SEAGATE

ABC SYSTEMS AG
APPLIED BRAINWARE & COMPUTER SYSTEMS

SEAGATE PARTNER PROGRAM BUILDER DIAMOND

White Paper

What Is Mozaic 3+, How Does It Work, and What Can It Do for My Data Center?

Find out how Seagate's breakthrough hard drive platform unlocks unparalleled areal density for sustainable, mass-capacity storage.

17 January, 2024

mozaic 3+

Table of Contents

Introducing Mozaic 3+

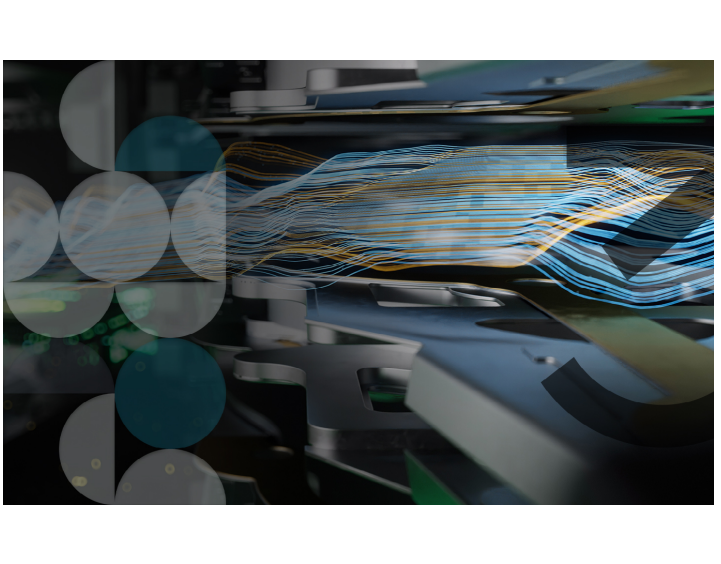
Why Does Areal Density Matter to Enterprises?

The Benefits of Mozaic 3+ for Cloud and Enterprise Data Centers

How Does the Platform Work?

Pulling Back the Curtain on Mozaic 3+ Tech

Beyond Cloud: The Future for All Data-Hungry Applications



Introducing Mozaic 3+

With cloud computing, artificial intelligence, and machine learning catalyzing unprecedented data generation, the insatiable demand for data storage capacity is an ever-escalating challenge. Extensible mass storage is more crucial than ever, and Seagate is years ahead in delivering the most viable solution: a breakthrough in areal density per disk that enables greater scalability, lower total cost of ownership (TCO), and improved sustainability for less impact on the planet.

Seagate recently launched its state-of-the-art Mozaic 3+™ technology platform, which incorporates Seagate's trailblazing implementation of heat-assisted magnetic recording (HAMR). The launch heralds unparalleled areal densities of 3TB+ per platter—and a roadmap that will achieve 4TB+ and 5TB+ per platter in the coming years. Seagate Exos 30TB+ hard drives enabled by Mozaic 3+ are shipping in Q1 of calendar year 2024 to leading cloud customers.

Mozaic 3+ is a feat of atomic engineering. A labor of research and development, grit and determination, investment and belief. A masterpiece of heat and light and bits. With Mozaic 3+, data is stored to media at density levels that were previously inconceivable, all while using the same material resources and delivered in the same trusty 3.5-inch form factor as all Seagate enterprise hard drives. Mozaic-enabled drives are fully compatible with today's data centers and exceed every customer specification for performance, reliability, and robustness.

Mozaic 3+ is an answer to the call from the ever-expanding cloud ecosystem, and the countless exabytes it will inevitably generate. It's how data center operators will be able to store more of those exabytes in the same footprint, amounting to massive TCO savings—including acquisition and operational costs.

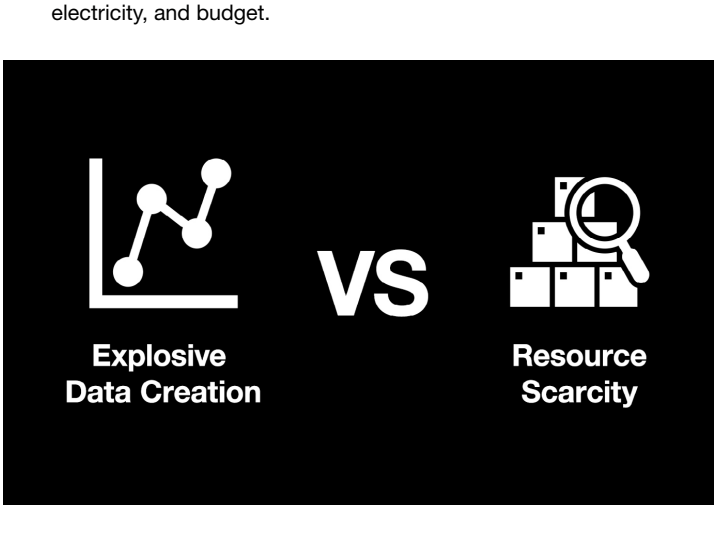
Mozaic 3+ is an inflection point in the storage industry. It's where the future is read and written.

Why Does Areal Density Matter to Enterprises?

