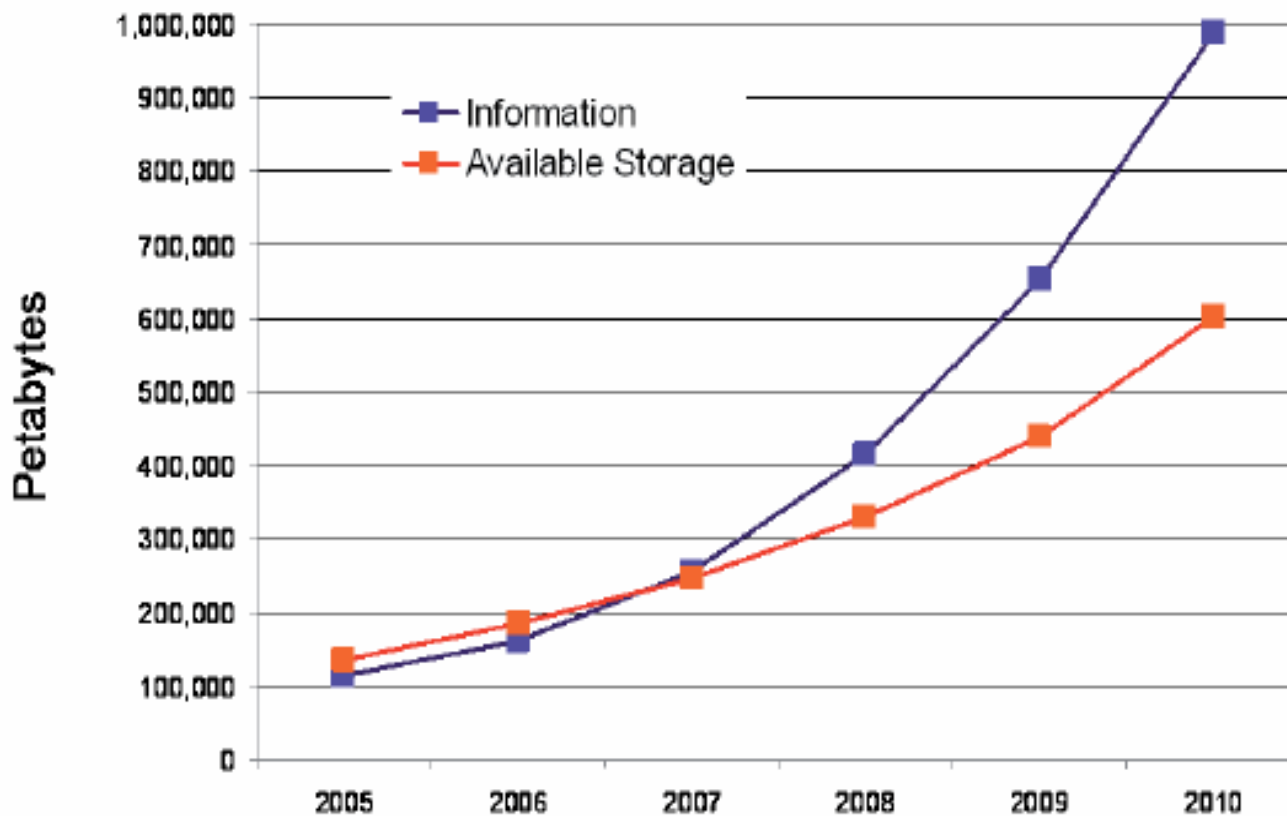


Market Drivers ~ Information Created, Captured, Replicated in 2006



Source: IDC

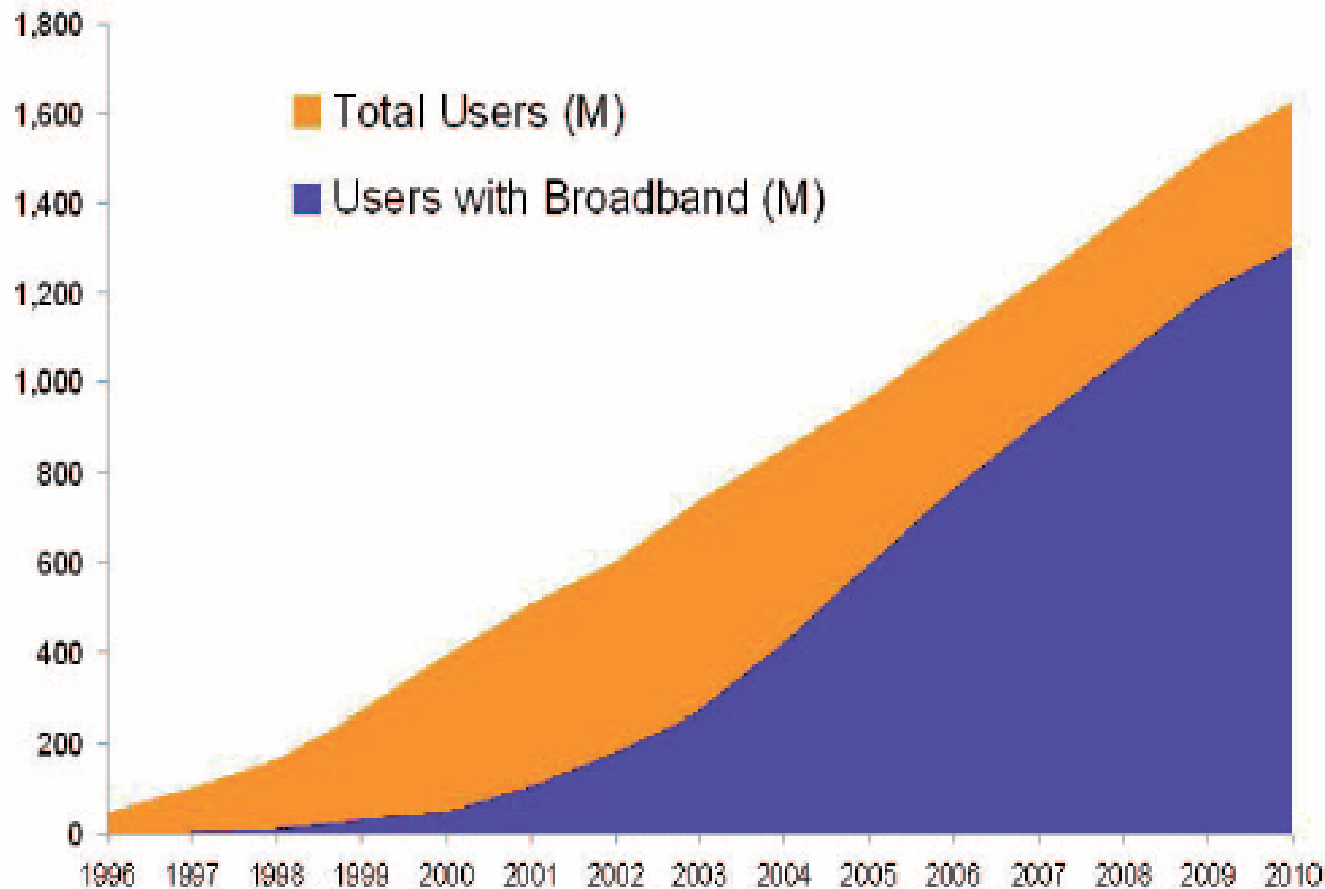
Market Drivers ~ Information Versus Available Storage



- In 2007, 255 Exabytes will be created, surpassing the available storage capacity available (264 Exabytes).
- Between 2006 – 2010, storage media growth will = 35% per annum, while info will grow 57% per annum

Source: IDC

Market Drivers ~ Internet Growth



- In 1996, the world-wide web (www) was only four (4) years old and there were 48million internet users at the time.
 - 1.1Billion internet users in 2006
 - Expected to be over 1.6Billion internet users by 2010
- Broadband adoption will drive additional interest for people to communicate even more.
 - Easy and inexpensive

Source: IDC

Market Drivers ~ Email Growth

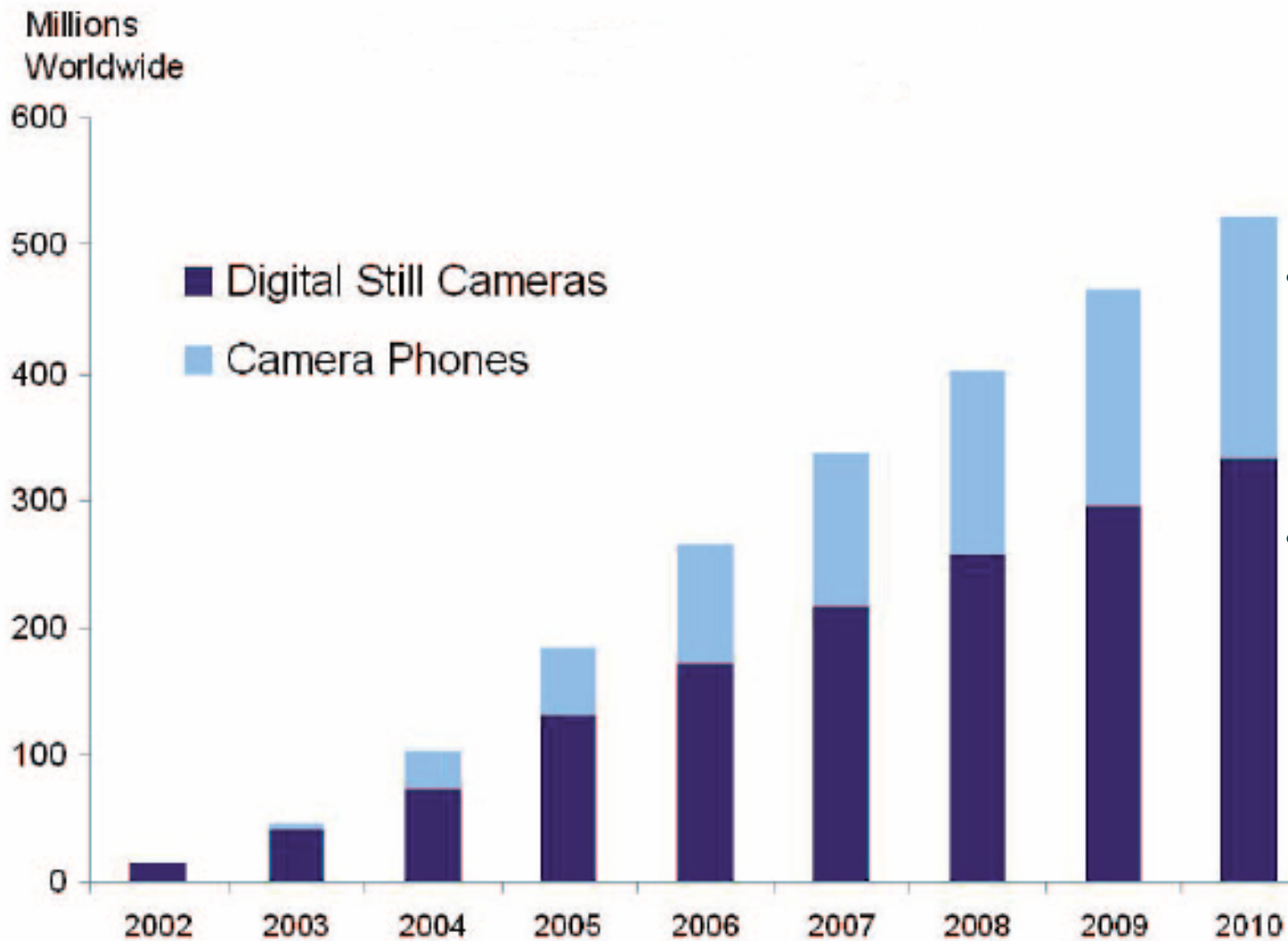
Trillions per Year



- **253 Million email boxes in 1998**
 - **1.6Billion email boxes in 2006**
 - **2Billion+ email boxes by 2010**
 - **# of Emails sent grew 3x faster than email users during same period.**

Source: IDC

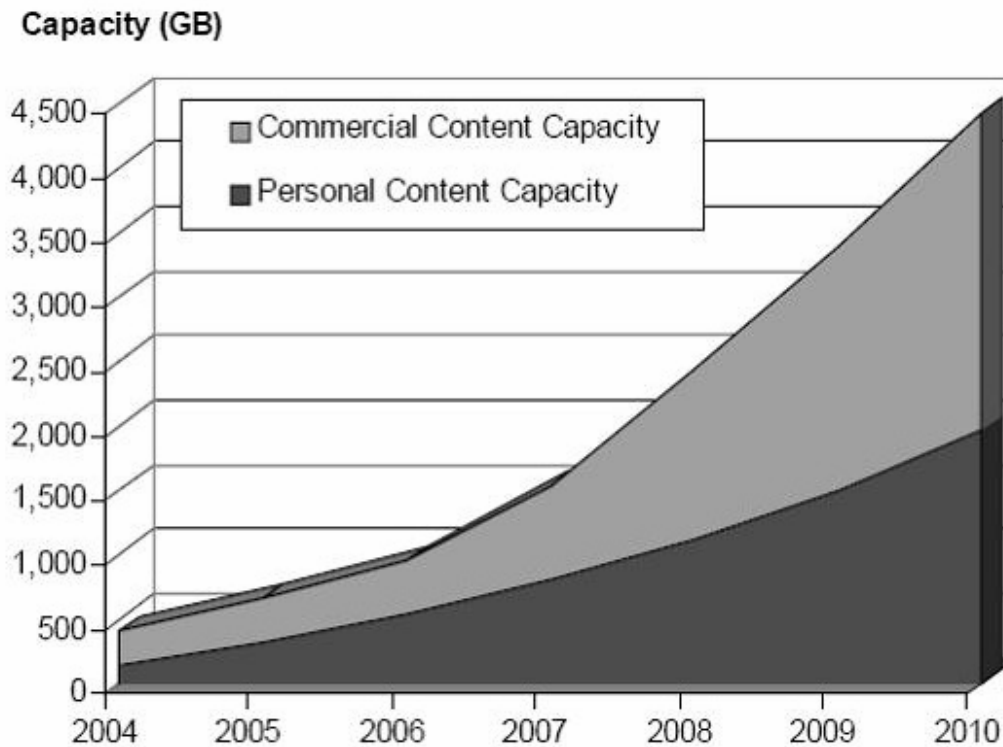
Market Drivers ~ Image Growth



- Camcorder use expected to double by 2010
- Digital surveillance camera storage expecting 10x growth by 2010

