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3D Optical Data Storage

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Abstract: Storage and retrieval of long data in a relatively smaller space is a challenging task for communication engineer. Now a day's CD's, DVD's, pen derives and hard disk are usually used for this purpose which are not capable holding large amount of data and also retrieval of data takes relatively last time . This study is a small effort to review the storage of data in 3D optical medium which will hold the large amount of data and will make retrieval easier.

Keywords: Optical Storage, optical memory, 3D optics, holographics.

I. INTRODUCTION

Optical data storage is an 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. Optical 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. Optical data storage systems are very close to becoming economically feasible. Photo-refractive crystals and photopolymers have been used successfully in experimental optical 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.

Optical memory lies between main memory magnetic disk in regards to data access times, data transfer rates, data storage density. Optical memory uses the basic principles of holography for the recording purposes and hence it is also called as holographic memory system. Optical memory is a promising technology for data storage because it is true three dimensional storage system, data can be accessed an entire page at a time instead of sequentially, and there are very few moving parts so that the limitations of mechanical motion are minimized.

Optical memory uses a photosensitive material to record interference patterns of a reference beam and a signal beam of coherent light, where the signal beam is reflected off of an object or it contains data in the form of light and dark areas. The nature of the photosensitive material is such that the recorded interference pattern can be reproduced by applying a beam of light to the material that is identical to the reference beam. The resulting light that is transmitted through the medium will take on the recorded interference pattern and will be collected on a laser detector array that encompasses the entire surface of the holographic medium. Many holograms can be recorded in the same space by changing the angle or the wavelength of the incident light. An entire page of data is accessed in this way.

II. OVERVIEW

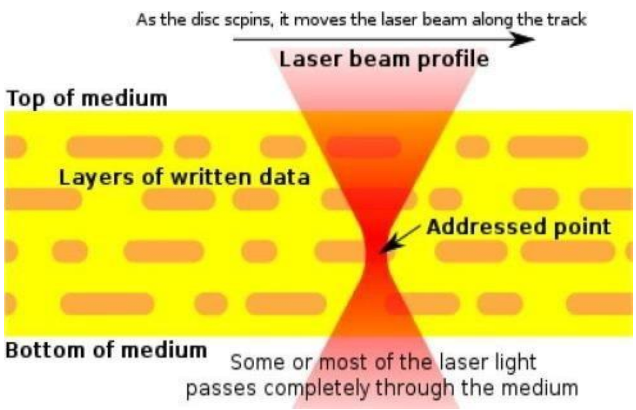

Figure i. Schematic representation of a cross-section through a 3D optical storage disc (yellow) along a data track (orange marks).

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Four data layers are seen, with the laser currently addressing the third from the top. The laser passes through the first two layers and only interacts with the third, since here the light is at a high intensity [2][3].

The basic principle of optical data storage is that of holography. Holography was invented by Deni Gabour in 1948.Holographic method was a two step coherent image forming process in which a record is made of the interference pattern produced by the interaction of the waves diffracted by the object and a coherent background or a reference wave. When this hologram is illuminated, the original wave front is reconstructed. Hence we get an image of the original diffracting object as a real 3 dimensional object. When two light beams one from the object whose image is to be recorded and the other being a reference beam, interference in space then form an interference pattern of alternate bright and dark fringes as shown in the diagram. Now if a photosensitive material or medium is placed at the position of the interference then these interference patterns are recorded on the material in the form of change in refractive index or the absorption property to replicate the original beam. This is the basic principle used to record and read data in the case of optical storage system. As an example, a prototypical 3D optical data storage system may use a disk that looks much like a transparent DVD. The disc contains many layers of information, each at a different depth in the media and each consisting of a DVD-like spiral track. In order to record information on the disc a laser is brought to a focus at a particular depth in the media that corresponds to a particular information layer. When the laser is turned on it causes a photochemical change in the media. As the disc spins and the read/write head moves along a radius, the layer is written just as a DVD-R is written. The depth of the focus may then be changed and another entirely different layer of information written. The distance between layers may be 5 to 100micrometers, allowing>100 layers of information to be stored on a single disc.
Optical data storage system requires certain important materials for its data storage and retrieval processes. The important components required for the optical data storage are: Laser, Lens and Mirrors, Spatial Light Modulators (SLM), Photosensitive materials (Photorefractive crystals, Photopolymers), Charge Coupled Devices(CCD).

III. LASER

Light amplification by stimulated emission of radiation is abbreviated as LASER.

