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# Optical Storage Shines Over the Horizon

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## ABSTRACT

Ranging from read-only, write-once and erasable designs, optical storage promises to store large amounts of data at lower than Winchester costs. But lack of media, standards and software is slowing market acceptance.

## INTRODUCTION

Using special Galium Arsenide diode lasers, no bigger than a pencil eraser, and exotic rare earth based recording surfaces, Optical disk drives are promising to store from 40M bytes of data on a 3[1/2]-inch disk to over 1G byte on single-sided 12-inch models.

Currently, three distinct classes of optical drives exist. They are:

- Optical-read-only memories (OROM),
- Write-once-read many (WORM),
- and Write-many-read always (WMRA) or erasable.

The first category, OROM, devices are for the near future the most promising for numerous applications.

The WORM drives although available in limited quantity are still in the infancy stage and are about 18-to-24-months away from realizing volume potentials.

The final category erasable (WMRA) optical drives are most likely still four-to-five years away in terms of full scale production and market acceptability.

## STANDARDS STILL UNCLEAR

Both the WORM and WMRA drives suffer from similar problems. Specifically, even though the basic technology is developed, good reliable media is still not available. Additionally, several questions regarding the interface and data format remain to be answered. Additionally, there are major questions regarding the controlling and data handling software. Furthermore, no standards currently exist for data interchange. Interestingly, manufacturers of 12-inch optical products argue that standards aren't needed since their products are being used in niche markets that establish their own standards.

However, that doesn't appear to be the case for 5[1/4]-inch WORM and WMRA products. Already a cartridge standard has been more or less agreed on by ANSI members and they are looking into the interchange problems as well. Many industry observers concur that 5[1/4]-inch will probably benefit from standards well before 12-inch products. This is primarily since the 5[1/4]-inch products will be more pervasive than 12-inch drives due to low-cost.

## READ ONLY HERE TODAY

Of the available optical disk technologies that is the most promising short term, is optical-read-only memory (OROM). These devices have data that is pre-written on a phonograph record-like platter and can't be written over. The data which is mastered from video tape is written with a laser beam onto a "gold" master, which in turn is used to press PMMA substrate based platters. Once pressed, the platters are then covered with metal and put in a protective coating to minimize water absorption. The resulting disk contains anywhere from 500M bytes to 2G bytes of data--depending on diameter and number of data surfaces used. Typically, a 2G byte platter has 1G byte of data per side.

One company, Reference Technology Inc., has developed a 12-inch OROM 2G-byte system called the DataDrive Series 2000, for publishing archive information. In addition, they are an OEM to Hitachi for a 5[1/4]-inch drive that they bundle in the DataDrive 500, a 550M byte system.

Besides the drive(s), Reference has also developed the necessary software to use the data properly. For example, they have a keyed information retrieval package, STA/F Key, designed for assisting in the writing of application software, a full text retrieval package, STA/F Text, and a complete file management system STA/F File. Moreover, they also provide a data preparation service to ready data to be etched on to the optical disks.

They believe that the OROM is a data distribution and publishing device that can be used now.

Apparently other companies agree since manufacturers such as Hitachi, Sony Corp., Toshiba, and Victor Company of Japan (JVC Brand) are all preparing OROM devices and data preparation services.

Interestingly, it hasn't been the digital storage aspects of OROM's that have been pushing the technology. Rather, it has been the consumer market, specifically digital audio on compact discs (CD). Already the price of CD players has dropped, with store prices expected to be under $100 this year.

## WORM'S IN THE SYSTEM

Even though OROM drives do offer information publishers a low-cost (typically about $20,000 for mastering a disk and $6 per copy) method of distributing information, optical disk drive manufacturers see the need for write-once and eventually erasable capability.

The write-once-read many (WORM) drive is similar in some respects to the OROM device, in that once written the data can't be changed. However, there are several complications in the WORM type drive.

Specifically, once the data is written, it can't be overwritten, thus the data area has to be protected. Hence, the data blocks are arranged with a write protect block which signals the drive electronics not to turn the laser on until an unwritten block is available. The next block is the data block and ranges in size from 512-bytes, the standard sector size used on an IBM PC, to 1024 bytes. There are pros and cons on the sector size. Some believe that the larger sector size improves efficiency and is easier to perform error-correction on; others contend that the 512-byte sector is easier to work with from a systems and software stand-point. Thus both sizes can be found on WORM drives. The final data block is used to contain information about the previously written data. For example, if an error occurred during a Write cycle, a pointer to the next usable block is written. Additionally 16-bytes are fused to point to new data that is associated with the record.