Source: IDC

Market Drivers ~ Personal Data



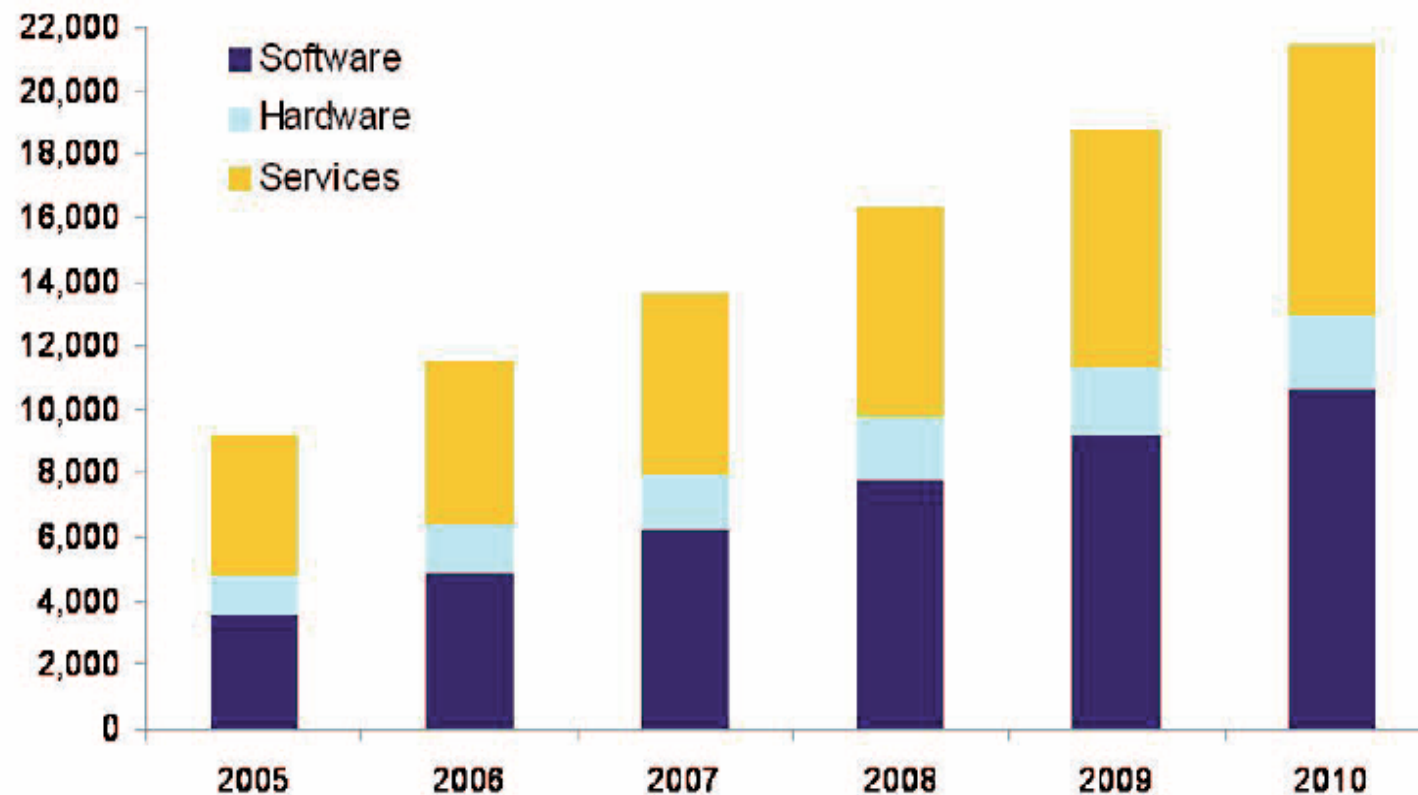
**Almost 5 TB of
combined personal
reference data and
home commercial
content
by 2010**

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Market Drivers ~ Information Compliance

(Spending on Infrastructure to Support Regulatory Compliance Initiatives)

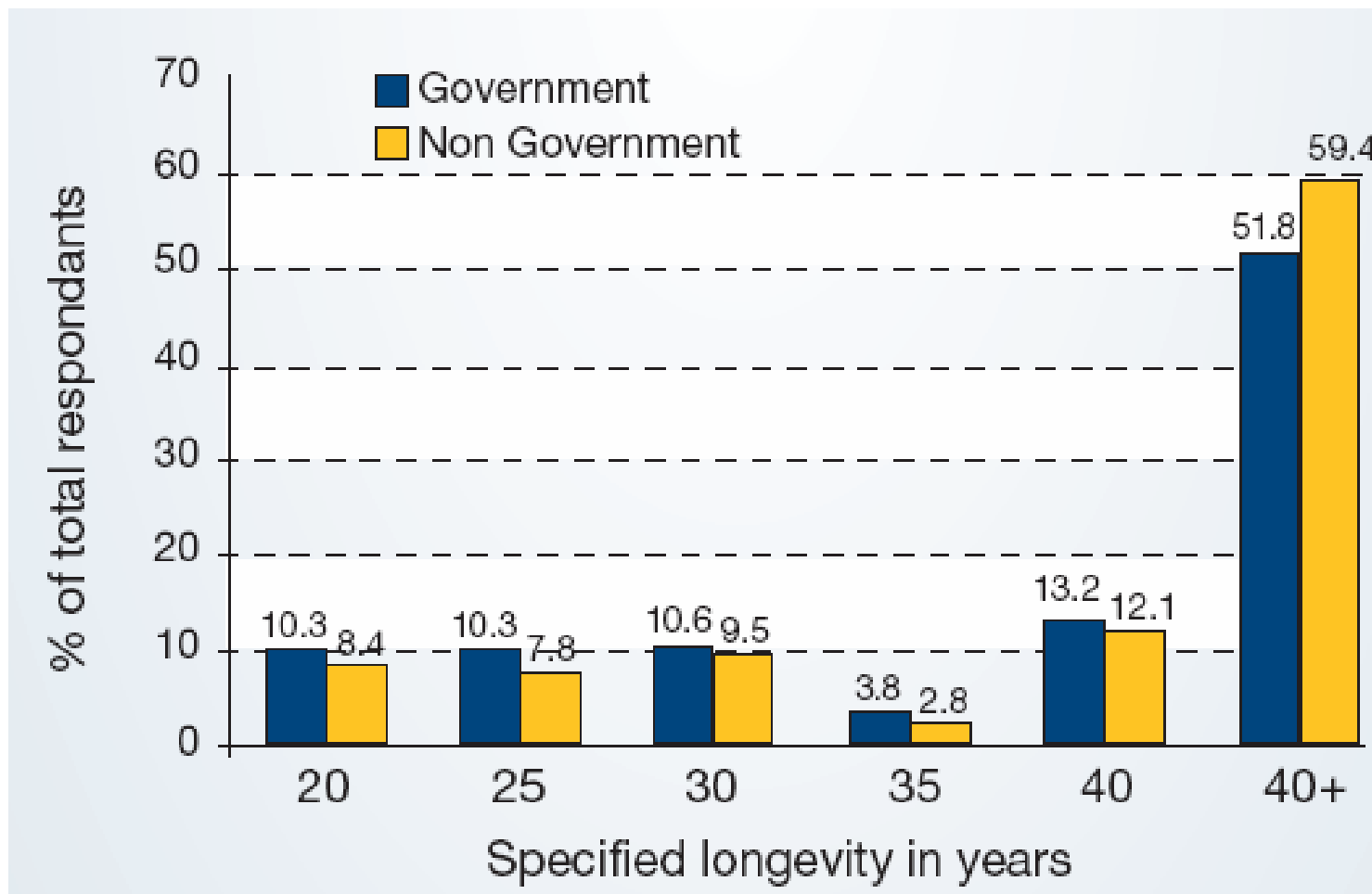
\$ Millions Worldwide



- In 2006, only 20% of IT infrastructure generating data were subject to compliance or standards rules.
- Expected to double by 2010 to over \$21.4Billion

Source: IDC

Market Drivers ~ How Long To Keep Data?



Source: NIST

Market Drivers ~ Applications

- Business: **document management, email archive,...**
- Legal: **records management, case files,...**
- Healthcare: **PACS, medical imaging, patient records,...**
- Financial: **bank records, files, transactions, checks,...**
- Broadcast: **video, graphic, design, editing,...**
- Government: **records, case files, compliance,...**
- Engineering: **blue prints, drawings, CAD, CAM,...**
- Insurance: **customer files, transactions, records,...**
- Document imaging: **scan, PDF, Word, spreadsheets,...**
- Medical imaging: **MRI, CT, Ultrasound, records,...**
- Email archive: **messages, attachments, records,...**

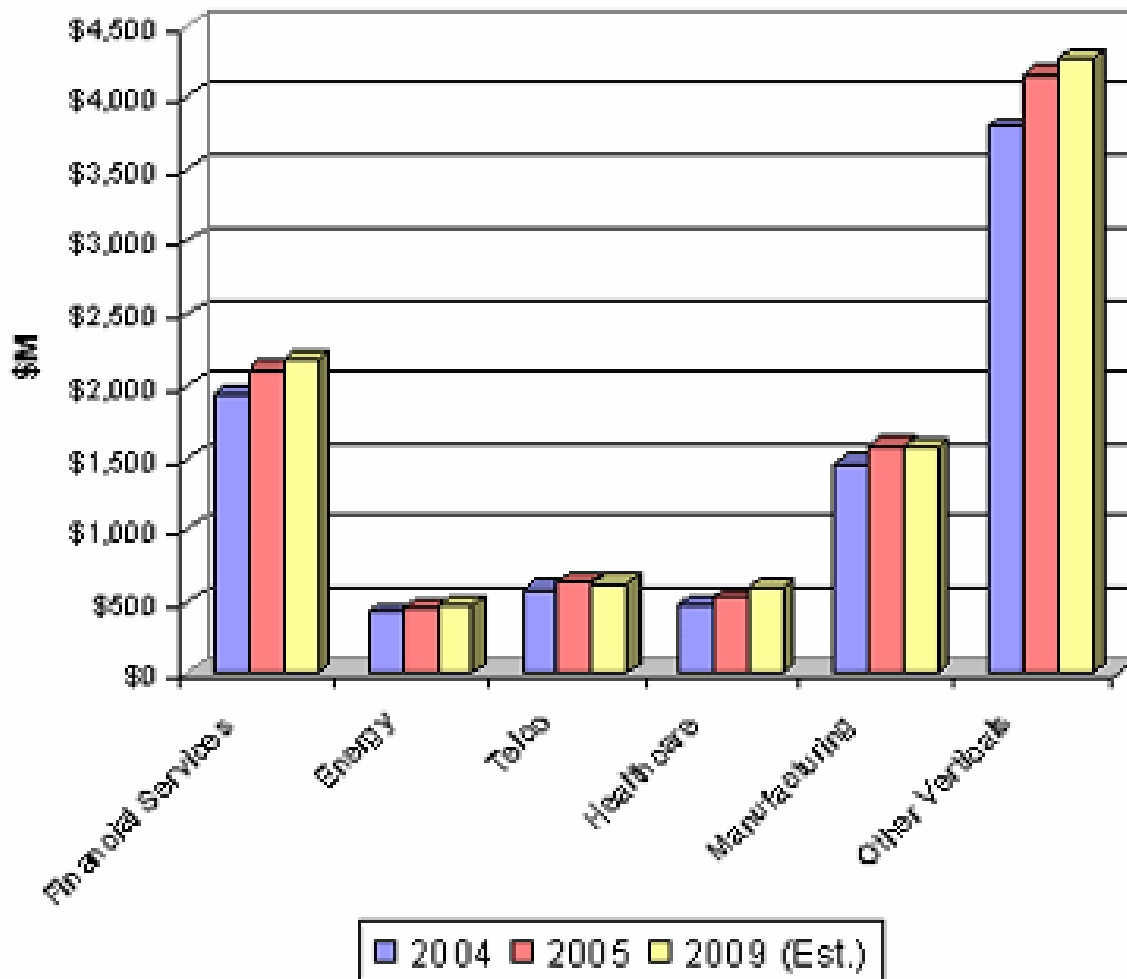


Market Drivers ~ Key Markets for Archival Storage

- Healthcare
 - **HIPAA**
 - **PACS, Patient records, etc.**
- Financial
 - **SEC, FSA**
 - **Banks, institutions, Investment, etc.**
- Government & Legal
 - **ISO, FDA, Sarbanes-Oxley**
 - **NASA, CIA, Health & Human Services, VA**
- Broadcast & Publishing
 - **Digital Asset Management**
 - **Video production, newspapers, magazines, etc.**

