VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELAGAVI-590018

A Seminar Report Report

on

Holographic Memory

Submitted in partial fulfillment of the requirements for the final year degree in
Bachelor of Engineering in Computer Science and Engineering
of Visvesvaraya Technological University, Belagavi

by

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ESTD : 2001
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Department of Computer Science and Engineering
RNS Institute of Technology
(Accredited by NBA upto 30-06-2025)
Channasandra, Dr.Vishnuvardhan Road, Bengaluru-560098

2022-2023

RNS INSTITUTE OF TECHNOLOGY

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DEPARTMENT OF COMPUTER SCIENCE ENGINEERING

(NBA ACCREDITED FOR ACADEMIC YEARS 2018-19, 2019-20, 2020-21, 2021-22, 22-25)

ESTD : 2001

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CERTIFICATE

Certified that the Seminar topic on **Holographic Memory** has been successfully presented at **RNS Institute of Technology** by **Nitheesh Shetty**, bearing USN **1RN19CS091** , in partial fulfillment of the requirements for the VIII Semester degree of **Bachelor of Engineering in Computer Science and Engineering** of Visvesvaraya Technological University, Belagavi during academic year 2022-23. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The Seminar report has been approved as it satisfies the academic requirements in respect of Seminar work for the said degree.

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Acknowledgement

At the very onset, I would like to place on record our gratefulness to all those people who have helped us in making this Technical seminar work a reality. Our Institution has played a paramount role in guiding us in the right direction. I would like to profoundly thank the **Management of RNS Institute of Technology** for providing such a healthy environment for the successful completion of this seminar work.

I would like to thank our beloved Principal, **Dr. M K Venkatesha**, for providing the necessary facilities to carry out this work.

I am extremely grateful to **Dr. Kiran P**, for having accepted to patronize me in the right direction with all his wisdom.

I place my heartfelt thanks to all the Coordinators of Technical Seminar work. I would like to thank the internal guide, **Mrs. Yashasvi B N** , Assistant Professor, for her continuous guidance and constructive suggestions for this work.

Last but not the least, I am thankful to all the teaching and non-teaching staff members of the Computer Science and Engineering Department for their encouragement and support throughout this work.

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Abstract

Holographic data storage as a viable alternative to magnetic disk data storage. Currently data access times are extremely slow for magnetic disks when compared to the speed of execution of CPUs so that any improvement in data access speeds will greatly increase the capabilities of computers, especially with large data and multimedia files. Holographic memory is a technology that uses a three dimensional medium to store data and it can access such data a page at a time instead of sequentially, which leads to increases in storage density and access speed. Holographic data storage systems are very close to becoming economically feasible. Obstacles that limit holographic memory are hologram decay over time and with repeated accesses, slow recording rates, and data transfer rates that need to be increased.

Photorefractive crystals and photopolymers have been used successfully in experimental holographic data storage systems. Such systems exploit the optical properties of these photosensitive materials along with the behavior of laser light when it is used to record an image of an object. Holographic memory lies between main memory and magnetic disk in regards to data access times, data transfer rates, and data storage density. As the computer evolves, so do the applications that computers are used for. Recently large binary files containing sound or image data have become commonplace, greatly increasing the need for high capacity data storage and data access. A new high capacity form of data storage must be developed to handle these large files quickly and efficiently.

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Chapter 1

INTRODUCTION

We know that data storing capacity of processors and buses roughly double every three years, data storage has struggled to close the gap. CPU is shaving capacity of executing instructions at every nanosecond. Single magnetic disk is required almost six times more time than this CPU execution speed. There are so many research been done to lose this gap between CPUs and data storage. Pipelining, cache, optimizing compilers and RAM are some advances of these type. For almost two decades for data storing devices are used that use light for storing and reading data. In the early 1980's revolution happens in data storing field as a Compact Disc (CD) which is having 12 centimetres of diameter and 1.2 millimetres of thickness. These CDs allows multimegabit of data to be stored on disc. Digital Versatile Disc (DVD) is an improved version of CD which was invented in 1997. The full-length movie can be stored a single DVD.

At initial level CDs and DVDs are famous to store data like music, personal computing, software and video. A CD is having capacity of data storing up to 783 megabytes, which is almost equal to one hour and 15 minutes of music. DVDs which are double-sided, doublelayer having data storing capacity of 15.9 GB, which is approximately 8 hours of movie. Today's needs are met by these conventional storage mediums, but consumer demands also increases so companies working on storage technologies have to make changes to keep pace. In these all technologies data is stored bit by bit on a recording medium. However, technology is either optical or magnetic, data is combination of bits and each bit is stored as distinct changes of magnetic or optical recording medium on its surface. This technique of storing data bit by bit is approaching to physical limits because bit is a very small part of whole data. If data can be stored on entire volume of storing material, it will increase high density of data storing.

With a purpose of increasing storage capabilities, researchers and scientists are now majorly working on a new optical storage technique, called Holographic Memory. Holographic memory is technology which uses entire volume of storing material to store data instead of only the surface area. So, this three dimensional data storing technique will increase data density per volume and also offers faster data transfer rate. Actually, volumetric approach is used for holographic memory which was introduced almost a decade ago. Holographic memory is having capacity storing data up to 1 Terabyte in a single sugar cube sized crystal. The main advantage of holographic memory is that it is storing data page by page not bit by bit and also same for retrieving. Holographic memory system's capacity is almost equal to 1,000 CDs.The three features of holographic memory that make it an attractive candidate to replace magnetic storage devices are redundancy of stored data, parallelism, and multiplexing . Stored data is redundant because of the nature of the interference pattern between the reference and signal beams that is imprinted into the holographic medium. Since the interference pattern is a plane wave front, the stored pattern is propagated throughout the entire volume of the holographic medium, repeating at intervals.

Currently, holographic memory techniques are very close to becoming technologically and economically feasible. The major obstacles to implementing holographic data storage are recording rate, pixel sizes, laser output power, degradation of holograms during access, temporal decay of holograms, and sensitivity of recording materials [3]. An angle multiplexed holographic data storage system using a photorefractive crystal for a recording medium can provide an access speed of 2.4 s, a recording rate of 31 kB/s and a readout rate of 10 GB/s, which is between the typical values for DRAM and magnetic disk. At an estimated cost of between $161 and 236$ for a complete holographic memory system, this may become a feasible alternative to magnetic disk in the near future.