Further complicating WORM devices is the choice of media format. Designers use either a spiral track which can be likened to a tape or concentric ring tracks which more closely resemble the track layout on magnetic disks. Most optical drive manufacturers claim that their drives can use either track format.

Laserdrive is one of the manufacturers of a 5[1/4]-inch WORM drive that uses the spiral tracking method. They expect to treat the surface as a long track and aim the product at low-end applications such as storage on home computers like the Apple Corp., Macintosh, Atari ST series, and Commodore Amiga. Thus speedy access times aren't necessarily a consideration.

Moreover, designers can use either CLV or CAV technology to maximize the performance of the drive. In the former the recording density remains constant over the entire disk, thus the disk spins slower at the outside tracks than at the inner. In contrast, the CAV drive maintains a constant rpm but the densities are higher at the inner tracks. The CLV method does yield high capacities but is expensive in hardware and software overheads. The CAV method more closely resembles the operation most integrators expect.

## MEDIA QUESTIONS REMAIN

Still causing drive makers difficulty is the availability of write-once media. Although companies such as 3M, Maxell, and Plasmon, to name a few, are manufacturing WORM, OROM, and to a limited degree, erasable media supplies aren't high and bit-error rates (BER's) are still in the $10^{-4}$ range which can be corrected using error-correction code schemes. Additionally, the WORM media can be preformatted and scanned to map defect areas and build a defect map. This map is a list of the physical sectors that are denoted bad. This information is later used by the controller to skip over the bad sectors and or tracks.

Typically optical recording uses a minute precisely focused laser beam to burn tiny "pits" on a recording platter. The presence or absence of pits, when they rapidly pass under a light beam in playback, triggers a photoelectric receptor to convert that presence or absence to electrical signals which are then transformed into digital data. This is the technique used by many of the WORM drive manufacturers.

This technology, however, does have drawbacks. Specifically, the pits don't always have clean edges thus fouling the read back system and presenting non-correctable errors. Moreover, the CNR is poor and the noise far outshines the reflected signal.

One method in media manufacture developed by 3M that improves the reliability of the media is using a blistering or bubble technique.

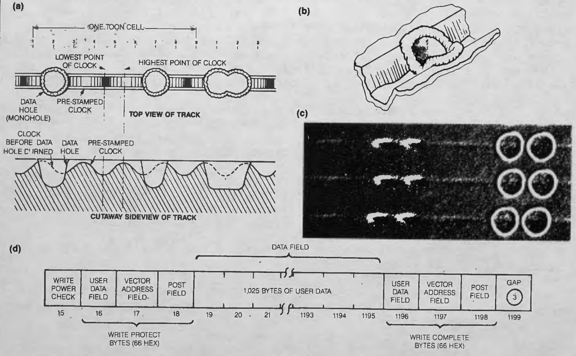
With the blister method the laser burst raises the temperature of a spot on the media to about 2,000 degrees centigrade, causing the lower layer to vaporize and force the covering layer up into bubble or blister.

The blister then has no ragged edges which contribute to the surface noise. The readback system sense scattered light from the bubble, thus denoting a written bit. Interestingly, both the ablative-pitting and blister method have about a 50 nanosecond write or read time or a data rate of 10MHz.

## Stages in creating WORM media

In a write-once, read-many (WORM) drive that uses an ablative-pit recording method, the media is pre-grooved and formatted with clock information (a), and then is burned in, appearing as a hole (b). As shown (c), clock information appears as a series of bubbles (left) and the data as fringed holes (right).

The data is arranged in sectors (d)—much like magnetic disks—except that each sector begins with a write-protect field to prevent overwriting and destroying existing data. The write-protect fields are followed by the user-data field and the write-complete field. The latter points to either a new sector if an error was encountered during writing, or to a new data record if the record was updated.