The answer is simple. Data is growing faster than the world's ability to store it. In 2024, the people of Earth will generate 30 zettabytes of data each year—but only 2 zettabytes of storage capacity is manufactured each year.[1]

It's critical that enterprises have the tools needed to leverage the intrinsic value of all the available data. And the pressure is only increasing. Building, operating, and growing data centers are among our customers' greatest challenges—yet it also presents one of their greatest opportunities. Two forces stand at odds with each other: explosive data creation, and resource scarcity:

- Explosive data creation and the ability to capture that data is enabling richer customer insights and new revenue opportunities, thus driving faster AI productization which then relies on all that data to be available. By 2027, we expect 279 zettabytes to be created.
- Meanwhile, while the cost of building a data center can run from 1 to 1.5 billion, businesses face resource scarcity in the form of space, electricity, and budget.



As AI has exploded, cloud and data center customers have rushed to invest in and provide AI services to meet the demand, initially focusing on building out compute and AI architecture. Once this infrastructure is established, storage requirements will grow rapidly. To meet these challenges, enterprises must quickly increase storage capacity. To do so, they'll seek a decreasing per-TB cost and resource impact. Advanced areal density technology empowers customers to meet these requirements.

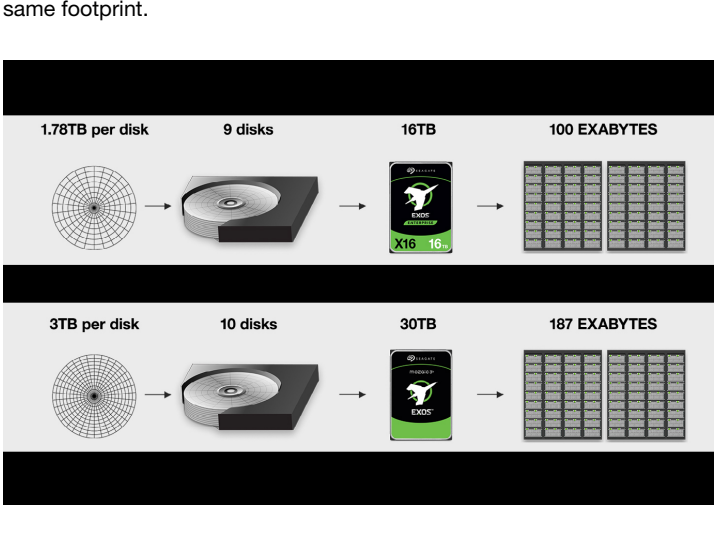
Mozaic 3+ is a hard drive architecture designed to deliver significantly more capacity without using additional power or resources. Seagate's areal density advantage enables us to provide the simplest, most elegant solution to increase data center capacity. It enables us to bypass more inefficient approaches to boosting capacity such as adding more platters, heads, and electronics, which tend to increase material costs, operating costs, power consumption, resource usage, and greenhouse gas emissions.

The Benefits of Mozaic 3+ for Cloud and Enterprise Data Centers

Scale, TCO, and Sustainability
Mozaic-enabled hard drives are the world's most efficient hard drive storage, capable of lowering acquisition and operational costs while increasing productivity. With Mozaic's increased areal density, customers can store more data without increasing consumption of space, power, or natural resources.

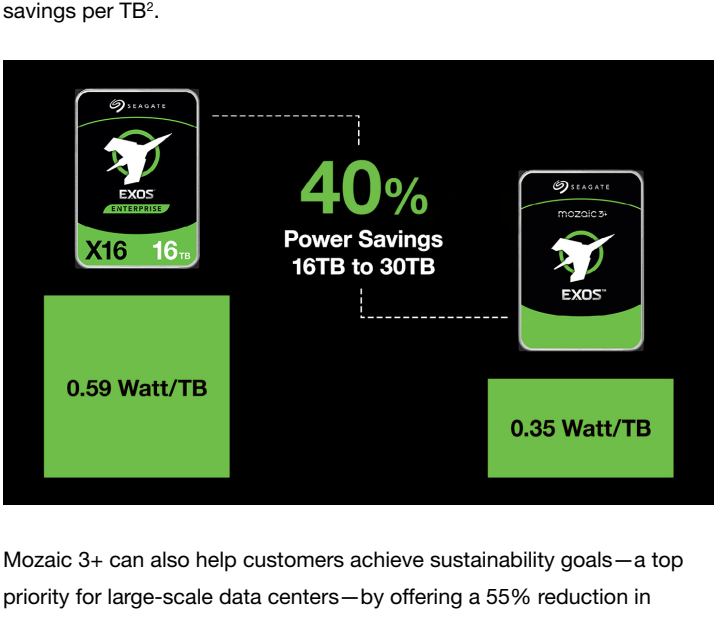
Mosaic 3+ has arrived at just the right moment to provide enterprises room to scale for emerging applications and explosive data growth. Customers can now more easily build new or optimize existing infrastructure that maximizes storage density and efficiency. Data centers can now more affordably retain and leverage more data for analytics, archiving, content delivery, and disaster recovery—and begin to close the currently massive gap between data created and data stored.

Seagate's areal density innovation—which increases the number of bits that can be stored on a platter—addresses common industry pain points. Mozaic 3+ enables customers to store more data using the same floor space. Upgrading from a 16TB conventional perpendicular magnetic recording (PMR) drive (the average capacity in large-scale data centers) to Seagate's Exos 30TB Mozaic 3+ drive nearly doubles capacity in the same footprint.



