Digital Optical Tape: Technology and Standardization Issues

Fernando L. Podio
National Institute of Standards and Technology
Building 225, Room A261
Gaithersburg, MD 20899
fernando.podio@nist.gov
+1-301-975-2947
+1-301- 216-1369 (fax)

Abstract

During the coming years, digital data storage technologies will continue an aggressive growth to satisfy the user's need for higher storage capacities, higher data transfer rates and long-term archival media properties. Digital optical tape is a promising technology to satisfy these user's needs. As any emerging data storage technology, the industry faces many technological and standardization challenges. The technological challenges are great, but feasible to overcome. Although it is too early to consider formal industry standards, the optical tape industry has decided to work together by initiating pre-standardization efforts that may lead in the future to formal voluntary industry standards. This paper will discuss current industry optical tape drive developments and the types of standards that will be required for the technology. The status of current industry pre-standardization efforts will also be discussed.

1. Introduction

The data storage industry needs to satisfy a substantial growth in user's requirements for high performance, large capacity mass storage subsystems. New applications and data types, and the need to store and quickly retrieve massive amounts of data require systems with large on-line and near on-line capacities, very high transfer rates and good archival media properties. A hierarchy of storage devices is needed to satisfy these requirements. Optical tape subsystems will fit well in that storage hierarchy. Optical tape media offers the potential for high aerial density, high transfer rates and an expected long archival life. As an emerging technology, however, the optical tape industry faces many challenges. Magnetic tape, a competing technology, is well established and also promises high performance products with high capacity and high transfer rates. The technological challenges that the optical tape industry faces are feasible to overcome. Standardization is also a challenge as it has been for other data storage technologies. Recent industry developments, and standardization issues will be addressed in the following sections.

2. Current Product/Developments[1]

There is only one optical tape drive on the market today. The CREO/EMASS drive offers one Terabyte of data on a 35 mm reel of optical tape. The sustained transfer rate is 3 Mbytes/s. The media used by this drive is WORM (Write-Once Read Many). The specified access time is 65 seconds average for one Terabyte.

In 1995, the Advanced Technology Program (ATP) of the National Institute of Standards and Technology (NIST) awarded two projects related to this technology [US Department of Commerce News, 1][2]. One awardee was LOTS Technology, Inc. ("Digital Data Storage Technology via Ultrahigh-Performance Optical Tape Drive Using a Short-Wavelength Laser"). The project includes the development of optical tape read/write technology which could lead to systems capable of storing one Terabyte and capable of transferring that data at a rate of at least 100 Megabytes per second. In order to achieve this performance, the project includes the development of optical tape storage technology in which up to 180 tracks can be simultaneously written and read with multiple, independently controllable laser beams. It is planned that the first application of this technology would be an "IBM-3480"-style cartridge.

The other ATP awardee in this technology field was a joint venture of Terabank Systems Inc., Polaroid Corp., Science Applications International Corp., Xerox Corp., Carnegie Mellon University, Energy Conversion Devices, Inc., NASA Goddard Space Flight Center, and the University of Arizona ("Technology Development for Optical-Tape-Based Rapid Access Affordable Mass Storage (TRAAMS)"). (Motorola Corp. joined the venture later on.) This project includes the development of a thin-gauge erasable/rewritable optical tape on which a bit of data can be recorded on a spot six-tenths of a micrometer in diameter. The proposed tape handling methods would move the tape at 2,500 centimeters per second. The expected transfer rate is 6 Mbytes/s and when accessing multiple tracks of the tape it can reach up to 100 Mbytes/s. Assuming the ATP project is successful, the expected user capacity of the first product that could result from the use of this technology is 100 Gbytes.

In addition to the projects awarded by ATP, technology projections indicate the following developments (see Table 1). Table 1 indicates technology <u>projections</u>, **not** product announcements.

[1] Certain trade names and company products are mentioned in the text in order to adequately describe industry developments. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products are or will be necessarily the best available for the purpose.

[2] The ATP cost shares high-risk industrial R&D projects to overcome technical barriers, rather than product development. If projects are successful, companies will develop products exploiting the technology with their own funds. In the descriptions of ATP projects in this paper, the technology projections reflect specifications of products that the companies hope to develop to exploit the new technology if the ATP projects are successful.

LOTS Technology's first development will hopefully result in a product with one 1 Terabyte capacity and a sustained transfer rate of 15 Mbytes/s using a WORM optical tape .5 in width and 400 m long. EMASS has plans for a line of optical tape drives. The first product is scheduled to have a capacity of 200 Gbytes at a 12.5 Mbytes/s sustained transfer rate. This product uses WORM media and specifies an average access time of 50 seconds, Chu [2]. (As of this writing, July 1, 1996, EMASS's parent company Raytheon has placed on hold this optical tape program and the company is for sale.)

