FLUORESCENT MULTILAYER DISC (FMD)

A SEMINAR REPORT

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Certificate

Certified that this is a bonafide record of the Seminar Entitled

"FLUORESCENT MULTILAYER DISC (FMD)"

Done by the following Student

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Of the VIIth semester, Computer Science and Engineering in the year 2008 in partial fulfillment of the requirements to the award of Degree Of Bachelor Of Technology in Computer Science and Engineering of Cochin University of Science and Technology.

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Seminar Guide

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Date:

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ABSTRACT

Compact discs were a revolutionary product at its time and influenced many spheres of human activity. People started recording music of high quality, which didn't get worse with the time as it happens to be on tape. As soon as CDs appeared in computer industry they immediately became an undoubted helper both for users and for programmers. The latter were able to increase volume of their program products by adding video and audio elements etc. Later discs were used for digital video (VideoCD).

But technologies are progressing. Data are growing faster and faster. A usual CD is far not enough (640 MBytes). So, there appeared DVD technology. Of course we are happy with those 17 GBytes that can be kept on one DVD disc, but this is a limiting point. So we need a completely new method of storing information on portable data medium. And at last, the company Constellation 3D demonstrates a new format: **FMD** (***Fluorescent Multilayer Disk***), which can provide us with a staggering 140 GB of storage space seems to be an enticing solution for the storage-hungry masses.

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1. INTRODUCTION

Compact discs were a revolutionary product at its time and influenced many spheres of human activity. People started recording music of high quality, which didn't get worse with the time as it happens to be on tape. As soon as CDs appeared in computer industry they immediately became an undoubted helper both for users and for programmers. The latter were able to increase volume of their program products by adding video and audio elements etc. Later discs were used for digital video (VideoCD).

But technologies are progressing. Data are growing faster and faster. A usual CD is far not enough (640 MBytes). So, there appeared DVD technology. Of course we are happy with those 17 GBytes that can be kept on one DVD disc, but this is a limiting point. So we need a completely new method of storing information on portable data medium. And at last, the company Constellation 3D demonstrates a new format: FMD (Fluorescent Multilayer Disk)

Constellation 3D's technology implements the concept of the volumetric storage of information. Data is recorded on multiple layers located inside a disc or a card, as opposed to the single layer method available in compact discs, and double layer method available in DVD’s. The recording, reading and storing of the information is accomplished through the use of fluorescent materials embedded in pits and grooves in each of the layers. The fluorescent material emits radiation when excited by an external light source. The information is then decoded as modulations of the intensity and color of the emitted radiation.

2. OPTICAL STORAGE MEDIA USED TODAY

2.1. CD-ROM

The CD-ROM standard was established in 1984 when the CD-audio standard was modified to give PCs access to the technology. CD-ROM drives and discs quickly evolved into a low-cost digital storage option because of the established CD-audio industry. Data bits are permanently stored on a CD in the form of physically molded pits in the surface of a plastic data layer that is coated with reflective aluminum. Smooth areas surrounding pits are called lands.

CDs are extremely durable because the optical pickup (laser light source, lenses and optical elements, photoelectric sensors, and amplifiers) never touches the disc. Because data is read through the disc, most scratches and dust on the disc surface are out of focus, so they do not interfere with the reading process. With a 650-MB storage capacity, one CD-ROM disc can store the data from more than 450 floppy disks. Data access speeds are reasonable, with random access rates ranging from 80 to 120 ms for any data byte on the disc. Maximum data transfer rates are approximately 5 MB/ sec. These attributes make CD-ROMs especially well suited for storing large multimedia presentations and software programs.

CD-ROM drives are distinguished by different disc rotation speeds measured relative to the speed of an audio CD player. A 1X CD-ROM accesses data at approximately 150 kilobytes per second (KB/sec), the same as an audio player. A 32X CD-ROM reads data thirty-two times faster at approximately 4,800 KB/sec. In general, faster speeds reduce data access time, but vibration and noise problems limit maximum speeds to approximately 48X.