TCO is paramount for data center operators, and here, Mozaic 3+ stands out. Seagate's hard drives now offer the industry's highest areal density per disk at 3TB per disk, with a clear trajectory towards areal density of 5TB per disk and beyond to enable 50TB+ drives in the coming years.

The platform uses roughly the same material components as PMR hard drives while dramatically increasing capacity, allowing data centers to significantly lower storage acquisition and operational costs—including a 40% improvement in per-terabyte power consumption. A typical 16TB CMR drive with 1.78 TB/disk areal density utilizes 0.59 watt per TB. Comparatively, a Seagate Exos 30TB drive using Mozaic 3+ technology with 3TB/disk areal density utilizes 0.35 watts per TB—a 40% power savings per TB[2].



Mozaic 3+ can also help customers achieve sustainability goals—a top priority for large-scale data centers—by offering a 55% reduction in embodied carbon per terabyte[3].

Proven Compatibility and Reliability
Mozaic 3+ drives integrate into existing data center ecosystems seamlessly, adhering to industry-standard form factors and interfaces, allowing for straightforward, plug-and-play deployment. No modifications to hardware, software, or host awareness are needed. Mozaic 3+ technology has been validated through all standard integration benchmarks, assuring 100% compatibility with existing data center storage systems and architecture. This level of compatibility simplifies the adoption of hard drives built on the Mozaic 3+ platform, enabling data center operators to leverage the latest advancements without disrupting their infrastructure.

Built to last, Mozaic-enabled drives sport the same 5-year warranty, 2.5 million hours mean-time-between-failure (MTBF) rating, and 550TB-per-year workload rating that Seagate's entire Exos hard drive line offers. Since 2016, the Mozaic 3+ platform has undergone rigorous testing to ensure it meets the high standards required by today's data centers. In extensive shock and vibration tests, Mozaic 3+ drives demonstrate robustness beyond industry norms, ensuring data integrity even in physically demanding environments. Mozaic read/write heads have far exceeded industry standards for reliability and lifetime data transfer capability, surpassing customer requirements and standard hard drive specifications by a factor of 20.

Seagate has built well over half a million Mozaic development drives to date, with total cumulative power-on hours in the tens of millions. Several generations of the drives have met all expectations for how a drive should interact in every benchmark—including power efficiency tests, sg3_utils utilities that test interface commands, smartmontools utility programs, and four-corners tests of reads, writes, random, sequential, and mixed workloads. The drives have been thoroughly vetted through long-term engagements with many of the world's largest data center operators, with many thousands of drives shipped to multiple CSPs.

The years of tests and their outstanding results have cemented customers' confidence in the platform's readiness for mass deployment into standard cloud and IT environments. Seagate is experiencing strong demand from data center customers that have fully qualified Mozaic 3+ and have moved into volume ramp. A leading cloud service provider is focused on shifting all Seagate-provided drives to Mozaic 3+, reflecting their confidence in the technology.

Looking to the future, the strategic advantage of adopting Mozaic 3+ is clear. The platform is not just a response to current demands but a forward-thinking solution that will scale with the growing needs of data centers. It represents Seagate's steadfast commitment to meeting the demands of an ever-growing datasphere, offering cloud and enterprise data centers a reliable, scalable, and cost-effective storage solution.

How Does the Platform Work?

Mozaic 3+ is the realization of Seagate's two decades of pioneering research and development in HAMR technology. With its significant advancement in areal density, the platform provides a clear path to cost-effective, large-scale storage that delivers on data density, capacity, efficiency, and TCO savings.

At the heart of Mozaic 3+ technology, Seagate addresses the challenges of nanoscale recording. Where traditional materials have been unable to achieve areal density levels required to achieve capacity points beyond 2.4TB per platter, Mozaic 3+ introduces a superlattice structure to enhance magnetic stability, facilitating high-fidelity data inscription under extreme conditions. The writing process uses a nanophotonic laser and a quantum antenna that focuses heat for an instant with surgical precision, transforming the recording medium in nanoseconds.

Mozaic 3+ must also perform at the atomic scale, transcending conventional measures to angstrom precision and picosecond timing. Within this realm, a sophisticated dance unfolds, orchestrated by a nanoscale-integrated chip. The platform employs complex algorithms to manage billions of bits, enabling precise data manipulation and recording. Its read-write heads operate with nanorobotic finesse, hovering mere angstroms from the spinning disk. For data retrieval, Mozaic's magnetic sensors leverage Nobel Prize-winning technologies to decipher the densely written information.

"Seagate is now the world's only hard drive manufacturer with the areal density capability to get to 3TB/disk and with 5TB/disk close on the horizon," said David Mosley, Seagate's CEO. "When it comes to making data centers sustainable, we've entered the era where capacity per platter matters as much as capacity per drive. We have invested heavily in R&D over two decades to enable this sustainable reality. Our customers' interest in Mozaic's TCO proposition is strong. It's clear that Seagate's persistent focus on helping humanity get the most value out of data is bearing fruit."