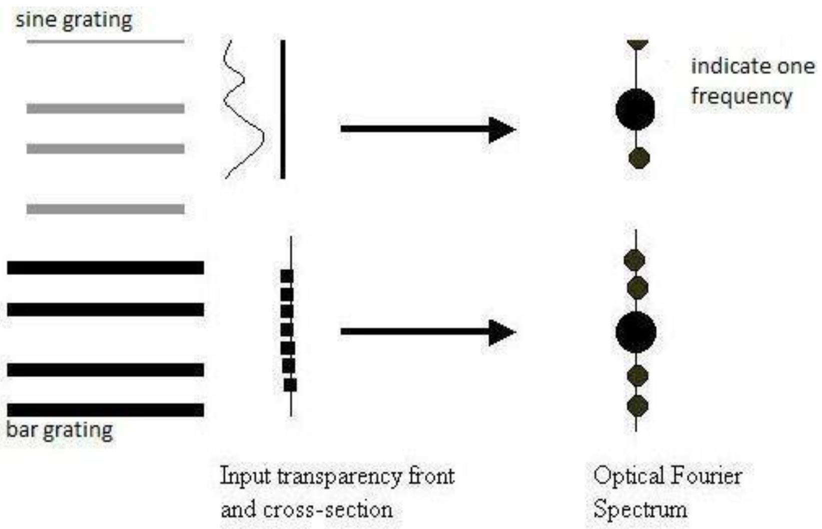

Figure ii. The lens as a Fourier transforms system [4]

Laser is a device for the generation of coherent, nearly monochromatic and highly directional electromagnetic radiation emitted, somewhere in the range from sub- millimeter through ultraviolet and X-ray wavelengths. More than two hundred types of lasers have been fabricated which range in power, size, performance, use and cost. Fundamental attributes of a laser are directionality, monochromaticity, coherence and brightness. These attributes make it ideal for optical recording. To record holograms on the crystals usually argon ion lasers, krypton lasers and diode lasers are used.

This Figure shows how a Fourier transform and inverse transform can be achieved optically. A collimated beam is projected through a signal, f(x, y), contained on a transparency. The transform lens causes parallel bundles of rays to converge in the back focal plane of the lens. This back focal plane is known as the Fourier transform plane. In this plane the spatial image is transformed into spatial frequency spectra. In affect the lens has carried out a two- dimensional Fourier transform at the speed of light. A far field diffraction pattern is observed by placing a screen in the transform plane.

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The intensity of the pattern is related to the square of the amplitude of the Fourier Transform of the input signal. By placing a stop at a particular frequency lobe in this plane a spatial frequency can be removed from the image. Typically all but the zero order diffraction is removed, thus removing the noise from the image.

This cleaning of the beam is achieved by using a spatial filter. The diameter and quality of the lens limit the upper frequency bandwidth. The lower bandwidth is limited by the ability of the user to discriminate all but the zero order diffraction information. This analog optical system is difficult to adapt into alternative kinds of filters and so is not very versatile.

The aperture of the lens limits the resolution of the Fourier transform. The second lens forms the inverse transform and recovers the original signal. If the input signal is a sinusoidal grating, figure2, there will be two spots either side of the central DC component. The two spots correspond to the spatial frequency content of the input signal. The radial distance between these spots and the DC term represents the spatial frequency of the input signal. There will be a row of spots in the transform plane of the square wave bar grating, indicating the presence of harmonics of the fundamental frequency.

IV. SPATIAL LIGHT MODULATORS(SLM)

SLM is an optical device that is used to convert the real image or data into a single beam of light that will intersect with the reference beam during recording.