Chapter 2

LITERATURE SURVEY

- **Title :** Holographic data storage

  Authors : D. Psaltis , G.W. Burr

  Research into and the development of data storage devices is a race to keep up with the continuing demand for more capacity, more density, and faster readout rates. Improvements in conventional memory technologies-magnetic hard disk drives, optical disks, and semiconductor memories-have managed to keep pace with the demand for bigger, faster memories. The two-dimensional surface storage technologies are approaching fundamental limits. An alternative approach for next-generation memories is to store data in three dimensions. This article describes developments in holographic 3D memories, in which high density is achieved by superimposing many holograms within the same volume of recording material. Holographic storage is a promising candidate for next-generation storage. The next step is to build these systems at costs competitive with existing technologies and optimize storage media.

- **Title :** Recent Advantages in Holographic Data Storage

  Authors : Lambertus Hesselink , Jeffrey P. Wilde

  In this paper we discuss recent advances in holographic data storage using ferroelectric SBN as the recording medium. A novel optical architecture involving an array of SBN fibers is discussed that allows 2 - 3 orders of magnitude faster access times than for conventional magnetic data storage devices of Gbyte size. To realize this potential we are studying fundamental materials issues related to SBN fiber growth and photorefractive processes underlying prolonged readout in SBN.

- **Title :** Improvements of holographic data storage technology

  Authors : Huang, Zhen , Wang, Zhengzi, Cao, Guoqiang, Hou, Yibing

  Holographic data storage has many advantages, which makes it become one of the most hopeful next-generation data storage techniques. In the past, the struggles of holographic data storage have been frustrated for the absence of suitable system components and recording materials. Recently, the development of practical components for holographic systems, such as SLMs, CCDs and some newly recording materials, has rekindled interest in this technology. In this paper, we analyze the present situation of holographic data storage techniques and some latest improvements of key components and recording materials in relative companies or laboratories are summarized. At last, market outlook of holographic data storage products is discussed.

- **Title :** Theoretical Study of a Surface Collinear Holographic Memory

  Authors : Soki Hirayama, Ryushi Fujimura, Shinsuke Umegaki, Tsutomu Shimura

  Holographic memory is currently attracting attention as a data storage system capable of achieving a data transfer rate of about 105 106 times that of an optical disc such as Blu-ray disc. In conventional holographic memory, data is generally recorded by optical writing using volume holograms. However, a volume hologram has the problem not only that it is required to have high mechanical accuracy of a system and low coefficient of thermal expansion of a recording medium, because reconstruction tolerance is extremely low, but also that duplicating time efficiency is poor because whole data cannot be recorded at once. In this paper we proposed surface holographic memory that achieved a high data transfer rate, stable readout performance, and collective duplication by expressing holograms with fine surface asperity. Furthermore, the theoretical formulas of recording and reconstruction processes in the proposed system were derived and the reconstruction characteristics of the hologram were evaluated by numerical simulation. As a result, the proposed method generated reconstructed image readout with sufficient signal for a single page recording. However, the reconstructed image had noise, which was particular to a surface holographic memory.

Chapter 3

Holographic Memory

There are many ways of storing data like optical memory, flash memory, magnetic memory etc. But next will be Holographic Memory. Holographic memory is a technology that allows holograms containing millions of bits of data to be written or read in a single flash of light. Thousands of overlapping holograms can be stored in a common volume of recording medium which increases storage capacity per volume. Holography breaks through the density limits of conventional 2D storage by recording throughout the full depth of a 3D medium. Holography can write and read millions of bits of data in parallel, enabling significantly higher data transfer rates than current optical storage devices which gives high data transfer rate.

3.1 What Is Holography?

The word “Holography” comes from Greek words which are having meaning of “whole” and “Drawing”. In normal photography we store only intensity level of image but in holography with intensity we also store phase for image while construction an image. So while reconstructing of an image we can get 3D view of image. But here one thing is to be noticed that we can get feel of 3D image only in horizontal direction that means if we either move our eyes or an image horizontally then only we can feel 3D image. If we move our head in vertical direction then it will image will be looked like rainbow i.e. all seven colors.

3.2 Roadmap of Memory

Initially in 1970s to store data LASER discs were used which is having capacity of storing 30 minutes or 60 minutes per side in size if 30 cm. After that they were replaced by Compact Discs and Magneto Optical Discs which are having different storage capacity. The 12 cm sized CD can store 700 MB data while 8 cm CD can store 200 MB of data. The 13 cm sized Magneto optical disc can store from 650 MB to 9.2 GB. In 1990s Mini discs were invented which is having storing capacity of 650 MB at initial stage. At present it is having capacity of 1 GB data storing. These all were then replaced by Digital Versatile Discs (DVDs) which is having storage capacity up to 8.5 GB. In these CDs data were written only on single layer which restrict storing capacity so BLURAY discs were invented in 2000s. BLURAY discs are having layers. The single layer disc can store data of 25 GB while dual layer can store data of 50 GB. This also restricts data storing capacity because still data is to be stored on surface of disc. Whole volume of disc is not utilized to store data. So, solution for that is Holographic Versatile Disc (HVD) in which to store data entire volume is to be utilized which increases data storing capacity in small volume.

Year	Memory Type
1978	LASER Disc
1982	Compact Disc
1985	Magneto Optical Disc
1992	Mini Disc
1995	Digital Versatile Disc (DVD)
2006	Blu-Ray Disc
Future	Holographic Versatile Disc (HVD)

Table 3.1: Roadmap of Memory

3.3 Holographic Memory vs. Existing Memory Technology

In the memory hierarchy, holographic memory lies somewhere between RAM and magnetic storage in terms of data transfer rates, storage capacity, and data access times. The theoretical limit of the number of pixels that can be stored using volume holography is V2/3/ 2 where V is the volume of the recording medium and is the wavelength of the reference beam. For green light, the maximum theoretical storage capacity is 0.4 Gbits/cm2 for a page size of 1 cm x 1 cm. Also, holographic memory has an access time near 2.4 s, a recording rate of 31 kB/s, and a readout rate of 10 GB/s. Modern magnetic disks have data transfer rates in the neighborhood of 5 to 20 MB/s [8]. Typical DRAM today has an access time close to 10 – 40 ns, and a recording rate of 10 GB/s.

Holographic memory has an access time somewhere between main memory and magnetic disk, a data transfer rate that is an order of magnitude better than both main memory and magnetic disk, and a storage capacity that is higher than both main memory and magnetic disk. Certainly if the issues of hologram decay and interference are resolved, then holographic memory could become a part of the memory hierarchy, or take the place of magnetic disk much as magnetic disk has displaced magnetic tape for most.