Pulling Back the Curtain on Mozaic 3+ Tech

To fully appreciate the remarkable achievements of Mozaic 3+, we need to look into the core components that embody Seagate's cutting-edge design. This design represents a convergence of advanced fields, including nanotechnology, nanophotonics and plasmonics, and quantum physics, each playing a pivotal role in elevating the storage capabilities of HDDs to new heights.

Central to the Mozaic 3+ platform is its **superlattice platinum-alloy media**, a breakthrough disk media material that enables data to be stored more densely than ever on a hard drive platter. Its uniquely high magnetic coercivity prevents magnetic instability at the nanoscale so that data can be written at significantly higher densities. Written data will never fluctuate—it can only be rewritten in conjunction with Mozaic's plasmonic writer, another central breakthrough.

The **plasmonic writer**, a marvel of miniaturization and precision engineering, enables data to be written to the high-coercivity superlattice media. The writer is composed of three primary elements that together redefine the boundaries of magnetic recording:

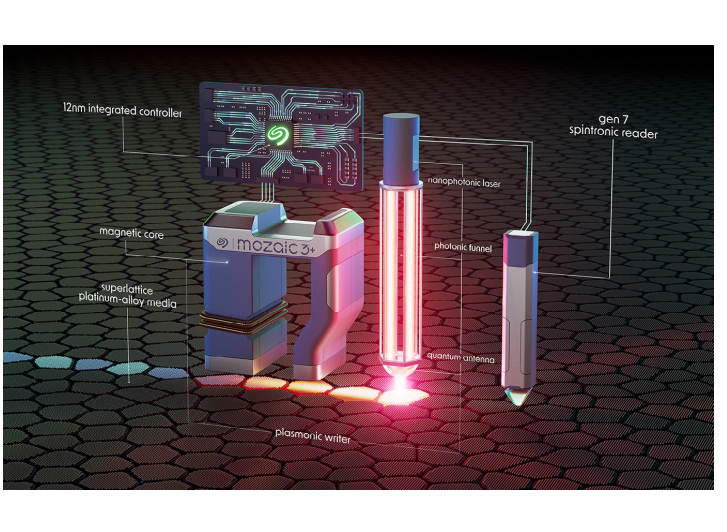
- **Nanophotonic laser:** This component emits a focused beam of light, providing the precise energy needed to momentarily heat the recording media.
- **Photonic funnel:** This channels the laser light from its source to the quantum antenna.
- **Quantum antenna:** As an energy transducer, this focuses the laser's photonic energy onto an incredibly small spot on the disk's superlattice platinum-alloy media surface with remarkable precision to convert it into a plasmonic state that enables the recording process.

The **Gen 7 spintronic reader** marks a significant advancement in reading data from the densely packed tracks enabled by Mozaic 3+. This reader is capable of discerning the minute changes in magnetization, ensuring that even at ultra-high densities, data can be read accurately and swiftly.

Lastly, enabling all these elements to work together, is the **12nm integrated controller**, a testament to Seagate's leadership in integrating complex control systems within a hard drive. This controller is the brain behind the operations, managing the intricate dance of reading and writing data with unmatched efficiency and reliability.

Plasmonic recording is the linchpin of Mozaic 3+'s capabilities, leveraging the interactions between light and metal at the nanoscale to facilitate higher-density recording. The use of an embedded laser and the conversion of light energy to plasmons allow for energy concentration beyond what traditional optics can achieve, enabling a precise, localized heating of the recording media to momentarily reduce its magnetic coercivity. This results in the precise alignment of magnetic bits to effectively capture the binary data that forms the backbone of digital storage.

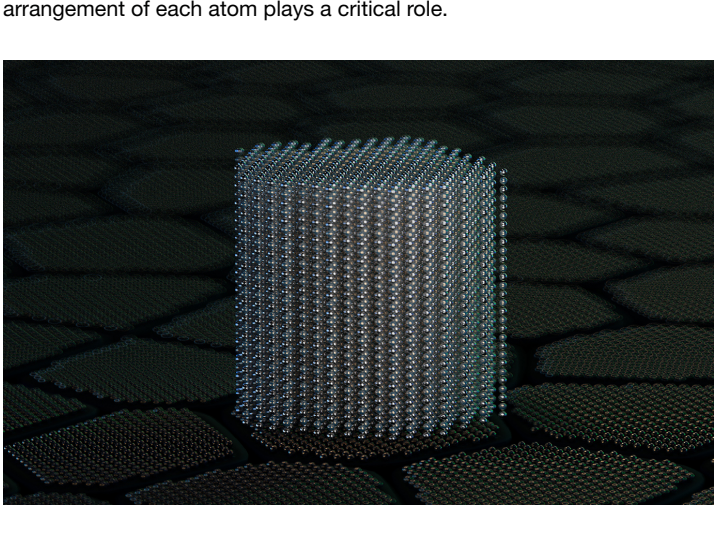
These combined breakthroughs will propel future generations of data-storage technologies for years to come, solidifying Seagate hard drives as a cornerstone of the data-driven world.



Now, let's take a deeper look at each Mozaic 3+ element in detail to understand how it contributes to making Seagate's breakthrough areal density a reality.