Terabank's technology projections include doubling the capacity and the transfer rate of the first product that might result from the ATP technology to 200 Gbytes and 12 Mbytes/s. Support for WORM and rewritable media is expected. Researchers at Philips Research Laboratories have described a compact optical tape recorder with a 80 Gbytes capacity in a 8 mm cassette at approximately 30 Mbits/s transfer rate and 15 seconds access time, van Rosmalen, Kahlman, Put, and van Uijen [3]. Primelink proposes an optical tape drive with 36 Gbytes and 72 Gbytes with an access time of less than 1 second and a transfer rate for the first version of the drive of 15 Mbit/s, Newell [4].

Other plans and developments were reported by NHK and Sony researchers. NHK researchers reported development of a high capacity optical tape recorder able to store information for high definition TV and future TV systems, Tokumaru, Arai, Yoshimura, and Oshima [5]. Sony researchers reported developments of a helical scanning optical tape recorder and new tracking methods for that recorder, Narahara, Kamtami, Nakao, Kumai, and Ozue [6].

Media manufacturers include: ICI Imagedata (dye polymer media)[3], Eastman Kodak (WORM phase change media), Polaroid (phase change media) and Southwall/Dow (bubble forming media). Other companies have researched the use of magneto-optical (MO) media. Details of these media characteristics and formulations can be found in different publications, Ashton [7]. Changes might be expected in these media. Final media configurations cannot be designed independently of the drive manufactures' specifications and requirements.

3. Standards for Optical Tape Media/Subsystems

In order to establish optical tape as a recognized data storage technology, the optical tape industry will need to provide users with storage solutions that conform, if possible, to voluntary industry standards. A family of standards is required for any particular data storage technology. One classification of these standards includes:

- ⇒ Data interchange standards
- ⇒ Test methods standards
- ⇒ Data integrity standard

[3] ICI Imagedata will be withdrawing from the optical tape business over the next two years.

Table 1 - AIIM Optical Tape Study Group Technology Roadmap(*)

System name	Average Access Time (sec)	User Capacity (GB)	Sustained Data Rate (MB/sec)	Year of Introduction	Tape Width Tape Length
CREO/EMASS OTR	65	1000	3	1991	w=35mm, L=800m
Terabank TRAMMS1	2	100	6	1998	w=8mm, L=120m
Terabank TRAMMS2	2	200	12	1999	w=8mm, L=120m
Terabank TRAMMS3	2	400	24	2001	w=8mm, L=180m
LOTS Lasertape 15T	20	1000	15	4Q 1997	w=0.5in, L=400m
Lots Lasertape 100T	20	1000	100	4Q 1998	w=0.5in, L=400m
Philips	15	80	3.75		w=8mm, L=110m
Primelink	0.05 - 2	72 - 1350	1.88	1995 - 2000	w=8mm, L=100m
EMASS Harrier *	25	200	12.5	4Q 1997	w=0.5in, L=450m
EMASS Osprey *	15	600	15	3Q 1998	w=0.5in, L=708m
EMASS Rewritable **				4Q 1999	
EMASS Extended Future **		800, 2400	80	2001	

(*) Technology projections, **not** product announcements
(**) Raytheon has placed on hold the E-MASS optical tape program

3.1 Data interchange standards

Data interchange standards promote the availability of competitive products and multiple sources of media. They also increase the user's confidence in the technology by assuring media/data interchange between products and the long-term availability of drives and media. The following model represents four levels of compatibility, Hogan [8]

- **Level 4 - Applications**

There are many application level standards. The following are some examples of this type of standards:

⇒ data compression schemes for raster-scanning documents
⇒ control codes for word processing
⇒ media error monitoring and reporting techniques for verification of stored data

- **Level 3 - Logical format for the media**

Logical volume label and file structure standards are in this level. They facilitate the interchange of data among different information processing systems.

- **Level 2 - Physical format of the media**

This level of standards deals with the recorded characteristics of the media. It includes characteristics such as:

⇒ data and track format
⇒ track locations
⇒ modulation schemes

- **Level 1 - Media properties**

This level of standards specifies the unrecorded or unformatted characteristics of the media. It specifies the physical and optical properties and assures the interchange (read/write) of media among different drives. The media properties that must be standardized include characteristics such as:

⇒ mechanical properties
⇒ dimensional properties
⇒ optical properties
⇒ read/write/erase properties

3.2 Test methods standards

Test methods standards for the media characteristics help avoid conflicts between media suppliers and drive manufacturers, allows for easy documentation of round-robin tests, and allows testing for conformance to media interchange standards.

