Coughlin Associates

WHITEPAPER

Optera Data, An Attractive Archive Storage Option

Tom Coughlin
Coughlin Associates, Inc.

Introduction

Digital data demand is growing with information from more connected sensors and cameras and with the growth of AI driven applications. Much data is created for immediate use and isn't saved, but with the rise in demand to train AI models and other big data applications, data storage growth is increasing. There are also projections that the traditional growth rates of conventional storage technologies don't match the potential growth rates of data that could be stored for later use.

In data centers, data is likely stored in a hierarchy of storage technologies, trading off cost versus performance for the optimal storage system. Coughlin Associates projects that annual storage capacity shipments for solid state drives (SSDs), hard disk drives (HDDs) and magnetic tape should grow over 5X from 2024 through 2029. The majority of this stored data is for secondary or active archive applications where data is retained for later access and it is generally transferred to faster SSDs and DRAM for primary storage and immediate use. The percentage of data in secondary and archived storage is growing faster than primary storage.

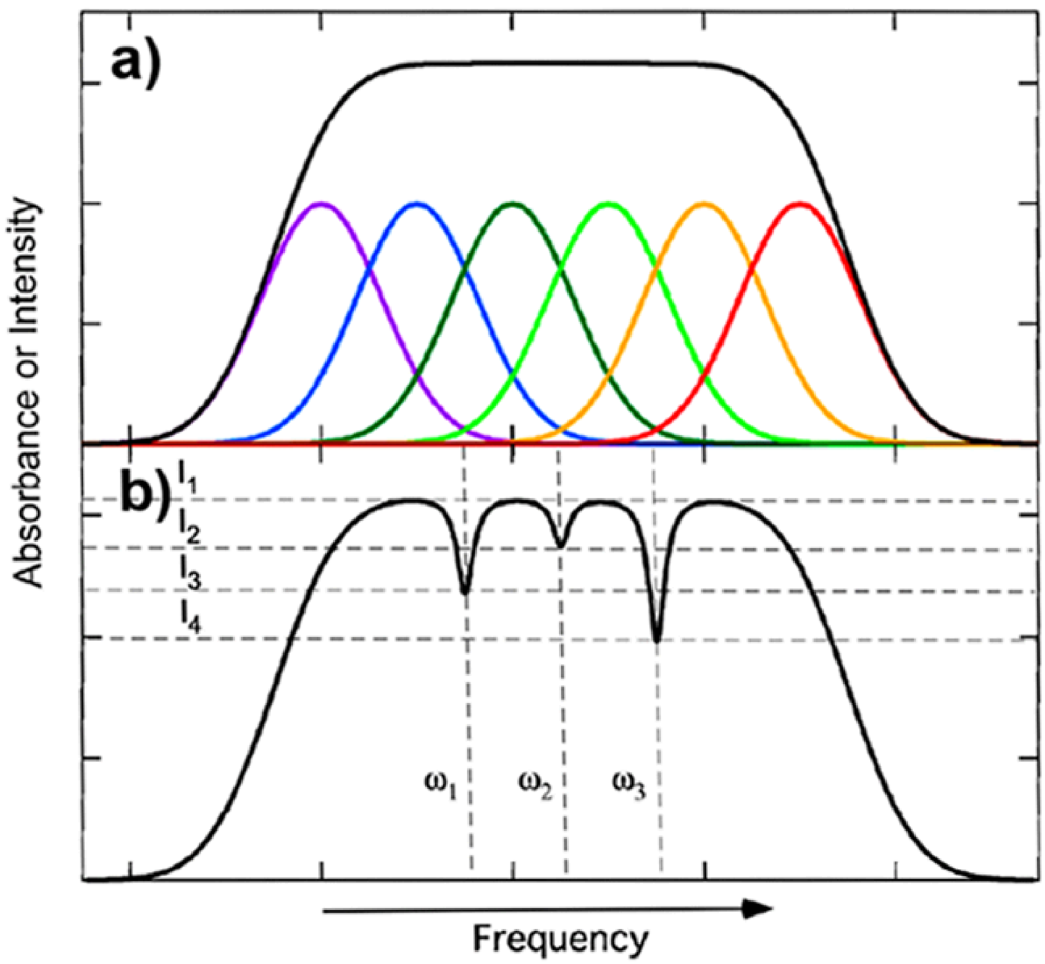
As secondary and archive storage demand grows there may be opportunities for new storage media to play a role, particularly if they can provide higher performance, lower cost (including ongoing energy costs) and greater longevity than current archive storage media. Some of the new storage media technologies that are contending for roles in archive storage include synthetic DNA and several types of optical storage. Synthetic DNA is attractive because of its long-term stability when dry and protected from oxygen and because write and read speeds will improve as genomic-based medicine goes mainstream, but that may take some time. DNA and optical storage, like magnetic tape storage, will primarily be implemented in robotic library-based systems, which only use power when data is written or read.