Superlattice Platinum-Alloy Media

In the pursuit of increased areal density, Seagate's superlattice platinum-alloy media represents a major advancement in magnetic storage media. This breakthrough technology combats the challenge of magnetic instability at the nanoscale by making it harder to flip magnetic bits that represent data. To develop a "harder" storage layer—with higher magnetic coercivity than that found in conventional drives—Seagate engineers have crafted a superlattice structure where the precise arrangement of each atom plays a critical role.



In the Mozaic platform, where data must be stored in the form of magnetic bits that are closer together than is possible with conventional PMR hard drives, the recording media had to be rethought from the ground up. The advanced materials and structures used in Mozaic 3+ media support data writing that's far more precise than any previous hard drive technology. The media is not simply a passive component but an active participant in the data storage process, allowing for more data storage within the same physical footprint.

The essence of this technology lies in its use of platinum (Pt) and iron (Fe) particles, which compose the recording medium of Mozaic 3+ hard drives. Each nanoparticle, only a few nanometers in size, acts as an individual bit of data. Attaining such a fine granularity while preventing magnetic fluctuations between the bits is made possible by the media's high magnetic anisotropy—which means that the magnetic orientation of the material tends to remain steady over time, ensuring that each bit remains stable and unaltered by the writing of adjacent data. This innovation enables Mozaic 3+ hard drives to write data with remarkable precision while preserving the integrity of surrounding data.

The recording media's specialized magnetic alloys favor a predetermined magnetic orientation. This orientation is key to stabilizing the magnetic state of individual bits, thereby reducing their susceptibility to thermal fluctuations. Seagate's choice of a chemically-ordered, granular iron-platinum (FePt) alloy is critical. Its high magnetic anisotropy provides the stability needed for recorded bits achieving record areal densities.

Achieving a high degree of order within the superlattice platinum-alloy media is crucial to Mozaic 3+ technology. It involves a sophisticated manufacturing process that uses epitaxial growth to deposit FePt thin films on crystalline underlayers on a special glass substrate. These underlayers serve as a template, dictating the orientation and ordering of the FePt grains during the deposition process. Subsequent annealing at high temperatures further promotes ordering in the FePt grains, leading to a phase transformation that enhances the media's magnetic properties and grain alignment.

This intricate and carefully controlled process ensures that the superlattice platinum-alloy media provides a robust, stable platform for high-density data storage. The precise arrangement of atoms within the superlattice structure is what allows Seagate's media to contribute significantly to the increased areal density of Mozaic 3+ hard drives, marking a substantial progression in the field of data storage technology.

The Plasmonic Writer

Since the media is made magnetically "harder" to prevent data instability, the design requires a revolutionary writer.

At the core of this writer's operation is the ability to precisely heat the superlattice platinum-alloy media, a task achieved by raising the temperature to over 800º Fahrenheit in less than two nanoseconds. This rapid thermal cycle is critical to Mozaic's effective recording process. The intricacies of this operation involve a laser that is precisely controlled and directed through a photonic funnel toward a quantum antenna. Together, these components create a plasmonic field that heats a focused area on the disk, preparing it so that data can be written by the magnetic core write head.

The design of the magnetic core write head has evolved to integrate seamlessly with Mozaic 3+ technology. Each refinement, from laser integration to wear resistance, has been carefully considered to enhance the effectiveness of Mozaic 3+.

Components of the Plasmonic Writer

The plasmonic writer is composed of a traditional magnetic core plus three new, groundbreaking elements, each with a specific function to enable writing within the Mozaic 3+ platform: the nanophotonic laser, the photonic funnel, and the quantum antenna.

Let's look at each new element in detail:

Nanophotonic Laser
The nanophotonic laser is a product of extensive innovation by Seagate to reshape the landscape of data storage technology.

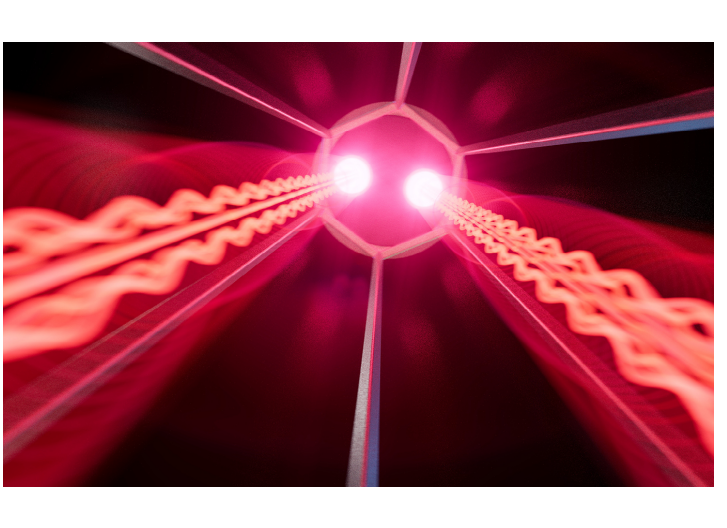
The laser is the source of the energy that temporarily alters the magnetic properties of the superlattice platinum-alloy media, thus preparing the area for data writing. The precision and transience of the energy's effect allow for the increase in the density of bits that can be stored per disk. Through sophisticated control in conjunction with the photonic funnel and quantum antenna, the laser heats only the necessary nanoparticles on the media, reducing their magnetic resistance and enabling data to be written with less magnetic field strength than would otherwise be required. The controlled heating ensures that only the bit being written is affected, maintaining the stability and integrity of surrounding data.