2.2. DVD ROM

The DVD ROM standard, introduced in 1995, came about as the result of a DVD Consortium composed of ten founding companies viz. Hitachi, Matsushita Electronic,

Mitsubishi Electric, Toshiba, Time Warner, Pioneer Electric, Thomson Multimedia, Victor Company of Japan, Sony, and Philips Electronics.

Like CD drives, DVD drives read data through the disc substrate, reducing interferences from surface dust and scratches. However, DVD-ROM technology provides seven times the storage capacity of CD discs, and accomplishes most of this increase by advancing the technology used for CD systems. The distance between recording tracks is less than half that used for CDs .The pit size also is less than half that on CDs, which
requires a reduced laser wavelength to read the smaller-sized pits. These features alone give DVD-ROM discs four times the storage capacity of CDs. MultiRead is an international trade association standard for CD-ROM and DVD-ROM drives that increases amplification so the photodiodes in the drive can detect the lower contrast between the pits and lands of CD-RW discs.

Other features include a more efficient error correction code (ECC). Fewer data bits are required for error detection, thus freeing space for recorded data. DVD discs can also store two layers of data because they can have a translucent reflective layer with data on top of a second opaque reflective layer containing more data. The drive changes the focus of the laser to switch between the two data layers.

DVD-ROM drives rotate the disc more slowly than CD drives, but data throughput is considerably higher be-cause the data density is much greater than on CDs. A 1X DVD-ROM drive has a data transfer rate of 1,250 KB/ sec compared with a 150-KB/sec data transfer rate for a 1X CD-ROM drive. Current DVD-ROM drives can read DVD discs at 12X maximum speeds and can read CDs at 40X maximum speeds.

DVD-ROM discs provide a 4.7-GB storage capacity for single-sided, single data-layer discs. Single sided, double data-layer discs increase the capacity to 8.5 GB. Double-sided, single data-layer discs offer 9.4 GB, and double-sided, double data-layer discs pro-vide 17 GB of storage capacity. DVD-ROM drive costs range from $200 to $500, and also read CD-ROM, CD-R, CD-RW, and DVD-R discs. As new software programs push the storage limits for CD-ROM discs, DVD-ROM discs offer storage capacities that should satisfy these requirements for many years to come.

3. Fluorescent Multilayer Disk (FMD)

3.1. OVERVIEW

Compact Disc (CD) and Digital Versatile Disc (DVD) use single and dual metallic layers, respectively, to store data in pits and grooves, similar to the way grooves store music on vinyl records.

The limitation of CD and DVD is that the laser cannot accurately penetrate the solid, reflective layer where data is stored. In the case of DVD, the laser can penetrate one layer deep to read the second layer, but after that, the laser becomes diffused and unable to read the data clearly. FMD-ROM is a totally clear disc. Instead of reading a single layer, the data is stored on fluorescent materials in multiple layers, which give off light. The existence or nonexistence of these materials on a layer tells the drive whether there is information there or not, which allows the whole system to handle many more layers. Constellation 3D has talked about 10 or more layers per disc.

The five-inch disc, which is the same size as CD-ROMs and DVD-ROMs, can hold up to 140GB of data -- almost 30 times the capacity of a DVD-ROM disc.

3.2. TECHNOLOGY OVERVIEW

Figure 3.1

The figure 1 shows how an FMD looks like.You can see that a disc is transparent. But where is a reflective layer like on CD and DVD discs? The matter is that this technology doesn't need it. Let's consider FM disc in detail.

In optical discs such as CD, DVD the process of reading is implemented the following way. A beam of a semi conducting laser gets on the surface of an informational

layer and then reflects from aluminum (or any other metallic) layer and fixed with a detector-receiver.