Storage Medium	Access Time	Data Transfer Rate	Storage Capacity
Holographic Memory	2.4μ	10 GB/s	400 Mbits/cm2
Main Memory(RAM)	10–40 ns	5 MB/s	4.0 Mbits/cm2
Magnetic Disk	8.3 ms	5–20 MB/s	100 Mbits/cm2

Table 3.2: Holographic Memory vs. Existing Memory

3.4 Holographic Memory System

Wide possibilities in this case are provided by technology of optical recording, it's known as holography: it allows high record density together with maximum data access speed. It's achieved due to the fact that the holographic image (hologram) is coded in one big data block, which is recorded at one access. And while reading this block is entirely extracted out of the memory. For reading and recording of the blocks kept holographically on the light-sensitive material (LiNbO3 is taken as the basic material) they use lasers. Theoretically, thousands of such digital pages, which contain up to a million bits each, can be put into a device measuring a bit of sugar. And theoretically they expect the data density to be 1 TBytes per cubic cm (TBytes/cm3). In practice, the developers expect around 10 GBytes/cm3, what is rather impressive when comparing with the current magnetic method that allows around several MBytes/cm2 - and this without the mechanism itself. With such recording density an optical layer which is approx 1 cm in width will keep around 1TBytes of data.Data transfer rate that is an order of magnitude better than both main memory and magnetic disk

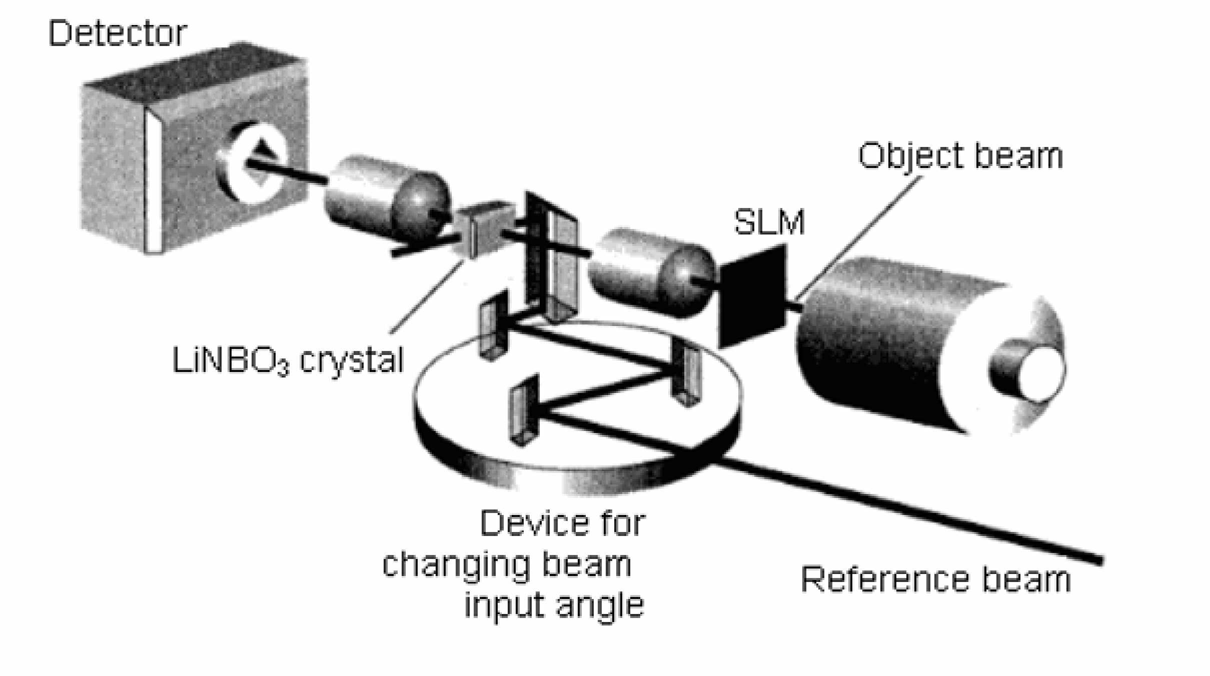

Figure 3.1: System of Holographic Memory

Exceptional possibilities of the topographic memory have interested many scientists of universities and industrial research laboratories. This interest long time ago poured into two research programs. The first of them is PRISM (Photorefractive Information Storage Material), which is targeted at searching of appropriate light-sensitive materials for storing holograms and investigation of their memorizing properties. The second program is HDSS (Holographic Data Storage System). Like PRISM, it includes fundamental investigations, and the same companies participate there. While PRISM is aimed at searching the appropriate media for storing holograms, HDSS is targeted at hardware development necessary for practical realization of holographic storage systems.

Chapter 4

Holographic Versatile Disc

An HVD is hot topic for researchers at present as it can support more data density per volume and with that high data transfer speed which are highly required for any storage device. So there is possibility that in a few years all CDs and DVDs will be replaced by HVDs. Now a day two sided blu-ray discs are becoming famous because it can store data on more than on surface i.e. it is having multi-layer structure so data storing capacity increases with same area. HVD is having capacity of transferring data at speed of 1 Gigabit per second. Till now researchers have reached up to level that DVD's same sized HVD can store data up to 1 terabyte of data and they are claiming that they will able to store 1 terabyte of data in just one cube sugar size.

We can say that HVD is having 60 times more capacity of storing data than DVD and can support 10 times more data transfer speed than DVD. So, we can say that 1 HVD is equivalent to 830 DVDs and 160 Bluray discs in comparison of data storing capacity. The HVD process uses a blue green laser beam, used for reading and writing data, collimated (made parallel) with a red laser beam, which is used for servo and tracking. HVD uses the concept of holographic memory.For writing to and reading data from HVD, proper setup should be made. For that main components are required that are

- Spatial Light Modulator (SLM)
- Multiplexing Agent
- Storage Medium
- Coupled Device (CCD)

4.1 Spatial Light Modulator (SLM)

An SLM - Spatial Light Modulator is used to convert electrical or optical signal into image. It can create 1000 of images in a second which gives an entire system high speed. It is used in many various applications like optical devices like televisions, projectors. Normally, the medium used in SLM is liquid crystal. It is also used as variable electro-optic mirror which is used in optical systems for beam splitting, shutters and mirrors. SLM is having feature of working at different frequencies. To analyse the image, SLM can be used as it gives output as pixel by pixel of an image. SLM is having capacity of precisely controlling light which is very much required for holographic memory and optical computing as light is just modified in pixels.

