**OPTICAL STORAGE TECHNOLOGY**

**AJAI PATIENCE MLUWAM**

**(ST/CS/ND/20/204)**

**A SEMINAR REPRESENTED TO THE DEPARTMENT OF COMPUTER SCIENCE, SCHOOL OF SCIENCE AND TECHNOLOGY, FEDERAL POLYTECHNIC MUBI, ADAMAWA STATE, NIGERIA**

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**Abstract**

*Optical techniques for data storage have advanced rapidly during the last decade. Optical data storage presents many unique advantages, notably the high storage density and low access time, not attainable by conventional recording techniques. The special features of optical recording, the proposed materials and techniques, the components for optical storage as well as some representative optical bit-by-bit and holographic recording systems are reviewed. It is noted that in spite of the lack of widespread commercial success of the optical recording at the present, some unique devices have been successfully demonstrated. The knowledge accumulated in the development of optical data storage should be useful for many recent Applications such as video recording. It is expected that when the conventional magnetic memory technology reaches its limit, optical storage technology should be a competitive contender for the next generation data storage.*

**Keywords**: Optical disk, Optical memory, Mass storage.

**Introduction**

**Optical storage** is an electronic storage medium that uses low-power [laser](https://www.britannica.com/technology/laser) [beams](https://www.britannica.com/dictionary/beams) to record and retrieve digital (binary) data. In optical-storage [technology](https://www.britannica.com/technology/technology), a laser beam encodes digital data onto an optical, or laser, disk in the form of tiny pits arranged in a spiral track on the disk’s surface. A low-power laser scanner is used to “read” these pits, with variations in the intensity of reflected [light](https://www.britannica.com/science/light) from the pits being converted into electric signals. This technology is used in the [compact disc](https://www.britannica.com/technology/compact-disc), which records sound; in the [CD-ROM](https://www.britannica.com/technology/CD-ROM) (compact disc read-only memory), which can store text and images as well as sound; in WORM (write-once read-many), a type of disk that can be written on once and read any number of times; and in newer disks that are totally rewritable (Glezer et al., 2016).

Optical storage provides greater memory capacity than magnetic storage because laser beams can be controlled and focused much more precisely than can tiny magnetic heads, thereby enabling the condensation of data into a much smaller space. An entire set of encyclopedias, for example, can be stored on a standard 12-centimetre (4.72-inch) [optical disk](https://www.britannica.com/technology/optical-disc). Besides higher capacity, optical-storage technology also delivers more authentic duplication of sounds and images. Optical disks are also inexpensive to make: the plastic disks are simply molds pressed from a master, as phonograph records are. The data on them cannot be destroyed by power outages or magnetic disturbances, the disks themselves are relatively [impervious](https://www.merriam-webster.com/dictionary/impervious) to physical damage, and unlike magnetic disks and tapes, they need not be kept in tightly sealed containers to protect them from contaminants. Optical-scanning equipment is similarly durable because it has relatively few moving parts (Lott et al., 2011).

Early optical disks were not erasable i.e., data encoded onto their surfaces could be read but not erased or rewritten. This problem was solved in the 1990s with the development of WORM and of writable/rewritable disks. The chief remaining drawback to optical equipment is a slower rate of [information retrieval](https://www.britannica.com/technology/information-retrieval) compared with conventional magnetic-storage media. Despite its slowness, its superior [capacity](https://www.britannica.com/dictionary/capacity) and recording characteristics make optical storage ideally suited to memory-intensive applications, especially those that incorporate still or animated graphics, sound, and large quantities of text. Multimedia encyclopedias, video games, training programs, and directories are commonly stored on optical media (Zhang et al., 2020).

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 Blotekjaer (2019). 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. 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 (Cumpston et al., 2019).

