HOLOGRAPHIC VERSATILE DISC

A SEMINAR REPORT

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Certificate

Certified that this is a bonafide record of the seminar entitled

" HOLOGRAPHIC VERSATILE DISC "

presented by the following student

Nikesh Bharti

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

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Many people have contributed to the success of this. Although a single sentence hardly suffices, I would like to thank Almighty God for blessing us with His grace. I extend my sincere and heart felt thanks to **Dr. David Peter, Head of Department,** Computer Science and Engineering, for providing us the right ambience for carrying out this work. I am profoundly indebted to my seminar guide, **Ms. Remyamol K M** for innumerable acts of timely advice, encouragement and I sincerely express my gratitude to her.

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ABSTRACT

The Information Age has led to an explosion of information available to users.While current storage needs are being met, storage technologies must continue to improve in order to keep pace with the rapidly increasing demand. However, conventional data storage technologies ,where individual bits are stored as distinct magnetic or optical changes on the *surface* of a recording medium, are approaching physical limits. Storing information throughout the volume of a medium — not just on its surface —offers an intriguing high-capacity alternative. Holographic data storage is a volumetric approach which , although conceived decades ago, has made recent progress toward practicality with the appearance of lower-cost enabling technologies , significant results from longstanding research efforts , and progress in holographic recording materials.

Holographic versatile disc (HVD) is a holographic storage format capable of storing far more data than DVD. Prototype HVD devices have been created with a capacity of 3.9 terabytes (TB) and a transfer rate of 1 gigabit per second (1 Gbps). At that capacity, an HVD could store as much information as 830 DVDs or 160 Blu-ray discs.

This paper presents an introduction to holographic versatile disc, its challenges , and opportunities.

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1. INTRODUCTION

An HVD (Holographic Versatile Disc) , a holographic storage media, is an advanced optical disk that's presently in the development stage. Polaroid scientist J. van Heerden was the first to come up with the idea for holographic three-dimensional storage in 1960. An HVD would be a successor to today's Blu-ray and HD-DVD technologies. It can transfer data at the rate of 1 Gigabit per second. The technology permits over 10 kilobits of data to be written and read in parallel with a single flash. The disk will store upto 3.9 terabyte (TB) of data on a single optical disk.

Holographic data storage, a potential next generation storage technology, offers both high storage density and fast readout rate. In this article, I discuss the physical origin of these attractive technology features, and the components and engineering required to realize them. The strengths and weaknesses of available write-once and read-writeable storage media are discussed, including the development issues of achieving non-volatile readout from read-write media. Systems issues such as the major noise sources and avenues for defeating or finessing them are detailed, including the potentials and pitfalls of phase-conjugate readout and holographic storage on spinning media. I conclude by describing the current state of holographic storage research and development efforts in the context of ongoing improvements to established storage technologies.

1.1BRIEF HISTORY

Although holography was conceived in the late 1940s, it was not considered a potential storage technology until the development of the laser in the 1960s. The resulting rapid development of holography for displaying 3-D images led researchers to realize that holograms could also store data at a volumetric density of as much as $1/\lambda^3$ where λ is the wave-length of the light beam used.

Since each data page is retrieved by an array of photo detectors in parallel, rather than bit-by-bit, the holographic scheme promises fast readout rates as well as high density.
If a thousand holograms, each containing a million pixels, could be retrieved every second, for instance, then the output data rate would reach 1 Gigabit per second. Despite this attractive potential and fairly impressive early progress research into holographic data storage died out in the mid-1970s because suitable devices for the input and output of large pixelated 2-D data pages were just not available.

In the early 1990s, interest in volume-holographic data storage was rekindled by the availability of devices that could display and detect 2-D pages, including charge coupled devices (CCD), complementary metal-oxide semiconductor (CMOS) detector chips and small liquid-crystal panels. The wide availability of these devices was made possible by the commercial success of hand-held camcorders, digital cameras, and video projectors.
With these components in hand, holographic-storage researchers have begun to demonstrate the potential of their technology in the laboratory. By using the volume of the media, researchers have experimentally demonstrated that data can be stored at equivalent areal densities of nearly 400 bits/sq. micron. (For comparison, a single-layer of a DVD disk stores data at ~ 4:7 bits/sq. micron) A readout rate of 10 Gigabit per second has also been achieved in the laboratory.

1.2 LONGEVITY

Holographic data storage can provide companies a method to preserve and archive information. The write-once, read many (WORM) approach to data storage would ensure content security, preventing the information from being overwritten or modified. Manufacturers believe this technology can provide safe storage for content without degradation for more than 50 years, far exceeding current data storage options. Counterpoints to this claim point out the evolution of data reader technology changes every ten years; therefore, being able to store data for 50-100 years would not matter if you could not read or access it.

1.3 FEATURES

- Data transfer rate : 1gbps.
- The technology permits over 10 kilobits of data to be written and read in parallel with a single flash.
- Most optical storage devices, such as a standard CD saves one bit per pulse. HVDs manage to store 60,000 bits per pulse in the same place.
- 1 HVD = 5800 CDs = 830 DVD =160 BLU-RAY Discs.

