3-D OPTICAL STORAGE TECHNOLOGY

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***Abstract* - 3-D optical data storage technology is one of the modern methods of storing large volumes of data. This paper, discusses in details the fundamentals of 3D optical data storage. This includes the features of the 3D optical data storage and the major components that make up the devices. Nonresonant Multiphoton, Sequential multiphoton absorption, microholography and data recording are some of the writing methods used in the 3D optical data storage. The major challenges that are facing these devices as discussed in the paper are; media sensitivity, Thermodynamic stability and destructive reading.**

Index Terms--**: 3-Dimensional, technology, data, storage, media, optical** *(key words)*

I. INTRODUCTION

The best medium for data storage has been a main concern over the past decades. The main digital circulation has been the optical data storage which has been being improved to accommodate new changes in technology and applications. With time, optical data storage has had various limitations such as space and speed have demanded more improvements leading two-dimensional storage devices. These, however, have their limitations which that have demanded more improvement resulting in the three dimension data storage which overcomes all the other limitations due to speed and accommodation of a large amount of data.

Optical data storage involves storage of data in an optically readable medium such as storage discs where a device referred to as optical drive uses laser beams to burn bumps of data in writing data on the optically readable medium [14]. The laser beam facilitates the recording of the data on a special material on the optically readable medium. Data are usually stored on the optically readable medium in a spiral manner where it starts working especially when being read from the innermost section of the medium going outwards [3]. Data from these mediums is read using a device known as optical drive found in computers this storage and reading has been through a two-dimension resolution.3dimensional optical data storage, therefore, is any way in which data can be stored and read in a three-dimensional resolution.

II. FEATURES OF THREE-DIMENSIONAL OPTICAL DATA STORAGE

Different from 2Ddata storage where data is stored on an aluminum film built in a disk and read through focusing of laser beams on its surface, 3D optical data storage uses nonlinear methods of reading and recording data. In 3D, data storage and reading are facilitated through the focusing of a laser on the storage medium where in this case, the laser passes through other points as it moves in a nonlinear way before it reaches the point where data recording or reading is wanted [4]. This is an improvement of the 2D optical data storage where the laser light bypasses every layer of data stored in the storage medium before reaching the desired point leading to the recording of only 10 layers of data which is a limitation of the current technology. 3D optical data storage uses methods in which the light interacts with only the addressed volumetric pixel [1]. In this method, laser light also passed through other data points but due to its nonlinearity, it has no effect on them. 3D optical data storage has the ability to provide mass storage of up to 1024 TB on a single DVD disk which beyond the current 2D optical storage.

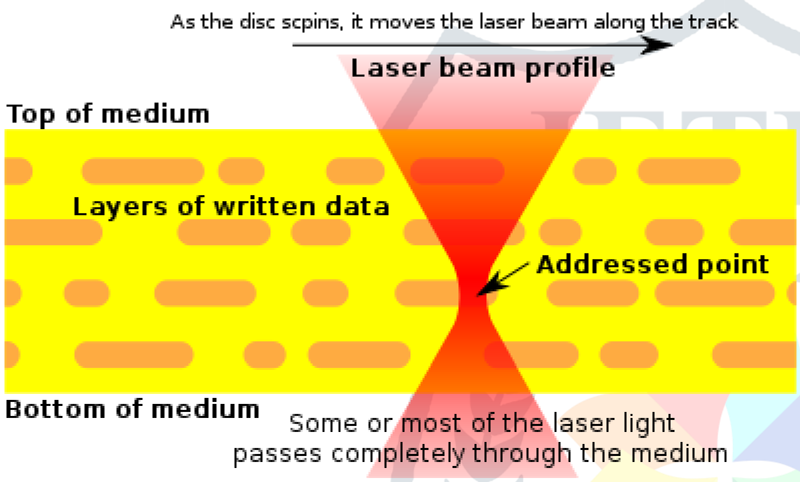

Figure a): A schematic diagram showing a cross-section of an optical 3D storage

III. BASIC COMPONENTS IN 3-D OPTICAL DATA STORAGE

The process of storing and retrieving data in optical devices requires special devices. The following involves a discussion of some of these components.

Laser

Laser (light amplification by stimulated emission of radiation) is a device used to generate coherent and almost monochromatic radiation. The super directional electromagnetic radiation is emitted somewhere in the ranges of sub-millimeter through X-ray and ultraviolet [8]. The fundamental attributes of a laser beam that make them ideal for optical recording are their directionality, coherence, monochromaticity, and brightness. Krypton lasers, argon ion lasers, and diode lasers are used to record holograms on crystals.

Spatial Light Modulators (SLM)

During recording, the real image or data is converted to a single beam of light which intersects with the reference beam [2]. This conversion is done by a spatial light modulator device. The SLM consists of an array of pixels that are usually composed of microscopic shatter that can be controlled by a computer [8]. LCD displays are also used in place of microscopic shutters. Ever SLM pixel corresponds to a bit of data. Therefore, the bits cause a shut or open in microscopic shutters or go dark or transparent depending on the condition of the bit whether it 0 or 1.

Lens and Mirrors

The lenses and mirrors are the major components used to achieve an inverse transform and a Fourier transforms optically [8]. To form the transform a collimated beam projected on transparency and the transform lens makes the parallel ray bundles make a convergence of the focal plane of the lens. The back focal plane, referred to as the Fourier transform plane, is where the transformation of the spatial image is done into a spatial frequency spectrum. The lens carries out, at the speed of light a two dimensional Fourier transform, which leads to the formation of a far-field diffraction pattern that can be observed on a screen placed on the transform plane [8]. The square of Fourier transform amplitude of the input signal determines the intensity of the pattern. A spatial frequency lobe of the image is removed using a stop placed at particular frequency lobe on this plane. Two lenses are used in the processes, with the aperture of the lens limiting the Fourier transform resolution and the second lens forming the inverse transform as well as recovering the original signal.