ERASING THE DATA

Companies such as Eastman Kodak are also developing optical media. Kodak puts a protective polymer coating over the sensitive layer. And like 3M is exploring ablative and blister methods as well as phase change. This latter method uses a technique whereby the physical state of the material is changed from a crystalline to an amphorous state which denotes a written bit. Reversing the process to change back to crystalline erases the data. Although Sony Corp. has more than ten years of experimentation with phase change technology, reliability data on media life is still sketchy. It is believed that it is somewhere between 3 to 5 years and possibly 10, depending on how the media is stored. But phase-change media is temperature sensitive reverting back to the crystalline state at about 100-degrees C.

Currently being viewed with favor for erasable drives, however, is magneto-optical (MO) media. With this media no physical structural change takes place with burning, blistering or change in the crystal structure. Rather, a high coercivity media (2000-to-30000e) with the magnetic domains in a vertical orientation is used. The laser is used to heat a spot and make it susceptible to magnetic reorientation by a surrounding bias field, by lowering the coercivity. The bit is erased using the same process.

The MO media is apparently easier to make since manufacturers can borrow from methods used in creating sputtered vertical media and the scale-up process developed for WORM media. Moreover, the BERs more closely resemble magnetic media.

Among the companies that are currently developing MO type drives, is Verbatim, who this past summer demonstrated a 3[1/2]-inch 40M byte model. Startup Daisar Corp. is developing an 8-inch 700M byte version which they plan to begin sampling by the end of 1986. The Daisar drive uses a media developed by sister company Kerdix Inc., who is borrowing technology developed by Nakamichi U.S.A. Corp., originally for erasable audio systems.

## ECC IMPROVES RELIABILITY

Of great concern to drive manufacturers and system integrators is the error or defect handling on optical drives. The method used by OSI is to use a direct-read-during draw to detect errors. This method reads back the data the moment it is written and compares it to the data in the write buffer, if an error exists, a new section of disk is chosen. This is different than so-called DRAW drives that read after the writing is performed, thus necessitating a full rotation of the drive before a new area can be written. Hence, OSI achieves a bit-for-bit error checking.

But most error handling is done after the fact--on read back. When an error is encountered--detected, the system attempts to correct it using a polynomial that is set to correct a given number of errors over a specified burst period. In addition, the ECC circuitry and associated firmware must be able to account for the interleave--staggering of sectors, and loss of signal synchronization.

The Reed-Solomon codes are capable of handling random, single, or multiple error symbols and correcting on multiple bursts and errors.

An implementation of this in silicon has been developed by Neal Glover president of Data Systems Technology. The NG-8510 uses an interleaved Reed-Solomon code that can handle up to 3 interleaves, or by cascading several chips in parallel the interleave is a factor of 3*N, N being the number of chips used. Moreover, the chip can accommodate up to 669 bytes per physical sector, or 669*N for additional chips in parallel.

## VERTICAL RECORDING, A CHALLENGE TO OPTICAL?

Optical recording isn't the only technology that promises to store large amounts of data on single platters. Vertical, or perpendicular recording, holds similar promise.

Vertical recording is properly named since the domains of the magnetic material are oriented up and down or perpendicular to the recording plane, rather than horizontally as in typical longitudinal magnetic recording. As a result, greater resolution--more bits-per inch--can be packed on a surface.

But achieving vertical recording isn't without some major technology changes. For example, a special double-layer media is required that has the proper magnetic particle orientation and allows the flux to travel between the poles of the read/write transducer.

The read/write transducer is unlike a standard Winchester head. The write flux is generated by one pole piece and sensed by the other as it travels in the semipermeable underlayer of the magnetic media surface. In the process the bit orientation is changed for one direction to the other denoting a written bit. One company, Censtor Corp., has developed both a vertical transducer called a Monopol head and a 1.38G Byte 5[1/4]-inch drive using this technology.

Similarly, Toshiba Corp. has developed a 3[1/2]-inch drive using Barium Ferrite media and a ring-type transducer. This drive can store up to 4M bytes formatted on 135 tpi. Toshiba also claims that the drive can also use conventional 3[1/2] Cobalt Gamma Ferrous Oxide media as well.

## MAGNETO-OPTICAL USES SAME PRINCIPLE

Interestingly, magneto-optical drives, such as that demonstrated by Verbatim Corp., (MMS July, 1985 Pg 133), combines the features of optical technology and vertical recording to produce capacities of 40M bytes on a 3[1/2] drive.