2. UNDERLYING TECHNOLOGY

2.1 HOLOGRAPHY

Holographic data storage refers specifically to the use of holography to store and retrieve digital data. To do this, digital data must be imposed onto an optical wavefront, stored holographically with high volumetric density, and then extracted from the retrieved optical wavefront with excellent data fidelity.

A hologram preserves both the phase and amplitude of an optical wavefront of interest - called the **object beam** - by recording the optical interference pattern between it and a second coherent optical beam - **the reference beam**. **Figure 2.1** shows this process .

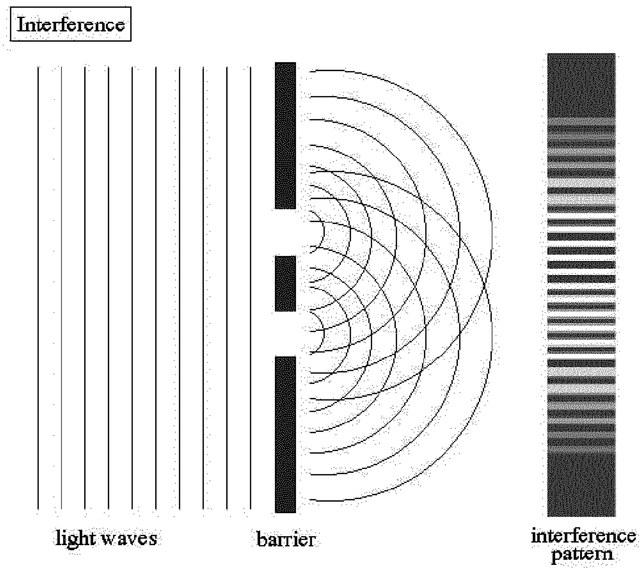

Fig 2.1

The reference beam is designed to be simple to reproduce at a later stage. (A common reference beam is a plane wave: a light beam that propagates without converging or diverging.) These interference fringes are recorded if the two beams have been overlapped within a suitable photosensitive media, such as a photopolymer or inorganic crystal or photographic film. The bright and dark variations of the interference pattern create chemical and/or physical changes in the media, preserving a replica of the interference pattern as a change in absorption, refractive index or thickness.

