How Storage Solutions Are Evolving To Meet Insatiable Global Data Demands

Technology Paper

Four Key Technologies That Will Help Steer the Storage Industry Into the Future

How often do customers approach you asking for a storage solution just like the one they bought two years ago? A fair bet would be "never." Storage needs constantly evolve and inevitably increase.

In Tintri's March 2015 survey, 40% of data center professionals reported scaling as a storage pain point; 50% cited performance. The oft-cited IDC/EMC Digital Universe study shows the digital universe, fueled by billions of consumer and business endpoints, doubling in size every two years. "In 2013," notes IDC, "enterprises had liability or responsibility for 85% of the digital universe." Compared to 2009, CSC numbers show that data production will be 44× greater in 2020, with enterprises creating 10.5 of the 35 total zetabytes generated that year.

Although studies have stretched on for years, specific trends are becoming clear: The need for storage capacity keeps increasing, the ability to manage and leverage capacity is a competitive differentiator, and IT spending on capacity continues to increase.

However, increasing areal density—the number of data bits per square inch of storage medium—is only half the battle. Like packing people on a bus, increasing areal density works only so long as those bits can move in and out efficiently without being damaged. Increasing density without preserving reliability, at least at an application-appropriate level of performance, is of little help.

Nevertheless, we know where we need to go. Even as the market embraces 10TB drives, the need for 20TB+ drives remains an imperative, so let's review just a few of the ways Seagate technology leadership will get you there.

Four Ways Forward

Shingled Magnetic Recording (SMR)

In the days of magnetoresistive technology, read and write heads separated into discrete components where each could be optimized for its task. Today the read head is somewhat narrower than the write head, and that opens an opportunity to optimize data layout a bit.

For example, visualize a row of roof shingles and a large letter stamp (representing a write head) about as wide as each shingle (the track width) that is able to print a word on each shingle. As you can see in Figure 1, your eyes and brain (representing a read head) are still able to read the text even with one shingle overlapping the row atop the next.

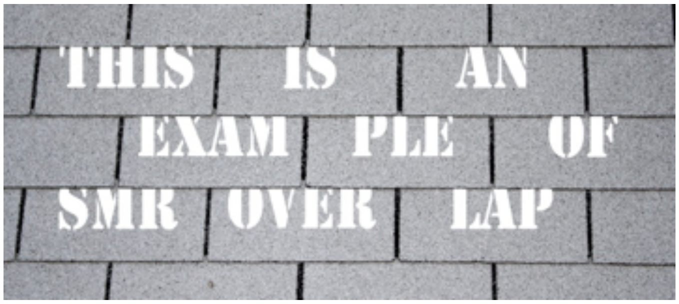

Figure 1. Imagining how an SMR read head might see data.

Rather than set the tracks edge to edge, as is traditionally done, SMR overlaps one track atop the bottom portion of the track that precedes it. This results in a track density advantage, and a per-platter capacity gain of about 25%. Consider a comparison between conventional and shingled magnetic writing (Figure 2):

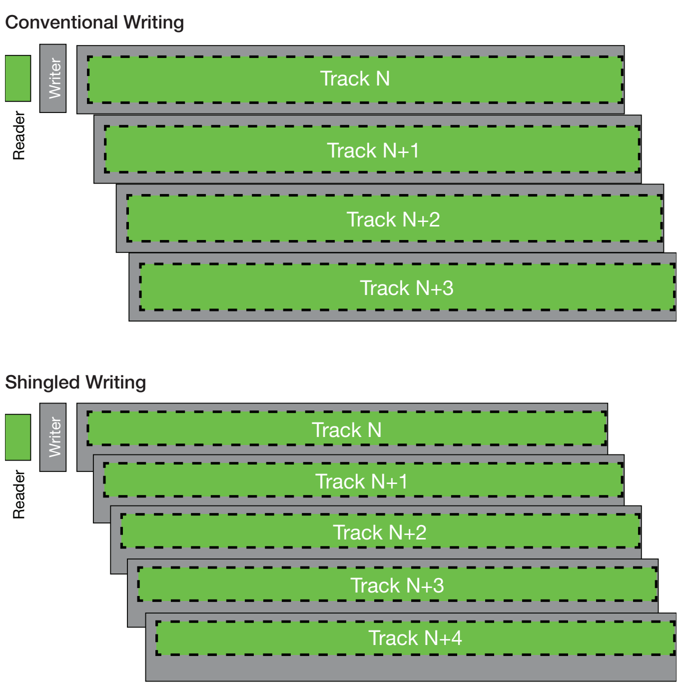

Figure 2. Comparison between conventional and shingled magnetic writing

If SMR track N+4 is finished writing, but data needs to be written onto Track N+2, the write head will overwrite half of track N+3 in the process. As a result, the drive would correct the data in subsequent tracks, rewriting until the end of the drive is reached. However, SMR drives efficiently write tracks that are divided into logical zones or bands, where the shingling rewriting process appropriately stops, thereby improving the drive performance by managing the number of tracks that need to be rewritten. The processes of SMR entail certain latencies when compared to their non-SMR counterparts, which is why early-generation SMR drives targeted archive or backup applications. Currently, advanced buffering methods among other technology advancements will soon close the performance gap and allow the capacity advantages of SMR to competitively penetrate most HDD markets.