However, MO type drives differ in that unlike a typical Winchester or vertical recording drive, the read/write head can be a significant distance from the media (vertical recording allows 4-to-6 microinches, Winchesters 6-to-10 micro-inches). This is possible since the head is a laser and isn't flown but uses optics to focus the spot. Moreover, the media is heated to allow a surrounding bias field to change the bit orientation. However, the result is the same--vertical orientation of the bits.

Depending on the microprocessor used and the number of errors encountered, the error-correction times vary. For a 12MHz 8-bit processor encountering 8 errors, the typical correction time is 7,600 microseconds. Implemented in an SCSI or an ESDI controller, with full buffer management, error-correction times drop and raw BER's can be reduced from $10^{-4}$ to an acceptable $10^{-12}$ on optical drives. Although the correction time may appear excessive, using an intelligent interface hides the operation from the user, thus data is delivered corrected in about the same time as non-corrected data.

## A "SCUZZIE" INTERFACE

Regardless of the type of optical drive, how it gets coupled to the system is of major concern to system integrators.

Since optical drives have characteristics that are different than Winchesters, how they are interfaced and used in a system can be difficult. To this end drive manufacturers are considering using either the enhanced-small-device interface (ESDI), or the small-computer-systems interface (SCSI). In some cases, there is consideration of employing an ESDI/SCSI combination. This latter possibility does have a great deal of merit since ESDI is a device interface and SCSI is a system interface.

All three interface approaches do remove most of the integration burdens from the system integrator. For example, when using ESDI it is expected that existing Winchester controllers can be leveraged into an optical system by basically changing the ROM code. Similarly, SCSI can be employed in the same manner.

Already several of the manufacturers, as shown in the table, are already using SCSI. And ISI is settling on ESDI.

The advantage of SCSI is that the drive can be easily matched to any system by using a host adapter rather than creating a complete controller, which must be done with an ESDI interface.

For example, Optimem uses a SCSI controller implemented using 2900 bit-slice processors. Included on the SCSI controller, is an interleaved Reed-Solomon code used for error detection and correction. This code is capable of detecting and correcting multiple bursts of errors, or a single burst up to 40 bytes in length within a 1024 byte sector. Besides the error-correction, the Optimem SCSI controller also implements a 4K byte buffer (4-sectors), thus allowing a continuous flow of data.

ESDI, on the other hand provides similar attributes, but isn't as well defined for optical implementations as SCSI. It is expected that by mid-1986, the specification will be fully defined and numerous semiconductor companies will be making ESDI chip sets.

The intended goal of the interface is to make the drive characteristics transparent to the integrator and system.

Currently, Optotech is employing a proprietary design and expects to implement an ESDI/SCSI combination at a later date.

An important aspect of the SCSI approach, as opposed to device and host specific controllers, is that many of the tough technical details of the drive can be made transparent to the user/integrator. Therefore, all that is necessary is to deal with the data stream, which can be made to match 5M bits/second or ESDI data of 10M bits per second.

## NOT ALL ROTATING

Not all the optical products are in the form of rotating memory.

The optical memory LaserCard, developed by Drexler Technology Corp., for example, is the size of standard credit card and can store 800 pages of digitized alphanumeric information. The pre-written data is laid down on the card in the form of strips that are then scanned to yield their data content. Blue Cross/Blue Shield of Maryland has negotiated a license to manufacture the card. They plan to provide insurance customers with the cards that contain detailed coded information about their policy.

Additionally, other companies are planning on using the card for electronic publishing. Thus, you might eventually be able to pick up the entire anthology of Nero Wolfe novels on a single card.

Another approach that is being taken to using optical technology is for tape storage.

DOCdata NV in the Netherlands has developed a datacassette cartridge that holds up to 6G bytes of data. The cassette, is used with the company's DOCdatarecorder that links to the system via SCSI.

## CAPTURING THE DATA

Although many applications using optical storage will call for capturing new data, there is an expected large market for archiving old alphanumeric and graphic data as well.

To capture this data requires the use of a scanning device such as that developed by Microtek Labs. Their system, which is priced under $3,000, is designed to interface to an IBM PC using a special add-in board, or by the serial RS-232C port.

The Microtek scanners, MS-200 and MS-300, have a resolution of 200- and 300-dots per inch respectively. Both can accept both text and imaging data. Currently, however, the company is only shipping a demonstration diskette that allows capturing bit images, and optical character recognition (OCR) software is at beta test.

