Volume : 3 | Issue : 4 | April 2014 • ISSN No 2277 - 8160

Research Paper | Computer Science

3D Optical Data Storage Techniques

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ABSTRACT

Optical Data Storage refers to store and retrieval of data in optical manner. Large volume of data is stored with some pattern and retrieves the same by focusing light or laser on the transmitted medium. A twist to this concept is "3D Optical Data Storage". In which data storage and retrieval is done with three-dimensional resolution. All the products related to this are under development phase and will be launched soon. This innovative concept provides pet byte- mass storage and retrieval achieve through passing laser on the medium. 3D optical data storage is related to (and competes with) holographic data storage. Recently 3D holographic storage has been realized by the use of micro holograms. Layer-selection multilayer technology (where a multilayer disc has layers that can be individually activated e.g. electrically) is also closely related. The main challenge of development of 3D Optical products is time. This results in financial backing in the field as well as technical issues as Destructive Reading, Thermodynamic stability and Media sensitivity.

KEYWORDS :

Introduction

The origins of the field date back to the 1950s, when Yehuda Hirshberg developed the photochromicspiropyrans and suggested their use in data storage. In the 1970s, ValeriBarachevskii demonstrated that this photochromism could be produced by two-photon excitation, and finally at the end of the 1980s Peter T. Rentzepis showed that this could lead to three-dimensional data storage. This proof-of-concept system stimulated a great deal of research and development, and in the following decades many academic and commercial groups have worked on 3D optical data storage products and technologies. Most of the developed systems are based to some extent on the original ideas of Rentzepis.



Fig 1 Transparent Optical Media

A wide range of physical phenomena for data reading and recording have been investigated, large numbers of chemical systems for the medium have been developed and evaluated, and extensive work has been carried out in solving the problems associated with the optical systems required for the reading and recording of data. Currently, several groups remain working on solutions with various levels of development and interest in commercialization. 3D optical data storage uses technology that allows more than 100 layers to be written on a disc that looks like a traditional DVD. This creates an exponentially larger data capacity in the same amount of space. There are estimates that 3D optical data discs will be able to store 5 terabytes of data or more.

Optical Recording Technology

Current optical data storage media, such as the CD and DVD store data as a series of reflective marks on an internal surface of a disc. In order to increase storage capacity, it is possible for discs to hold two or more of these data layers, but their number is severely limited since the addressing laser interacts with every layer that it passes through on the way to and from the addressed layer.

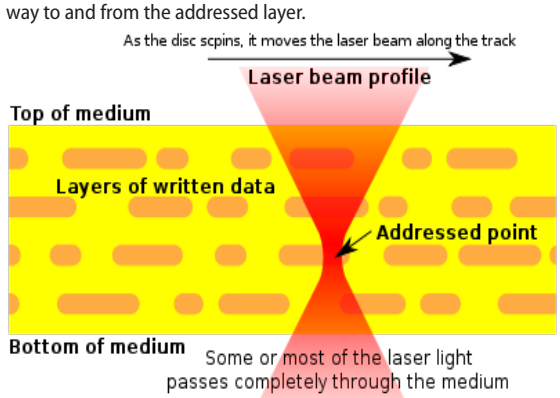

Fig 2. Detail View of Written Data on Medium

The active part of 3D optical storage media is usually an organic polymer either doped or grafted with the photo chemically active species. Alternatively, crystalline and so-gel materials have been used. N order to read the data back (in this example), a similar procedure is used except this time instead of causing a photochemical change in the media the laser causes fluorescence. This is achieved e.g. by using a lower laser power or a different laser wavelength. The intensity or wavelength of the fluorescence is different depending on whether the media has been written at that point, and so by measuring the emitted light the data is read.

The size of individual chromophoremolecules or photoactive color centers is much smaller than the size of the laser focus (which is determined by the diffraction limit). The light therefore addresses a large number (possibly even 109) of molecules at any one time, so the medium acts as a homogeneous mass rather than a matrix structured by the positions of chromophores.

Holographic data storage contains information using an optical interference pattern within a thick, photosensitive optical material. Light from a single laser beam is divided into two separate optical patterns 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 stored data is read through the reproduction of the same reference beam used to create the hologram. The reference beam's light is focused on the photosensitive material, illuminating the appropriate interference pattern, the light diffracts on the interference pattern, and projects the pattern onto a detector. The detector is capable of reading the data in parallel, over one million bits at once, resulting in the fast data transfer rate. Files on the holographic drive can be accessed in less than 0.2 seconds. 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 are that the evolution of data reader technology has – in the last couple of decades – changed every ten years. If this trend continues, it therefore follows that being able to store data for 50–100 years on one format is irrelevant, because you would migrate the data to a new format after only ten years. However, claimed longevity of storage has, in the past, proven to be a key indicator of shorter-term reliability of storage media. Current optical formats – such as CD– have largely lived up to the original longevity claims (where reputable media makes are used) and have proved to be more reliable shorter-term data carriers than the floppy disk and DAT media they displaced.