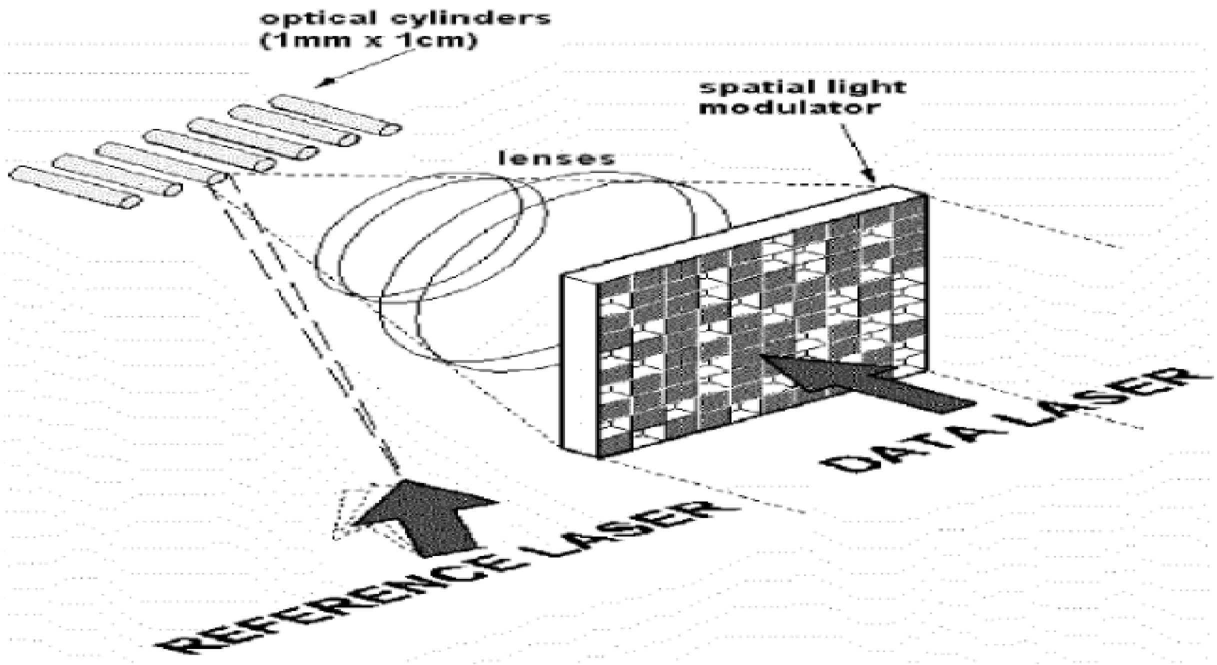

Figure 4.1: Spatial Light Modulator

4.2 Multiplexing Agent

As we have discussed earlier that on basis of interference pattern storing material properties will be changed and here by changing angle, position or wavelength we can create different holograms so for that multiplexing agents are used.

- **Angular Multiplexing :** In this type of multiplexing, angle of reference beam is changed to generate different interference pattern and same angle is used at time of reading data. Here it should be noticed that a very small change in angle will generate different data or say wrong data.

- **Wavelength Multiplexing :** This type of multiplexing is used majorly when conjunction is there with other multiplexing methods. In this different wavelength's lasers are used while recording the data so that on same medium more than one pattern can be stored.
- **Spatial Multiplexing :** In this type of multiplexing, position of point source is changed so that from same two sources different interference pattern will be generated. But in this more mechanical work is required in comparison of other two multiplexing.

4.3 Storage Medium

As we have discussed earlier that on basis of interference pattern physical and/or chemical properties of storing medium is changed. There are mainly two storage mediums are used that are
1. Lithium-niobate crystals
2. Photopolymers

4.4 Charge Coupled Device (CCD)

CCD is nothing but an array of sensors which gives responses on basis of pixels of SLM. It is mainly used to read interference pattern at time of recording and reading of data. It is able to read 1 Mb of data at one instance. In general CCDs are of one square centimeter and having typical access rate of 1000 frames per seconds or say 1 Gigabit per second.

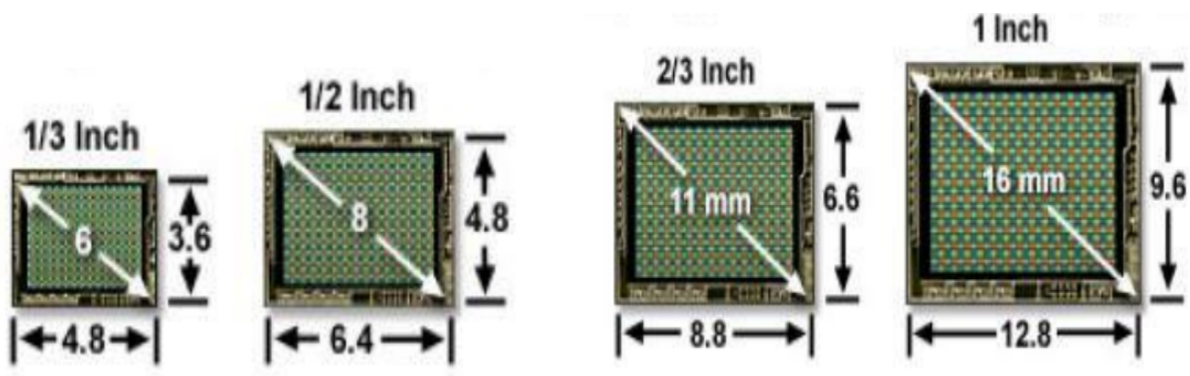

Figure 4.2: Common CCD Image Sensor Formats

Chapter 5

Recording to HVD and Reading from HVD

5.1 Recording to HVD

Till now we have seen how to store hologram of an image. But, now we are talking about holographic memory which mean there are much more then only an image. Holographic memory is optical type of memory which means we are using lasers in a procedure of storing data.