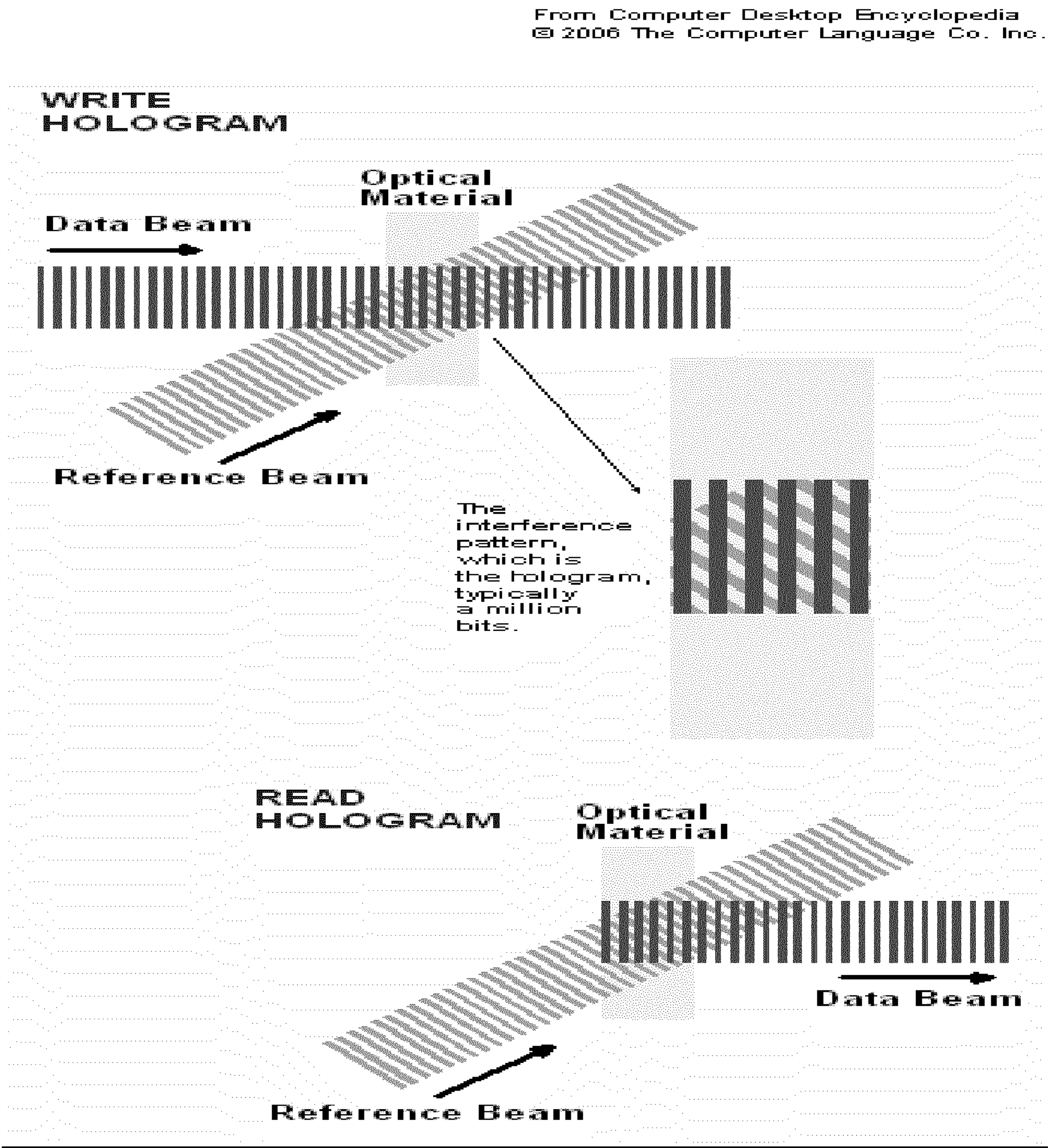

Fig 2.2

When the recording is illuminated by a **readout beam** similar to the original reference beam, some of the light is diffracted to “reconstruct" a copy of the object beam as shown in **Figure 2.2** . If the object beam originally came from a 3-D object, then the reconstructed hologram makes the 3-D object reappear.

2.2 COLLINEAR HOLOGRAPHY

HVD uses a technology called 'collinear holography,' in which two laser rays, one blue-green and one red, are collimated into a single beam. The role of the blue-green laser is to read the data encoded in the form of laser interference fringes from the holographic layer on the top, while the red laser serves the purpose of a reference beam and also to read the servo info from the aluminum layer - like in normal CDs - near the bottom of the disk. The servo info is meant to monitor the coordinates of the read head above the disk (this is similar to the track, head and sector information on a normal hard disk drive).

Fig 2.3 shows the two laser collinear holography technique and fig 2.4 shows the interference fringes pattern stored on the disc.

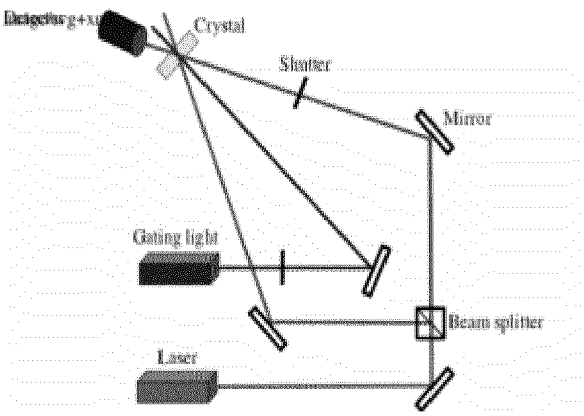

Fig 2.3

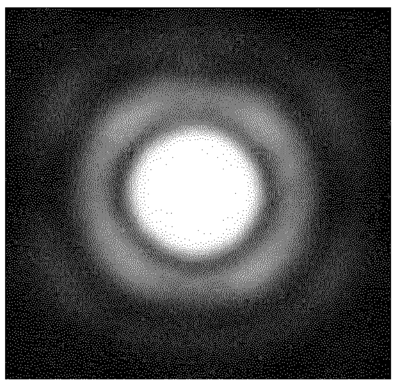

Fig 2.4

3. STRUCTURE

3.1 HVD STRUCTURE

HVD structure is shown in fig 3.1. The following components are used in HVD.

1.Green writing/reading laser (532 nm)

2. Red positioning/addressing laser (650 nm)

3. Hologram (data)

4. Polycarbon layer

5. Photopolymeric layer (data-containing layer)

6. Distance layers

7. Dichroic layer (reflecting green light)

8. Aluminium reflective layer (reflecting red light)

9. Transparent base

P. PIT

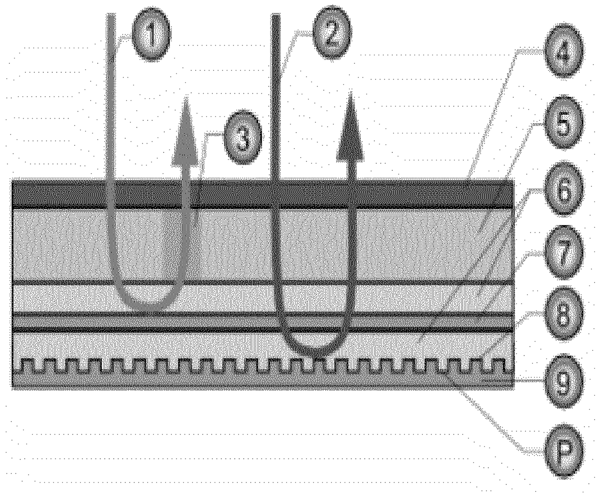

Fig 3.1

3.2 HVD READER PROTOTYPE

To read data from an HVD we need an HVD reader.The following components are used to make a raeder.

A blue-green argon laser, beam splitters to spilt the laser beams, mirrors to direct the laser beams, LCD panels (spatial light modulator), lenses to focus the laser beams, lithium-niobate crystals or photopolymers, and charge-coupled device (CCD) cameras.