In FMD there is no reflected laser beam: when a laser beam reaches an informational layer the latter starts radiating. The principle of operation of FM-discs is based on a phenomenon of photochromism. Some years ago Russian chemists discovered a stable organic material a "stable photochrome" which when acted upon by a laser beam obtains fluorescent properties. The matter is that an informational element of FM-disc (photochrome) can change its physical properties (such as color and presence of fluorescence) under influence of a laser of a definite power and wavelength. Initially photochrome doesn't possess fluorescent properties. When switching on a laser a photochemical reaction starts what causes fluorescent properties to appear. When reading, this matter becomes excited again but with a laser of lower power. The fluorescence is caught up by a photo-receiver and is fixed as a value "1".

Besides, according to the company there will be no worsening of the photochrome state with the time. Excited photochrome radiates shifting the spectrum of falling light to the red color side within 30-50 nm what allows to differ laser signal from the light from the disc.

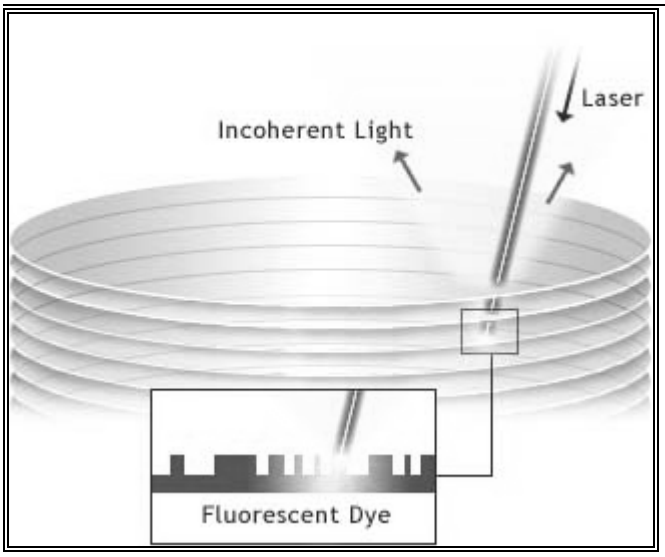

Figure3. 2

Figure 3.2 shows how the laser beam strikes and get deflected from the surface of a Fluorescent Multi Layer Disk

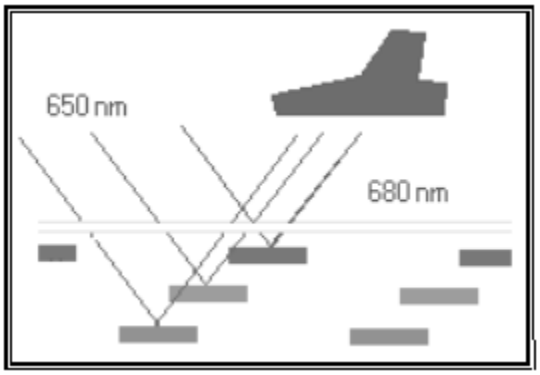

Figure 3.3

From Figure 3.3 it could be seen that the laser beam of same wave length falling on the fmd surfaces get deflected in different wave lengths

Note that this technology allows preventing a problem of multiple inference between layers since the reflected light is not coherent; it passes through layers without any difficulties and is easily defined by a receiver. Let's talk about it a bit in depth.

In usual optical discs (CD/DVD) with increasing number of informational layers a signal gets worse. It's explained by the fact that these technologies use a reflected signal, it means that there is necessity in mirror surfaces. That's why in DVD technology an external layer is made to be semitransparent in order to allow a laser to reach an internal one.