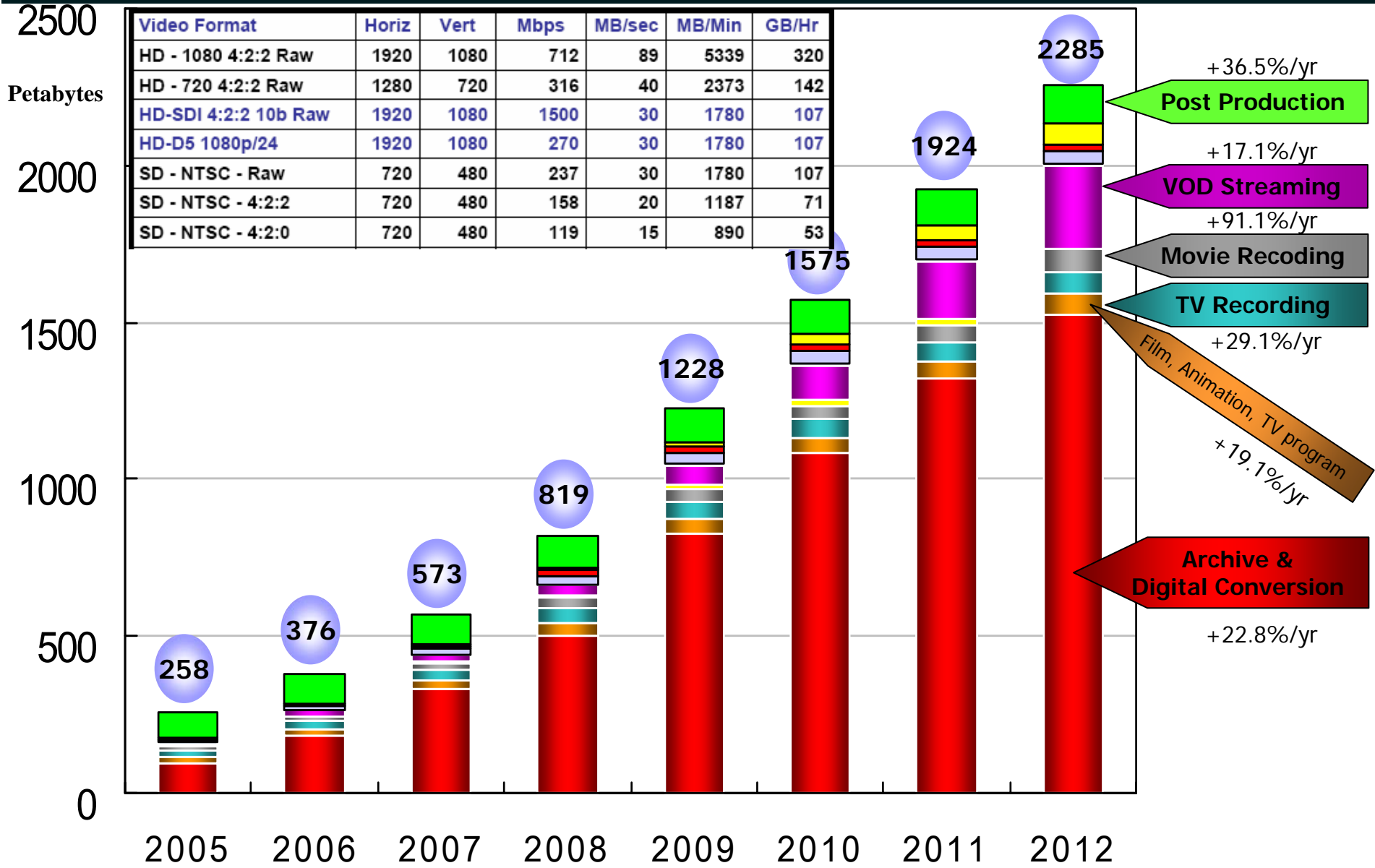


Market Review ~ US Storage By Market



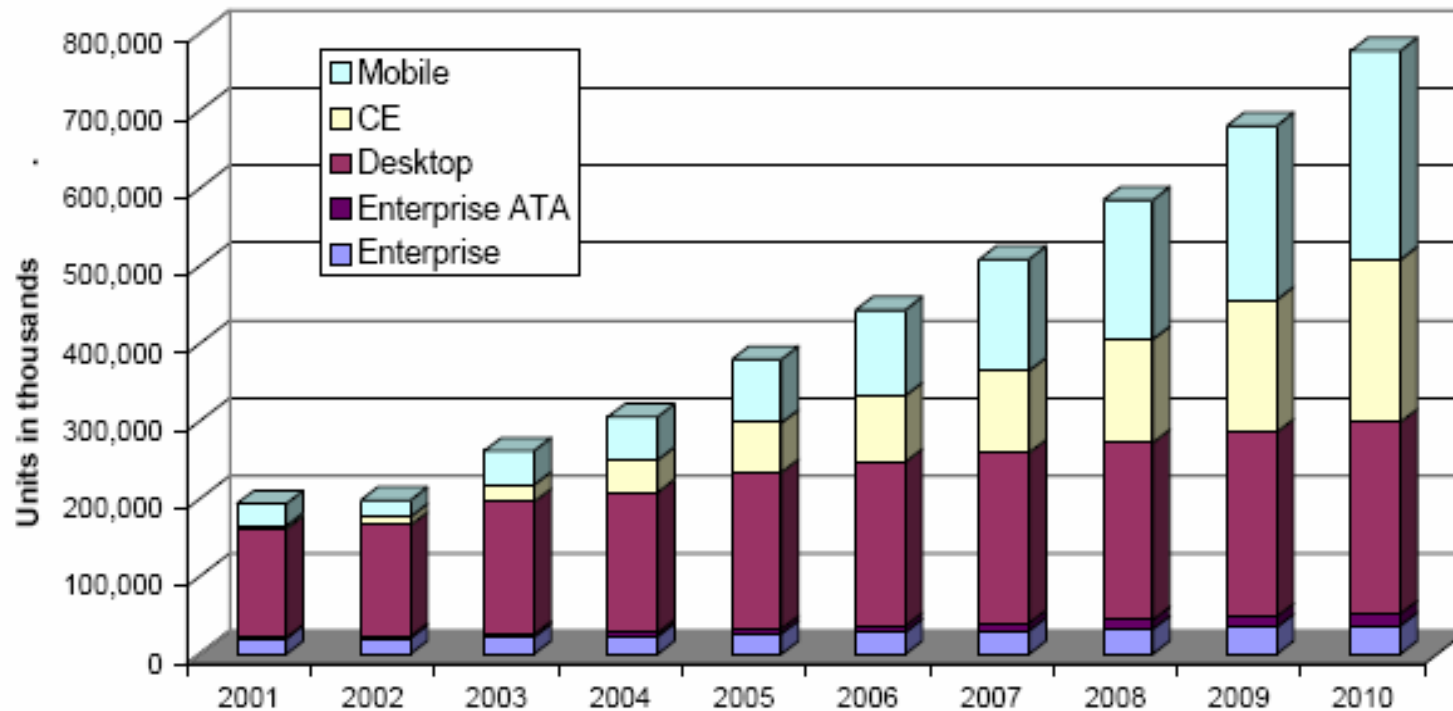
- \$23Billion in 2006
- 6% increase from 2005
- 60% OTHER VERTICALS represents Entertainment /Film/VOD, ASP/ISP
 - 30% Gov't.

Source: IDC



Source: Disc, IDC, Panasonic

Market Review ~ Disk Storage



- 15% per annum increase projected through 2010

Source: Coughlin

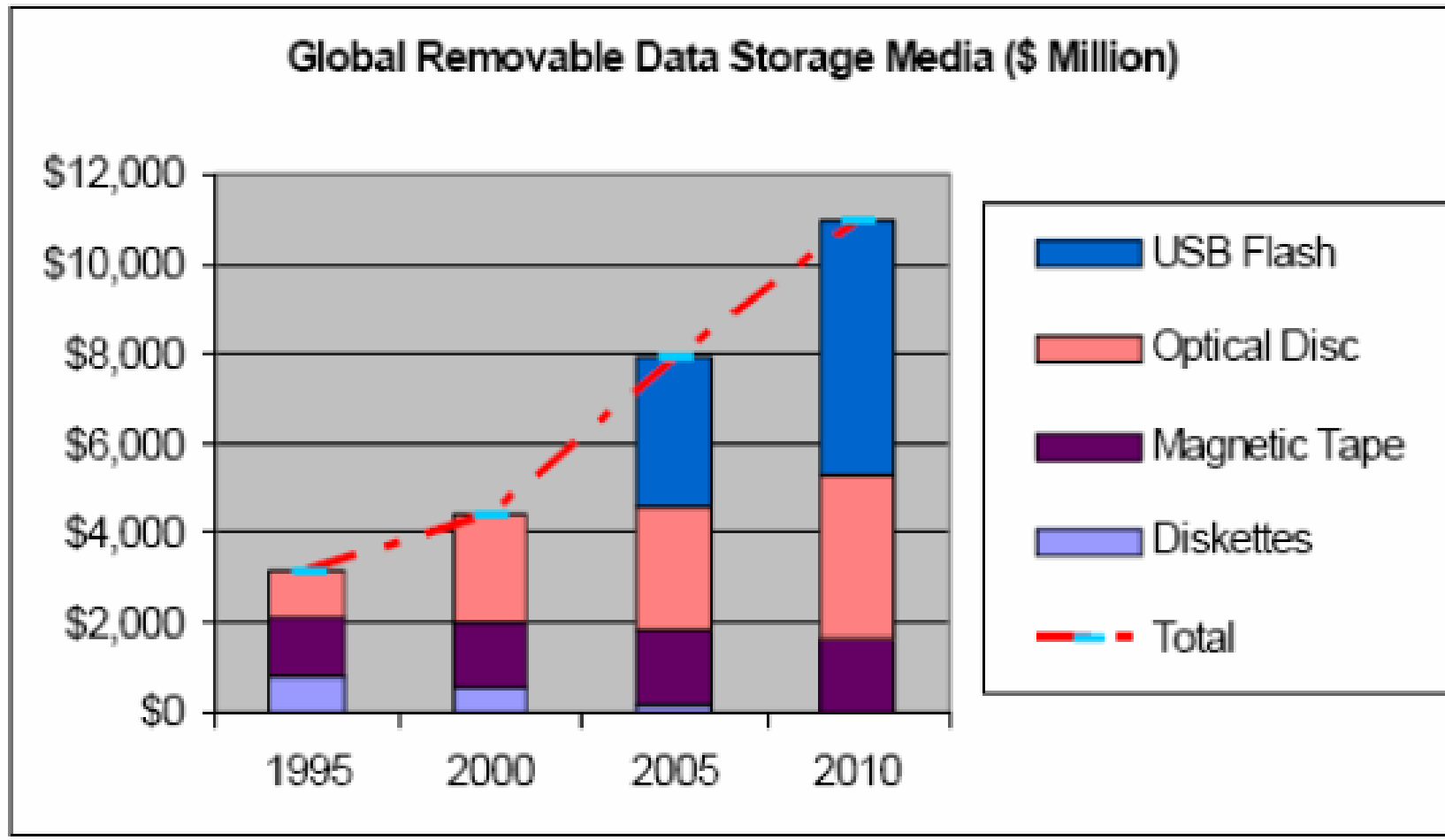
Market Review ~ Declining Tape Sales

- **2006 Tape Library Revenues = \$18.1Billion**
 - Down 15% from 2005
 - Only LTO Up 4%, smallest increase since 2000
 - D2D backup cheaper, faster
 - VTL on disk replacing need for tape backup
- **IBM tape market share = 29%**
- **Quantum tape market share = 26.7%**
- **Sun/STK tape market share = 26.2%**
- **Overland tape market share = 6.8%**
- **HP tape market share = 5.3%**
- **Optical storage took 6% of tape archive market share in 2006 !**



Source: Freeman

Market Review ~ Removable Data Storage Revenues

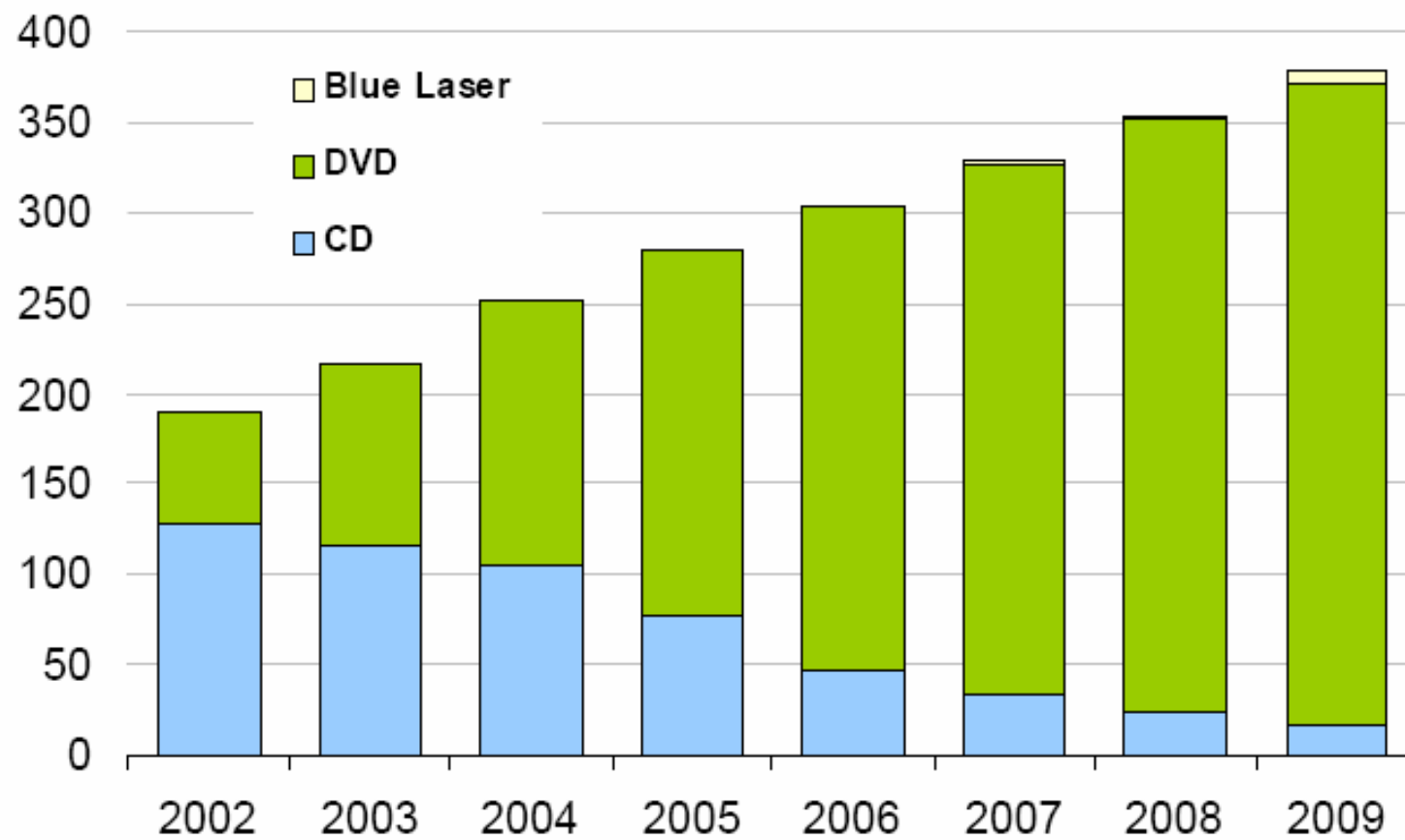


Source: Imation

Market Review ~ Optical Drive Shipments

Worldwide CD/DVD/Blue laser Drive Shipments

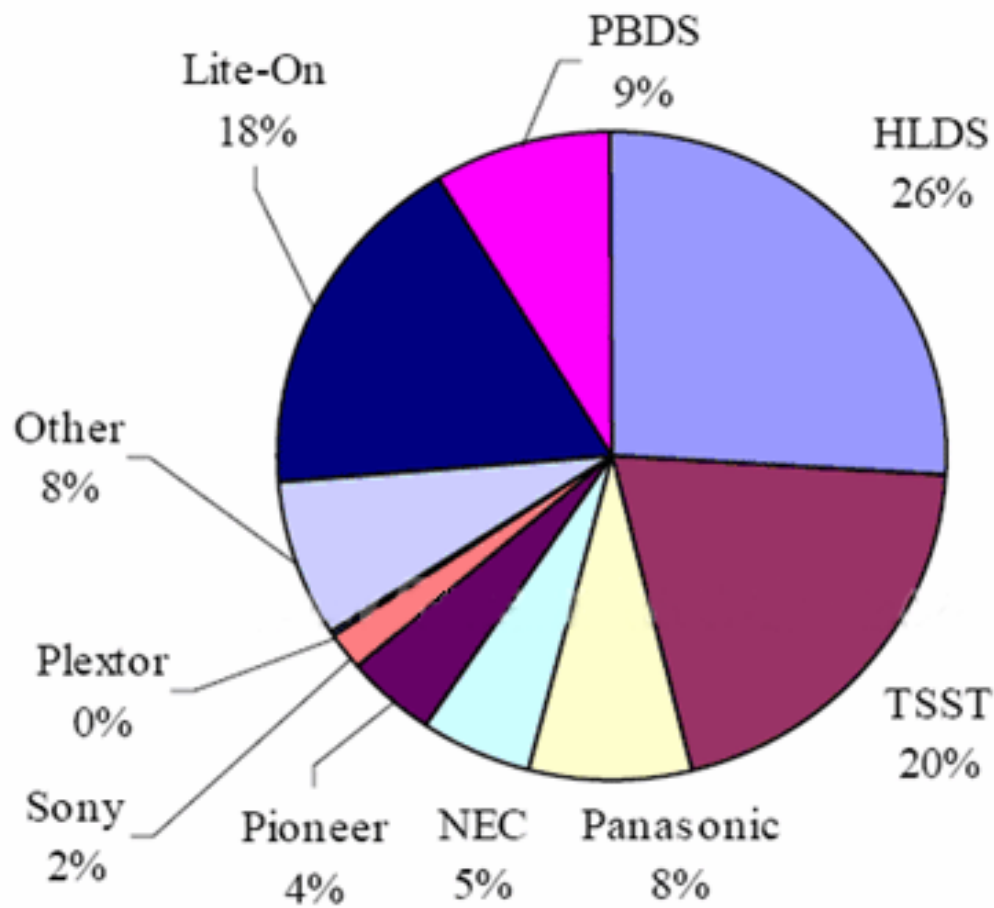
Units, Millions



Source: IDC

Market Review ~ Drive Marketshare

Market Shares Distribution of Global Major Optical Drive Manufacturers in 2006Q1



- Hitachi still #1 optical drive vendor
- BenQ/LiteOn taking marketshare away from #2 Toshiba / Samsung
- OTHER includes Plasmon UDO