Fig 3.2 shows the prototype of a reader.

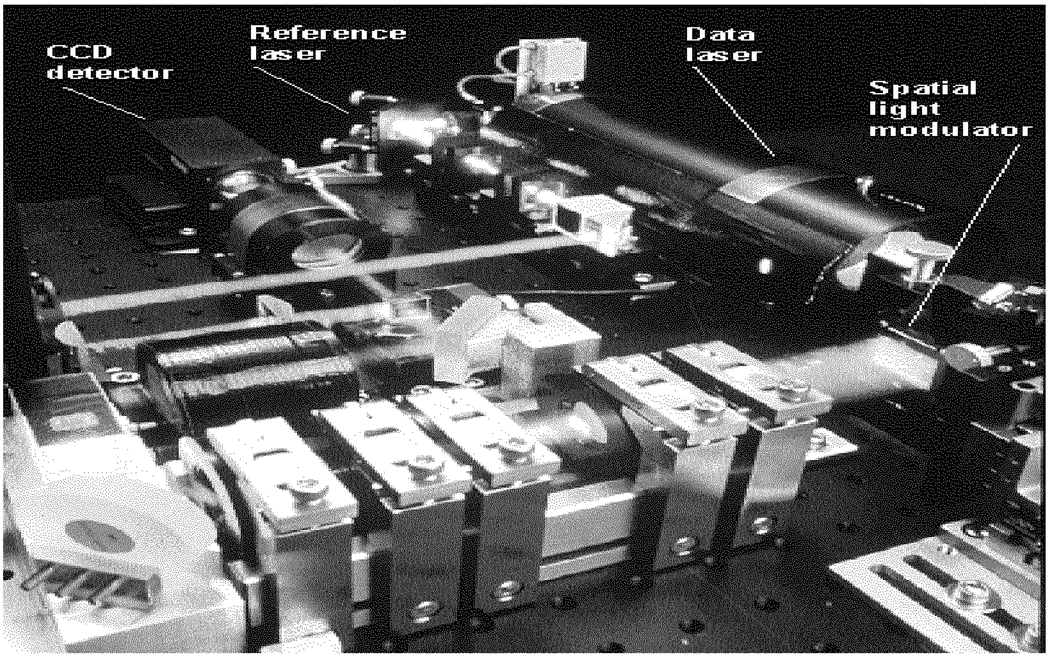

Fig 3.2

4. DATA STORAGE

4.1 RECORDING DATA

Holographic data storage works on the principle of holography. In holographic data storage an entire page of information is stored at once as an optical interference pattern within a thick, photosensitive optical material (Fig 4.1). This is done by intersecting two coherent laser beams within the storage material. The first, called the object beam, contains the information to be stored; the second, called the reference beam, is designed to be simple to reproduce. The resulting optical interference pattern causes chemical and/or physical changes in the photosensitive medium. A replica of the interference pattern is stored as a change in the absorption, refractive index, or thickness of the photosensitive medium. Illuminating the stored grating with the reference wave reconstructs the object wave.

Light from a single laser beam is divided into two separate beams, a reference beam and an object or signal beam; a spatial light modulator is used to encode the object beam with the data for storage. An optical inference pattern results from the crossing of the beams' paths, creating a chemical and/or physical change in the photosensitive medium; the resulting data is represented in an optical pattern of dark and light pixels. By adjusting the reference beam angle, wavelength, or media position, a multitude of holograms (theoretically, several thousand) can be stored on a single volume. The theoretical limits for the storage density of this technique are approximately tens of terabits (1 terabyte = 1,000 gigabytes) per cubic centimeter.