Technical Issues

Despite of highly attractive nature of 3D optical data storage, the development of commercial products has taken a significant length of time. This includes technical issues as: destructive reading, thermodynamic stability and media sensitivity.

➔ **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**. 2-photon absorption is a weak phenomenon, and therefore high power lasers are usually required to produce it. Researchers typically use Ti-sapphire lasers or Nd:YAG lasers to achieve excitation, but these instruments are not suitable for use in consumer products.

The revolutionary approaches promise much higher densities at substantially higher risk. Some of the risk arises because laboratory development tends to demonstrate features individually, avoiding effects which show up when performance is pushed across the board. Issues that rise are mainly the need for better media, and relatively high complexity and cost of the drive.

Development Techniques – Simulation

Rapidly growing applications of PBG structures have already resulted in an impressive progress in the development of theoretical approaches for the analysis of the properties of light in such structures. By using a laser to reversibly combine and separate molecules, scientists have demonstrated a new optical data storage technique. Because the data can be read by only one kind of imaging technique (second-harmonic generation-assisted imaging), the new method could be used for hidden 3D data storage.

The researchers designed a new class of nonlinear optical (NLO) coumarin-based polymers that can be reversibly transformed into dimers (which are large molecules made of two identical smaller molecules) under irradiation by different wavelengths of light. Whereas wavelengths greater than 300 nm can produce dimers, wavelengths less than 280 nm do the reverse, separating each dimer into two individual molecules. Since each type of molecule is electronically and structurally very different, optically controlling this process can provide the basis for writing, reading, erasing, and rewriting data.

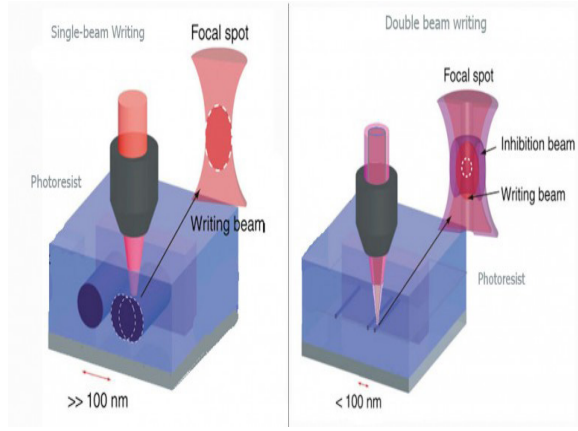

Fig 3. Comparison of Writing Methods

The recorded data could be read by a method called second-harmonic generation (SHG)-assisted imaging, in which photons interacting with the NLO material combine to form photons with twice the energy. The level of SHG signals is significantly lower than the unwritten background area, resulting in two distinct logical levels. No loss of recorded bits along the reading process was observed because the UV light generated by SHG is not absorbed by the molecules, avoiding the erasing of information by further chemical reaction.

The data could be erased and rewritten in the same area. To erase, the written polymer was exposed to a UV light with a wavelength of less than 280 nm, which converted the dimer polymer back into its original form. After using SHG imaging to confirm that the data was erased, writing process repeated with the longer wave-length.

Future of 3D Optical Data Storage

The biggest hurdle for 3D optical data storage right now is making it commercially viable for the public. Although working prototypes have been developed, 3D optical data storage has a long ways to go before it becomes a useful data storage format. Multiple companies are working on 3D optical data storage, but it will still be a while before we see something hit the consumer market.

There are three major technical difficulties that need to be overcome:

- The potential for data to be damaged by lasers that read the data
- The possibility of chemical reactions that damage data over extended periods of time
- Media that is easily damaged by lasers

The next step up may not be 3D optical storage in particular, but it will be something similar. Technology firms are also working on similar technology called "holographic data storage." It's only a matter of time before something new hits the market.

Data storage technology is a constantly evolving field of study. From the first days of humans drawing on cave walls to today's digital storage technology, people have yearned to store their technology in increasingly efficient manners. One day even 3D optical data storage will be remembered as a thing of the past.

Conclusion

The evolutionary approaches that are based on current technologies have the potential to be forward compatible. Such as use of depth of focus and have the lowest risk in terms of media, storage device and cost. However the benefits for potential density gains are also limited. When the key features of optical data storage – removability and interchangibility are to be retained. Optical storage will continue to evolve but it is only depend upon on both technical feasibility and commercial viability. Development phase for the 3D optical data storage devices mainly faces the problem of maximum development time due to experimentation apply on it. This can be overcome by integrate methods for the reading and retrieval.

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