Source: DigiTimes

Market Review ~ Consumer \$\$

U.S. CONSUMER HOME ENTERTAINMENT SPENDING (in billions)

YEAR	DVD SALES	DVD RENTAL	TOTAL CONSUMER SPENDING ON DVD	TOTAL CONSUMER SPENDING ON HOME VIDEO (DVD & VHS - RENTAL & SELL THROUGH)
1999	\$0.7	\$0.1	\$0.8	\$12.8
2000	\$1.9	\$0.6	\$2.5	\$14.0
2001	\$5.4	\$1.4	\$6.8	\$16.8
2002	\$8.7	\$2.9	\$11.6	\$20.3
2003	\$11.6	\$4.5	\$16.1	\$22.5
2004	\$15.5	\$5.7	\$21.2	\$24.5
2005	\$16.3	\$6.5	\$22.8	\$24.3
2006	\$16.6	\$7.5	\$24.1	\$24.2

Source:DEG

Market Review ~ DVD Hardware

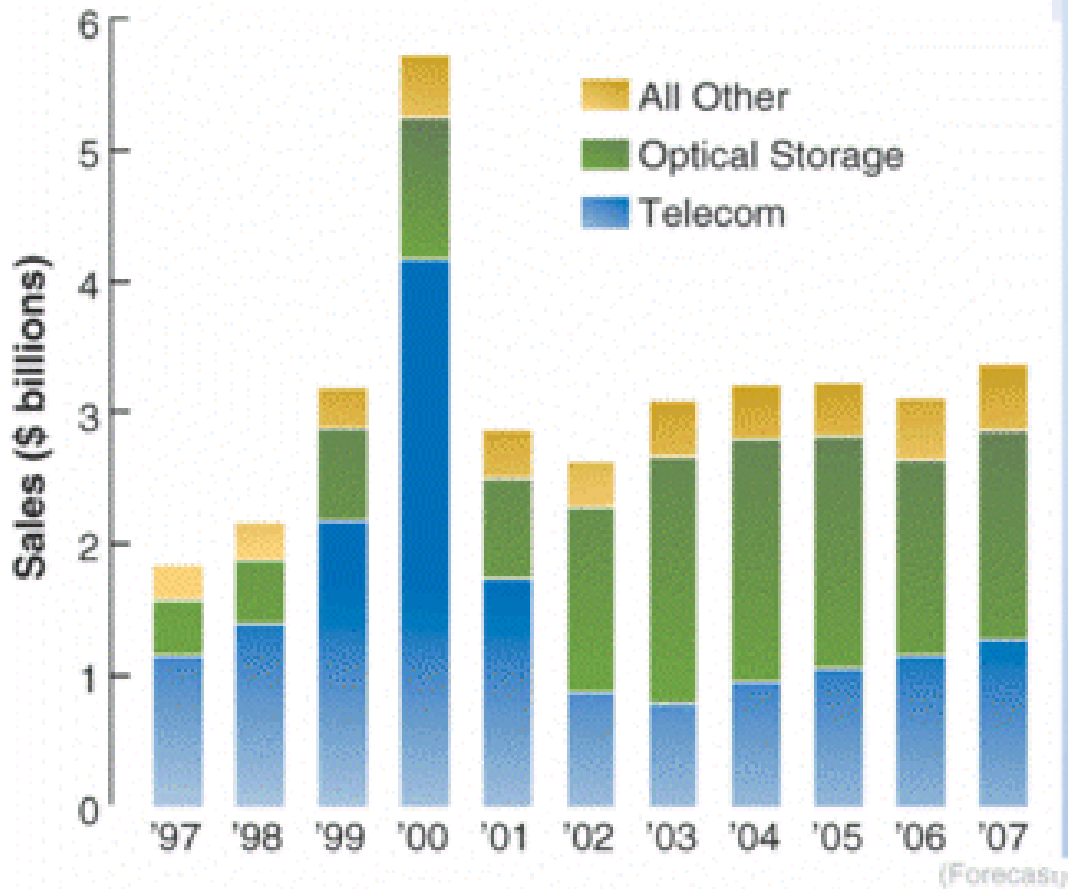
U.S. DVD HARDWARE SALES (in millions)

QUARTER	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1st Quarter	.030	.094	.358	1.350	2.220	3.565	4.858	6.855	7.741	7.852
2nd Quarter	.079	.149	.611	1.435	2.404	3.750	5.506	6.057	6.006	6.676
3rd Quarter	.077	.244	.880	1.550	2.537	4.740	6.470	6.593	6.250	6.831
4th Quarter	.119	.459	1.701	5.542	9.501	13.058	16.9	17.621	16.740	11.301
YEARLY TOTAL	.305	.946	3.550	9.877	16.662	25.113	33.734	37.125	36.737	32.66
TOTAL (since launch)										194.362

*Includes set-top and portable DVD players, Home Theater in Box systems, TV/DVD and DVD/VCR combination players
DEG: Digital Entertainment Group

Market Review ~ Laser Diodes

Worldwide diode-laser market



OPTICAL DATA STORAGE

Lasers used in devices such as CD players, disc mastering, magneto-optical, optical ROM, and holographic storage are included in this category.

Sales	2003	2004	2005	2006	2007
Units (M)	531	644	691	722	748
\$ (M)	1,865	1,844	1,753	1,486	1,600

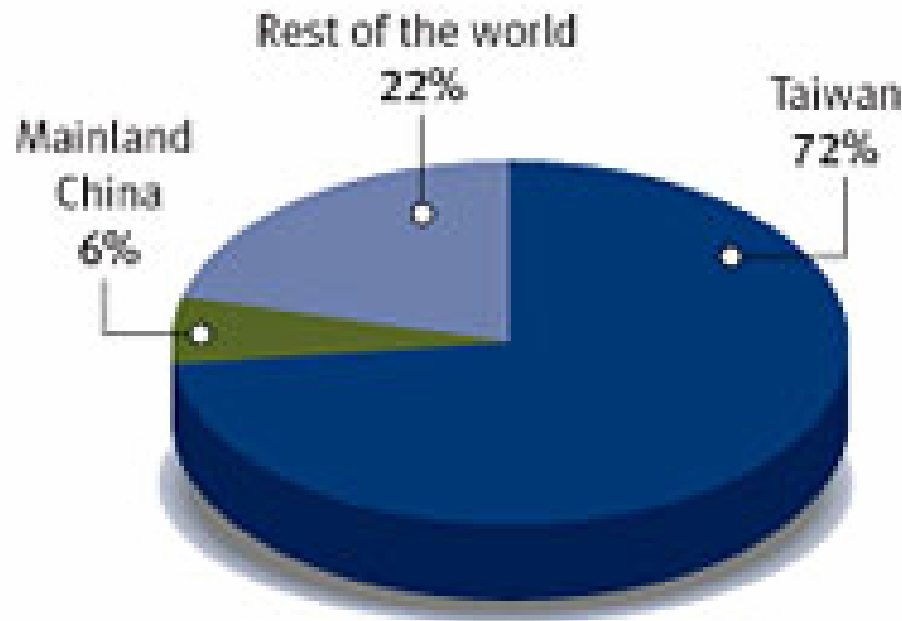
Revenues

Avg pricing

Although revenues for this category contracted by 15% in 2006 to \$1.49 billion, unit shipments continued to grow. Even though the market is shifting to higher-value lasers, ASPs fell in 2006 among all laser types, thus causing revenue to shrink.

Market Review ~ Optical Media

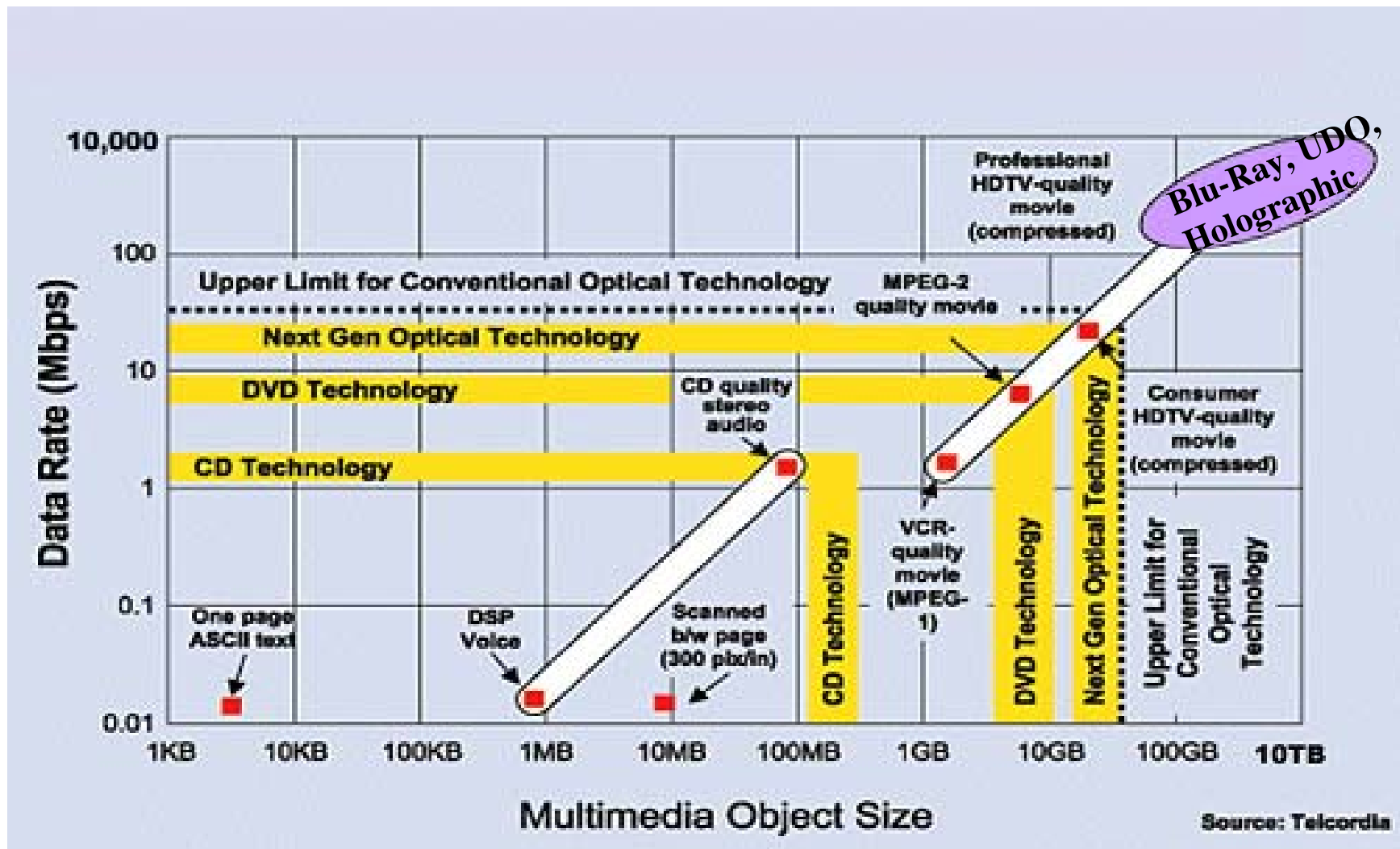
world optical disc production
(percentage)



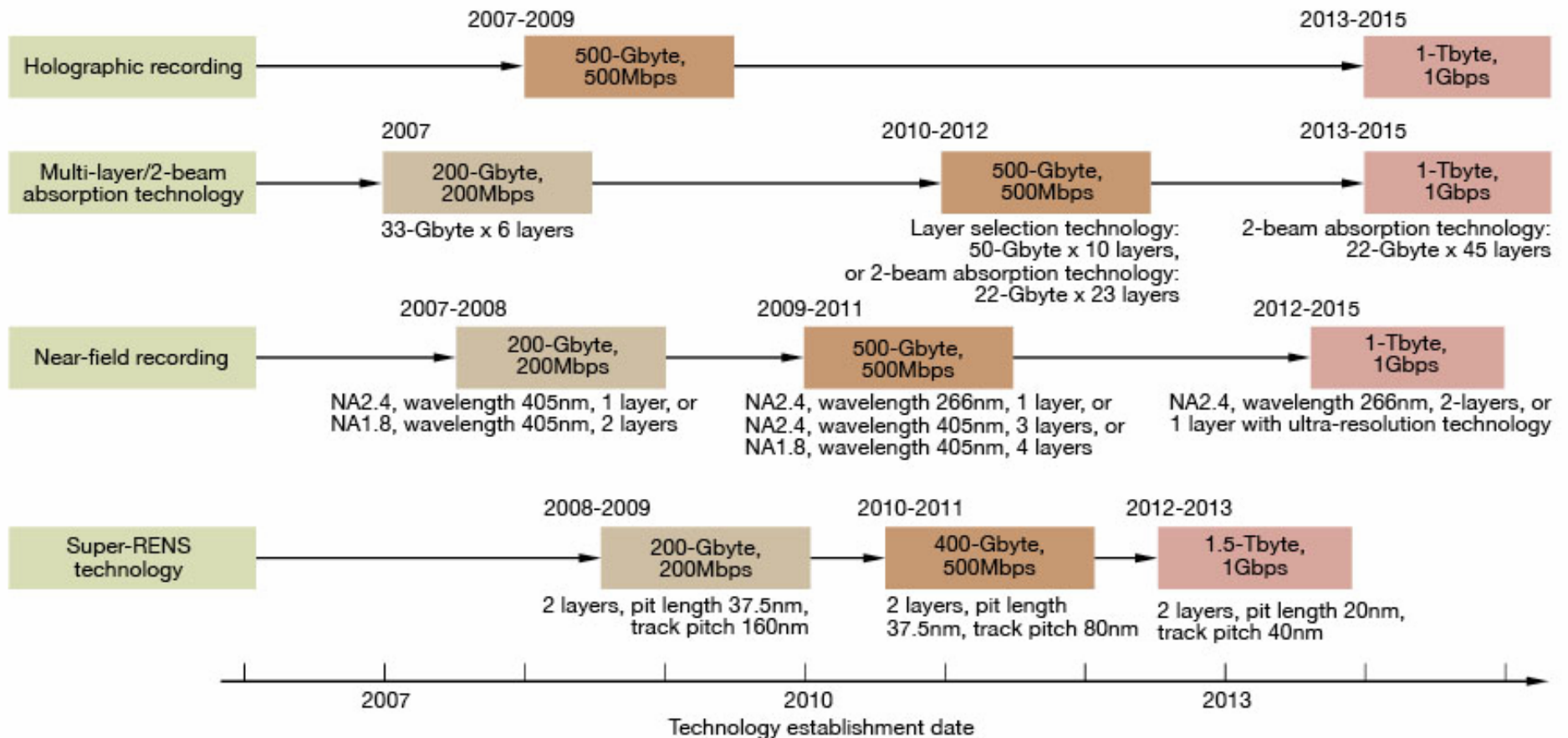
- **\$30.6Billion** worldwide optical media revenues by 2010
- **4% of** marketshare by 2010 to be holographic/near-field media