The type of characteristics that require test methods are:

⇒ mechanical properties
⇒ optical properties
⇒ recording layer properties
⇒ substrate properties
⇒ preformat properties
⇒ environments: operational and storage

3.3 Data integrity standards

Long term availability of data depends on many factors including data integrity, media life expectancy and the availability of subsystems that can access the media where data resides. As noted above, data interchange standards improve the chances of the long-term availability of drives and media. Standards for data/media preservation are also required.

They include:

⇒ standard media error monitoring and reporting techniques to verify stored data
⇒ life expectancy standards

Media error monitoring and reporting techniques allow users to monitor the status of the stored data. An example of standard media error monitoring and reporting techniques (for optical disk drives) can be found in ANSI/AIIM MS59 [9]. Life expectancy standards allow users to select media according to their long-term requirements by comparing manufacturer's media life expectancy claims.

4. The Association for Information and Image Management International (AIIM) Optical Tape Study Group

AIIM formed the Optical Tape Study Group (OTSG) in response to industry interest in initiating technology discussions and pre-standards work. AIIM OTSG is an open forum where industry and users can together discuss technical issues such as media characteristics, metrology and data integrity of optical tape media/systems and user's needs. The Study Group has attracted broad industry and user's participation. OTSG does not have the responsibility for developing formal standards. However, the OTSG may generate, in the future, standard development projects proposals.

The OTSG has prepared a matrix of unrecorded media characteristics and it is planning to develop a document specifying these characteristics. Test methods for the media characteristics are also discussed and they will be documented. In addition, OTSG is specifying media error monitoring and reporting (MEMR) techniques to verify stored data on optical tapes. The documentation of these MEMR techniques is underway. Table 1 shows the Technology Roadmap developed by the OTSG. Table 2 shows industry and user organizations included in AIIM OTSG's participant's list. The OTSG held two meetings in 1995 and three meetings in 1996. The next meeting will be held October 3 - 4, 1996 at AIIM Headquarters, 1100 Wayne Ave., Suite 1100, Silver Spring, MD.

5. Conclusions

Any emerging data storage industry faces many technological and standardization challenges. The technological challenges are great, but feasible to overcome. Standardization will also be a challenge. In addition to the only existing commercial drive, several drive developments are taking place. Some of them might become commercial products in the coming years. The industry is not mature enough to address formal standards developments. However, recognizing that standards are necessary when products become available, the optical tape industry has initiated pre-standards work through the AIIM Optical Tape Study Group. Drive and media makers as well as other organizations are discussing media characteristics, test methods for these characteristics, data integrity issues and user's needs. This industry anticipatory work may lead to formal standardization efforts.

Table 2 - Organizations Participating in OTSG

Ampex Data Systems	Apex	Boeing	Callicot	CIO
Customer Refocus	LDS Church	Eastman Kodak	E-MASS	E-Systems
Filetek	Genealogical Society of Utah	ICI Imagedata	IIT Reserach Institute	IRS
LaserTape	Library of Congress	Loral Federal Systems	LOTS Technology	MITRE
Mobil Oil	NASA/GSFC	National Archives	NML/3M	NIST
NSIC	Philips Research Laboratories	Polaroid	Primelink	Radix Systems
SAIC	Systems Engineering & Security	StorageTek	SUN Technologies	SyntheSys Research
Technology Solutions	Terabank Systems	TRW	University of Arizona	

6. References

[1] US Department of Commerce News, August 15, 1995.

[2] John Chu, Response to AIIM OTSG Request for Information, April 1996.

[3] G. E. van Rosmalen, J. A. H. Kahlman, P. L. Put and C. M. J. van Uijen, SPIE, Vol. 2338, 1994.

[4] Chester W. Newell, "Petabyte Mass Storage Memory System Using the Newell Opticell (tm)", Fourth NASA Goddard Conference on Mass Storage Systems and Technologies", March 1995, NASA Conference Publication CP-3295.

[5] Haruki Tokumaru, Kiyotaka Arai, Shin-ichi Yoshimura, and Hideo Oshima, "Recording Experiment with Rotating optical Head for Magneto-Optical tape Recording System", SPIE Vo. 2514, 1995.

[6] Tatsuya Narahara, Yoshiteru Kamtami, Takashi Nakao, Satoshi Kumai, and Tadashi Ozue, "A New Tracking Method for Helical Scanning Optical Tape Recorder', Jpn. J. Appl. Phys., Vol 32, Part 1 No. 11B, August 1993.

[7] Gary Ashton, "New Opportunities in Optical Tape", Dataquest Conference, June 1996.

[8] Michael D. Hogan, "Digital Data Interchange Reference Model for Removable Computer Storage Media", September 1988.

[9] ANSI/AIIM MS59, "Media Error Monitoring and Reporting Techniques for Verification of Stored Data on Optical Digital Data Disks", March 1996.