Recently, Seagate revealed plans to launch products based on two-dimensional magnetic recording (TDMR). With this, multiple read heads can be used to improve accuracy when reading increasingly narrow tracks, which can be prone to interference from adjacent tracks. Seagate may start shipping TDMR drives in 2016.

Helium

If you've watched movies depicting spacecraft entering an atmosphere—or even spied the fleeting tails of a meteor shower within our own—then you know that air creates friction, especially at high speeds.

The same principle applies within a hard drive's enclosure. As platters whiz along at 5400 RPM, 7200 RPM, or even faster, disk surfaces collide with air molecules, exciting them and resulting in drag and heat. At the same time, drive form factors dictate their own limits on enclosure dimensions (although there is some flexibility here in both z-axis directions). Most 3.5-inch hard drives feature an outer measurement of 1 inch (25.4mm). Within this specification, manufacturers have been able to run up to six platters at 7200 RPM.

However, if the air inside the drive is replaced with helium, the second-lightest known element, and the enclosure is correctly sealed to prevent leakage, then more platters can be added. This lowers power consumption, which reduces the need for external cooling, thus allowing for increases in drive capacity.

Seagate has publicly announced its own helium drive; expect this technology to push capacities even higher in 2016. The combination of increased storage density with improved power savings should play particularly well among data center storage solutions.

Heat-Assisted Magnetic Recording (HAMR)

The long-anticipated HAMR exploits a loophole of sorts in the laws of superparamagnetism. As described earlier, conventional head technologies cannot reliably manipulate perpendicular magnetic recording (PMR) bits beyond a certain size—but they *can* if the disk surface is heated. The trick, of course, is only to heat the desired bit (Figure 3).

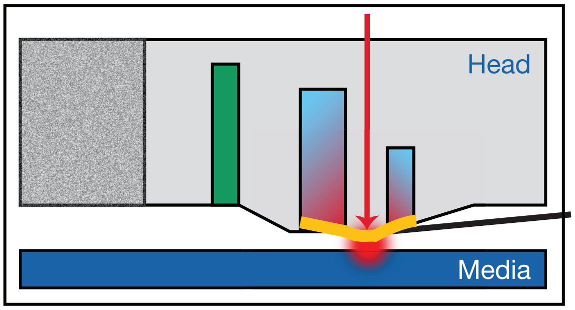

Figure 3. Micro-scale view of a HAMR head shows the laser beaming down through the head and onto the media's surface.

A laser is placed in the write head, warming an extremely small portion of media. This *softens up* the magnetic resistance, so to speak, just enough to control the magnetic bit located in that position. The magnetic orientation of the grain locks into place an instant later when the region cools. The laser adds surprisingly little additional energy consumption to the drive yet provides an exceptional improvement in areal density. Seagate speculates that HAMR could yield 3.5-inch hard drives with capacities of up to 60TB within 10 years of the technology's market introduction.

Researchers and engineers across the industry have been developing various types of HAMR for decades. For example, in the 1980s, magneto-optical (MO) drives and Sony MiniDiscs both used similar heat-assisted methods for writing data. Not until 2012, however, did Seagate become the first hard drive manufacturer to demonstrate 1Tb/in^2 areal densities with HAMR.

Bit-Patterned Magnetic Recording (BPMR)

Also known more simply as patterned media, BPMR may eventually supplant PMR. Today's thin magnetic films rely on weak exchange coupling between grains, which allows grains in a bit cluster to share a common orientation without affecting adjacent bits. With patterned media, strong exchange coupling during thin film deposition allows for much tighter grain cohesion, and nanolithography allows for the grouping of smaller grains into magnetic islands. The end result is that these islands are magnetically discrete for high reading accuracy and pack onto a media surface with much higher areal density than is possible with PMR. Moreover, that density will increase as substrate chemistry, nanoimprinted bit geometries and BPMR head technologies evolve. In PMR recording applications, a group of grains represents one bit of data while in BPMR each individual grain represents a bit of data, packing more data into the same space to increase areal density (Figure 4).