Source: GlobalSources

Technology Review ~ Optical Storage



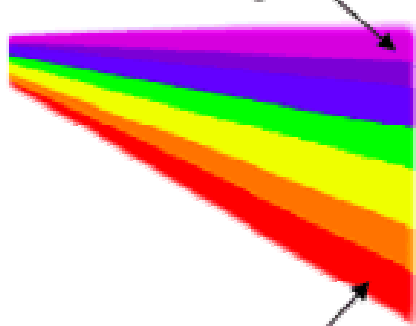
Technology Review ~ Future Density Trends



4th-Generation Optical Discs to Reach 1Tbyte in 2011-2015

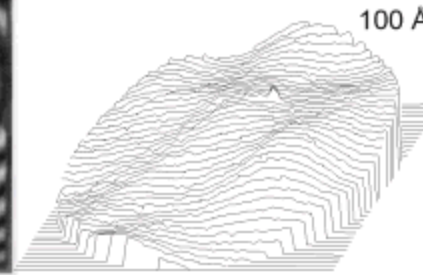
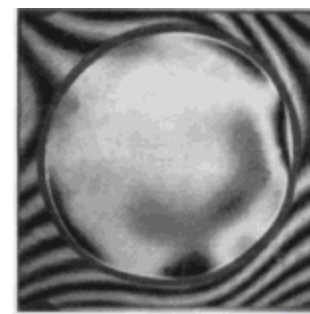
Technology Review ~ Lasers

HD DVD Laser light 405 nm



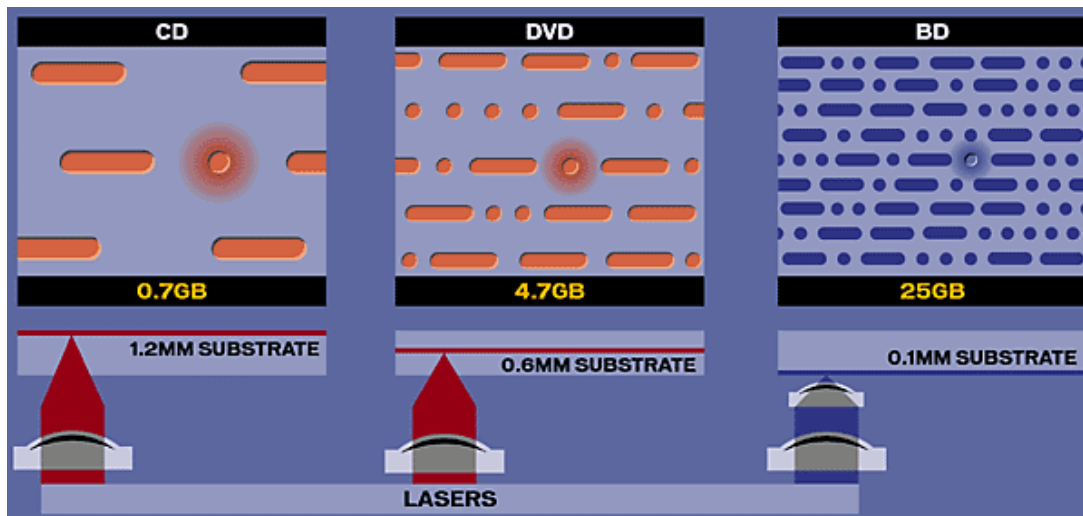
Violet = 400 nanometers
Indigo = 445 nanometers
Blue = 475 nanometers
Green = 510 nanometers
Yellow = 570 nanometers
Orange = 590 nanometers
Red = 650 nanometers

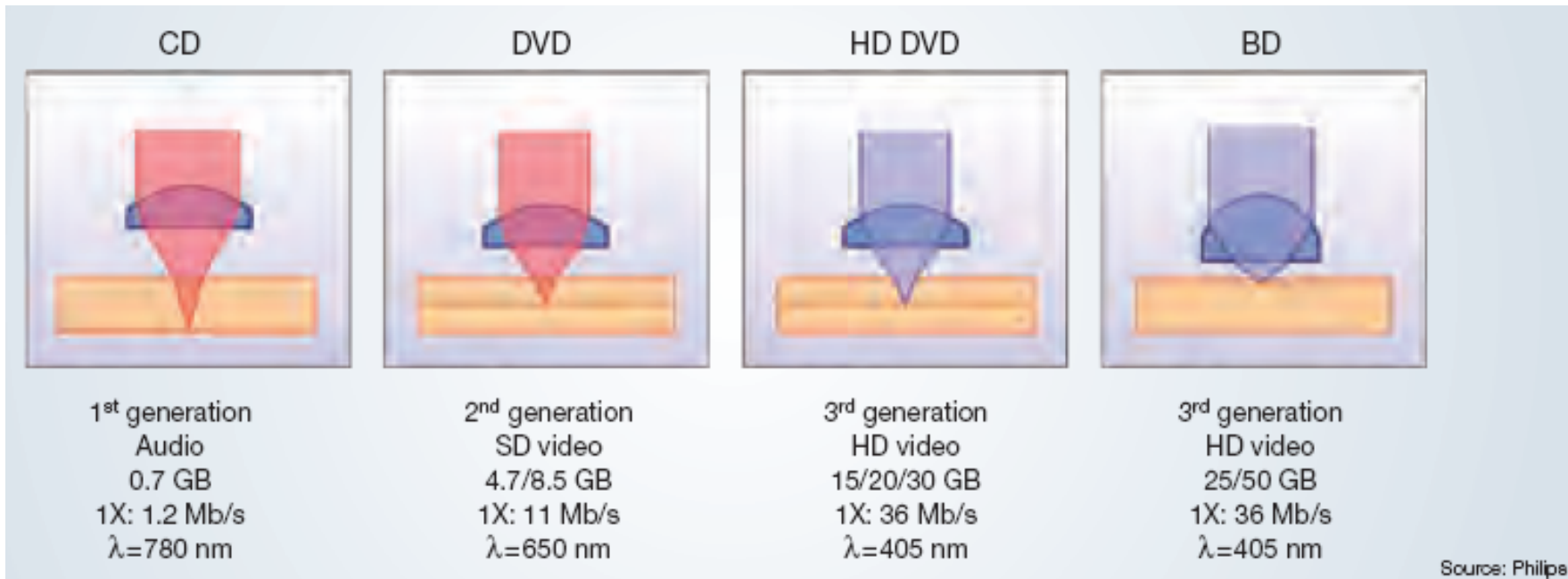
DVD Laser light 650 nm



1 cm

1 cm





Parameters

	Blu-ray	HD-DVD
Storage capacity	25GB (single-layer) 50GB (dual-layer)	15GB (single-layer) 30GB (dual-layer)
Laser wavelength	405nm (blue laser)	405nm (blue laser)
Numerical aperture (NA)	0.85	0.65
Disc diameter	120mm	120mm
Disc thickness	1.2mm	1.2mm
Protection layer	0.1mm	0.6mm
Hard coating	Yes	No
Track pitch	0.32 μ m	0.40 μ m
Data transfer rate (data)	36.0Mbps (1x)	36.55Mbps (1x)
Data transfer rate (video/audio)	54.0Mbps (1.5x)	36.55Mbps (1x)
Video resolution (max)	1920 \times 1080 (1080p)	1920 \times 1080 (1080p)
Video bit rate (max)	40.0Mbps	28.0Mbps



Technology Review ~ UDO

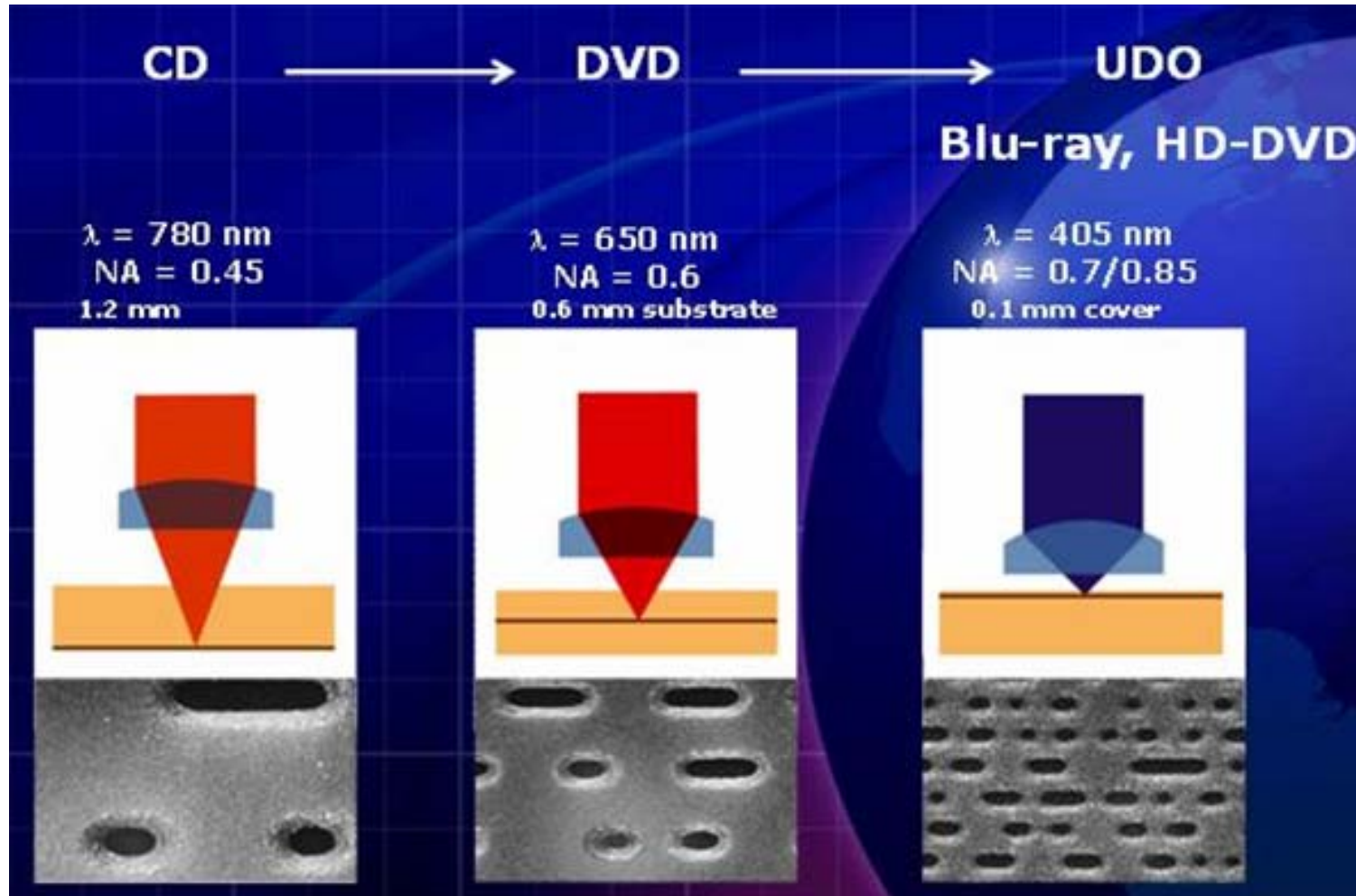


UDO2 Technology Roadmap



- **Plasmon Ultra-Density Optical (UDO)**
 - 20+ year history
 - HP, IBM and Mitsubishi OEM partners
 - Archival storage of choice by Medical community for over 15+ years
- **60GB/side today – 240GB by 2012**
- **Phase-change media**
 - Superior long-term archival storage properties compared to Blu-ray/DVD.
- **Blueviolet laser-based, 405nm (same as blu-ray/HD-DVD)**

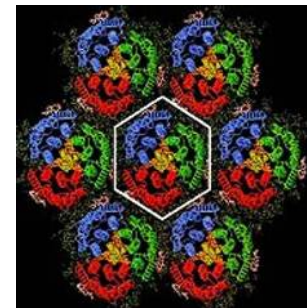
Technology Review ~ UDO



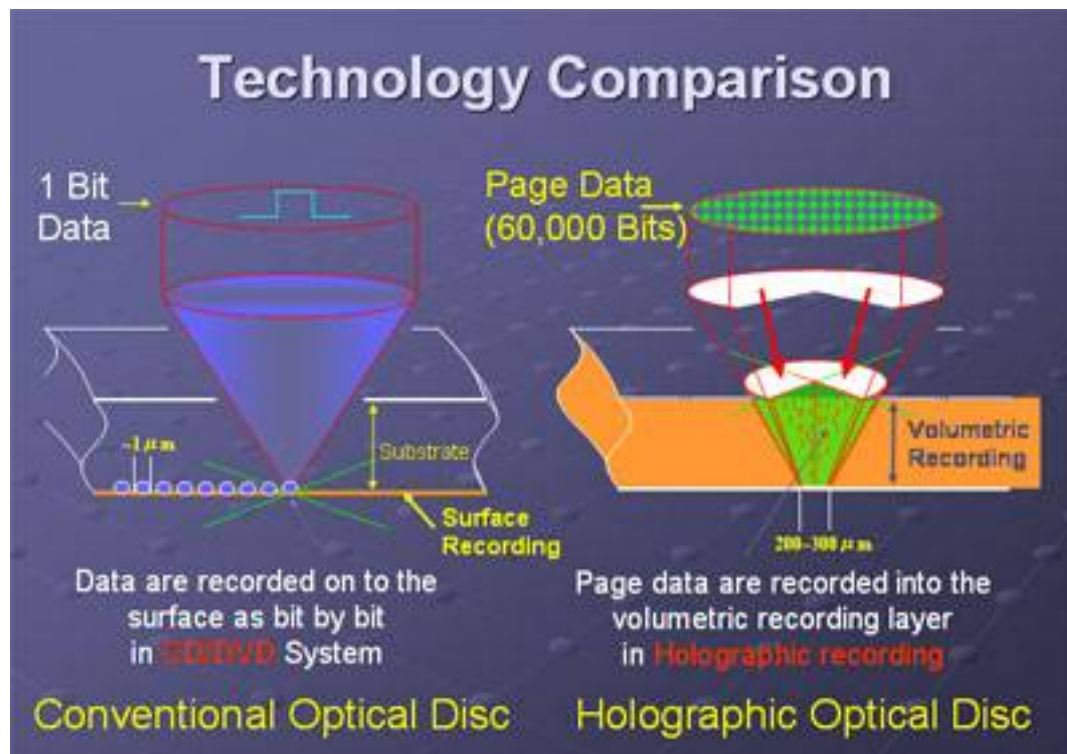
Source: Plasmon

Technology Review ~ Holographic

- **Photopolymer-based media**
 - Like photography only with laser light source
 - Media stability biggest challenge
- **Several competing technologies**
 - **Angle Multiplexing**
 - Overlapping holograms increase volumetric capacity (*InPhase*)
 - **Collinear Multiplexing**
 - Red & green laser collimated into single beam
 - Backwards compatible with Blu-ray/DVD
 - Standards based (ECMA/ISO)
 - **Atomic Photon 3D**
 - Multiple layers, 1TB+ per surface