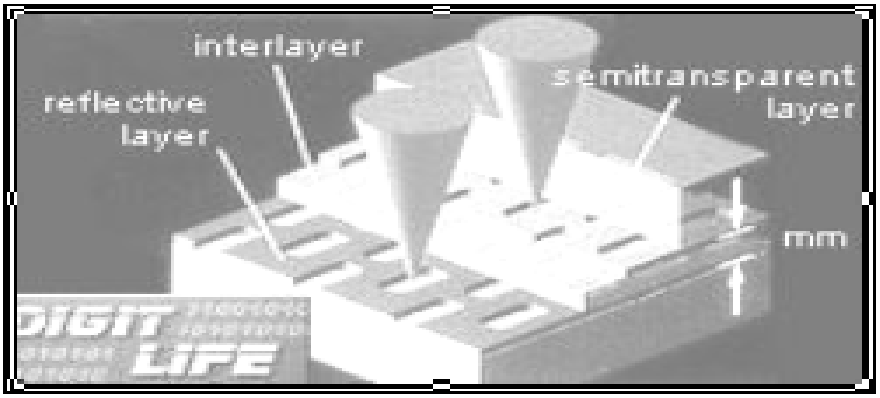

Figure 3.4

And a signal while passing an external layer leaves a part of its energy because of reflecting. Signals reflected from both layers interfere because of their coherence; it results in losses of useful signal. Increasing number of layers aggravates an effect of multiple interference between the layers what makes reading more complicated. Improving detector-receivers can solve the problem, but it is possible only in laboratory. In case of fluorescent discs the quality of the signal gets worse much slower with increasing number of layers. Look at Figure 3. 5.

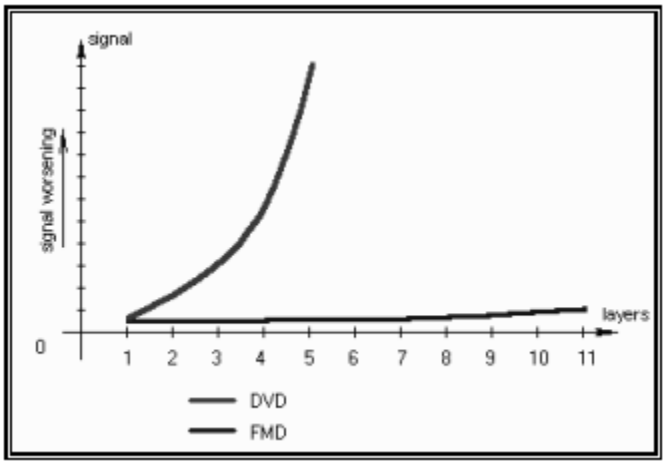

Figure 3.5

According to FMD-ROM developers, even with a hundred layers a useful signal will be acceptable

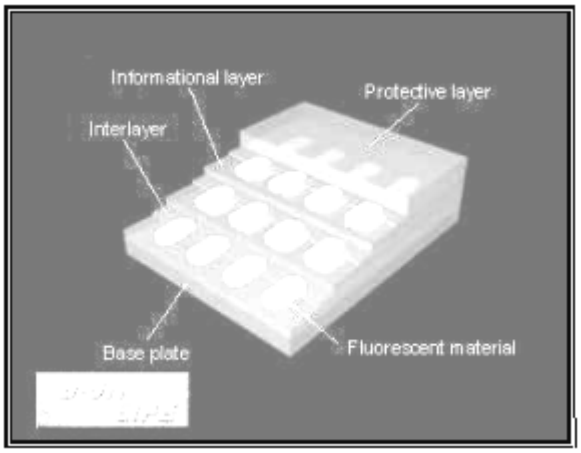

Figure3. 6

As you can see in the Figure 3.6 a disc consists of several plastic (polycarbone) layers connected to each other. A layer contains surface structures (pits), which are filled with fluorescent material. When reading a laser focuses on a certain layer and excites its fluorescent elements, and then a photo detector catches this radiation.

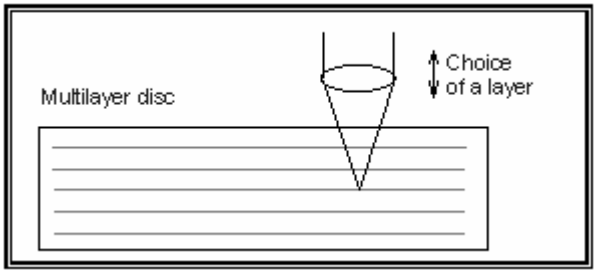

Figure 3.7

The developers state that with a blue laser (480 nm) it's possible to increase record density up to tens Terabyte on one FM disc.