Already, OSI has demonstrated the viability of the Microtek scanner by capturing image data and storing it on an optical disk. Similarly, New Zealand based Kiwisoft, has developed a full imaging system graphics work-station using the Microtek scanner.

But Kiwisoft has added considerable value by using a color filter to accommodate color images as well as monochrome. Moreover, they have developed additional interfaces so that the scanner can be used on other systems such as the Digital Equipment Corp., PRO 350, for example.

### LINE BY LINE SCANNING

The Microtek scanner works by using a roller mechanism to move the paper past a lighted window. A charge-coupled device (CCD) located at the back of the machine with a pre-focused lense to accommodate the full (8[1/2]-inch) window senses the variations in light as the copy moves past the window. These light fluctuations are then changed to digital data and transferred to the computer and stored as a bit map.

Once the scanned image is stored in the computer, it can be manipulated by software. Kiwisoft, for example, has developed a full range of software designed to manipulate the picture.

Additionally, Digital Research's GEM Paint and GEM Write software for the IBM PC can also use the stored data as well.

For example, using GEM Write a document can be created, and an image that was scanned by the Microtek scanner and enhanced by GEM Paint can then be merged into the final document. Moreover, full-page layout with graphics can be performed using this method.

Microtek OCR software which transforms bit mapped images to recognizable ASCII character sets that can be word processed, is expected to recognize Pica prestige elite, and courier type faces. Rather than use lengthy and time consuming lookup tables, the OCR software is designed to use feature extraction and pattern recognition. Thus the letters can be identified since it has multiple curves.

This technique, they believe to be the most promising since it doesn't require extra memory and the system can be made to learn new features and patterns. Hence virtually any character font should be recognizable.

## CHEAP ART

Since the scanner is relatively cheap (previously scanners were priced from $15,000 to $100,000), it is expected that publishers will begin offering large libraries of art on OROM disks. A typical OROM with 700M bytes of storage can hold about 50,000 images.

Kiwisoft also believes that there is a potential market for engineering and architectural drawing as well.

Since large amounts of data can be stored on the datacassette, DOCdata has also developed a 128-cassette carousel with an average access time of eight-seconds. Thus huge volumes (up to 750G bytes) of data can be kept on-line at the same time.

The DOCdata cassette contains optical tape (similar to that used in VCRs) wrapped around two spindles situated on either side of the read/write window. Static coils located inside the cassette are used to sense a magnetic field to move the tape, thus removing the need for a drive motor. The tape is preformatted with a series of bits all with the same reflectivity. Writing a bit uses the laser to melt the surrounding substrate coat to make the region non-reflective, thus denoting a written bit.

Reading of the tape is achieved by sensing the difference in the reflective nature of a bit-region. Thus a highly-reflective area is non-written, while one with reduced reflectivity is a written region.

Taking a similar approach, is LASERstore who is developing a 2.5G byte tape cartridge and drive. The drive is expected to match a standard 8-inch disk drive foot print.

## SOFTWARE STILL A PROBLEM

Related to the interface, is the software. Most operating systems don't recognize devices with 15,000 tracks-per-inch and the need to turn lasers on and off in critical time patterns.

For OROM devices, the problem isn't as critical as in WORM or WMRA devices. These latter two require precise timing and control over the laser, spindle speed if the device uses constant linear velocity, and sector size and track density. In addition, WORM drive software must be able to detect that a region has been previously written, and recognize post fields to locate pointers to new data. Furthermore, full file management and information retrieval has to be built in.

Since companies like Information Storage and Optotech, are offering 5[1/4]-inch WORM drives for the IBM-PC/XT, they have developed supporting software that operates with MS-DOS.

ISI, for example has ISDOS that is a sophisticated device driver that installs in the Configure system file (CONFIG.SYS) on the PC. It is this file that is used by MS-DOS to attach foreign devices such as optical disk drivers to the system. One of the functions of ISDOS, is to allow the mounting of the data file. This is necessary due to the limitations of MS-DOS, which cannot request data beyond a 32-M byte limit. Moreover, the MOUNT function also recognizes most recent versions of the file, thus removing the need for the user to specify which is new.

Similarly, Optotech also offers an IBM PC support package that provides such disk I/O primitives as: open, close, read, write and seek. In addition, it allows for error or fault reporting of the optical system, as well as reporting when a cartridge is changed. This package is designed to assist integrators in developing software that uses the optical disk.