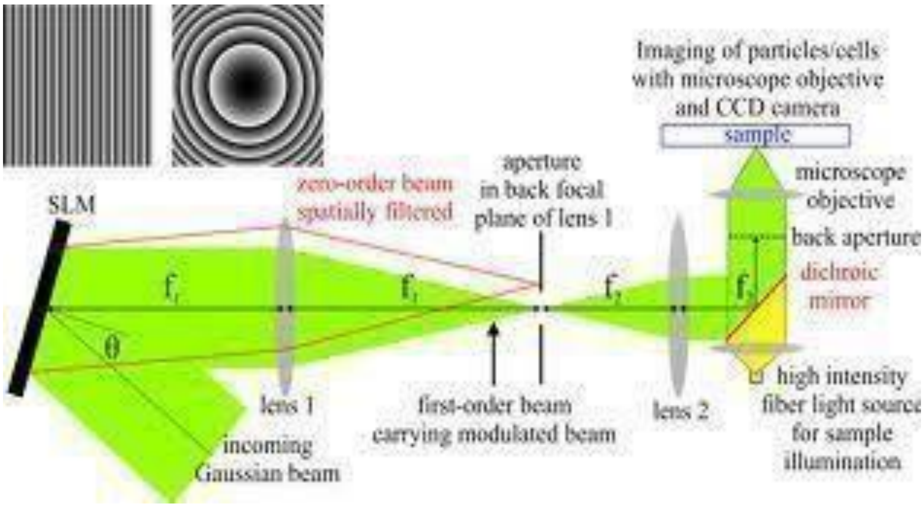

Figure iii. Spatial light modulators

It basically consists of an array of pixels which are usually microscopic shutters or LCD displays. These can be controlled by a computer. The computer sends binary data to the SLM. Each pixel of the SLM corresponds to bit of data. So depending on whether the bit is a 1 or a 0 the pixel will go dark or transparent in the case of a LCD, or will be open or shut in the case of microscopic shutters.

V. PHOTOREFRACTIVECRYSTALS

There are two main classes of materials used for the holographic storage medium. These are photo refractive crystals and photo polymers. The recording medium usually used is a photo refractive crystal such as LiNbO3 or BaTiO3 that has certain optical characteristics. These characteristics include high diffraction efficiency high resolution, and permanent storage until erasure, and fast erasure on the application of external stimulus such as UV light.

One characteristic of the recording medium that limit the usefulness of holographic storage is the property that every time the crystal is read with the reference beam the stored hologram at that location is disturbed by the reference beam and some of the data integrity is lost. With current technology, recorded holograms in Fe-and Tb- doped LiNbO3 that use UV light to activate the Tb atoms can be preserved without significant decay for two years.

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VI. CHARGE COUPLED DEVICES(CCD)

The charge-coupled device is, by far, the most common mechanism for converting optical images to electrical signals. CCD's are silicon devices, which contain an array of potential wells created through a series of column, implants (for vertical confinement).

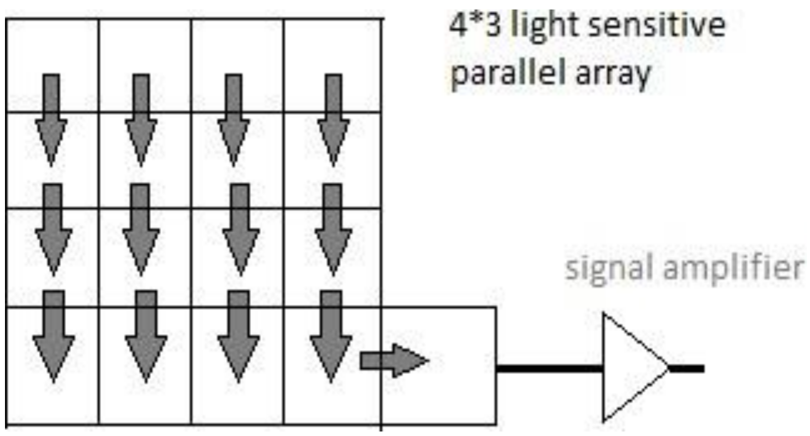

Figure iv. Special cell used for readout

A **CCD** is a silicon-based semiconductor arranged as an array of photosensitive elements, each one of which generates photoelectrons and stores them as a small bucket of charge or potential wells. Each pixel is typically 15 to 30 micrometer square. Current CCD's have formats or resolution better than 2048 *2048 pixels, with a size of about 25mmsquare.

VII. CONCLUSION

So from the study of 3D optical data storage technology we conclude that by using this technology we can store terabytes amount of data with high speed in very less space. It can bring the great revolution in the field of data recording and data reading. It is believed that the substantial advances in recording media, recording methods and the demonstrated densities of > 30 channel Gbits/inch2 coupled with the recent commercial availability of system components remove many of the obstacles that previously prevented the practical consideration of optical data storage and greatly enhance the prospects for Holography to become a next generation storage technology. The field of 3D optical data storage is a workable field for the communication engineers .This study is glimpse of the revolutionary change-out in the field of data storage and retrievals but engineers involved in communication field can think about this and bring a revolution in the field of data storage reading by utilizing the knowledge, available resources and facilities.

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