### Literature review

Optical storage is the [storage of data](https://en.wikipedia.org/wiki/Computer_data_storage) on an optically readable medium. [Data](https://en.wikipedia.org/wiki/Data) is recorded by making marks in a pattern that can be read back with the aid of [light](https://en.wikipedia.org/wiki/Light), usually a beam of [laser](https://en.wikipedia.org/wiki/Laser) light precisely focused on a spinning [optical disc](https://en.wikipedia.org/wiki/Optical_disc). An older example of optical storage that does not require the use of [computers](https://en.wikipedia.org/wiki/Computer), is [microform](https://en.wikipedia.org/wiki/Microform). There are other means of optically storing data and new methods are in development. An [optical disc drive](https://en.wikipedia.org/wiki/Optical_disc_drive) is a device in a computer that can read [CD-ROMs](https://en.wikipedia.org/wiki/CD-ROM) or other [optical discs](https://en.wikipedia.org/wiki/Optical_disc), such as [DVDs](https://en.wikipedia.org/wiki/DVD) and [Blu-ray](https://en.wikipedia.org/wiki/Blu-ray) discs. Optical storage differs from other data storage techniques that make use of other technologies such as [magnetism](https://en.wikipedia.org/wiki/Magnetism), such as [floppy disks](https://en.wikipedia.org/wiki/Floppy_disk) and [hard disks](https://en.wikipedia.org/wiki/Hard_disk), or [semiconductors](https://en.wikipedia.org/wiki/Semiconductor), such as [flash memory](https://en.wikipedia.org/wiki/Flash_memory) (Pu & Psaltis, 2018).

Optical storage in the form of discs grants the ability to record onto a compact disc in real time. Compact discs held many advantages over [audio tape players](https://en.wikipedia.org/wiki/Audio_tape), such as higher sound quality and the ability to play back [digital sound.](https://en.wikipedia.org/wiki/Digital_audio) Optical storage also gained importance for its [green](https://en.wikipedia.org/wiki/Environmentalism) qualities and its efficiency with high energies.

Optical storage can range from a single drive reading a single CD-ROM to multiple drives reading multiple discs such as an [optical jukebox](https://en.wikipedia.org/wiki/Optical_jukebox). Single CDs ([compact discs](https://en.wikipedia.org/wiki/Compact_discs)) can hold around 700 MB ([megabytes](https://en.wikipedia.org/wiki/Megabyte)) and optical jukeboxes can hold much more. Single-layer DVDs can hold 4.7 GB, while dual-layered can hold 8.5 GB. This can be doubled to 9.4 GB and 17 GB by making the DVDs double-sided, with readable surfaces on both sides of the disc. HD DVDs were able to store 15 GB with a single-layer and 30 GB with a dual-layer. Blu-ray discs, which won the HDTV optical [format war](https://en.wikipedia.org/wiki/Format_war) by defeating HD DVDs, can hold 25 GB for single-layer, 50 GB for dual-layer and up to 128 GB for quad-layer discs. Optical storage includes CDs and DVDs (Lott et al., 2011).

**Common examples of Optical Storage**

Over the years, optical media have taken a variety of forms, including LaserDisc (LD), [HD-DVD](https://www.techtarget.com/searchstorage/definition/HD-DVD), write-once, read-many ([WORM](https://www.techtarget.com/searchstorage/definition/WORM-write-once-read-many)) optical cartridges and several others. From this mix, three formats have emerged as standards in today's optical storage market (Glezer et al., 2016):

1. **Compact disk (CD).** The CD represents the first generation of commercial optical storage. After its introduction, it quickly replaced both vinyl records and cassette tapes as the audio medium of choice. Originally, CDs were available only as prerecorded read-only disks, but it wasn't long before they became available as recordable discs and rewritable discs that could be used for data storage. The CD can hold up to up 700 megabytes ([MBs](https://www.techtarget.com/searchstorage/definition/megabyte)) of [data](https://www.techtarget.com/searchdatamanagement/definition/data).
2. **Digital versatile disc (DVD).** Also referred to as the digital video disc, the DVD started out as a read-only medium similar to CDs but with the ability to hold enough data to store a full-length movie. A single-layer DVD can hold 4.7 gigabytes ([GB](https://www.techtarget.com/searchstorage/definition/gigabyte)) of data, and a double-layer disc can hold 8.5 GB. Not long after DVDs were introduced, recordable and rewritable discs became available for data storage.
3. **Blu-ray.** The Blu-ray disk has emerged as clear leader in today's optical storage market. Unlike CDs and DVDs, which use a red laser to read and write data, a Blu-ray disk uses a blue laser, which dramatically increases capacities and data transfer rates over CDs and DVDs. Today's Blu-ray discs can store up to 128 GB of data and are available as read-only disks that can hold prerecorded high-definition feature films as well as recordable and rewritable disks for data storage.