OSI is also taking the full system approach and offers a complete range of system level and application development software as well. Additionally, since the OSI LaserDrive 1200 employs a SCSI interface/controller, they have implemented a rich set of SCSI commands including message system, reserve and release and logical unit and block address functions. Interestingly, the OSI implementation of SCSI and software is the first full implementation of the intelligent interface and command set.

Currently, none of the software houses that develop operating systems are providing optical disk support either OROM or WORM. However, companies such as startup Guaranteed Software, along with the previously mentioned manufacturers, are developing file handling products typically for the IBM-PC.

## MULTIFUNCTION DRIVES THE IDEAL

Even though optical drives can't be found attached to every computer, manufacturers and system integrators are already speculating over the ideal drive. Most integrators want a drive that can read all track formats, and use either OROM, WORM, or WMRA media.

Currently, ISI is stating that they can read OROM disks as well as use WORM media. As enticing as this may sound, there are still system considerations on the software level to be worked out.

## PAPER AND FICHE STILL HERE

Even with expected gains on the part of optical storage devices, both paper and computer output microfiche are still the major storage devices.

Currently, it is estimated that about 85-percent of all data is either in paper in file cabinets, books, and microfiche, while magnetic recording represents about 10-percent. Optical is estimated to have about 5-percent since the majority of devices are still being using in niche markets such as large banks.

Of interest is the use of optical disk drives for the storing of images. But getting the data onto the optical disk is primarily the function of data preparation services such as that offered by Reference Technology. However, low-cost scanners coupled with microcomputer (See Capturing the Data), offer integrators a low-cost alternative when coupled with WORM or WMRA drives.

What can be expected, however, is that Fortune 500 companies who generate mounds of paper daily will most likely be the impetus behind making writable optical storage viable. These companies, however, are expected to use in excess of 100 optical disks daily, thus automated libraries (See Jukeboxes Tune in on Data) are a must and represent a significant growth area of optical technology.

## JUKEBOXES TUNE IN ON DATA

Looking something like miniature elevators, robotic disk libraries, called jukeboxes, are enhancing optical disk storage by allowing up to 300 billion bytes of information to be available on line.

The Cygnet Systems Series 1800 Jukeboxes, for example, are used to manage single-side and/or double-sided 12-inch optical media and associated read/write units. The Jukebox can contain up to seven optical read/write units and 141 optical disks yielding about 281G bytes of on-line storage. Moreover, multiple Jukeboxes can be cascaded--linked together--to extend the data base capacity.

### THROUGHPUT NEEDS SPEEDY MECHANICS

Since most data base operations require high throughput, jukeboxes must be able to respond with rapid mechanical motion. A typical configuration to handle one-request per-minute requires a minimum of four read/write units. Therefore, as data is being accessed on one drive, other drives can be loaded by the robotics of the jukebox.

There are many factors involved in the actual response time of the system. Among these are: load and server queue delays, the indexing scheme used, the data organization, document size, how the jukebox(s) are configured, and the request arrival rate. Typically about 12-seconds is required for the system to retrieve a cartridge from the library, exchange it with one currently in a read/write unit, and bring the new disk up to speed for reading or writing.

However, if the target drive doesn't contain a disk at the time the request is made, the time is reduced to about eight seconds.

MECHANICS AND ELECTRONICS COMBINE

A jukebox, consists of three stacks: the drive and media stack, the elevator stack and the media only stack.

The drive and media stack contains the data file server, up to seven optical disk drives and 61 optical disk cartridges. The Elevator portion includes the control electronics and the retrieval and feeding mechanisms which move the cartridge from the library to the drive unit. The final stack stores up to 80 optical disk cartridges.

The elevator uses a servo-motor driven high-speed (90-ips) low-mass elevator that moves the cartridges vertically and a crossfeed mechanism that moves them horizontally to either insert or extract them from a drive.

To ensure proper latching onto the cartridge, the crossfeed mechanism uses two grippers. The primary gripper retrieves the requested cartridge while the disk in the target drive is being spun down. When the crossfeed arrives at the target drive, the secondary gripper removes the spun down disk and the primary gripper inserts the requested disk. The two gripper design eliminates delays if two trips were required.

Besides handling the mundane tasks of inserting and extracting platters, the jukebox also is able to "flip" double-sided cartridges so either side can be read.