Seagate has innovated a cost-optimized and scalable process that integrates lasers with our advanced recording head technology. Extensive characterization has been conducted to ensure that our internally fabricated lasers maintain the same level of consistency and quality as those from other leading manufacturers, thereby creating long-term supply flexibility.

Design considerations for the nanophotonic laser are meticulous, focusing on factors such as the type and wavelength of the laser, power output, beam quality, and modulation control. Each parameter is fine-tuned to ensure the laser's effectiveness and precision during the writing process. The integration into the write head is a precise alignment endeavor, ensuring that the laser beam, delivered through the photonic funnel, is accurately focused on the recording media via the quantum antenna.

Thermal management is another critical aspect of the laser's design. Seagate has incorporated efficient cooling mechanisms to dissipate energy generated during the recording process, maintaining stability and reliability. These design optimizations are not merely about achieving higher areal densities; they ensure the Mozaic 3+ platform continues Seagate's leadership in sustainable and reliable high-capacity data storage.

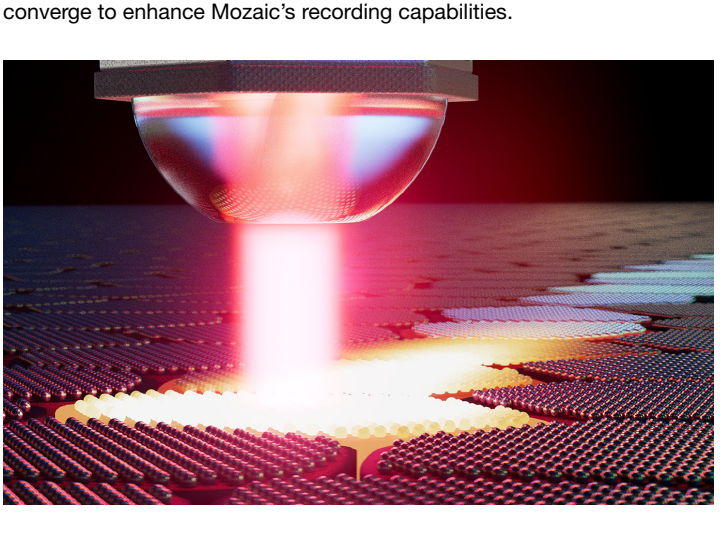
Photonic Funnel
The photonic funnel is a waveguide that channels laser light directly to the quantum antenna with exacting accuracy. Its structure, a product of cutting-edge materials science and nanofabrication, is designed to confine the laser's path, preserving the integrity and power of the beam as it traverses to its target. The choice of materials is deliberate; a high refractive index is critical to guide the light efficiently, with minimal dispersion or loss.



Seagate's breakthrough in waveguide technology was not just in its material selection but also in its structural design. The geometry and dimensions of the photonic funnel are meticulously calculated to ensure efficient mode matching, a synergy between the light and the quantum antenna that maximizes energy transfer. This precision is not merely about controlling light—it's about intensifying the potential for data storage. By delivering a focused beam to heat the recording media at precise points, the funnel is instrumental in Seagate's ability to increase areal density, enabling more data to be stored within the same physical space of a hard disk drive.

High-volume production of this component has required Seagate to innovate beyond traditional methods. Thermal management strategies are integral to the funnel's design. Seagate's cooling mechanisms ensure the funnel operates within the optimal temperature range, maintaining stability and extending the longevity of the recording head.

Quantum Antenna
The quantum antenna, a brainchild of Seagate's engineers, is where the profound complexities of quantum physics and material sciences converge to enhance Mozaic's recording capabilities.



Its primary function is to convert the laser energy into heat at an incredibly precise scale, enabling the platform's high-density data writing. It does this through the generation of surface plasmons—quantum-level oscillations of electrons induced by light at the metal's surface. This conversion is highly localized, affecting only the area where data is written.

Seagate's development of the quantum antenna required innovation in several key areas. The antenna itself is a product of meticulous fabrication, made from materials selected for their optical absorption properties and ability to withstand the thermal rigors of the recording process. The focus on plasmonic properties allows the quantum antenna to effectively confine the laser's energy so that heating is concentrated and precise.

The integration of the quantum antenna within the write head assembly is a critical aspect of its design. It necessitates precision alignment to ensure the laser's energy is accurately focused on the recording media, enabling the pinpoint heating necessary for writing data one bit at a time.

The quantum antenna acts as a transducer, transforming the incident laser light into a high-intensity near-field electromagnetic field. This field is then used to locally heat the recording media above its Curie temperature, which reduces the coercivity of the magnetic bits and allows them to be realigned, thus writing data. The quantum antenna's design enhances the coordination between the near-field energy from the laser and the magnetic field from the write head to ensure precision.