Photorefractive Crystals

Photopolymers and photorefractive crystals are the two main materials used in the holographic storage devices. To record data, photorefractive crystals of material such as BaTiO3 or LiNbO3 are used due to their optical properties such as high diffraction efficiency and high resolution [8]. Additionally, the materials also show the ability to store data permanently till erasure as well as fast erasure through the application of an external stimulus such as ultraviolet light.

Photopolymers

The recent advancement in technology is in the development of photopolymers that can be used as a medium of holographic storages [8]. Photopolymers have less thickness compared to photorefractive crystals as polymers are usually limited by their optical quality and mechanical stability. Some of the photopolymers used in the market include HRF-150 from DuPont [2]. This film from DuPont can reach 12bits/ μm2 when used with a thickness of 100 millimeters which is much greater than DVD-ROM with a factor of 2. The imprinting of the pattern in the photopolymer is done by inducing photochemical changes.

Charge Coupled Devices (CCD)

Charge-coupled devices are silicon-based devices that contain an array of wells and are created through implants and a series of column [2]. They provide the mechanism to convert optical images to electrical signals.

IV. 3D OPTICAL STORAGE DATA WRITING PROCESSES

For the writing of data to take place in 3D optical storage, a change has to be made on the recording medium which usually achieved through excitation [15]. The change is usually a photochemical reaction on the medium. In this, several chemical reactions that can effectively work in this new storage have been researched on and they include photodecomposition, polymerization, photoisomerization as well as photobleaching [5]. Investigators, however, have mostly focused on photochromic materials which mostly consist of the stilbenes, azobenzenes, and spiropyrans. The writing works on the principle that if the photochemical used is reversible it is possible to rewrite the data. Several methods used in recording data on three-dimensional optical data storage include:

Nonresonant Multiphoton Absorption Writing Method

Significantly high energy is usually needed to both excite the molecules in the storage medium electronically and result in a chemical reaction for this 3D writing method. This is only achievable through the use of multiphoton absorption as it has the capabilities of driving the required energy in the storage media [6]. So far, a two-photon absorption has been in use as it is considered to be the most stronger in effecting the absorption of multiphoton although it is much weaker causing media sensitivity.

Writing is done by focusing the laser light being used in the writing to the point where the writing process is needed. The writing wavelength travels I nonlinear way interacting with the storage medium only at the focal point where two-photon absorption takes place [12].

Two laser coincidences can also be used to enable the two-photon absorption writing method leading to parallel writing at the same time. In this case, the first laser light causes a plane on the media while the second one goes to the plane created affecting the writing where it is intended.

Sequential multiphoton absorption

This method is also referred to as "sequential" 2-photon absorbance and the two photons travel at the same time to the writing media [9]. The method is relatively weaker hence the 2-photons have to be focused almost jointly to the chromophore to avoid losing the nonlinearity way of laser traveling and compromising the 3D resolution.

Microholography writing method

This is used in the recording of submicrometre-sized holograms using collinear light beams and uses photorefractive writing media

Data recording method

This method is most common in the recording of commercial data where data is created during the manufacture of the 3D optical storage media. This means no writing can be done on the disk [10]. The process uses very high laser light which eliminates issues of media sensitivity.

Some of the other data writing methods in 3D optical data storage include:

a) Chromophore poling method which involves reorientation of chromophores in the 3D media using laser light which changes the chromophores to a readable form.
b) Persistent spectral hole burning (PSHB) method which uses low temperatures to avoid issues of losing data in the writing processes [13].
c) The void formation which involves the introduction of microscopic bubbles into the 3D writing media by use of high-intensity laser

V. 3D OPTICAL DATA STORAGE READING PROCESSES

Several methods have been used in reading data from 3-dimensional optical data storage where most of them depend on the nonlinear nature of light traveling in the 3D writing [11]. Some of these reading methods are:

a) Optical coherence tomography which is commonly used in parallel reading
b) Two-photon absorption method
c) The second harmonic generation which is used mostly in reading information recorded on poled polymer materials.

d) Use of phase contrast microscope in measuring small differences in between data states in a refractive index

VI. DEVELOPMENT OF 3D OPTICAL DATA STORAGE ISSUES

Despite the major improvements observed with the use of 3D optical data storage and its accommodation to the highly changing technology, there have been hindrances in the development of the 3D optical data storage leading to a significantly longer period. Some of the major issues being experienced include:

a) Media sensitivity: the commonly used 2-photon absorption is usually weak. This, therefore, requires the use of high power lasers which result in media sensitivity that are usually not safe for use in consumer products [7]. Additionally, high powered lasers are bulky and are challenging to cool posing a challenge on the 3D optical data storage.

b) Destructive reading: there usually high possibilities of small writing taking place during the writing process. This, therefore, requires that there be repetition in the writing which may result in erasing of the other written work.

c) Thermodynamic stability: 3D is mostly achieved through the use of chemical reactions. In some cases, a reaction that had not been intended may slowly take place where some may lead to a reversal of the writings done or cause writing where it was not meant.

VII. CONCLUSION

Technology has resulted in the use of computers in all areas. Though they provide good data storage, the increased improvements in technology demand for high amount data storages and that can be easily accessible. Further, the challenges posed by other data storage devices push for a move to other improved and advanced data storages that have high capabilities; high speed and can accommodate quite large data. These requirements are fulfilled by the use of 3-dimensional optical data storage devices. The 3D device can be applied in various fields such as researches in the space, storage of satellite data and relatively cheaper compared to current storage devices. As a result, 3D optical data storage is the technology that best fits the future data storage needs.

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