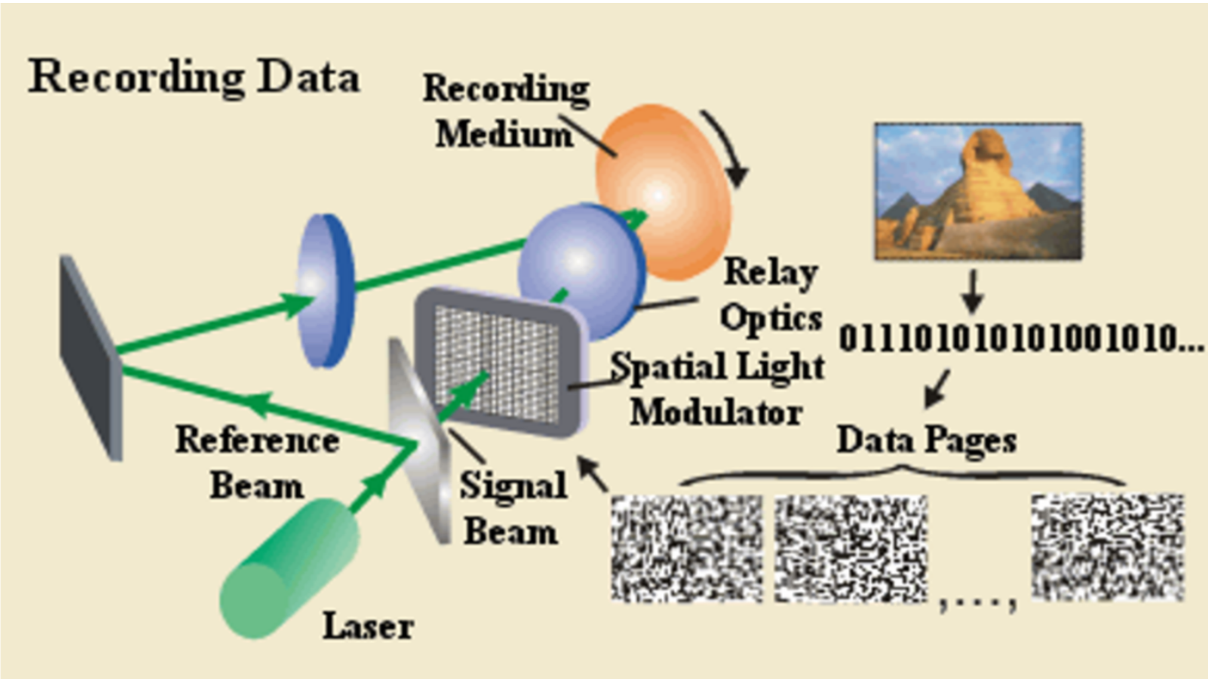

Figure 5.1: Recording of data to HVD

So we are having information in a form a LASER which will be split in to two laser beams by lens. These two beams are signal beam and reference beam. Signal beam is having information to be stored. Now this signal beam pas through the spatial light modulator (SLM) which converts this beam into pixels of black and white as SLM is a 1024*1024 pixels square where each pixel will either allow or stop the laser. On basis of this pixel charge coupled device (CCD) generates a string of 1's and 0's and that entire page is stored on hologram with a help of reference beam. On basis of data physical and/or chemical characteristics of storing material will change. This all procedure of data recording is shown in figure 5.1 .

5.2 Reading from HVD

Now data reading is also following the same method used for recording. As shown in fig 4 reference beam is used for reading data from storing material. Once again these data passes through CCD for conversion and Detector will detect that data.Till now we have seen all basic concepts of Holography, how hologram is constructed and reconstructed. With help of this how data can be stored to HVD and can be read from HVD. Now, In next chapter we will see each component of HVD in detail and structure of HVD.Figure 5.2 shows the exact process.

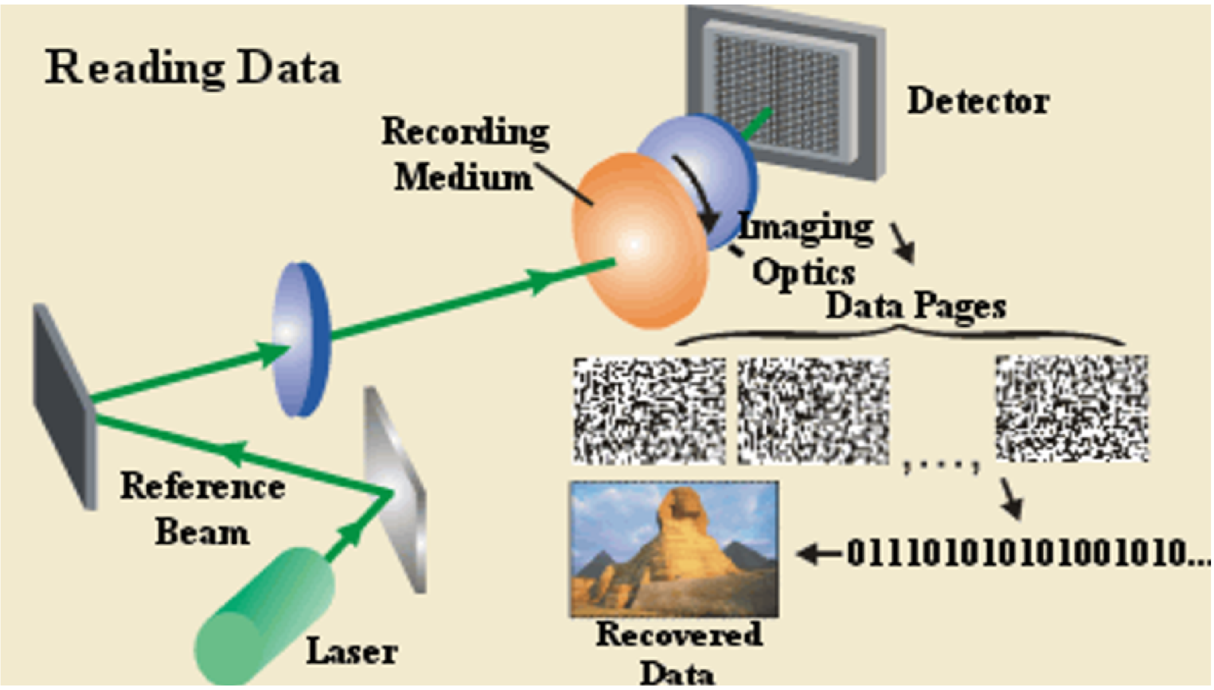

Figure 5.2: Reading data from HVD

Chapter 6

Collinear System

By studying the conventional problems noted above, it becomes especially important to fundamentally reconsider a holographic recording and reconstruction optical system using the two-beam interference method noted. The collinear system is based on the coaxial read/write type in which the reference and information beams are handled as a pencil of coaxial light, rather than the two-beam interference method that was widely used in the past. This enables the comprehensive optical disk technologies to be easily fused to realize large storage capacity, and high transfer rate memories of a new concept while exploiting the advantages of the holographic memory.

6.1 Collinear Holographic Memory

The following shows the concept of collinear holographic memories

1. Thick volume-recording media are used to increase the recording capacities
2. A batch of two-dimensional page data are recorded and reconstructed as a hologram to improve the transfer rates.
3. The information beam and reference beam are collinearly optically arranged on the same axis without angles to perform holographic recording and reconstruction.
4. Disk construction with a coated reflection film is employed to configure an optical system that completes on a single side of the disk
5. An optical disk is preformatted with addresses and optical servo information
6. The optical servo technique is applied so that interference patterns are recorded even in the

presence of disk rotation, eccentricity, or plane deflection

7. A two-wavelength optical system is configured to read out addresses at a wavelength that does not photosensitize a holographic recording material, and perform optical servo operations.
8. A beam for the optical servo is utilized to provide upward compatibility with the existing CDs or DVDs.