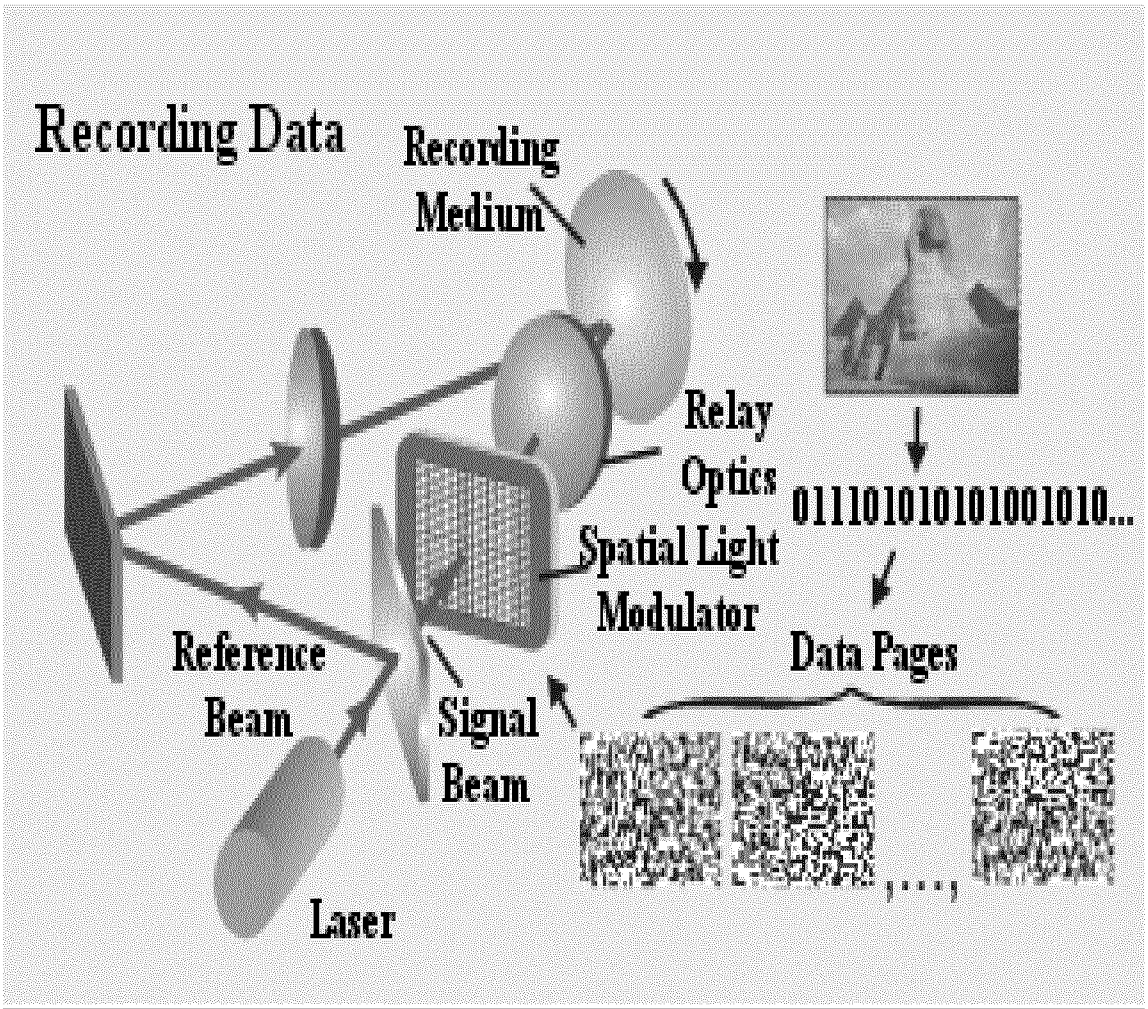
Recording Data
Recording Medium
Relay Optics
0111010101010010 10...
Spatial Light Modulator
Data Pages
Reference Beam
Signal Beam
Laser

Fig 4.1

4.2 READING DATA

A backward-propagating reference wave, illuminating the stored grating from the "back" side, reconstructs an object wave that also propagates backward toward its original source where the bit value can be read.

A large number of these interference gratings or patterns can be superimposed in the same thick piece of media and can be accessed independently, as long as they are distinguishable by the direction or the spacing of the gratings. Such separation can be accomplished by changing the angle between the object and reference wave or by changing the laser wavelength. Any particular data page can then be read out independently by illuminating the stored gratings with the reference wave that was used to store that page. Because of the thickness of the hologram, this reference wave is diffracted by the interference patterns in such a fashion that only the desired object beam is significantly reconstructed and imaged on an electronic camera.

Another way to retrieve data involves illuminating it with a diverging object beam, which reconstructs the original plane wave reference beam. This beam can be focused onto a detector and provides an optical measurement of the correlation between the stored data and the illuminating object beam. This technique can allow one to search the stored data according to its content, rather than according to its address (**Fig 4.2**).