Another interesting feature is parallel reading, which will be dealt later. If we record a sequence of bits not along a track but deep into layers we can increase speed of data access. That's why such disc is called "3-dimensional".

Here is a list of advantages of FMD:

Multilayer disc is transparent and homogeneous

Small loss of useful signal while passing through several layers

Fluorescence of a separate element easily passes through disc layers

- Less sensitivity (than of CD/DVD) to different imperfections of reading devices. Fluorescent technology doesn't require special manufacturing conditions
- Reflective fluorescent light from any layer is not coherent, it prevents a problem of multiple interferences

FMD-technology is compatible with CD and DVD formats supporting the same data distribution system on each layer.

4. FM DISC PRODUCTION

Many stages of the production of FM Disks are put on the basis of CD and DVD manufacture. However, some alterations are to be made here. In particular, they concern form of surface structures and methods of filling with fluorescent material. Besides, there is no technology of sputtering of aluminum layer what reduces the number of steps.

Mastering process is very similar to that of CD/DVD. A few words regarding the process of manufacturing CD discs.

As a storage device they use a glass plate covered with a thin photo resistive layer. A laser beam, intensity of which is modulated with digital information, gets into photo resist causing markings that correspond to bits of digital code. After that the photo resist is developed and covered with a metallic layer. This Master-copy after recording contains digital information in the form of pits. Then they make an exact negative copy by a galvanic way which later serves as a press-matrix. This negative can already be used for CD manufacture. But in order to save this single matrix they produce several intermediate copies (negative), and then several press matrix (the same way), which serve for stamping CDs. After recording of data on an informational surface in vacuum a thin layer of aluminum is sputtered. Outside, the metallic layer is lacquered in order to prevent mechanical damage.

In FMD technology an exact copy of pit is of vital importance since later it's filled with fluorescent material. That's why these two technologies differ. Here, a master-copy is a nickel matrix (a stamp). It is a negative copy, like in CD-technology. A FM disc consists of several layers and that's why the process contains several steps: informational layers are produced separately and then they are combined together.

4.1. TECHNOLOGICAL PROCESS

The technological process of FMD manufacture is divided into two. They are :

Hot stamping

Photo Polymerization

4.1.1. HOT STAMPING

In this method each layer is reached by pressing of polycarbon layer with two stamps (Master-copies) at high temperature. So we receive one layer with two informational sides. Then the pits are filled with fluorescent material. And when it becomes hard the informational layers are pressed.

In Figure 4.1 you can see a structure of a 7-layer disc produced according to the described method.

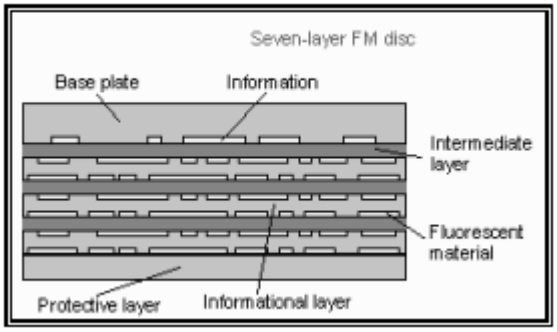

Figure 4.1

4.1.2. PHOTO POLYMERIZATION

The second method uses a process of photo polymerization when a multiple disc is reached by stacking of discs one after another, which is made from thin informational layers.

Manufacture of one informational layer lies in manufacture of plastic film with definite optical characteristics. The film is 25 to 30 micron in width. The film, which will get information, soon is either stamped or cut out with a laser.

After that the film is installed on an external surface of a nickel matrix that carries a negative copy of produced informational layer. While rotating, photopolymer matter is evenly brought in the space between stamp surface and plastic film.

Later, when the photopolymer matter becomes hard the film gets detached from the stamp surface. The base plate now contains pits of definite geometry. A pit's geometry is better in terms of quality than that received when manufacturing matrices for CD or DVD since those technologies use a process of stamping of pits. When a layer with the required position of pits is ready, they are filled with fluorescent material (it covers evenly the whole informational side).