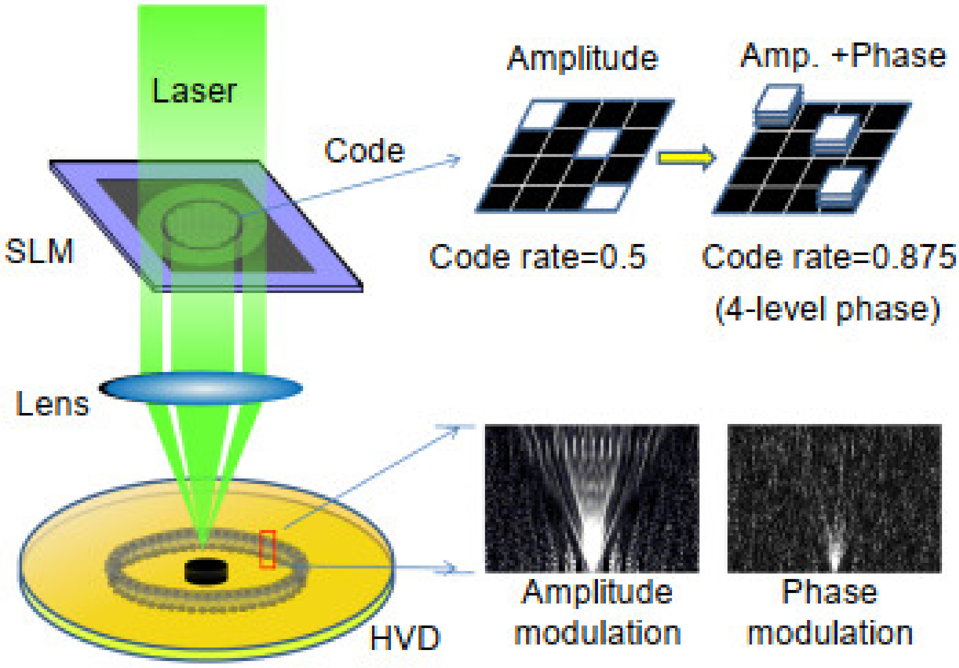

Figure 6.1: Collinear System

The collinear system set up is shown by figure 6.1 . HVD is designed to be a special six-layered structure17. On the base layer, there are preformatted address pits and reflective meta-data layer. The material in the meta-data layer is a rewritable phase change material, like DVD-RW. It is used to write address information by red laser to locate holograms and reflect red laser for servo control. The diffraction noise caused by address pits is eliminated by placing a dichroic mirror interlayer placed between the reflective layers. The red laser beam will pass through this layer and reach to the reflective layer while the green (or blue) laser beam will stay in the recording layer due to reflection by this dichroic mirror interlayer. The image quality with the dichroic mirror interlayer is much better than without one19. The disk structure is generated by the simplified optical systems of CHDSS, characterized as small volumetric optical disc storage system, allowing small and compact packaging on the same side of the disk. Besides, the generated disk structure is compatible with the already existent storage disc systems, such as CD and DVD.

6.2 Optical configuration of CHDSS

Collinear holographic data storage system (CHDSS) is a more compact, compatible and practical HDSS. The illustration of CHDSS is shown in Figure 6.2 . The unique feature of CHDSS is that 2-D data pages are recorded by an interferometry structure. The volume holograms generated by a co-axially aligned information beam and a reference beam. In the writing process, the information pattern in the center and the reference pattern circling it are used, and two parts of modulated laser beam interfere with each other in the recording media called holographic versatile disc (HVD) through a single objective lens. In the reading process, only the reference pattern is used. The modulated laser beam illuminates the volume hologram in the HVD. The reconstructed image beam is passed back to the same objective lens with a reflective interlayer in HVD, and is received by a complementary metal oxide semiconductor (CMOS) image sensor. In the CHDSS, the green (or blue) laser and red laser beams are combined to the same axis and are transmitted through a single objective lens. The green (or blue) laser is used to read and write holograms because it is sensitive to recording media. A red laser which is not sensitive for recording media is employed for adjusting the focal point of the objective lens correctly in optical servo control system and locating the holograms address in the HVD.

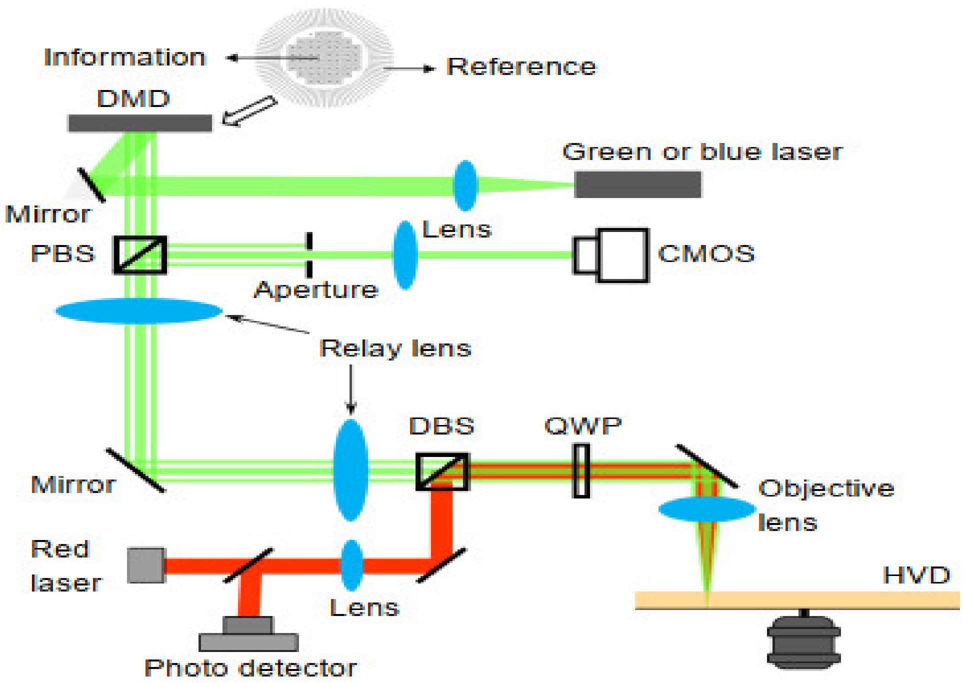

Figure 6.2: Optical configuration of CHDSS

6.3 Data page format in the CHDSS

The format of data page will greatly influence the amount of recording information. In the conventional CHDSS, the code is amplitude modulation. Here, the subpage format is designed to eliminate the problems such as illuminated intensity distribution in a data page, the distortion, the tilting and the aberration of the optical system, as well as the estimation error caused by amplification. As shown in Fig. 4, one data page is made of 51 subpages and 1 synchronous mark. One subpage is made of 32 symbols (4×4 pixels) and 1 synchronous mark (8×8 pixels). The synchronous mark, which includes a 4×4 pixels rectangular block, is used to locate the subpage and to provide the necessary coordinate information for data decoding. The symbol includes 4×4 pixels. There are only 3 ON-pixels in the symbol and others are OFF-pixels. The combination of ON-pixels' positions denotes different 8-bit code. In this data page format, the code rate is 8/16=0.5, and the white rate is 3/16=19% approximately.Data page format in the CHDSS with the working can bu analyzed with the help of following figure i.e figure 6.3 .