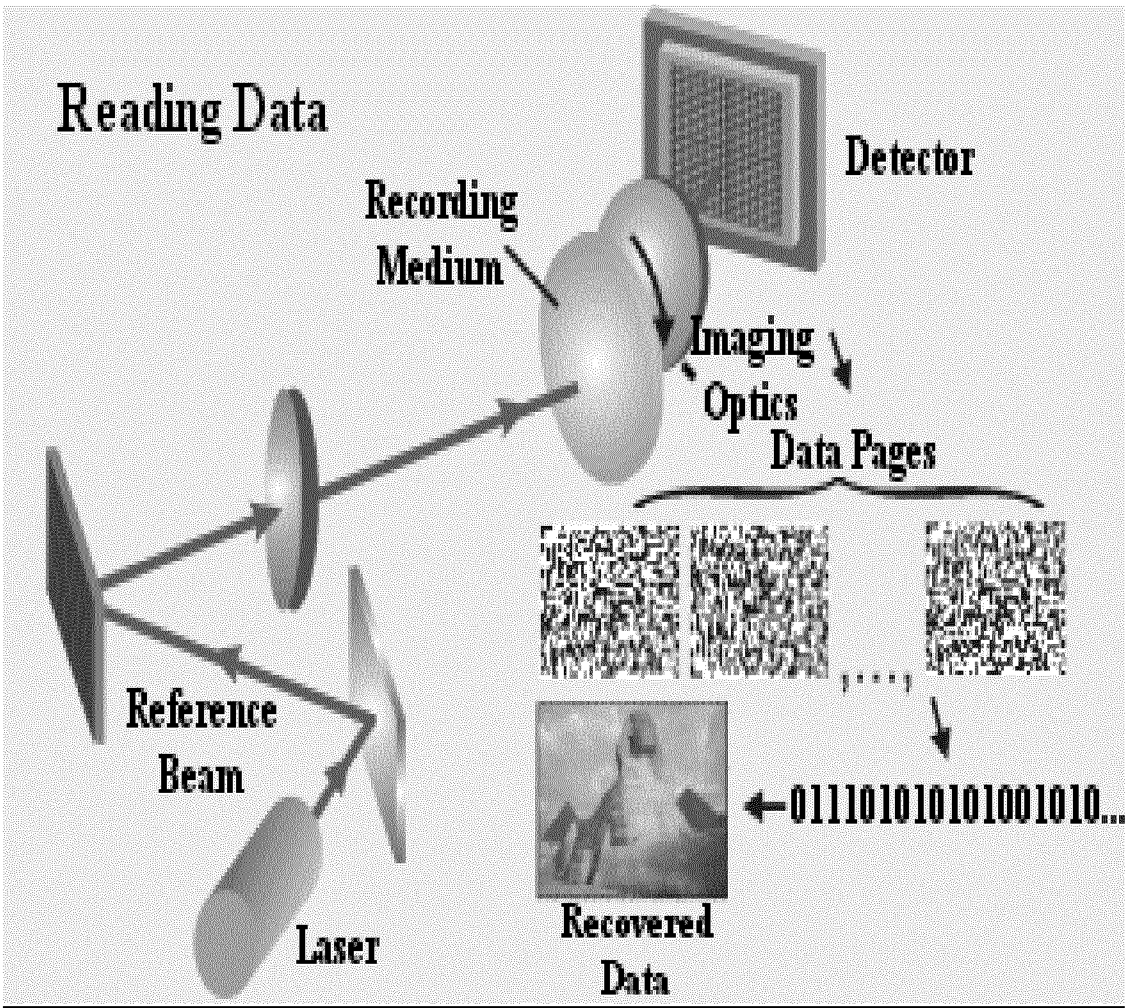
Reading Data
Detector
Recording
Medium
Imaging
Optics
Data Pages
Reference
Beam
Laser
Recovered
Data
0111010101010010 10...

Fig 4.2

5. HARDWARE

5.1 SPATIAL LIGHT MODULATOR

To use volume holography as a storage technology, digital data must be imprinted onto the object beam for recording and then retrieved from the reconstructed object beam during readout. The device for putting data into the system is called a **spatial light modulator (SLM)** - a planar array consisting of thousands of pixels. Each pixel is an independent microscopic shutter that can either block or pass light using liquid-crystal or micro-mirror technology. Liquid crystal panels and micro-mirror arrays with 1280 X 1024 pixels are commercially available due to the success of computer-driven projection displays. The pixels in both types of devices can be refreshed over 1000 times per second, allowing the holographic storage system to reach an input data rate of 1 Gbit per second - assuming that laser power and material sensitivities would permit. The data are read using an array of detector pixels, such as a CCD camera or CMOS sensor array.