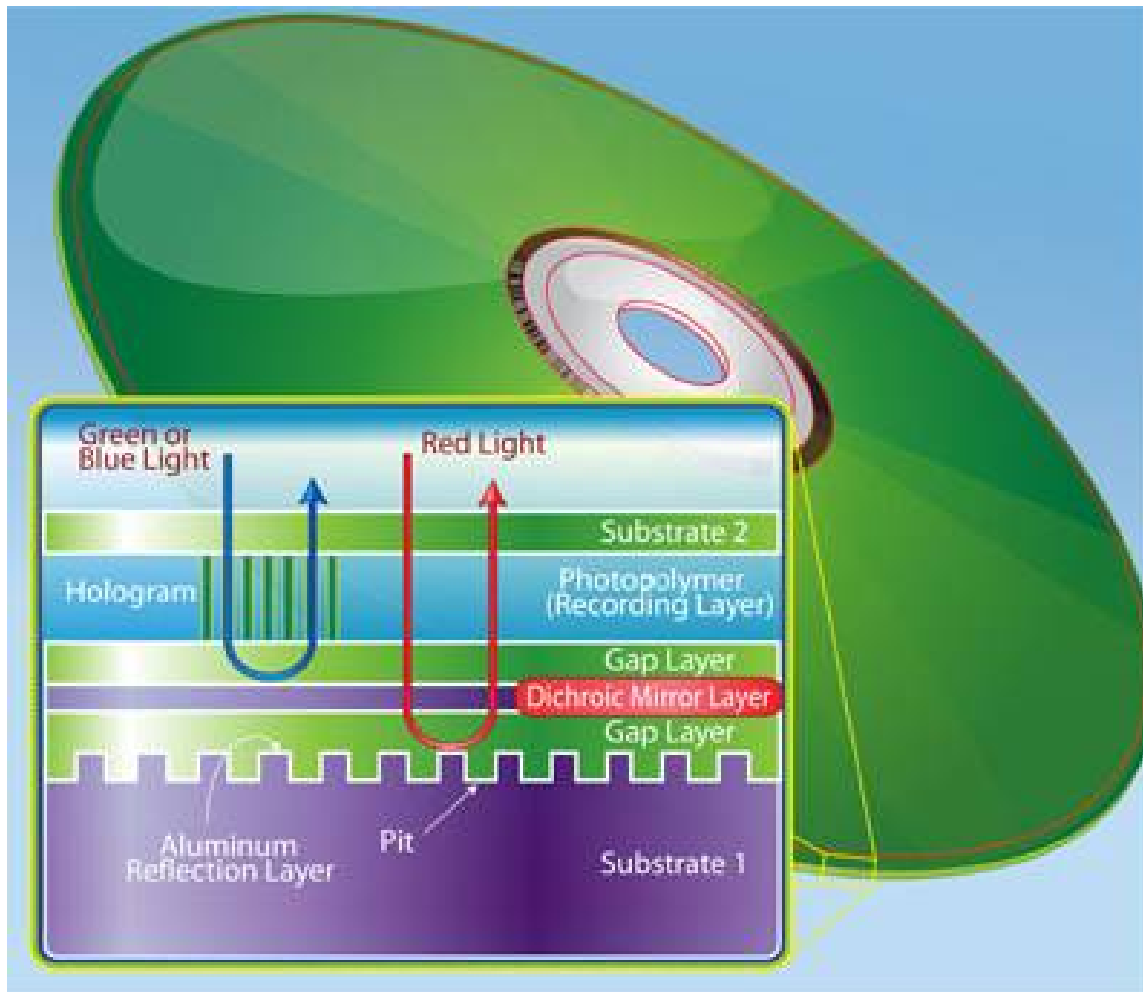


Technology Review ~ Holographic



- Current optical technology stores 1 bit per pulse
 - 60,000 bits per pulse for Holographic
 - Truncated cone shape 200-500 micrometers wide
- Single disc can store up to 3.9TB !
 - 5,500 CD's
 - 830 DVD's
 - 160 Blu-ray (25GB)
- Transfer rate = 125MB/sec
 - Blu-ray = 54Mbs/sec (6.75MB/sec)
 - UDO = 12MB/sec
 - Tapestry = 20MB/sec

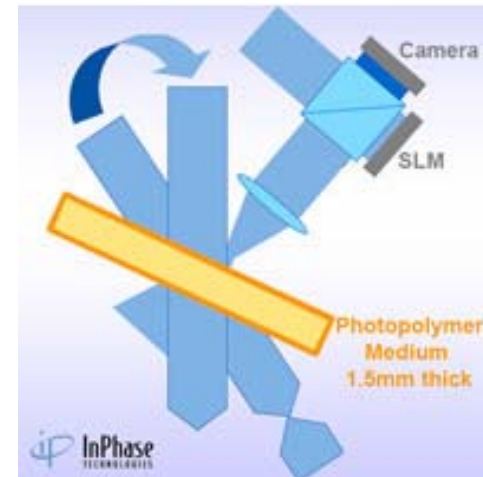
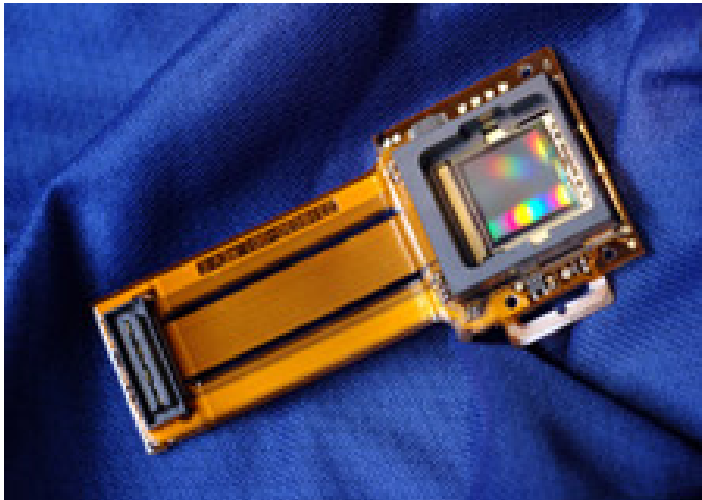
Technology Review - Holographic



- Collinear holography
 - Red laser used as reference beam and servo.
 - Green laser for reading/writing holographic recording layer.
 - Supports 10x+ recording layers.



Technology Review ~ SLM

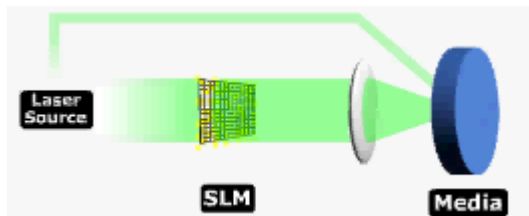
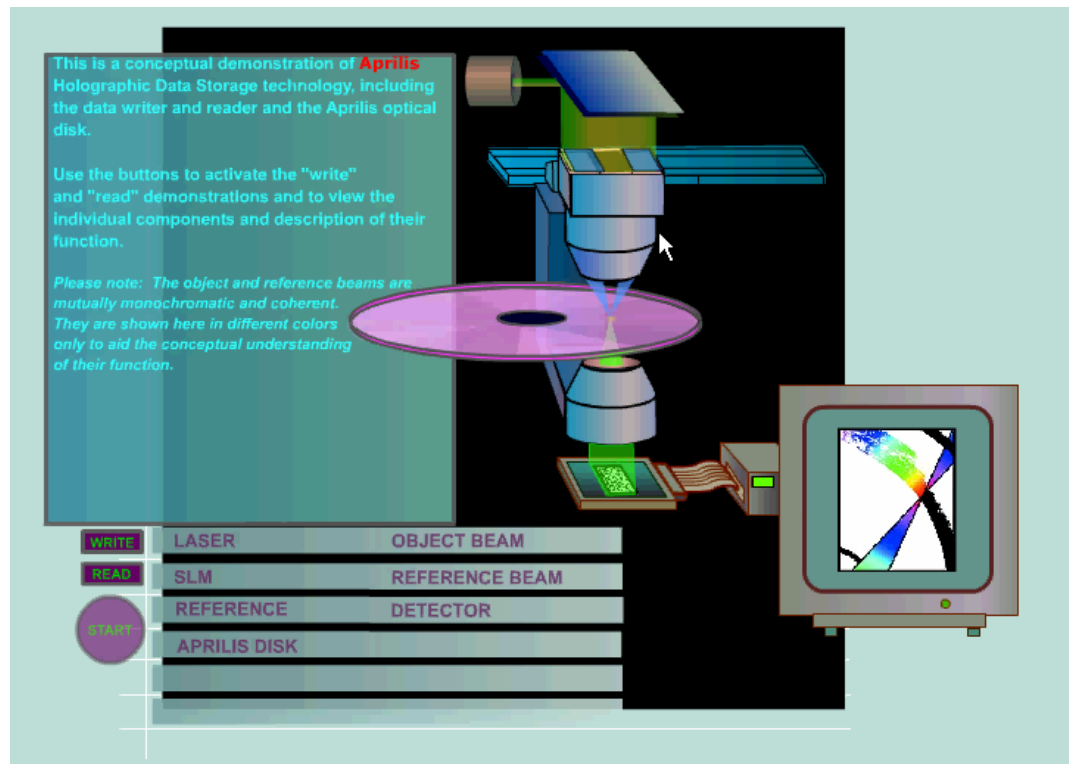


SLM - 1216 is used in InPhase
Technologies TM HDS Drive

- **Spatial Light Modulator (SLM) from DisplayTech is at the core of the holographic drive**
 - Integrated opto-mechanical holographic write head
 - 1216 x 1216 pixel resolution
 - Fast switching Ferroelectric Liquid Crystal (FLC) material
 - GA release December 2006
 - InPhase Technologies OEM partner



Technology Review ~ Holographic



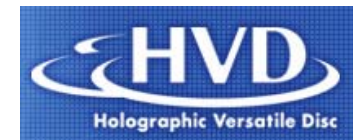
Writing



Reading

Technology Review ~ HDV Standards

- **Three (3) Holographic storage standards approved in 2007**
 - **ECMA 377: Information Interchange on Holographic Versatile Disc (HVD) Recordable Cartridges**
 - Specifies the mechanical, physical, and optical characteristics of a holographic disc cartridge (HDC) that employs holographic recording to enable data interchange between such discs.
 - 120mm, 200 Gbytes per Write-Once Cartridge



Technology Review ~ HDV Standards

- **ECMA 378: Information Interchange on Read-Only Memory Holographic Versatile Disc (HVD-ROM)**
 - Specifies the mechanical, physical, and optical characteristics of a holographic disc cartridge (HDC) that employs ROM holographic to enable multiple reading and data interchange between such discs.
 - 120mm, 100 Gbytes per Read-Only Cartridge



Holographic Versatile Disc
Terabyte class storage. The Future has arrived.



Technology Review ~ HDV Standards

- **ECMA 375: Case for 120 mm HVD-ROM disc**
 - Specifies the characteristics of a case for use with a Read-only Holographic Versatile Disc (HVD-ROM) to enable mechanical cartridge interchange between HVD-ROM drives.
 - 120mm, 100 Gbytes per Read-Only Cartridge

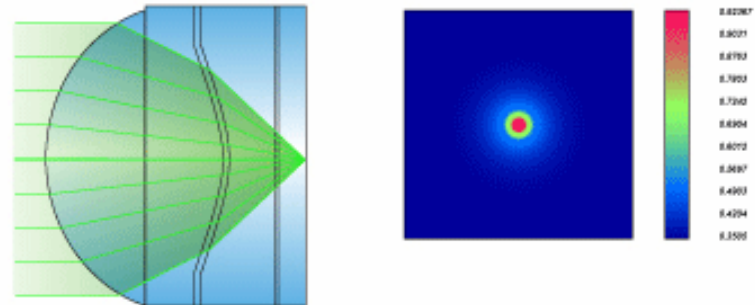


Technology Review ~ HDV Alliance

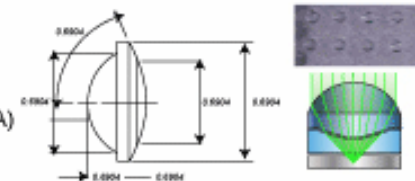


Technology Review ~ Other Holographic

- **1TB on 120mm disc**
 - 2photon 3D holographic technology
 - Roadmap to 5TB, 10TB, 15TB+
 - 100mb/sec transfer rate
 - Drive to be in \$500. range
 - Compatibility to read Blu-ray, CD, and DVD media

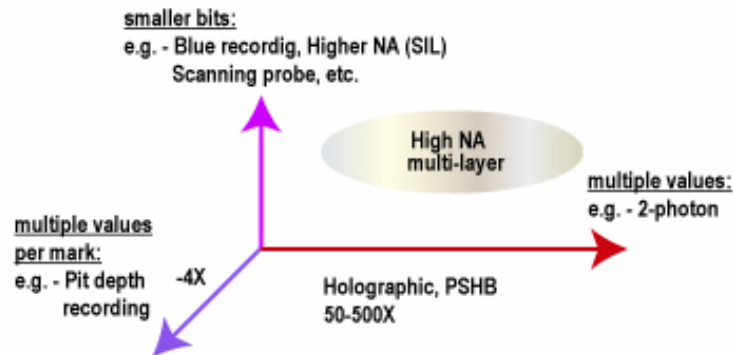


Design wavelength: 532 nm
NA: 1.0
Focal length: 2.144mm
Working distance: 1.286mm(PMMA)
1.404mm(PC)
beam diameter: 4.3mm



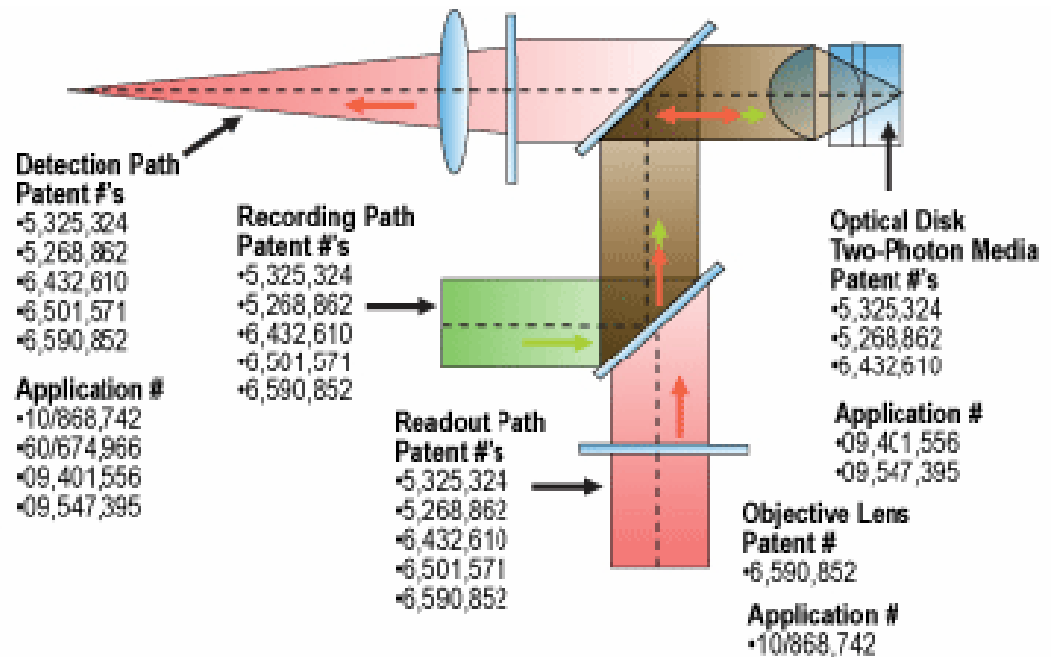
Volumetric capacity: > TB(120mm diameter, 1.2mm thick disk)