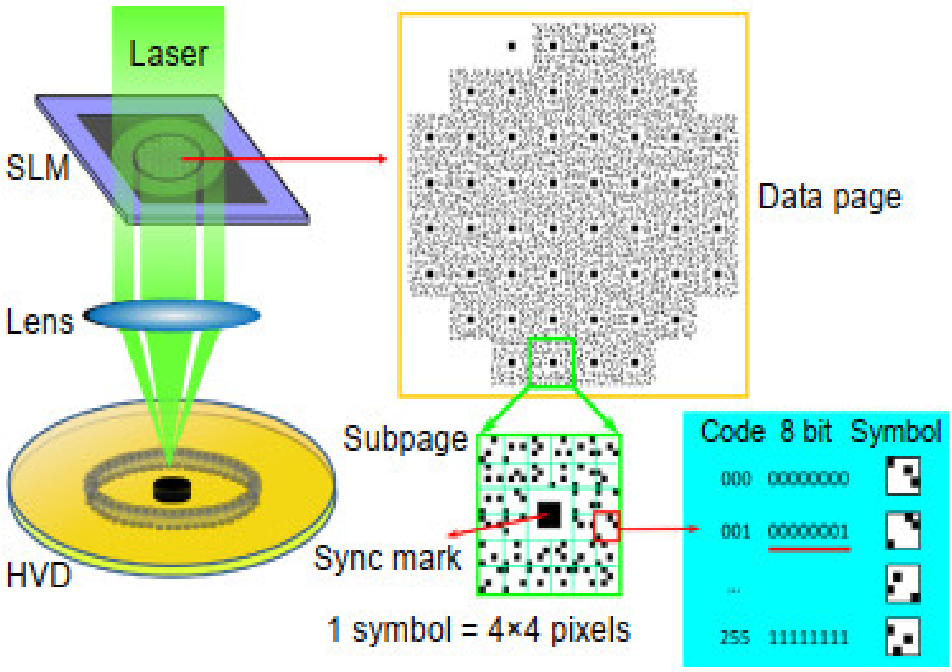

Figure 6.3: Data page format in the CHDSS

Chapter 7

Desktop Holographic Data Storage

After more than 30 years of research and development, a desktop holographic storage system (HDSS) is close at hand. There is still some fine tuning that must be done before such a high density storage device can be marketed, but IBM researchers have suggested that they will have a small HDSS device ready soon. These early holographic data storage devices will have capacities of 125 GB and transfer rates of about 40 MB per second. Eventually, these devices could have storage capacities of 1 TB and data rates of more than 1 GB per second – fast enough to transfer an entire DVD movie in 30 seconds.When the idea of an HDSS was first proposed, the components for constructing such a device were much larger and more expensive. For example, a laser for such a system in the 1960s would have been 6 feet long.

7.1 Holography as a Desktop Storage

Now, with the development of consumer electronics, a laser similar to those used in CD players could be used for the HDSS. LCDs weren't even developed until 1968, and the first ones were very expensive. Today, LCDs are much cheaper and more complex than those developed 30 years ago. Additionally, a CCD sensor wasn't available until the last decade. Almost the entire HDSS device can now be made from off-the-shelf components, which means that it could be mass-produced.Although HDSS components are easier to come by today than they were in the 1960s, there are still some technical problems that need to be worked out. For example, if too many pages are stored in one crystal, the strength of each hologram is diminished

If there are too many holograms stored on a crystal, and the reference laser used to retrieve a hologram is not shined at the precise angle, a hologram will pick up a lot of background from the other holograms stored around it. It is also a challenge to align all of these components in a low-cost system. Researchers are confident that technologies will be developed in the next two or three years to meet these challenges. With such technologies on the market, you will be able to purchase the first holographic memory players by the time ”Star Wars: Episode II” is released on home 3-D discs. This DVD-like disc would have a capacity 27 times greater than the 4.7-GB DVDs available today, and the playing device would have data rates 25 times faster than today’s fastest DVD players.

7.2 System Arrangement

Devices that use light to store and read data have been the backbone of data storage for nearly two decades. Compact discs revolutionized data storage in the early 1980s, allowing multi-megabytes of data to be stored on a disc that has a diameter of a mere 12 centimeters and a thickness of about 1.2 millimeters. In 1997, an improved version of the CD, called a digital versatile disc (DVD), was released, which enabled the storage of full-length movies on a single disc.CDs and DVDs are the primary data storage methods for music, software, personal computing and video. A CD can hold 783 megabytes of data, which is equivalent to about one hour and 15 minutes of music, but Sony has plans to release a 1.3-gigabyte (GB) high-capacity CD. A double-sided, double-layer DVD can hold 15.9 GB of data, which is about eight hours of movies.

These conventional storage mediums meet today’s storage needs, but storage technologies have to evolve to keep pace with increasing consumer demand. CDs, DVDs and magnetic storage all store bits of information on the surface of a recording medium. In order to increase storage capabilities, scientists are now working on a new optical storage method, called holographic memory, that will go beneath the surface and use the volume of the recording medium for storage, instead of only the surface area. Three-dimensional data storage will be able to store more information in a smaller space and offer faster data transfer times. You will learn how a holographic storage system might be built in the next three or four years, and what it will take to make a desktop version of such a high density storage system.The system arrangement can be viewed or shown using the figure 7.1 .