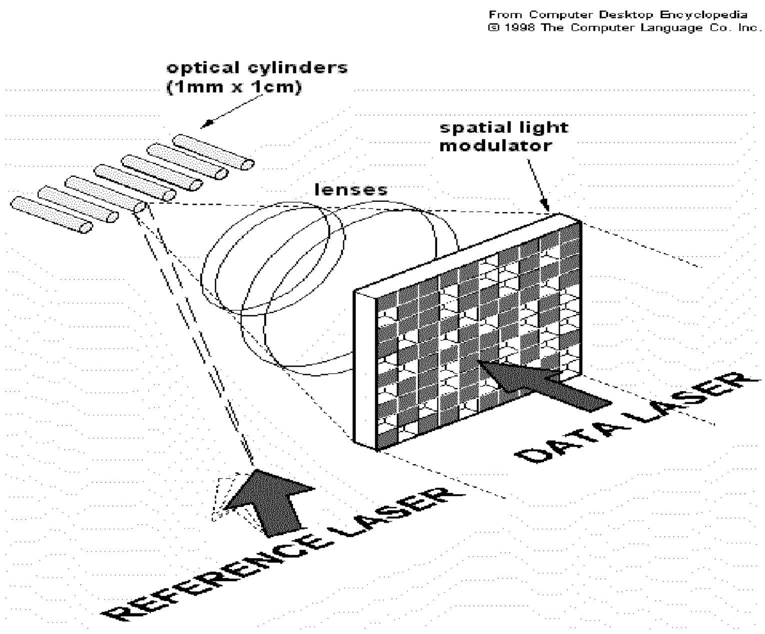

Fig 5.1

To access holographically-stored data, the correct reference beam must first be directed to the appropriate spot within the storage media. With mechanical access (i.e., a spinning disk), getting to the right spot is slow (long latency), but reading data out can be quick. Non - mechanical access leads to possibility for lower latency. A frequently mentioned goal is an integration time of about 1 millisecond, which implies that 1000 pages of data can be retrieved per second. If there are 1 million pixels per data page and each pixel stores one bit then the readout rate is 1 Gigabit per second. This goal requires high laser power (at least 1 W), a storage material capable of high diffraction efficiencies, and a detector with a million pixels that can be read out at high frame rates. Frame rates of 1 kHz have been demonstrated in such “megapixel" CCDs , but these are not yet commercially available. Low-noise megapixel CMOS detector arrays that can support 500 frames per second have also been demonstrated. Even with these requirements, faster readout and lower latency could be reached by steering the reference beam angle non-mechanically, by using a pulsed laser, and by electronically reading only the desired portion of the detector array. Both the capacity and the readout rate are maximized when each detector pixel is matched to a single pixel on the SLM, but for large pixel arrays this requires careful optical design and alignment.

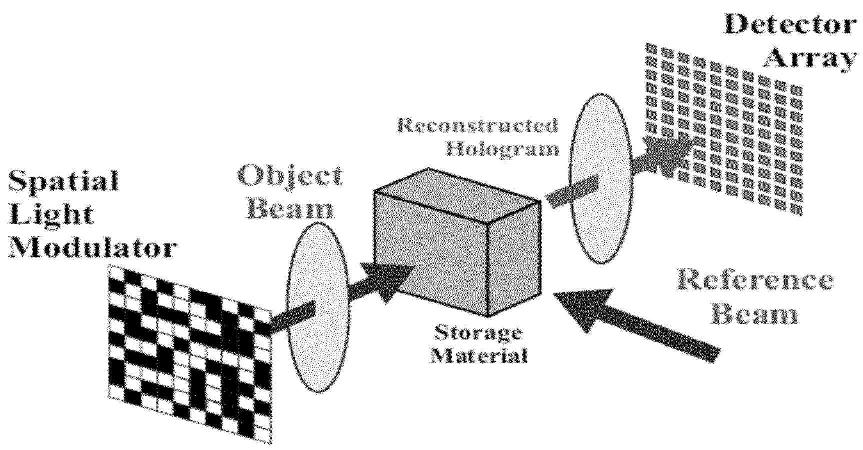

Fig 5.2

6. TYPES

6.1 READ ONLY

A material that permanently stores volume holograms must generally support some irreversible photochemical reaction, triggered by the bright regions of the optical interference pattern, that can lead to changes in index of refraction or absorption. For example, a photopolymer material polymerizes in response to optical illumination: material diffuses from darker to brighter regions so that short monomer chains can bind together to form long molecular chains. Because this diffusion process can be phototriggered, sensitivities can be made high enough to support holographic recording with single short pulses. However, the high sensitivity means that some of the media volume may be inadvertently affected by partial exposure as nearby spots are recorded. In contrast to photopolymers, the illuminated molecules in a so-called direct-write or photochromatic material undergo a local change in their absorption or index of refraction, driven by photochemistry or photo-induced molecular reconfiguration. Examples include photoaddressable polymers, and binding of absorbers to polymer hosts. Both types of materials are inexpensive to make in bulk, but both can have problems reproducing the object beam faithfully.

6.2 READ-WRITE

In contrast to the organic WORM media, most erasable holographic materials tend to be inorganic photorefractive crystals doped with transition metals or rare-earth ions. These materials react to an optical interference pattern by transporting and trapping electrons. In an ensemble sense, electrons photoexcited at the bright fringes diffuse or drift (are pushed by an electric field) and are retrapped at a dark fringe. By using noncentrosymmetric crystals exhibiting a linear electro-optic effect, the resulting spatial modulation of electric field leads to a corresponding local change in index of refraction. The trapped charge can be rearranged by later illumination, so it is possible to erase recorded holograms and replace them with new ones. This would seem to enable a read-write storage device, where small blocks of data are written, read, and erased with equal facility. However, the recording rates of photorefractive materials are typically 5-50 times slower than the achievable readout rate at any given laser power. In addition, erasing individual holograms from a small storage volume without affecting the other superimposed holograms is quite complicated.

Fig 6.1 shows spatial re-configuration of elotronic cloud ,thus producing modulation in electric fields.

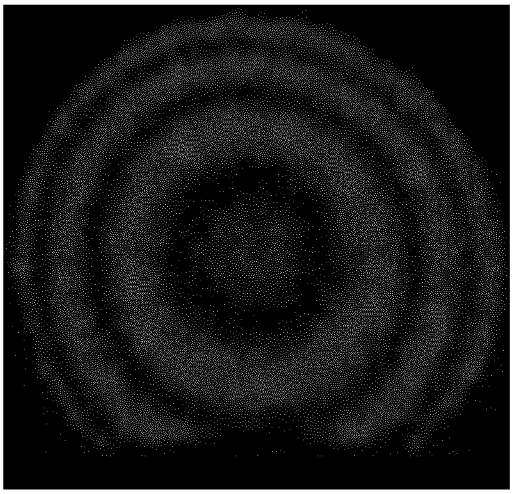

Fig 6.1

7. MORE ON HVD

7.1 COMPETING TECHNOLOGIES

HVD is not the only technology in high-capacity, optical storage media. InPhase Technologies is developing a rival holographic format called Tapestry Media, which they claim will eventually store 1.6 TB with a data transfer rate of 120 MB/s, and several companies are developing TB-level discs based on 3D optical data storage technology. Such large optical storage capacities compete favorably with the Blu-ray Disc format. However, holographic drives are projected to initially cost around US$15,000, and a single disc around US$120–180, although prices are expected to fall steadily. The market for this format is not initially the common consumer, but enterprises with very large storage needs.