Advanced archival write once optical storage is available with approaches using conventional optical disc formats with advanced media which can provide higher capacities than conventional Blu-ray discs. There are also archival optical approaches that don't use optical discs but rather ceramic coated glass sheets. Modern optical recording technologies are particularly interesting for archive applications because the various optical storage media can last 100 years or more in a much less controlled environment that magnetic storage technologies. In this white paper we will look at advanced optical storage from a startup called Optera Data and compare it to HDD, magnetic tape, synthetic DNA storage and other new optical storage technologies.

How Optera Data optical storage works

Optera Data's storage technology takes advantage of changes in the optical absorption/emission characteristics of its recording media during writing and then by reading these changes during reading. These changes are referred to as spectral holes. The founders of Optera Data were able to demonstrate room temperature persistent spectral hole-burning to record multiple-bits per recording region (size of laser spot) at room temperature. They do this using an optical media which consists of a mixture of nano-particles, where the nano-particles have different but adjacent optical emission/absorption frequencies. To prevent oxidation, these nano-particles may be encapsulated in plastic beads and spread across a conventional plastic (or other material) optical disc substrate. Many of these nanoparticles lie within the write/read laser spot.

The combination of these nano-particles, in which spectral sensitivities are close to and partly overlapping each other results in a combined spectral emission profile that is called a "top-hat" fluorescence emission profile (that is, the light emitted by the different nano-particles) combine together to make a pattern like that shown in (a) in the figure below. With this media, tuning the write laser frequency to match that of one of the nano-particle frequencies creates a spectral hole where the nanoparticle emission can be diminished as shown in (b) in the figure below. These spectral holes can have a depth that depends upon the level of laser energy during the spectral hole writing as shown in the figure.



Data can be encoded using these spectral holes both in their frequencies and in the depth of the holes. Reading is done with a lower energy laser which causes radiation emission at the spectral emission frequencies of the nano-particles in the laser beam, but does not change the spectral hole. This emission is reduced where there are recorded spectral holes. The lasers required for writing Optera Data media is lower than recording systems that use high-powered pulsed laser systems, like some alternative optical recording technologies.

Unlike conventional fixed frequency optical recording, reading these holes will require measuring the individual spectral holes. This may be done with a tunable laser to read the characteristics of the individual spectral holes (such as reflection or transmission changes) or a light source could excite the hole's luminescence which could be read with filters.

Developments in signal processing of the recovered signal will be needed as well and this capability may limit the frequency density of spectral holes and the number of levels of these holes than can be detected. Optera Data says that creating this media on conventional optical discs is feasible and that writing and reading these spectral holes can be done by modifications to conventional optical recording systems.

They believe that, short term, 1TB discs are feasible with particulate media and medium term, a thin film single layer write once archival disc with high volume manufacturing costs of $1/10TB ($0.10/TB) is possible before the end of the decade. Longer term (say within a decade or so), these costs could be reduced even further, if this technology were implemented as a volumetric recording technology (perhaps even having 10X lower cost, $0.01/TB). Actual costs of a library system with Data storage would be somewhat higher depending upon the costs of write/read drives and library robotics (as with other optical and magnetic tape library systems).

Optera Data has received interest in commercialization of this technology by conventional optical disc manufacturers as well as optical library manufacturers, such as HP. Investments in coating, writing and reading technologies are required to bring this interesting technology to market.

Comparison to current and future archive technologies

To be successful, Optera Data's technology must be able to be implemented in high density recording systems and must be competitive with conventional HDD and magnetic tape archive technologies as well as conventional or other proposed optical storage technologies. It must also take into account developments in new data recording technologies, such as digital recording using synthetic DNA.

HDD data density growth has undergone a recent growth spurt, enabled by energy assisted magnetic recording, particularly heat assisted magnetic recording (HAMR). Seagate has announced 32TB HDDs using HAMR that will start ramping into mass production in 2024 (Toshiba has said they will have this capacity by 2025) and with storage capacities of 40+TB by 2026 and 50+TB capacities before the end of the decade. Current high-capacity HDD storage prices are about $11.5/TB and are estimated by Coughlin Associates to be down to less than $4/TB by 2029.

Magnetic tape technology is also developing, with current LTO tape capacities of 18TB native and next generation LTO capacities of 36TB expected by 2025. IBM announced a new generation of their enterprise tapes with native capacities of 50TB in 2023. Advances in tape densities occur every 3-4 years and with LTO these are expected to double with each generation. Currently magnetic tape storage prices (LTO media only) are about $5/TB and likely will be less than half that price by 2029 (<$2.5/TB). Note that a library tape storage system cost will include tape drive costs as well as robotics for handling the tape cartridges. These will increase the actual system storage costs depending upon the library configuration used.

A magnetic tape library, like an optical disc library system generally uses much less energy for data storage than a HDD storage array, because a tape or optical disc cartridge uses no energy to store its data when it is sitting in the library. Power is only required to run the robotics to move the media and in writing and reading data in the library drives and to provide any environmental control. Thus, tape and optical library systems use less power and thus can provide a lower total cost of ownership and a more sustainable archive storage media compared to HDDs.

