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
• 161 Exabytes (161 Billion Gigabytes!) of digital data was created, captured and replicated in 2006
  – Majority generated from 1Billion+ devices
    • Digital cameras, camera phones, medical scanners, surveillance cameras
  – Will increase 6x to 988 Exabytes by 2010

• Major Contributors To This Growth
  – Film to digital image capture
  – Analog to digital voice
  – Analog to digital TV (DTV)
  – Internet
  – Email, IM

Source: IDC
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
In 1996, the world-wide web (www) was only four (4) years old and there were 48 million internet users at the time.

- 1.1 Billion internet users in 2006
- Expected to be over 1.6 Billion 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

- 253 Million email boxes in 1998
  - 1.6 Billion email boxes in 2006
  - 2 Billion+ 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

© 2006 Coughlin Associates
Market Drivers ~ Information Compliance

In 2006, only 20% of IT infrastructure generating data were subject to compliance or standards rules.

Expected to double by 2010 to over $21.4 Billion

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

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

Source: IDC
## Market Drivers ~ Video

### Optical Storage Technology Association

### Table: Video Format Specifications

<table>
<thead>
<tr>
<th>Video Format</th>
<th>Horiz</th>
<th>Vert</th>
<th>Mbps</th>
<th>MB/sec</th>
<th>MB/Min</th>
<th>GB/Hr</th>
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</thead>
<tbody>
<tr>
<td>HD - 1080 4:2:2 Raw</td>
<td>1920</td>
<td>1080</td>
<td>712</td>
<td>89</td>
<td>5339</td>
<td>320</td>
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<tr>
<td>HD - 720 4:2:2 Raw</td>
<td>1280</td>
<td>720</td>
<td>316</td>
<td>40</td>
<td>2373</td>
<td>142</td>
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<td>HD-SDI 4:2:2 10b Raw</td>
<td>1920</td>
<td>1080</td>
<td>1500</td>
<td>30</td>
<td>1780</td>
<td>107</td>
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<tr>
<td>HD-D5 1080p/24</td>
<td>1920</td>
<td>1080</td>
<td>270</td>
<td>30</td>
<td>1780</td>
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<tr>
<td>SD - NTSC - Raw</td>
<td>720</td>
<td>480</td>
<td>237</td>
<td>30</td>
<td>1780</td>
<td>107</td>
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<tr>
<td>SD - NTSC - 4:2:2</td>
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<td>480</td>
<td>168</td>
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<td>SD - NTSC - 4:2:0</td>
<td>720</td>
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<td>119</td>
<td>15</td>
<td>890</td>
<td>53</td>
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</table>

Source: Disc, IDC, Panasonic

### Market Drivers

- **Archive & Digital Conversion**
  - +22.8%/yr

- **Post Production**
  - +36.5%/yr

- **VOD Streaming**
  - +91.1%/yr

- **Movie Recording**
  - +17.1%/yr

- **TV Recording**
  - +29.1%/yr

- Film, Animation, TV program:
  - +19.1%/yr
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

Global Removable Data Storage Media ($ Million)

1995 2000 2005 2010

Source: Imation
Market Review ~ Optical Drive Shipments

Worldwide CD/DVD/Blue laser Drive Shipments
Units, Millions

Source: IDC
Market Review ~ Drive Marketshare

- 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)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>DVD Sales</th>
<th>DVD Rental</th>
<th>Total Consumer Spending on DVD</th>
<th>Total Consumer Spending on Home Video (DVD &amp; VHS - Rental &amp; Sell Through)</th>
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<tbody>
<tr>
<td>1999</td>
<td>$0.7</td>
<td>$0.1</td>
<td>$0.8</td>
<td>$12.8</td>
</tr>
<tr>
<td>2000</td>
<td>$1.9</td>
<td>$0.6</td>
<td>$2.5</td>
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<td>2001</td>
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<td>2002</td>
<td>$8.7</td>
<td>$2.9</td>
<td>$11.6</td>
<td>$20.3</td>
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<tr>
<td>2003</td>
<td>$11.6</td>
<td>$4.5</td>
<td>$16.1</td>
<td>$22.5</td>
</tr>
<tr>
<td>2004</td>
<td>$15.5</td>
<td>$5.7</td>
<td>$21.2</td>
<td>$24.5</td>
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<tr>
<td>2005</td>
<td>$16.3</td>
<td>$6.5</td>
<td>$22.8</td>
<td>$24.3</td>
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<tr>
<td>2006</td>
<td>$16.6</td>
<td>$7.5</td>
<td>$24.1</td>
<td>$24.2</td>
</tr>
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</table>