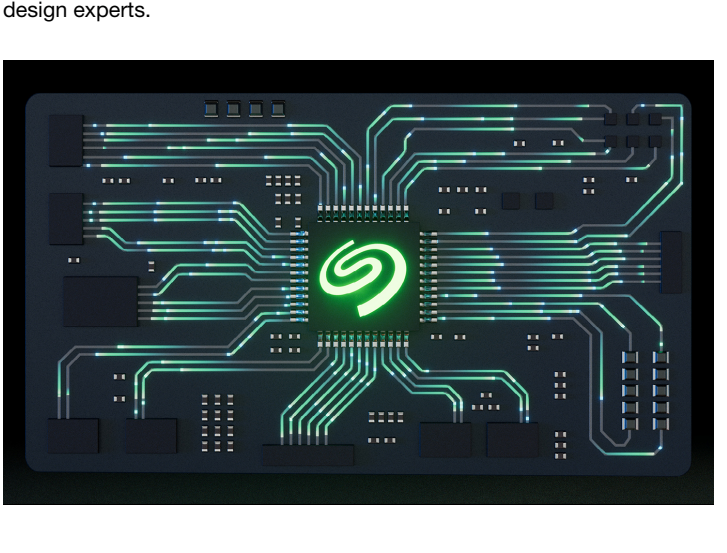
The design also incorporates advanced thermal management strategies. These are essential to ensure that the rapid heating and subsequent cooling occur with the required precision, preserving the integrity of the surrounding data and maintaining the overall stability of the storage process.

The quantum antenna is a key driver in achieving greater areal densities in hard drives. It represents a significant step forward from traditional recording technologies, with its ability to manipulate data at the nanoscale.

Enhancements to Areal Density
The collective operation of these plasmonic writer components leads to a substantial increase in areal density. By addressing the challenges of integrating a laser diode, precisely controlling the funnel, and optimizing the quantum antenna, Seagate's Mozaic 3+ technology can encode data more densely than any hard drive in history. This has been achieved through advancements in thermal management, materials engineering, and the miniaturization of components, reflecting a balance between innovation and practical implementation.

12nm Integrated Controller

The 12nm integrated controller's role is multifaceted. Delivering this areal density at a large scale and compelling TCO requires a unique approach to the electronics controlling everything on the hard drive, from actuation to recording and security. This called for an integrated controller, a system-on-a-chip (SOC), developed entirely in-house by Seagate's silicon design experts.



The controller consolidates read channels, disk management, and data exchange protocols, becoming the operational heart of the hard drive. It controls spindle speeds, manages head movements, and executes read, write, and motion control with unprecedented precision. The integration of multiple functions onto a single silicon die is a testament to its sophistication. This tailored SoC is perfectly sized for the application and is optimized for specific calculations, speed, memory, and power efficiency to reduce waste.

The controller contains innovations like Seagate's own high-performance RISC-V CPU, the first RISC-V processor ever used to control hard drive functions, delivering up to three times the performance compared to prior solutions. This performance leap enables the advanced algorithms that help deliver increased areal density.

Recording improvements include Automated Multi-Rev Recovery (AMRR), which automates high-impact data recovery operations, automated Adjacent Track Interference Cancellation (ATIC), and enhanced Iterative Outer Code (IOC), combining the correction power of LDPC decoding with Track-based ECC.

A critical feature of the 12nm integrated controller is its servo core, designed to target data tracks with greater precision. The processor's refined microarchitecture, combined with targeted instruction-specific latency reduction, enables enhanced performance in essential servo workloads. This includes real-time handling of disturbance detection, adaptive control features, feed-forward compensation, and high sample-rate computation. The processor can take less than half the time to execute the same amount of work as previous processors—and that's important, because of the need to make rapid real-time adjustments to the servo to keep the actuator on the incredibly narrow data track.

As hard drives now feature over a million tracks per inch, even ambient sounds could threaten the actuator's accuracy. Seagate's servo-processor, operating at picosecond intervals, processes up to 4 billion bits every second, executing complex algorithms to counteract potential disturbances and maintain the drive's tracking accuracy by effecting the exact movements required for the tri-stage actuators of the drive heads.

Seagate's controller includes a fully custom read channel analog front-end that samples at rates exceeding 4Ghz, equating to a new sample every quarter of a nanosecond. These processing enhancements do not compromise power efficiency.

The transition from a 24nm chip to a 12nm chip is another leap forward, enabling lower die costs and power consumption. This shift in process technology is crucial for accommodating more transistors within the same chip area, reducing voltage requirements, and offering an improved power profile.

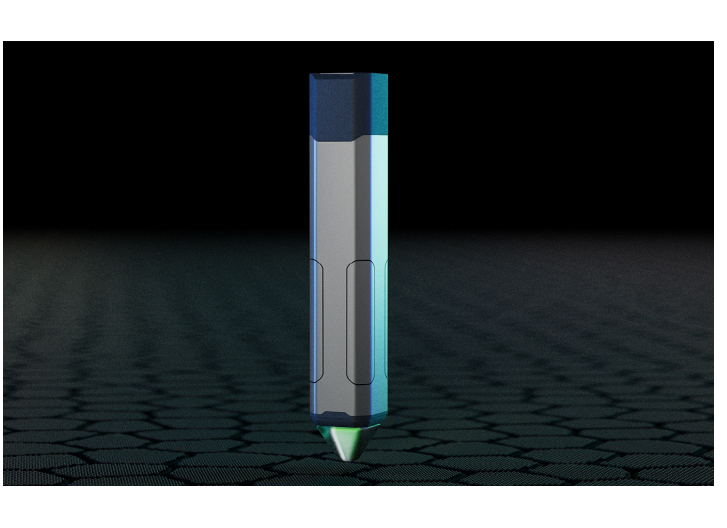
The RISC-V architecture plays a pivotal role, offering customization that facilitates application-specific computational tasks, including simulations and machine learning model training. Moreover, the use of open security architectures paves the way for secure data movement, a significant consideration in today's data-centric landscape.