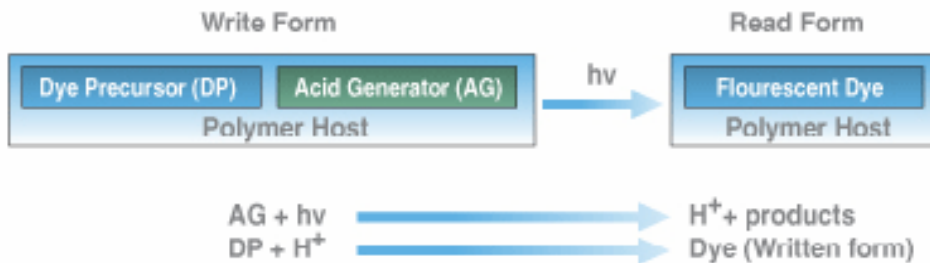


High NA Multi-layer Volumetric

- Traditionally separate technology paths
- Exploit the hybrid path of high NA and multi-layer volumetric optical data storage

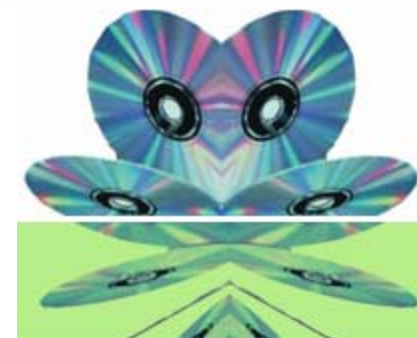


Compact design is basis for production prototype already in development



WORM material composed of:

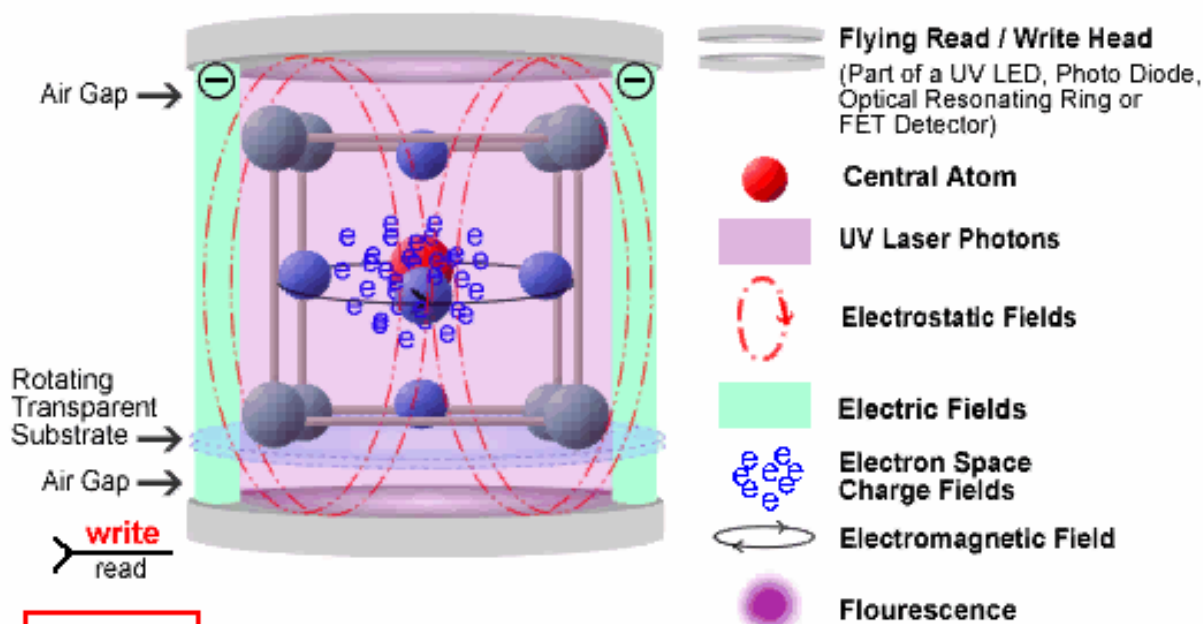
1. ACID GENERATOR - light sensitive component
2. DYE PRECURSOR - produce dye when react with acid
3. ADDITIVES - increase solubility and modify properties



Technology Review ~ Other Holographic

Schematics Atomic Switch*

*simplified schematics showing the function of one molecule



- Atomic 3D Holographic
- Spintronic data storage nano-technology
 - Ability to control direction of electrons/bits
 - Nanometer = 1/billionth of a meter

Status
write = 0



Technology Review ~ Other Holographic

- **3D Collinear Holographic Prototype**
 - Developed in (30) days using LabView FPGA, CompactRIO and Xilinx for under \$3K



Technology Review ~ Other Holographic

- **2-photon technology *TeraDisc***
 - 500GB, 1TB, 5TB roadmap on a single-sided volumetric disc
 - Easily and inexpensively produced
 - Data longevity >50 years
 - Natural successor to blue laser technologies for archival storage
 - Drive is based on existing drive technology
 - Functions in normal home/office environment
 - Able to reach consumer form factor over time
 - Lowest cost/TB predicted for 2010 for archival storage



Product Review ~ Blu-Ray



- Drives readily available, now under \$400.



- Natively supported in Microsoft Vista
- 25GB media plentiful, 50GB media mfg. encountering yield problems
- 100GB quad-layer media = 9 hours of HD video, by late 2008.



Product Review ~ Blu-Ray

- **Sony HES-V1000 Home Center**
 - Available October 2007
 - \$3,500.00 List Price
 - Includes 200disc blu-ray changer
 - 500 GB hard drive that can store up to 137 hours of video, 40,000 songs, or 20,000 digital photos that can then be burned to blu-ray media.

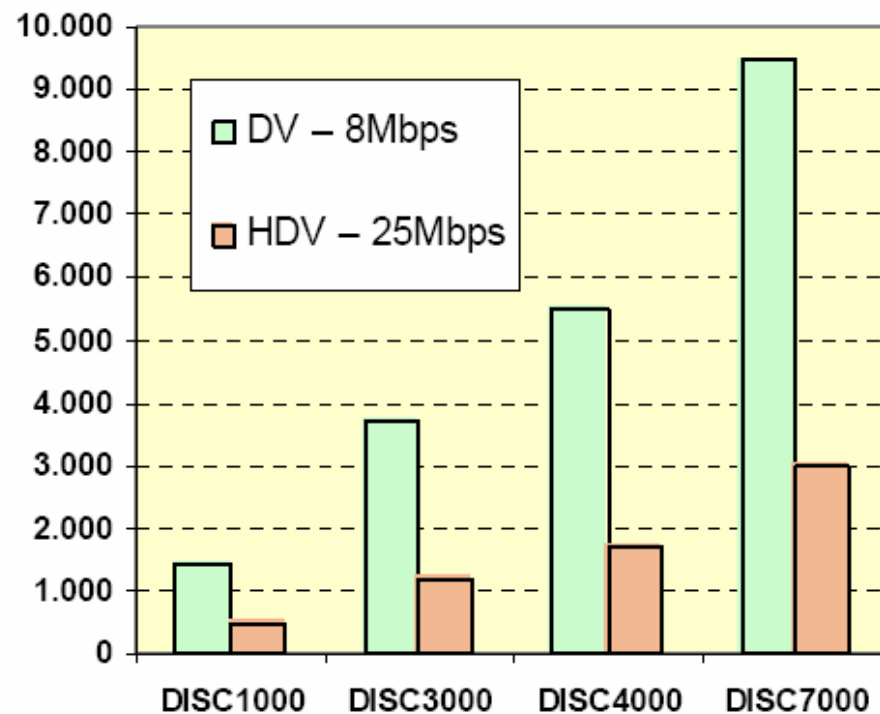


Product Review ~ Blu-Ray

- DISC blu-ray archival storage libraries
 - From 2-72TB configurations
 - Direct Attach, NAS or SAN

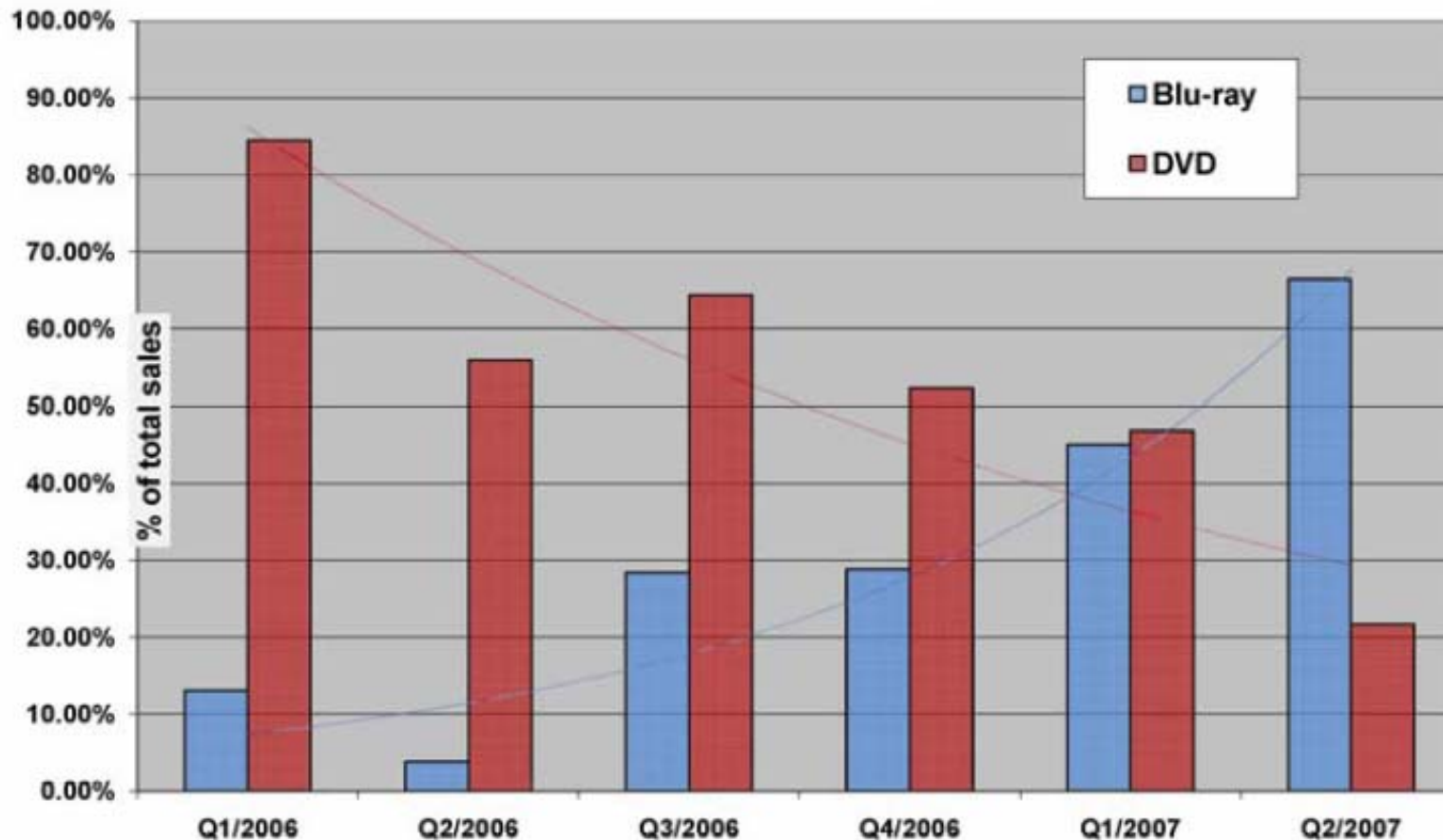


Hours of DV/HDV video content on a DISC Blu-ray library



Product Review ~ Blu-Ray

DISC LLC Sales by Technology - US market



Product Review ~ Blu-Ray

- **50 disc, single Blu-ray drive desktop media duplicator**
 - \$2,495. / Windows only
- **100 disc, 2-drive Blu-ray network-attach media duplicator**
 - \$7,495. /Windows only



PRIMERA
TECHNOLOGY, INC.



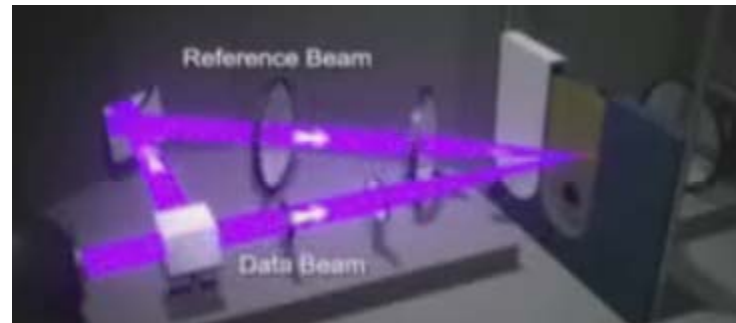
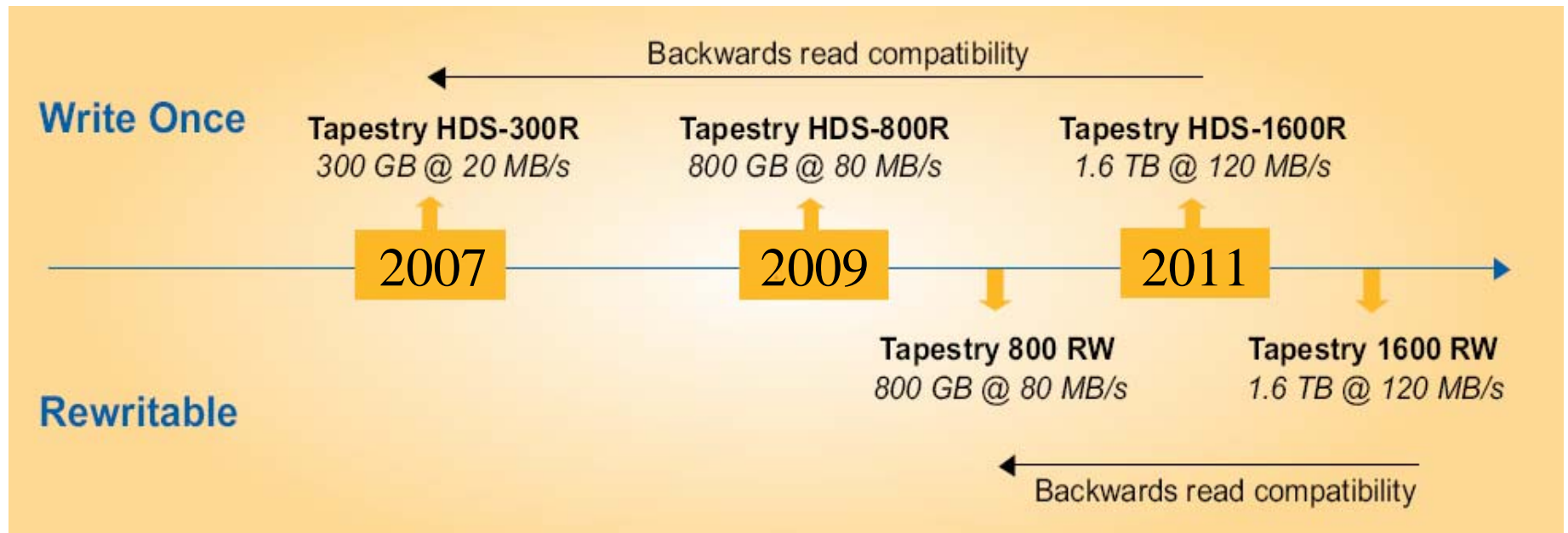
Product Review ~ Tapestry



- **300GB write-once holographic drive**
 - 7 hours HD, 64 DVD's
 - Maxell media partner
 - Shipping by 12/07 ?
 - \$18K drive, \$120./media
 - BDT, DISC and DSM are partners for library automation.