Conventional optical media uses lasers with a fixed wavelength to ablate regions of the media or to change the reflective characteristics of the media to create optical features that can be encoded to store digital information. This is how CDs, DVDs and Blu-ray discs work.

Over 10 years ago, Panasonic and Sony created a roadmap for multiple layer two-sided Blu-ray derived optical storage that they projected would reach at least one TB per disc (Archival Disc, AD). The laser used for writing or reading these discs could focus on these individual layers, not interfering with data recorded on other layers. The AD discs, were backward compatible with conventional Blu-ray technology and recorded in both the land and groove patterns on the optical discs to increase density in addition to using multiple layers per disc side. In practice this technology, while used in some facilities, never became mainstream for general data archiving and demonstrated product disc storage capacity have not exceeded 500GB (their second-generation product, introduced in 2020), although their roadmap projects 1TB disc capacities. Sony and Panasonic both introduced optical disc library systems using their AD technology.

There are many other optical recording media, which include PiqlFilm, which uses black and white, negative silver-halide film on a polyester base. This method is unique in that it can include recorded human readable instructions and file format and source code for reading data, in addition to digital data. This archive method is being used in some scientific, engineering and historical archives. PiqlFilm is also the initiator of the Arctic World Archive (AWA), a repository for world memory located in Northern Norway on the Arctic Ocean.

Microsoft and the University of Southampton have explored volumetric archive recording in fused silica using a fast laser. This is a write once method with a media that should be stable for 100's of years. A California-based startup, Group 47 developed the Digital Optical Tape System (DOTS) that it says can preserve data for more than 200 years using a phase change media sputtered on a polyester-based film.

Various holographic optical recording technologies have also been developed over the years, but, although research on this technology continues, no commercial products using holographic recording have been successfully implemented for archival storage.

Folio Photonics is a company which has developed a multilayer optical recording system for archiving applications which can result in photothermal recording similar to Blu-ray optical discs with either reflective or fluorescent recording technologies. Their technology uses photosensitive dyes dispersed in a polymer matrix to create a reflective or fluorescent optical media. This photosensitive material has a strong optical absorption at 405nm (the wavelength used for conventional Blu-ray discs).

Using roll-to-roll co-extrusion processes, multiple layers can be produced all at once in a media which can be cut and placed on plastic optical disc substrates, reducing the costs of making a multiple layer optical media. Rather than using a spiral tracking feature embossed on conventional optical discs (hence the land and grooves), Folio does head tracking with a separate laser focused on the disc substrate where the tracking pattern is embossed.

Folio Photonics believes that this could be done in multiple layers (dozens of layers all at once) with an initial manufacturing cost of less than $5/TB and with more layers going to less than $2/TB by 2029. Note that one of the on-going issues with multi-layer optical media has been the optical absorption of the layers which can reduce the storage capacity and signal from lower layers.

Another interesting optical recording contender is Cerabyte, founded in 2020 and with headquarters recently moved to Silicon Valley. Cerabyte uses sputtered 10nm ceramic layers on a glass substrate. Data is written encoded in an array of data matrices using a 2-D digital micro mirror with up to 2 million elements simultaneously written by femtosecond laser pulses in the UV spectrum with a write speed of 1GB/s and with less than 1W average power. Reading is done at

GB/s data rates using high-speed image sensors and parallel high speed image processing for decoding.

Both reading and writing are done across the square substrate by scanning the microscope optics using high-speed XY stages kept in focus using a piezo driven auto focus system enabling random data access. The 9X9 cm media sheets can be recorded on both sides and stacked in cartridges for robotic access similar to that used for conventional optical and magnetic tape libraries. Cerabyte projects media costs below $1/TB by 2030.

As mentioned earlier, synthetic DNA can be used for archival data storage (particularly if it is protected from water and oxygen), but write and read speeds are currently slow and expensive. It is likely that these speeds and costs will improve quickly over the next few years as genomic medicine requiring rapid reading of DNA sequences improves and as DNA synthesis (writing) costs decline with new genomic therapies and the development of new synthetic creatures for various application.

Conclusions

Archival storage demand is increasing, driven by data intensive application such as AI, but archival storage must be very cost effective versus other higher performance storage to be competitive. This puts constraints on $/TB costs of this storage. An archival storage media that can combine low costs per TB and higher performance would have definite advantages for long term accessible storage.

Current HDD and magnetic tape technologies continue to develop and by 2029 a competing optical storage technology, even with faster storage access, needs to provide less than $2.5/TB media storage costs (magnetic tape projected costs by 2029). Such an optical storage technology, such as Optera Data, could be a viable alternatives, assuming similar drive and library costs to magnetic tape storage.

Optera Data's projection of storage costs of less than $0.10/TB or better by the end of this decade are at least 10X lower than competing optical storage projections from Folio Photonics and Cerabyte and 25X lower than projections for magnetic tape storage. This cost advantage, combined with archival storage advantages such as lower energy consumption in a robotic library, media longevity and the use of conventional optical disc substrates (and thus easier integration into existing drives and library systems), makes the Optera Data optical storage technology an attractive option for archive storage.   https://www.opteradata.com/

References

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