Additionally, modifications specific to Mozaic 3+ such as 'Mode-hop' mitigation further bolster the drive's reliability and performance, ensuring Seagate's flagship enterprise hard drives retain the edge among high-density storage solutions.

By centralizing the entire stack, from design to fab, Seagate ensures direct control over the integration and performance of its silicon, setting it apart as the sole hard drive manufacturer with such capabilities.

Gen 7 Spintronic Reader

Smaller grains of written data are only useful if they can be read. Integrated along with the sub-components of the plasmonic writer, the reader also needed to evolve. Incorporating quantum technology, Mozaic 3+ includes one of the world's smallest and most sensitive magnetic field reading sensors, the Gen 7 spintronic reader.



A key feature of the Gen 7 spintronic reader is its very narrow track width, which ensures precise reading from the intended track while minimizing crosstalk from neighboring tracks.

At its core, the reader relies on the tunneling magnetoresistance effect—a quantum mechanical phenomenon where the electrical resistance of a magnetic tunnel junction (MTJ) changes depending on the relative orientation of magnetic layers separated by an insulating barrier. The reader's design ensures high-resolution magnetic readback, minimizing inter-track interference, which is vital for accurately reading the smaller and more densely packed recorded bits in Mozaic 3+ drives compared to traditional hard drives.

The reader includes a complex stack of layers integrated into the read head assembly. This stack comprises various magnetic and non-magnetic layers, each playing a specific role in the readback process. The layers work collaboratively to convert the magnetic signals from recorded bits into electrical signals, which are then processed and decoded to retrieve stored data.

The magnetic stack's composition and properties are meticulously selected to deliver optimal performance. The magnetic layers include the free layer (FL), which is sensitive to external magnetic fields from recorded data; the reference layer (RL), which maintains a stable magnetic orientation; and the synthetic antiferromagnet (SAF), acting as a buffer to prevent the RL's magnetic orientation from influencing the FL.

To prepare the reader stack for Mozaic 3+ technology, materials and layer thicknesses are selected for their thermal stability to withstand the temperature fluctuations during the write process. The tunnel junction's barrier layer, made of magnesium oxide (MgO), is subject to controlled oxidation to adjust the reader's sensitivity and effectiveness.

The reader's stack is constructed using a multiple-chamber deposition process under continuous vacuum conditions to prevent contamination. The precision required during the layering process demands exact controls over the thickness of each layer, which is crucial for the reader's performance.

Seagate's innovative stack design optimizes the sensitivity and signal-to-noise ratio, enabling accurate readback from Seagate's superlattice platinum-alloy media and facilitates higher data densities in Mozaic 3+ hard drives.

Beyond Cloud: The Future for All Data-Hungry Applications

Seagate's Mozaic 3+ technology will play a pivotal role in meeting the escalating demands of data-intensive applications. The push for higher areal density is fueled by the exponential creation of data across multiple sectors, from enterprise to cloud data centers, necessitating more efficient and cost-effective data storage solutions.

Data-hungry applications that will benefit from areal density advancements include machine learning models requiring vast datasets for training, video streaming services that need to store and deliver 4K and 8K content, and medical research databases that accumulate large-scale genomic sequences.

Seagate's Mozaic 3+ platform is poised to deliver these advancements not just for hyperscale and cloud data centers but across a spectrum of storage products.

As the technology is integrated over time into Seagate's diverse hard drive families—like IronWolf Pro, SkyHawk, and Exos—the benefits will permeate through various applications, from multicloud and hybrid cloud environments to high-capacity and mid-range capacity storage needs. Data-heavy applications of all kinds will increasingly rely on the efficient, high-capacity solutions that only Mozaic 3+ enables.

But Mozaic 3+ is more than a technological advance—it's a promise to sustain the inexorable growth of the digital universe. The platform's areal density technologies will be fundamental in sustaining the continued growth of data-intensive applications, underpinning the development of new services and the expansion of existing ones.

As we look to the future, the capacity to store, access, and leverage vast quantities of data will be integral to driving innovation and harnessing the full potential of the digital age. With the introduction of Mozaic 3+, Seagate isn't just keeping pace with the data explosion—it's setting the tempo, driving the advancement of storage solutions towards a horizon where data's potential is limitless.

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1. IDC Storagesphere. 2024 vs. 2025 install base, IDC Datasphere, 2024 vs. 2025 Incremental New Data Generated.
2. 16TB to 30TB capacity upgrade (or 1.78TB/Disk to 3TB/Disk) comparing Exos X16 to Exos 30TB Mozaic drive, max operating power, and weight.
3. 30TB Mozaic 3+ drive compared to a 16TB conventional PMR drive. Embodied carbon includes emissions generated during raw material extraction, product manufacturing/assembly, and all transportation of materials from extraction through manufacturing and from manufacturing to customers.

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