7.2 HVD ADOPTION

The biggest challenge for HVD will be in establishing itself in the commercial market, which as of now seems to be a distant dream, given its higher cost margins. It is anticipated that a single HVD, when commercially available, may cost anywhere between $100-120 , and the reader will be priced anywhere in the range of $10,000 to $15,000. However, like anything else associated with technology, the price will soon fall as R&DD costs are recouped and competitions lowers profit margins.

7.3 THE HSD FORUM

The HSD Forum (formerly the HVD Alliance, & HVD FORUM) is a coalition of corporations purposed to provide an industry forum for testing and technical discussion of all aspects of HVD design and manufacturing. By cooperating, members of the Forum hope to expedite development and engender a market receptive to HVD technology.

7.4 STANDARDS

On December 9, 2004 at its 88th General Assembly the standards body Ecma International created Technical Committee 44, dedicated to standardizing HVD formats based on Optware's technology. On June 11, 2007, TC44 published the first two HVD standards: ECMA-377, defining a 200 GB HVD "recordable cartridge" and ECMA-378, defining a 100 GB HVD-ROM disc. Its next stated goals are 30 GB HVD cards and submission of these standards to the International Organization for Standardization for ISO approval.

7.5 STORAGE CAPACITY IN CONTEXT

- The entire US Library of Congress can be stored on six HVDs, assuming that every book has been scanned in the text format. The Library of Congress is the largest in the world and contains over 130 million items.
- The pictures of every landmass on Earth - like the ones shown in Google Earth - can be stored on two HVDs.
- With MPEG4 ASP encoding, a 3.9 TB HVD can hold anywhere between 4,600-11,900 hours of video, which is enough for non-stop playing for a year.

7.6 HVD AT A GLANCE

Fig 7.1

Media type: Ultra-high density optical disc

Encoding : MPEG-2, MPEG-4 AVC (H.264), and VC-1

Capacity : Theoretically up to 3.9 TB

Developed : By HSD Forum

Usage : Data storage, High-definition video, & the possibility of ultra high definition video.

8. COMPARISON

Parameters	**DVD**	**BLU-RAY**	**HVD**
capacity	4.7 GB	25 GB	3.9 TB
Laser wave length	650 nm (red)	405 nm (blue)	532 nm (green)
Disc diameter	120 mm	120 mm	120 mm
Hard coating	no	yes	yes
Data transfer rate (raw data)	11.08 mbps	36 mbps	1 gbps
Data transfer rate (audio/video)	10.08 mbps	54 mbps	1 gbps

Table 8.1

9. MORE DEVELOPMENT ISSUES

Despite the highly attractive nature of 3D optical data storage, the development of commercial products has taken a significant length of time. This is the result of the limited financial backing that 3D optical storage ventures have received, as well as technical issues including:

- **Destructive reading**. Since both the reading and the writing of data are carried out with laser beams, there is a potential for the reading process to cause a small amount of writing. In this case, the repeated reading of data may eventually serve to erase it (this also happens in phase change materials used in some DVDs). This issue has been addressed by many approaches, such as the use of different absorption bands for each process (reading and writing), or the use of a reading method that does not involve the absorption of energy.

- **Thermodynamic stability**. Many chemical reactions that appear not to take place in fact happen very slowly. In addition, many reactions that appear to have happened can slowly reverse themselves. Since most 3D media are based on chemical reactions, there is therefore a risk that either the unwritten points will slowly become written or that the written points will slowly revert to being unwritten. This issue is particularly serious for the spiropyrans, but extensive research was conducted to find more stable chromophores for 3D memories.

- **Media sensitivity**. As we have noted, 2-photon absorption is a weak phenomenon, and therefore high power lasers are usually required to produce it.

10. CONCLUSION

The Information Age has led to an explosion of information available to users. While current storage needs are being met, storage technologies must continue to improve in order to keep pace with the rapidly increasing demand. However, conventional data storage technologies, where individual bits are stored as distinct magnetic or optical changes on the *surface* of a recording medium, are approaching physical limits. Storing information throughout the volume of a medium—not just on its surface—offers an intriguing high-capacity alternative. Holographic data storage is a volumetric approach which, although conceived decades ago, has made recent progress toward practicality with the appearance of lower-cost enabling technologies, significant results from longstanding research efforts, and progress in holographic recording materials.

HVD gives a practical way to exploit the holography technologies to store data upto 3.9 terabytes on a single disc.. It can transfer data at the rate of 1 Gigabit per second. The technology permits over 10 kilobits of data to be written and read in parallel with a single flash. So an HVD would be a successor to today's Blu-ray and HD-DVD technologies.

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