After that the surface is processed chemically in order to reach necessary contrast of pits and flats. Then, in order to check the copy for different defects, photo elements get excited and the whole picture is analyzed with the help of CCD cameras. After that the layers are "stuck" to the base plate 0.6 mm in width. And all this is covered with a protective layer, which can be used for graphics decoration. In order to prevent a physical contact with informational layers on the edge of the disc this area is filled as well with polymeric material, like in CD or DVD technologies.

5. RECORDING ON FMD-ROM

We still haven't seen a prototype of record device but the company says that it is under developing now. There used a technology WORM (Write Once Read Many). A series of rewritable discs will be called FMD WORM. A technology of manufacturing these discs will be the same as for FMD ROM except the fact that they will use another fluorescent material that will be able to change the state under the influence of a laser.

And when recording you should follow two rules:

Sufficient power of a laser in order to provide an element with fluorescent properties

Threshold power of laser should be used for recording (in order to change fluorescent properties of the material) and for reading must be used less power.

Besides, it's very important to choose a recording method. The FMD developers offer two record principles.

The first principle (thermal) implies usage of material that possesses fluorescent properties from the beginning (logical one). And when recording those segments, which are thermally acted upon with a laser, lose these properties (logical zero).

The second principle (chemical) means usage of a material that doesn't possess fluorescent properties form the beginning. When acting upon with a laser a photochemical reaction starts, and the material gets fluorescent properties. There, a low-power laser is enough, or even a usual LED. With the latter (LED matrix) there is possible a simultaneous record of the whole array of information.

Record devices don't differ much from read ones. The only difference lies in a bit different laser form allowing both reading and writing. Besides, we should note that it's possible to combine WORM and ROM on one storage device! For example, imagine a 20-layer disc with 10 layers already recorded and 10 left for a user.

The company C-3d also plans to release rewritable FM. The record principle is practically the same as in CD-RW technology except for the fact that there it isn't necessary to control reflective ability of a layer - there is enough to convert fluorescent material from one state (absence of fluorescence) into the other (presence of fluorescence). For example, the whole layer of a FM disc will be covered with a fluorescent material which initially doesn't possess fluorescent properties (logical zero) and when recording a logical one a low-power laser excites a photochemical reaction in the required place. Erasure will be done with the help of a more powerful laser.

An advantage of this technology is that the fluorescent material is much more resistant to phase transformations than that used in CD-RW discs that's why you can rewrite it much more times.

6. FMD READ DEVICES

You can see a prototype of an FMD Read Device in figure 6.1 . The developers say that the drives intended for FM discs will easily understand CD and DVD format. In structure the drives are similar to CD/DVD ones for example in such parameters as laser, optics, servo drive, tracking and focusing system, different controllers. There appear only systems that can catch and discern fluorescence, and a service in choosing an informational layer.

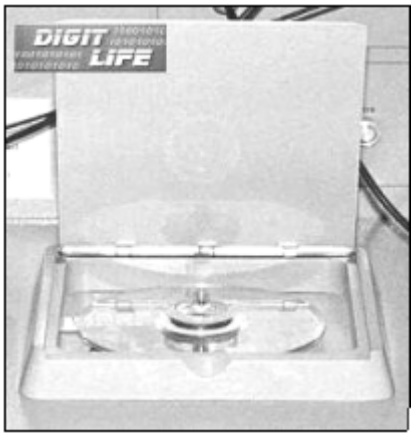

Figure 6.1

6.1. PARALLEL READING

As we have already mentioned this technology allows parallel reading; it means that a sequence of bits is recorded not along a track but deep into layers. That's why we receive three types of data reading: successive, successive-parallel and parallel.
A little about what in fact parallel reading is.

Reading process is carried out with the help of a solar cell (an array of CDD cameras). This device can read low-power fluorescence of several tens MHz. And the reading speed reaches 1 Gigabit/s. We should notice that mechanical speed of the drive is 450 times lower than that of DVD.Figure 6.2and figure6.3 clearly demonstrates the principles of parallel reading.