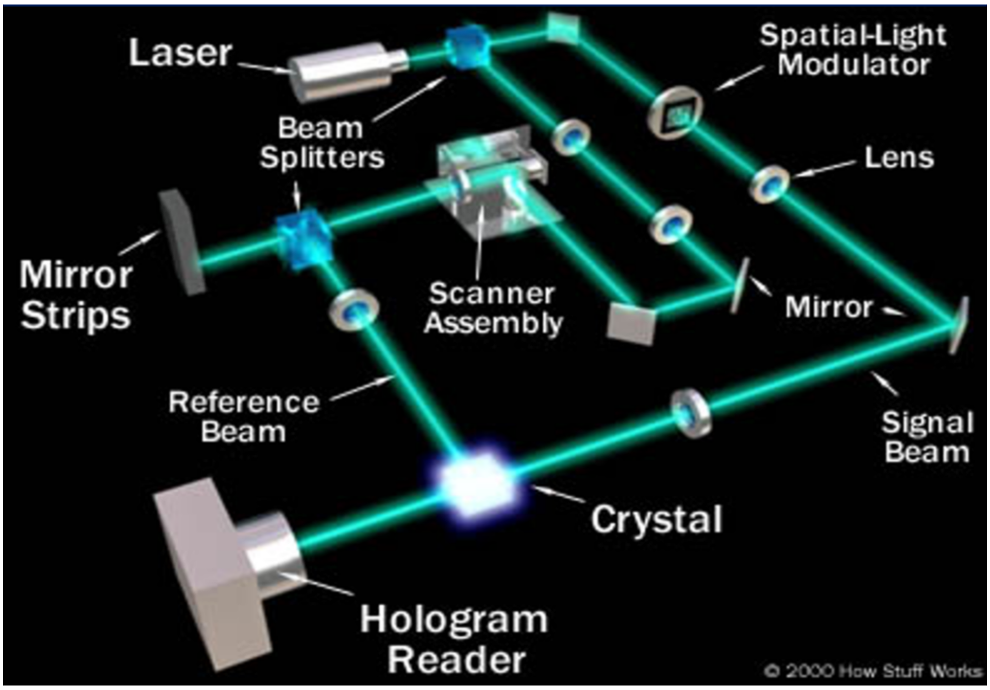

Figure 7.1: System Arrangement

7.3 System Working

Let us consider a device assembly in which a beam of cyan argon laser is divided into two components - a reference and an object beam (the latter is a carrier of data). The object beam undergoes defocusing in order it could entirely illumine the SLM (Spatial Light Modulator) which is an LCD panel where a data page is displayed in the form of a matrix consisting of light and dark pixels (binary data).The both beams go into the light-sensitive crystal where they interact. So we get an interference pattern which serve a base for a hologram and is recorded as a set of variations of the refractive exponent and the reflection factor inside this crystal. When reading data the crystal is illuminated with a reference beam, which interacts with the interference factor and reproduces the recorded page in the image of ”chess-board” of light and dark pixels (the holograms converts the reference wave into the copy of the object one). After that, this image is transferred into the matrix detector where the CCD (Charge-Coupled Device) serves a base. While reading the data the reference beam must fall at the same angle at which the recording was made; alteration of this angle mustn’t exceed 1 degree. It allows obtaining high data density.

Chapter 8

Advanced HVD and Applications

8.1 Comparison

	DVD	BLU-RAY	HVD
Capacity	9.4 GB	50 GB	Up to 3.9 TB
Laser wave length	650 nm	405 nm	407 nm
Disc diameter	120 mm	120 mm	120 mm
Read/write speed	11.08 Mbps	36.5Mbps	1 Gbps

Table 8.1: Comparison of HVD with other Discs

8.2 Applications of Holography

- **Holographic Interferometry :** It is a one of the technique to identify static and dynamic change of object's position. In which two interference patterns of object are again interfaced and gives another interference pattern which indicates the displacement of object.

- **Security :** Holograms are very useful in security and it is already used by many countries with a purpose of security on their currency notes. It is also used by banks for security of their credit cards. Now a days passports are also having holograms on them and with that sports equipment, books, ID cards are also having holograms on them.

- **Dynamic Holography :** Holography is of two types that are static and dynamic. Till now we have seen only static holography where hologram is constructed, stored and reconstructed. But in dynamic holography some type of materials are used that is having capacity of recording hologram very quickly and instantly we can reconstruct it using proper arrangements. These can be used in image processing to recognize pattern images which are time varying.

- **Data Storage :** Holography is having capacity of storing different data using entire volume of storing material like crystals or photopolymers. Now a day researchers are majorly working in the field of minimizing size of data storage devices which means they want to increase data density within specific volume of material.

8.3 Advantages

- **High Data Transfer Speed :** As we have discussed that holographic memory is giving data transfer speed up o 1 Gbps which is highest till date for any storage device.

- **High Data Density :** Holographic memory can store data up to 3.9 TB in in 120 mm diameter sized disc and researchers are claiming that they will reach up to 1 TB data in just 1 inch sized sugar cube.

- **Data Stability and Reliability :** One survey says that within a three year of period, 26.5% of seagate's drive failed, 5.2% of WD's (Western Digital) drives failed and 3.1% of Hitachi's drives failed whereas scientists of holographic memory are claiming that Holographic memory is reliable till 50 years which is very higher than these hard drives.

- **Data Security :** Holographic memory is of WORM (Write Once Read Many) type of memory so once data is written then nobody can edit it which gives high data security.

8.4 Drawbacks

- **Not guaranteed market leader :** Holographic memory is offering all required features but still it is not that much popular because recording and reading of data is very hard. If any other storing technique will come in market then it is very hard to find components to record and read data form HVD.

- **Expensive Development :** As we have discussed for recording and reading data, whole setup should be very much perfect. If there is any small displacement in any component, it will cause major errors in data.

8.5 Potential Competitors

- **Blu-ray Discs :** Blu-ray disc provides some of the strongest copy protection methods ever developed for any consumer format . It makes the blu-ray disc the best choice for any content publisher wanting assurance that their valuable assets are protected from privacy.

- **UV or X-rays :** These are cheaper and simple technique for storing the data and has lower radiation,X-rays are not absorbed very much by air, hence specimen need not be in an evacuated chamber.

8.6 Companies working on Holographic Memory

- Akonia Holographics
- IBM
- Intel
- Musion-The world leaders in holographic technology
- Zebra Imaging
- Realview medical holography

Chapter 9

CONCLUSION

9.1 Conclusion

Holographic memory is using lasers for recording and reading of data in which signal beam and reference beam are used and interfering pattern of these two beams is to be stored in memory. As interfering pattern is stored, by changing angle, position or wavelength of reference beam different patterns can generated which increases data density. Holographic Memory is having all required features of any storing device like high storage densities – 1 TB in just sugar sized cube, fast data transfer rate - 1 Gbps and with that 3D representation of image or video. So these all make Holographic memory a perfect suitable choice for storing data.

9.2 Future of Holographic Memory

Today holographic memory is very close to becoming a reality. The basic theory behind it has been shown to be reliable and has been implemented in numerous experiments. Materials research has yielded some promising results in photorefractive crystals such as LiNbO3 and BaTiO3, especially for use with rewritable, refreshed random access memory. Also, a read only version of holographic data storage is certainly feasible with some of the photopolymer films available today. For holographic memory to truly become the next revolution in data storage, data transfer rates must be improved, hologram decay must become negligible, and hologram recording time must be reduced. Then it will be economical for holographic memories to be produced for mass consumption.

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