3D optical data storage

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INTRODUCTION

- For any storage technology to remain competitive over time,
- Constant/reduced $\begin{cases} System\ volume \\ access\ time \\ cost \end{cases}$
- Increased $\begin{cases} capacity \\ data\ rate \end{cases}$
- This requires that an increasing amount of data should be accessed by low-cost pickup sensors that can move quickly and accurately.

What is 3D optical data storage

- This method of using the depth of the disk as a storage parameter is the basis of 3D optical data storage.
- Rather than storing data on a plane within a disk, the goal of 3D dat a storage is to use the entire volume of the disk.
- Addressing laser interacts with every layer that it passes through on the way to and from the addressed layer. These interactions cause noise that limits the technology .
- 3D optical data storage methods uses addressing methods where only the specifically addressed voxel (volumetric pixel) interacts with the addressing light.

Types of 3D optical data storage

- Several approaches to 3-D optical storage are being actively investigated.
- These approaches include extending conventional disk system storage technologies to

(1) 3-D layered format

(2) Volume holographic encoding, where data is recorded in a distributed fashion in the volume

Layered 3D optical storage

- Volumetric density (Mbit/in. ^{3}) becomes critical.
- Volumetric density can be limited by the layer density (layers/in.).
- 3 types -
  1. Double layer-optical disc
  2. Hybrid Multilayer Optical disk
  3. Monolithic multilayer 3-D optical disks

Double layer-optical disc

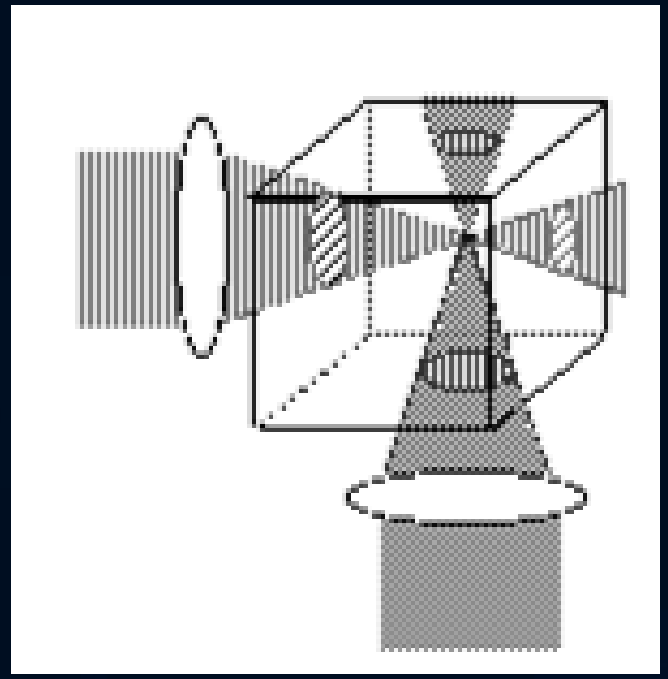
- A dual-layer disc employs a second physical layer within the disc itself.
- The drive with dual-layer capability accesses the second layer by focussing the laser through the first semi-transparent layer.

Hybrid Multilayer Optical disk

- Several conventional CD-ROM disks each with an active layer are stacked together.
- Dynamic focusing lens records or reads bits from a desired layer.
- crosstalk noise between bits at different layers will limit the total number of layers.

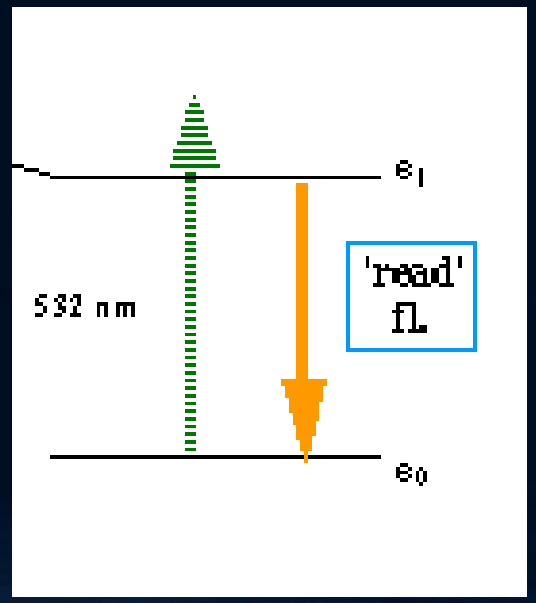
Monolithic multilayer 3-D optical disks

- Two-photon recording
- A spot is written in the volume at points of temporal and spatial intersection of two beams ,one carrying information and the other specifying location.



Monolithic multilayer 3-D optical disks

- Reading
- The recorded bits are read by fluorescence when excited by single green photons absorbed within the written spot volume.
- 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.



Monolithic multilayer 3-D optical disks

- The multi frequency optical memory by Matsushita
- Absorption wavelength of the written spots in each layer can be programmed during fabrication.
- A wavelength-tunable laser can then read the bits by tuning its wavelength to the wavelength associated with the desired layer.
- The capacity and density of such a memory are ultimately determined by how sharply the absorption bands are synthesized
- How well the relative positions in the spectra are controlled.

Holographic recording

- In bit-oriented memories, if any portion of the storage media is damaged or blocked, the data stored in that region is lost.
- This is not the case for holographic storage, where the information about each stored bit is distributed throughout a large region.
- If a portion of the holographic storage media is damaged or blocked, instead of causing catastrophic loss of some of the data, all of the data are partially degraded.

Volume-phase holograms

- Holograms are created by recording the interference pattern of two optical wavefronts.
- Holographic data storage contains information using an optical interference pattern within a thick, photosensitive optical material.
- 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.

Development issues

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

Media sensitivity

- 2-photon absorption is a weak phenomenon, and therefore high power lasers are usually required to produce it.
- These instruments are not suitable for use in consumer products.

Development issues

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.

Commercial development

Call/Recall

- Using 2-photon recording (at 25 Mbit/s with 6.5 ps, 7 nJ, 532 nm pulses)
- 1-photon readout (with 635 nm), and a high NA (1.0) immersion lens,
- they have stored 1 TB as 200 layers in a 1.2 mm thick disk.

Mempile

- Developed a commercial system with the name TeraDisc.
- In March 2007, they demonstrated the recording and readback of 100 layers of information on a 0.6 mm thick disc, as well as low crosstalk, high sensitivity, and thermodynamic stability.

Archival Disc

- Optical disc storage medium designed for long-term digital storage.
- First announced on 10 March 2014 and planned to be introduced in the second quarter of 2015.
- The discs are intended to be able to withstand changes in temperature and humidity, in addition to dust and water, ensuring that the disc is readable for at least 50 years.

Archival Disc

Disc size (type)	300 GB (write-once)
Optical parameter	Wavelength λ=405 nm
Disc structure	Double-sided Disc (3 layers/side), Land and Groove Format
Track pitch	0.225μm
Data bit length	79.5nm

CONCLUSION

- The potential impact of layered 3-D optical disks on the capacity of optical disks can be much greater than the impact of, for example, the blue lasers.
- This is because the growth factor in capacity is directly proportional to the number of layers. Assuming that the areal density is not affected, the 3-D layering provides the potential for realizing optical disks with capacities exceeding 1TB.

REFERENCES

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3-D 2-Photon Optical Data Storage

THANK YOU