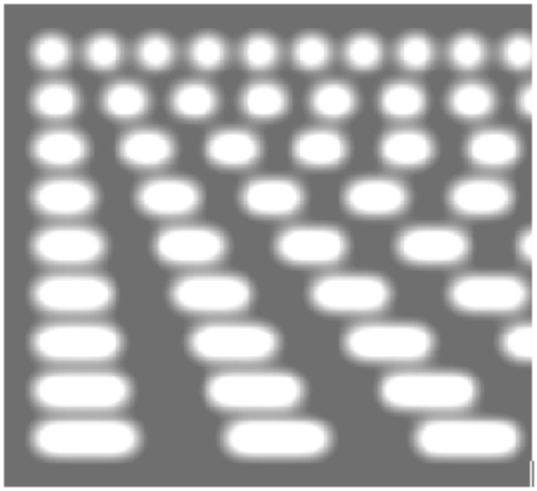

Figure 6.2

12x enlargement of FMD segment received with CDD cameras

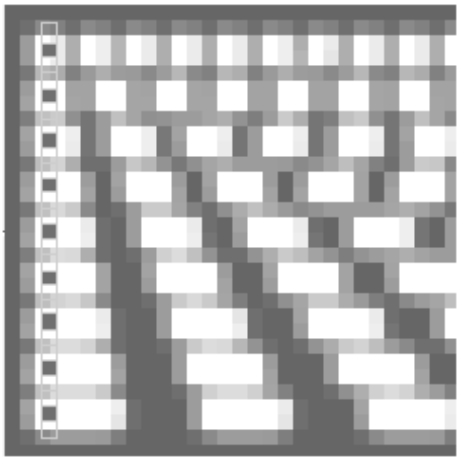

Figure 6.3

Signals received from each element of CDD array

7. SOME OF THE TECHNOLOGICAL ADVANTAGES

7.1. NCREASED DISC CAPACITY

DVD data density (4.7 GB) on each layer of data is up to 100 layers. Initially, the FMD disc will hold anywhere from 25 - 140 GB of data depending on market need. Eventually a terabyte of data on a single disc will be achievable.

7.2. QUICK PARALLEL ACCESS AND RETRIEVAL OF INFORMATION

Reading from several layers at a time and multiple tracks at a time - nearly impossible using the reflective technology of a CD/DVD - is easily achieved in FMD. This will allow for retrieval speeds of up to 1 gigabit/second.

7.3. MEDIA TOLERANCES

By using incoherent light to read data the FMD media will have far fewer restrictions in temperature range, vibration and air-cleanness during manufacturing. And will provide a considerably more robust data carrier than existing CD and DVD's.

7.4. USAGE FLEXIBILITY

FMD presents a wide variety of potential media sizes and types (read only, writeable and rewritable) for a broad range of applications

8. ABOUT THE COMPANY C3D & THEIR PRODUCT

The company C3D was founded in 1995. The company is aimed at developing progressive technologies in the field of data storage and in production in the sphere of consumption and education.

The first generation of disc productions from Constellation 3D will be a family of 120 mm multilayer FM-discs with capacity up to 140 GBytes and with read speed up to 1 GBytes/s. It's interesting to compare them with DVD that keep up to 17.4 GBytes. New discs will be capable for example to keep up to 20 hours of compressed movies in HDTV format

Constellation 3D Holding's FMD technology allows for the creation of a huge variety of advanced consumer products. Standard CD/DVD format 120mm disks with storage capacities initially of up to 140 GB will enable data storage-intensive activities such as production & archiving of Home Cinema and personal digital information libraries. In the FMD WORM (and later RAM) configuration, users will be able to include their own content as well as simply using supplied archive and reference data. FMD ROMs in 64mm format will be capable of holding up to 10 GB of data, for use in portable audio-video information systems and external memory systems for portable PC's.

A series of smaller disks (FMD ROM, diam. 40mm, 15 GB; FMD WORM/ROM, diam. 40mm, 13.5 GB; FMD WORM, diam. 40mm, 13.5 GB) are designed to support and expand the performance capabilities of hand-held PC's and audio-video equipment, including downloading of Internet data.