Source: DEG
# Market Review ~ DVD Hardware

## U.S. DVD Hardware Sales (in millions)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>2nd Quarter</td>
<td>.079</td>
<td>.149</td>
<td>.611</td>
<td>1.435</td>
<td>2.404</td>
<td>3.750</td>
<td>5.506</td>
<td>6.057</td>
<td>6.006</td>
<td>6.676</td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>.077</td>
<td>.244</td>
<td>.880</td>
<td>1.550</td>
<td>2.537</td>
<td>4.740</td>
<td>6.470</td>
<td>6.593</td>
<td>6.250</td>
<td>6.831</td>
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<tr>
<td>YEARY TOTAL</td>
<td>.305</td>
<td>.946</td>
<td>3.550</td>
<td>9.877</td>
<td>16.662</td>
<td>25.113</td>
<td>33.734</td>
<td>37.125</td>
<td>36.737</td>
<td>32.66</td>
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<tr>
<td>TOTAL (since launch)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>194.362</td>
</tr>
</tbody>
</table>

*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

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

<table>
<thead>
<tr>
<th>Sales (billions)</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
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</thead>
<tbody>
<tr>
<td>Units (M)</td>
<td>531</td>
<td>644</td>
<td>691</td>
<td>722</td>
<td>748</td>
</tr>
<tr>
<td>$ (M)</td>
<td>1,865</td>
<td>1,844</td>
<td>1,753</td>
<td>1,486</td>
<td>1,600</td>
</tr>
</tbody>
</table>

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.

Source: OptoElectronics
Market Review ~ Optical Media

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

Source: GlobalSources
Technology Review ~ Optical Storage

[Diagram showing the progression from CD Technology to Next Gen Optical Technology with labels for DVD Technology and Next Generation technologies like Blu-Ray, UDO, and Holographic.]
Technology Review ~ Future Density Trends

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

Source: ISOM
Technology Review ~ Lasers

HD DVD Laser light 405 nm

DVD Laser light 650 nm

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

CD
DVD
BD

0.7GB
4.7GB
25GB

1.2MM SUBSTRATE
0.0MM SUBSTRATE
0.1NM SUBSTRATE

LASERS

1 cm

100 Å
### Parameters

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

Source: Philips
Technology Review ~ UDO

- 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

- 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

This is a conceptual demonstration of Aprilis Holographic Data Storage technology, including the data writer and reader and the Aprilis optical disk.

Use the buttons to activate the "write" and "read" demonstrations and to view the individual components and description of their function.

Please note: The object and reference beams are mutually monochromatic and coherent. They are shown here in different colors only to aid the conceptual understanding of their function.

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Writing

Reading
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
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 ~ 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
High NA Multi-layer Volumetric

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

Write Form

Dye Precursor (DP) → Acid Generator (AG) → Polymer Host

hv

Read Form

Fluorescent Dye → Polymer Host

AG + hv → H⁺+ products → Dye (Written form)

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

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

Blu-rayDisc

SONY | sony style USA
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

- DV – 8Mbps
- HDV – 25Mbps
Product Review ~ Blu-Ray
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
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

Write Once

Tapestry HDS-300R
300 GB @ 20 MB/s

2007

Tapestry HDS-800R
800 GB @ 80 MB/s

2009

Tapestry HDS-1600R
1.6 TB @ 120 MB/s

2011

Rewritable

Tapestry 800 RW
800 GB @ 80 MB/s

Backwards read compatibility

Tapestry 1600 RW
1.6 TB @ 120 MB/s

Backwards read compatibility
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
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)

<table>
<thead>
<tr>
<th></th>
<th>Access</th>
<th>Longevity</th>
<th>Permanence</th>
<th>Security</th>
<th>Authenticity</th>
<th>Portability</th>
<th>Cost</th>
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<tr>
<td>Automated Tape</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
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<tr>
<td>Mag Disk/RAID</td>
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<td>x</td>
<td>x</td>
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<tr>
<td>Blu-ray / UDO</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
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</table>
# Product Review ~ Overall TCO

**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

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<table>
<thead>
<tr>
<th>Technology</th>
<th>Capacity GB</th>
<th>Access Time</th>
<th>Archive Life</th>
<th>Power Consumption</th>
<th>Special Req's.</th>
<th>Reliability</th>
<th>Maintenance</th>
<th>TCO</th>
<th>Cost Glyte</th>
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<tbody>
<tr>
<td>Blu-ray</td>
<td>50</td>
<td>VGood</td>
<td>50</td>
<td>Low</td>
<td>No</td>
<td>High</td>
<td>Low</td>
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<td>HDV</td>
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<tr>
<td>UDO</td>
<td>60</td>
<td>Good</td>
<td>50+</td>
<td>Low</td>
<td>No</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>DVD</td>
<td>9.4</td>
<td>Average</td>
<td>50</td>
<td>Low</td>
<td>No</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Tape</td>
<td>&gt;800</td>
<td>V Poor</td>
<td>30</td>
<td>Medium</td>
<td>No</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>RAID</td>
<td>&gt;1TB</td>
<td>Excellent</td>
<td>3</td>
<td>High</td>
<td>Req's Backup</td>
<td>Medium</td>
<td>High</td>
<td>V High</td>
<td>Low</td>
</tr>
</tbody>
</table>
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, i.e. 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?
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THANK YOU FOR ATTENDING