# Optical storage data writing processes

For the writing of data to take place in optical storage, a change has to be made on the recording medium which usually achieved through excitation. 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 (Lott et al., 2011). 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. 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 (Pu & Psaltis, 2018). 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. 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 (Pu & Psaltis, 2018).

## 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 (Zhang et al., 2020). 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:

1. Chromophore poling method which involves reorientation of chromophores in the media using laser light which changes the chromophores to a readable form.
2. Persistent spectral hole burning (PSHB) method which uses low temperatures to avoid issues of losing data in the writing processes (Pu & Psaltis, 2018).
3. The void formation which involves the introduction of microscopic bubbles into the writing media by use of high-intensity laser

# 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 writing (Parthenopoulos, & Rentzepis, 2019). Some of these reading methods are:

1. Optical coherence tomography which is commonly used in parallel reading
2. Two-photon absorption method
3. The second harmonic generation which is used mostly in reading information recorded on poled polymer
4. materials.
5. Use of phase contrast microscope in measuring small differences in between data states in a refractive index

**Advantages of Optical Storage Devices**

1. **Some optical storage devices are capable of storing a large amount of data.** Even though optical discs aren’t that big on storage capacity, some of them offer fairly decent storage space. For example, some Blu-ray discs offer up to 50 GB storage capacity. I know that’s quite small compared to other storage devices. However, that amount of storage space is impressive by optical disc standards.
2. Support for different types of files. Optical discs support various kinds of files.  
   VCDs, Blu-ray discs, and DVDs can store video files, audio files, text documents, and zipped files. What is more, these discs can even store folders or directories.
3. **Affordable price range.** Optical storage devices are considerably more affordable than most other storage types. Specifically, an 8 GB DVD plate costs much less than a flash drive with the same storage capacity. As a casual estimate, the cost of a single 8 GB DVD plate should be around $1. However, the price may vary depending on the place, time, and retailer.
4. **They are durable and have data stability.** Optical storage devices last very long if you keep them safe and handle them properly. Also, the data on them can be very stable. Speaking of their data stability, power outage or magnetic disturbances cannot destroy the data in these devices. As a matter of fact, some DVDs can retain data for 10 to 20 years or even longer.
5. **They are very lightweight and portable.** Optical storage devices are made from plastic materials with silicon or other metallic coatings. Thus, they are very light in weight. So, you can have up to 20 pieces of optical discs on you without feeling overloaded.

**Disadvantages of Optical Storage Devices**

1. **High vulnerability** **to physical damage.** Scratches on the surface of an optical storage device can affect or damage its content. Also, since their build material is mainly plastic, they can easily be broken. One way you can avoid this problem is by storing the disk inside a protective case when not in use.
2. **They are not secure.**Due to their small size and weight, optical storage devices can be easily misplaced or even stolen.
3. **They have a very slow speed**. Compared to other forms of storage devices, optical storage devices are significantly slower. For example, a CD has an average read and write speed of just 0.15 MB/s. Meanwhile, a DVD has an average read and write speed of 1.38 MB/s. In comparison, an HDD has an average read and write speed of between 80MB/s to 160MB/s, while an SSD can deliver between to 200MB/s to 550MB/s read and write speed.
4. **Mechanical noise and vibrations.** A desktop computer’s CD-ROM drive spins a CD plate using a 12-volt DC motor. Similarly, some modern laptops come with a DVD-RW drive that uses a 5-volt DC motor. These electric motors can spin a disk at the rate of 200 to 500 RPM. This creates vibrations and some mechanical noise during operation.

# 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 optical data storage devices.

CD-ROM, WORM and rewritable optical disk are effective devices for the storage of large programs and data files. With the increasing use of multimedia applications where sound, graphics and video are used, the data files used are often several Mbytes in size. The challenge is to be able to deliver these large amounts of data to the computing elements at a rate capable of supporting real-time audio, video and animation graphics.

**Recommendations**

1. It is recommended that more attention be drawn to the use of optical storage devices as they are more reliable and have higher storage capacity.
2. It is also recommended that more optical storage device be produced as they are light in weight and durable.
3. It is recommended that the technology be put to use considering its advantages it offers.

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