BUT WHICH DISK

Although the jukebox does solve the mechanical and labor related portions of handling large data libraries, it does rely on the computer system and software to ensure the proper cartridge is chosen. This, therefore, requires the use of an indexing system that identifies cartridges by location and a software label written on the disk.

TABLE I

# OPTICAL DRIVE MANUFACTURERS

| Manufacturer | Model | Type: OROM, WORM, erasable | Capacity (G bytes) | Interface | Surfaces | Data rate | Disk size (inches) | Notes |
|---|---|---|---|---|---|---|---|---|
| **Alcatel Thomson Gigadisc Inc.** | GM 1001 | WORM | 2 | SCSI | 2 | 1.5M BPS at 480 rpm | 12 | shipping |
| **Cherokee Data Systems** | Pathfinder | WORM | .3 | ESDI | 1 | N/A | 5¼ | samples early '86 |
| **Daisar Corp.** | unnamed | erasable | .7 | ESDI/SCSI | 1 | N/A | 8 | plan models by late '86; media developed by Kerdix and Nakamichi |
| **Fujitsu Ltd.** | F6441A1 | WORM | 1.3 | SCSI | 1 | N/A | 12 | drive available in Japan |
| | F6441B1 | WORM | 1.3 | similar to ESMD | 1 | 783K BPS | 12 | drive available only in Japan |
| **Hitachi America Inc.** | OC301-1 | WORM | 1.3 | IEEE-488 | 1 | 400K BPS at 600 rpm | 12 | shipping |
| | OC302-2 | WORM | 1.3 | IEEE-488 | 2 | 400K BPS at 600 rpm | 12 | shipping |
| | CDR-1502 | OROM | .552 | 8-bit parallel | 1 | 176K BPS | 5¼ | shipping |
| **Information Storage Inc.** | 525 WC | WORM | .1 | ESDI | 1 | 2.5M bps at 1,800 rpm; can read OROM disks | 5¼ | shipping |
| **Laserdrive Ltd.** | LD33 | WORM | .23 | ESDI/SCSI | 1 | 1.25M bps at 900 rpm | 5¼ | under development, due mid '86; spiral track format without sectors; aimed at low-end systems; may move to 1.6 micron track pitch |
| **Nippon Columbia Co. Ltd.** | Denon CD-ROM | OROM | .6 | 8-bit parallel | 1 | 153K BPS | 5¼ | shipping |
| **Nissei Sangyo America** | OD-301 | WORM | 2.6 | SCSI | 2 | N/A | 12 | sample quantities |
| | CDR-2500S | OROM | .552 | SCSI | 1 | N/A | 5¼ | sample quantities; WORM version in mid '86 |
| **North American Philips Corp.** | CM-100 | OROM | .6 | 8-bit parallel | 1 | 1.41M bps | 5¼ | shipping |
| **Optical Storage International** | Laserdrive 1200 | WORM | 2 | SCSI | 2 | 1.5M BPS at 480 rpm | 12 | shipping |
| **Optimen** | Model 1000 | WORM | 1 | SCSI | 1 | 5M bps | 12 | shipping; 5¼-inch model by mid '86 |
| **Optotech Inc.** | Model 5984 | WORM | .488 | proprietary; ESDI/SCSI | 2 | 2.2M bps at 1,200 rpm | 5¼ | shipping; provides development software for file management |
| **Reference Technology Inc.** | Datadrive 500 | OROM | .55 | IBM PC parallel | 1 | 150K BPS | 5¼ | shipping |
| | Datadrive 2000 | OROM | 2 | SCSI | 2 | 247K bps | 12 | shipping |
| **Sony Corp. of America** | CDU-1 | OROM | .54 | 8-bit parallel SCSI | 1 | 150K BPS | 5¼ | uses CLV; 200 to 530 rpm |
| | WDA-2000 | WORM | 1 | SCSI | 2 | N/A | 8 | shipping in small quantities |
| | WDA-3000 | WORM | 2/3.2 | SCSI | 2 | N/A | 12 | shipping in small quantities |
| **Toshiba America Inc.** | DF-050 | WORM | .5 | SCSI | 2 | 2.5M bps at 900 rpm | 5¼ | shipping in Japan |
| | DF-0450 | WORM | 3.6 | IEEE-488 | 2 | 2.5M bps at 900 rpm | 12 | shipping in Japan |
| **Verbatim Corp.** | prototype | erasable | .04 | undefined | 1 | N/A | 3½ | prototype planned for '87 |
| **Victor Co. of Japan** | JVC brand model | OROM | .7 | N/A | 1 | N/A | 5¼ | expected to ship early '86 |