A class of super disks (Super FMD ROM, diam. 120mm, 2.4 TB; Super FMD WORM, diam.120mm, 2.4TB and Super FMD RAM, diam 120mm, 2.4TB) promote the idea of advanced reference books and archives, art and cinema collections, new generations of video games with Virtual Reality effects; provide the base for stable storage systems for extra large, high security data bases required by the financial and medical industries and others, and a base f or high security, secondary memory systems for large and extra-large PC's. A smaller Super FMD RAM, diam. 64 mm, 75GB is a base for creating secondary memory portable systems with large capacity for portable PC's.

The Clear Card configurations are credit card-sized memory carriers and offer virtually limitless applications in the consumer market. ClearCard ROMs, with 1-20 GB per sq. cm. capacity will allow mass-market products for use in cheap miniature reading devices and e-books. The recordable ClearCard WORM, with first generation capacity of 1-3 GB, is envisioned as a part of "I-Net Video Terminal" systems. The card will be recorded on at the location of various information providers such as bookstores and information kiosks. It will then later be inserted into inexpensive devices capable of reading the ClearCard ROM.

Constellation 3D Holdings have established an international research and business development team of renowned scientists and experts from the computer and electronics industry. (See the attached Brief Resume.) They plan to seek industry partners, including manufacturers of OEM equipment, to bring products to market. The market potential for the products utilizing this FMD technology is in the billions of dollars.

C3D intends to commence negotiations immediately with several strategic joint venture partners and expects to begin production of the first commercial devices within twelve months, including:

A 20-layer FMC ClearCard-ROM in the form factor of a credit card having up to 10GB capacity;

A 10-layer FMC ClearCard-WORM (Write Once Read Many) in the form factor of a credit card having up to 1GB capacity;

format A 10-layer FMD-ROM disk in the standard 120mm (CD & DVD) disk having up to 140GB capacity;

C3D, Inc. has offices and laboratories in New York, California, Israel, Russia, and the Ukraine. Its web site is at http://www.c-3d.net/index.htm

9. FMD FOR MAC USERS

For the MacUser Constellation 3D has given the first public demonstrations of its high-capacity optical storage technology. The system, which will allow DVD-sized media to store up to 100Gb of data, is expected to be available as products by the middle of next year.

10. POTENTIAL FOR FURTHER GROWTH

The technology is young and will grow and evolve, providing a clear road map for the future of data storage.

The FMD/C technology is presently protected by over 80 Japanese, European, and US patents, approved and/or pending, dozens of priority establishing disclosures, and the exceptional know-how of an unprecedented group of physicists cooperating across the world.

11. **COMPARISON BETWEEN CD DVD and FMD**

Parameter	CD	DVD	FMD
Disc diameter, mm	120	120	130
Capacity, GBytes	0,64	17,4	50,8
Number of layers	1	2 (each side)	12
Distance between layers, micron	-	40	25¦5
Total width of informational layers, micron	0,11	2	275
Format	CD	DVD	Modified DVD
Distance between tracks, micron	1,6	0,74	0,8
Optical system: Wavelength, nm	780	635-650	532

Table 11.1

12. APPLICATION

The following table represents an approximate amount of storage space required by latest applications and technologies

No.	NEW APPLICATIONS	REQUIRED CAPACITY
1	Digital cinema, High Definition TV	100GB
2	Mobile computing	5GB
3	Digital Cameras	5GB
4	PDAs	1GB
5	Digital Video Recorders	40GB
6	G3 Mobile Phones	0.5GB

Table 11.1

FMD/FMC will be able to provide this much amount of storage capacity.

13.CONCLUSION

Man's need for additional storage space is something that is ever increasing. Hence no solution or data storage media is expected to achieve the status of a complete storage solution for long periods of time especially due to rapid developments taking place in many storage related fields. But for now the FMD, which can provide us with a staggering 140 GB of storage space seems to be an enticing solution for the storage-hungry masses.

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