Product Review ~ Tapestry

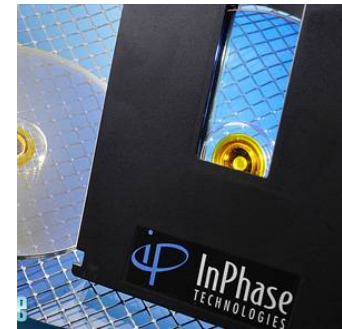


Product Review ~ Tapestry Library

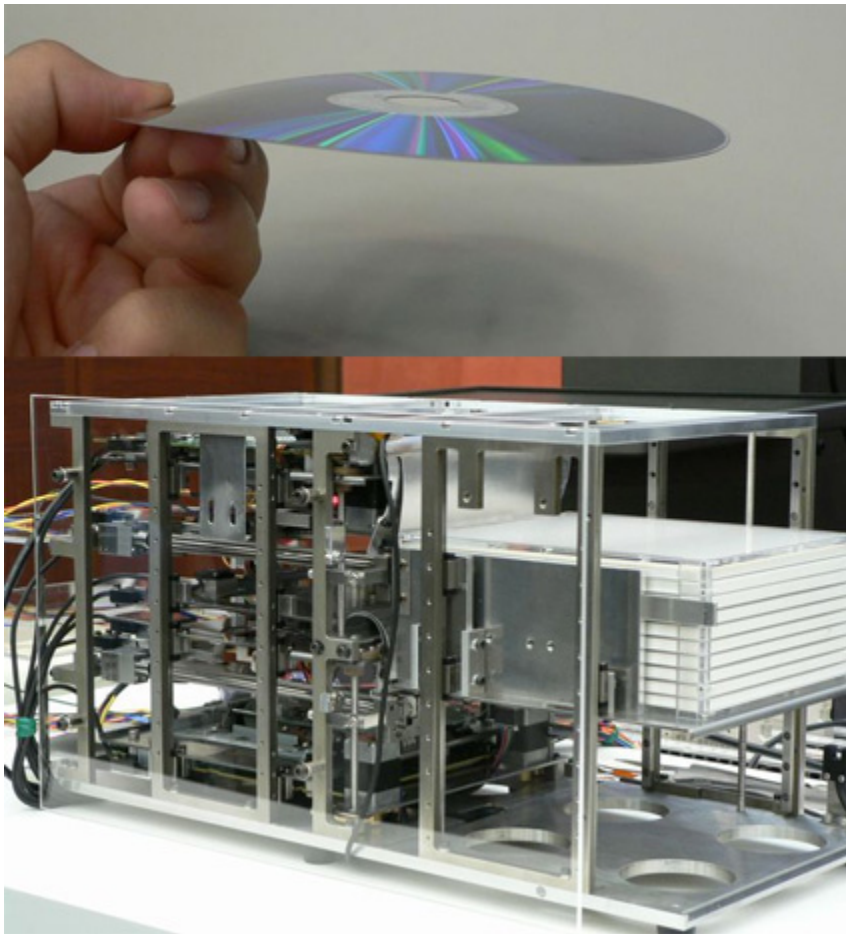


Key parameters:

- 300GB media capacity (WORM media), roadmap to 800 and 1.600GB
- 20MB/s Read/Write transfer rates, roadmap to 80- and 120MB/s
- 70TB to 660TB library capacity
- 1-2 \$/GB library hardware cost
- Media cost 60cent/GB
- Media life >50 years
- Available in Q4/2007



Product Review ~ SVOD



- **Stacked Volumetric Optical Discs (SVOD) Changer**

- 100 disc cartridge

- Double-sided 9.4GB DVD thin media = 946GB

- Single dual-layer 50GB blu-ray = 5TB



- \$325./DVD cartridge

- \$1,295./Blu-ray cartridge

- Rack mountable

- Available sometime in 2008, under \$3K ?



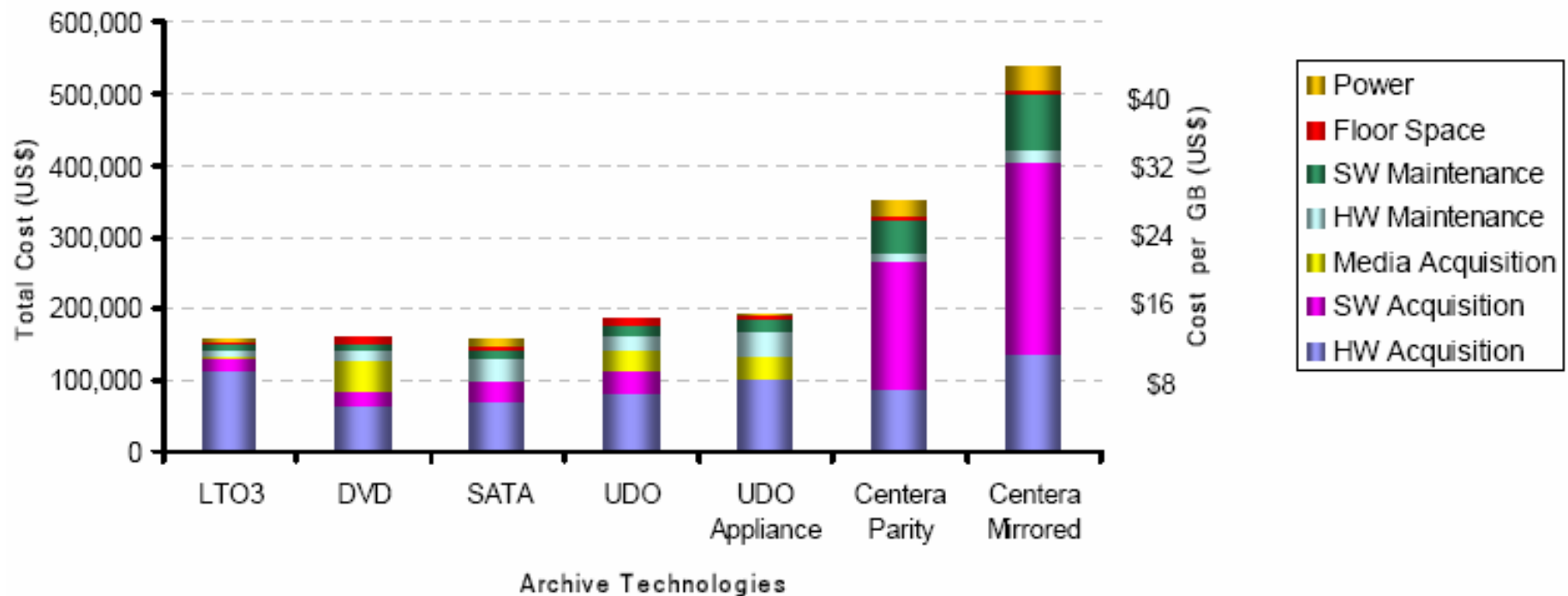
Product Review ~ UDO

- 20+ Years manufacturing optical drives, media and library automation products
 - 60GB double-sided media/UDO2
 - Complete family of storage solutions including CAS, NAS appliances
 - Phase-change media offers superb archival storage life
 - Complimentary to existing storage mgt. products



Product Review ~ UDO TCO

Archival Storage TCO
12 TB - 3 Years



Source: ESG, Plasmon

Product Review ~ Overall Optical TCO

- Permanence – long lasting media...50+ years
- Authenticity – true *"hardware"* WORM...data cannot be altered
- Fast Retrieval – direct file level access
- Removable Media – multiple copies...online, near-line, offsite vault DR
- Low Cost - long term viability of the technology (ROI)

	Access	Longevity	Permanence	Security	Authenticity	Portability	Cost
Automated Tape							
Mag Disk/ RAID							
Blu-ray / UDO							

Product Review ~ Overall TCO

Technology	Capacity GB	Access Time	Archive Life	Power Consumption	Special Req's.	Reliability	Maintenance	TCO	Cost Gbyte
Blu-ray	50	V Good	50	Low	No	High	Low	Low	Medium
HDTV	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Tapestry	300	V Good	50	Medium	No	TBD	TBD	High	Highest
UDO	60	Good	50+	Low	No	High	Low	Low	High
DVD	9.4	Average	50	Low	No	High	Low	Low	Low
Tape	>800	V Poor	30	Medium	No	Low	Medium	Medium	Low
RAID	>1TB	Excellent	3	High	Req's Backup	Medium	High	V High	Low

- **Blu-ray and UDO offer the best overall TCO for long-term archiving.**
- **Tapestry to be soon released.**
 - Ideal for video storage market.
 - InPhase claims not for IT market, yet will offer LTO emulation.
 - Will need OEM technology partners to succeed.
- **HVD is not on the market, but may rival Blu-ray and UDO technologies.**
 - Cost targeted to be in Blu-ray range
 - Standards already in place
 - 1TB disc = 212 DVD movies, 250,000 MP3 files, 1M Word docs

Final Analysis



- **Blu-ray** targeting consumer market to-date
 - Selected by entertainment, surveillance, VOD industries
 - Is cost-effective for archive, but slow adoption rate
 - Little to no marketing in non-video markets, ie. IT market ?
 - Technology partnering ?
- **UDO** is mature technology and has market penetration
 - Most reliable long-term archival storage medium
 - More marketing, additional OEM partners ?
 - Better pricing to keep abreast of Blu-ray in IT archive markets ?
- **Tapestry** holographic is still in 'beta'
 - Will need 12-18 months in market
 - Will media meet long-term archival storage requirements?
 - Additional OEM and technology partners ?
- **HVD** appears very promising
 - When?
 - How much?



Session Panelists

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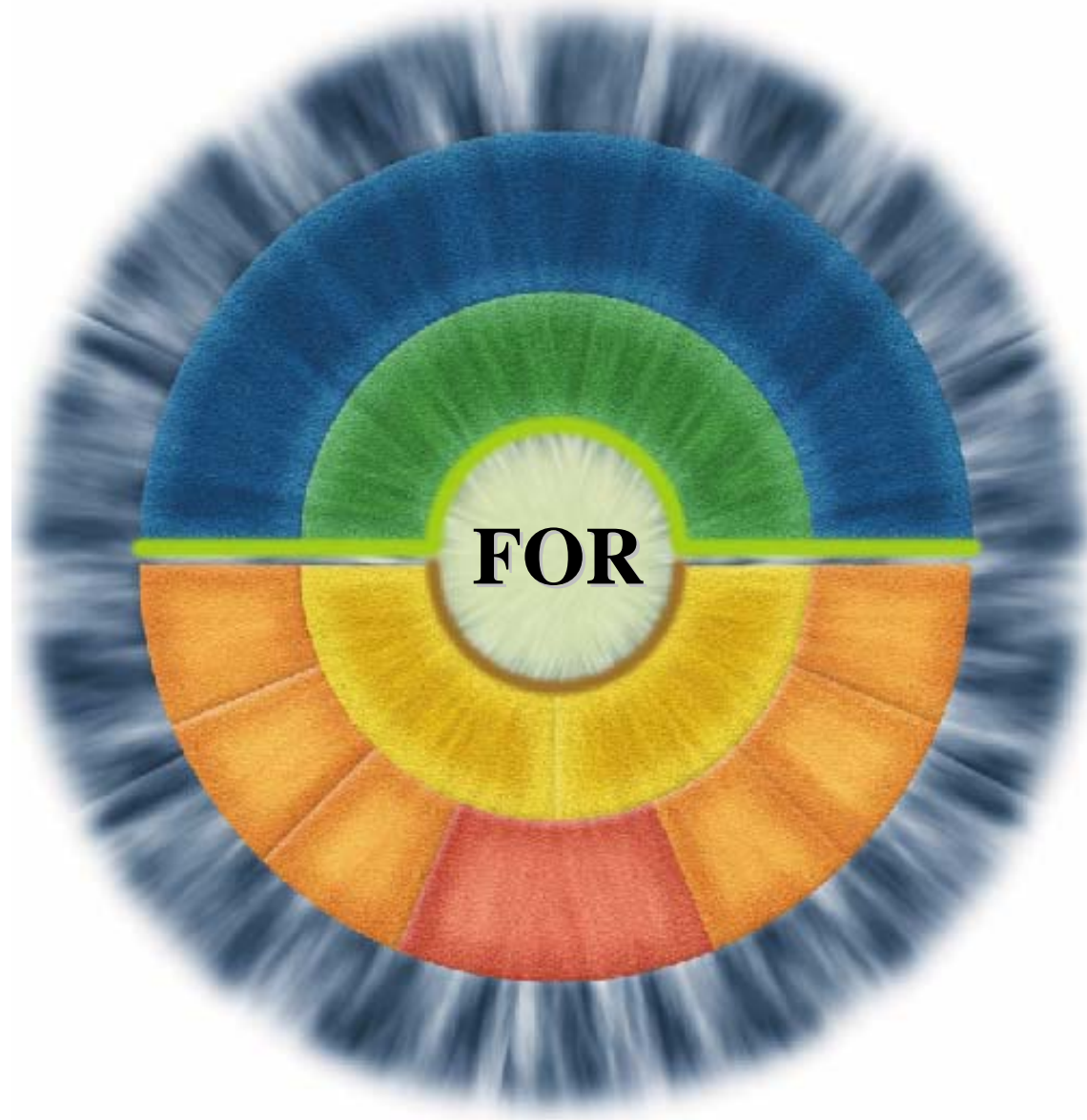


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