**Key:**
OROM = optical read only memory   WORM = write once, read many   BPS = bytes per second   bps = bits per second

## GLOSSARY

Ablative-pit forming is a method whereby the data bit is written by forming a pit, or depression, in the sensitive optical layer by removing or ablating material. This is achieved by the laser literally burning a pit in the surface. The difference in reflectivity caused by the pitted area is then read as a data bit.

Alloying. Two chemically compatible film layers are heated with a laser to create a "new" layer or alloy. The difference in reflectivity is then registered as a bit. This is the method used by DOCdata in their tape system.

Bubbleforming. In this process the laser causes the underlayer of the media to vaporize thus pushing the upper layer to form a blister. On reading, the reflected laser light is scattered rather than being at a constant angle, thus denoting a written bit.

CNR-Carrier-to-noise ratio is related to signal-to-noise ratio and can potentially impact the error rate of an optical recording disk. The noise component is comprised of substrate inconsistencies, amplifier and laser noise. Typically, for 100KHz bandwidth of carrier, noise of about 70 micro volts magnitude is read. Thus the optimum solution is to pick a bandwidth somewhere above the associated noise bandwidth that is wide enough to accommodate the data stream, yet narrow enough to avoid generating its own noise.

Constant Angular velocity (CAV). This technique, unlike CLV, maintains a constant rotation speed for all tracks. Thus access time is quicker, and expensive variable speed motors aren't necessary. However, capacities on drives using this method are less since bit densities at the inner tracks are higher than the outer.

Constant linear velocity (CLV) is a technique whereby a constant recording density is maintained across the entire disk. Thus the disk spins slower at the outside tracks and faster as the head moves inward. This method does yield high capacities, but at the expense of using a variable speed motor and slow access times.

Direct read after write (DRAW) is a method of ensuring that the laser wrote the data correctly before proceeding on to the next data block. The problem with this method is that the platter must make one full rotation to read the data before it can write again.

Direct read during write (DRDW) is a refinement of DRAW technology. The data as it is being written is read; thus if an error is detected, the next good sector can be skipped to and the writing process began anew. The advantage of course is speed. The disadvantage is the necessity of a more sophisticated light path than that used on DRAW devices.

Optical-read-only memory (OROM). This type of optical system is as the name implies--read only. The information (digital data and images) are laser etched onto the surface of a "gold" master that is used to press copies. A laser optical system, within the drive, is used to read the data. This method of optical storage is currently the most pervasive and is used with digital music in the form of compact disk (CD) ROM's.

Magneto optic (also called thermo-magneto optic) is the most promising method for creating erasable optical disk drives. This method, currently being used by Verbatim, uses the laser to heat a given spot on the media thus lowering its susceptibility to magnetic change. A surrounding bias field then causes the magnetic domain in this region to change orientation (i.e., from down to up) thus denoting a written bit. Erasing is the same process, only the bit orientation is reversed to the opposite direction.

Phase Change. This is a method whereby the optical sensitive layer has two states: amor phous and crystalline. The laser changes a spot to the amorphous layer to write a bit. Although this method has merit, it does suffer from temperature instability. Typically, at 100-degree Centigrade the media tends to switch to the crystalline state, thus destroying written data.

PMMA-polymethymethaacrylate is a substrate that is currently finding favor with optical media manufacturers. This substrate offers a number of advantages including cost and birefringence--maintains monochromicity of the light path--characteristics. However, PMMA is hydroscopic--absorbs water, which can affect its optical characteristics. To avoid this, manufacturers encapsulate the optical platter.

Post field is typically a 16-byte field attached to a data record on a WORM drive. Since data can't be erased or overwritten on a WORM drive, this field is used to contain pointers to the updated information.

Substrate is the foundation upon which the optical sensitive layer is placed.

Write-once-read many (WORM) optical drives are similar to OROM's in that once the data is written, it can be read many times but never erased. This type of optical drive uses a special pre-grooved media in which the data bits are written using a diode laser in the drive. Like the OROM, once written the data is then retrieved by using a laser optic system.

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