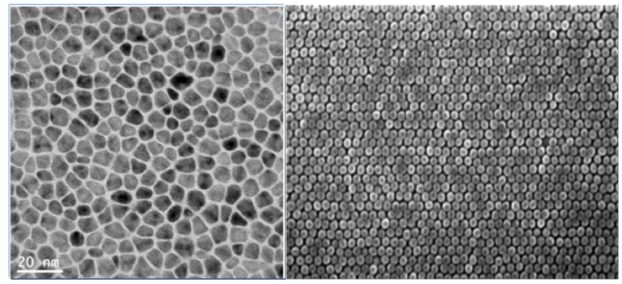

Figure 4. Comparison between granular media recording (pictured left) like perpendicular magnetic recording (PMR) and bit-patterned media recording (pictured right).

As with the other advances summarized in this paper, BPMR changes the platters and heads, but it does not necessitate much, if any, change in drive dimensions, connectivity or data management. In terms of the surrounding storage ecosystem, these upgrades are fairly transparent and painless. Ultimately, capacity growth could be 4× that of current PMR drives.

Combining Forces: To 20TB…and Beyond!

The beauty of these next-generation storage technologies is that they can often be deployed in tandem for even greater benefit. Figure 5 and Figure 6 illustrate this on a timeline.

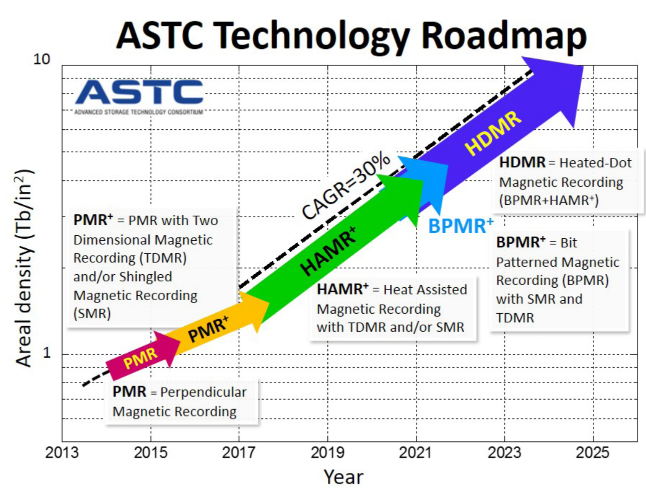

Figure 5. ASTC technology roadmap from 2013 to 2025 (courtesy of Advanced Storage Technology Consortium).

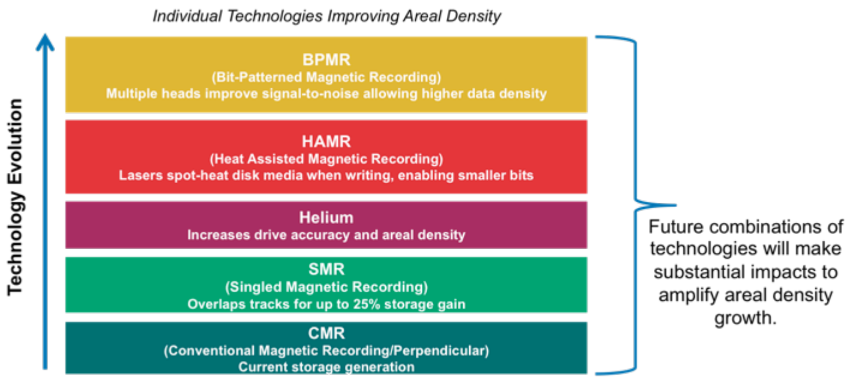

Figure 6. Specific technologies improving areal density (Seagate).

Both show conventional PMR persisting in the near term, perhaps with the enhancement of TDMR (multiple read heads). During this time, SMR as an implementation of PMR with shingled tracks will continue to gain in prominence while perhaps being elevated yet again by TDMR. In 2017, HAMR will likely start its rise to mass production. This, in turn, can also benefit from SMR and/or TDMR enhancement. Yet another conjunction can be had as BPMR joins hands with HAMR, and so on. This last possibility is already being evaluated in Seagate labs with scaling areal densities up to 3Tb/in^2.

Capacities need to meet the rising tsunami of global data over the next decade, so the potential for adding value to storage solutions throughout the channel should be as clear. The research and development behind these emergent technologies costs billions of dollars, but the expense is vitally necessary, not only for the consumers and enterprises that will rely on them to protect their livelihoods, but also for solution providers looking to enable and capitalize on the next generation of market opportunities.

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