



Western Digital.

TECHNICAL BRIEF

Energy-Assisted Magnetic Recording Technology for Higher HDD Capacities

Prepared by:
Western Digital

For 40 years, Western Digital has enabled data storage and retrieval innovation around a variety of storage technologies to increase hard disk drive (HDD) capacity on a regular cadence. These innovations expand the amount of data in the data center while lowering the data center infrastructure Total Cost of Ownership (TCO).

Data on an HDD is written on tracks, so higher Tracks per Inch (TPI) and higher Bits per Inch (BPI) on those tracks result in higher areal density, which enables more data per platter (Figure 1). Western Digital innovations for capacity-optimized Ultrastar® HDDs such as HelioSeal® technology, mechanical design breakthroughs, and Energy-Assisted Magnetic Recording (EAMR) technology have continually increased areal density, resulting in higher-capacity HDDs for cost-efficient data centers. EAMR is one of the latest breakthroughs in HDD recording technology, enabling industry-leading areal density through higher BPI (Figure 2).

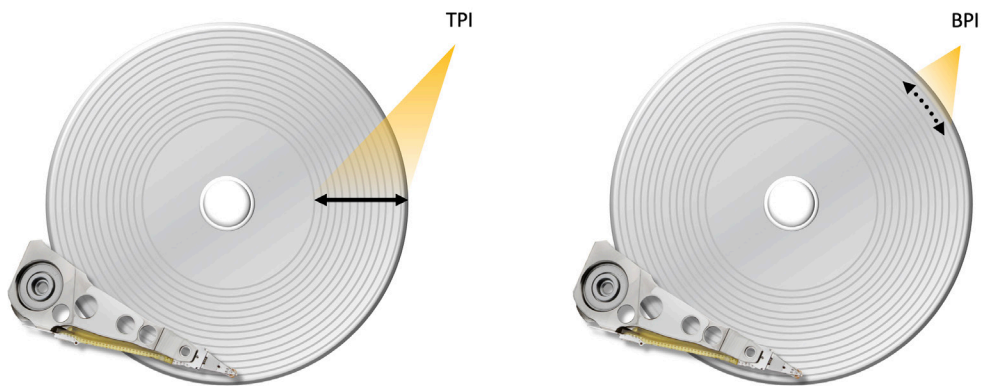


Figure 1: Visualization, Tracks per Inch (TPI) and Bits per Inch (BPI)

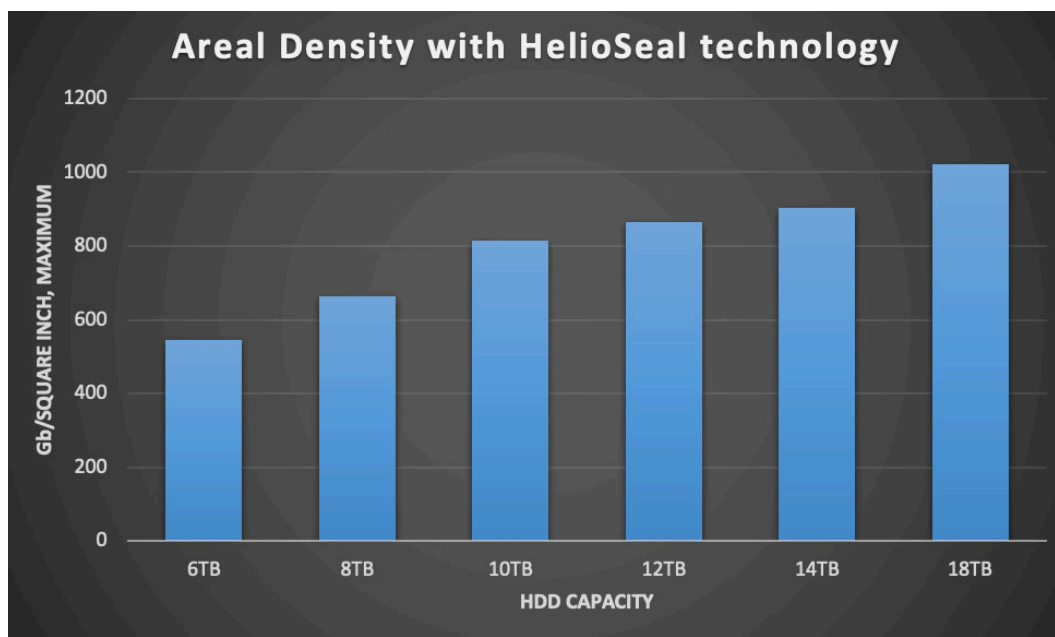


Figure 2: Ultrastar areal density

Energy-Assisted Magnetic Recording

Western Digital's Ultrastar DC HC550 18TB¹ CMR HDD and Ultrastar DC HC650 20TB SMR HDD are the industry's first hard disk drives to use EAMR technology, achieving areal densities of 1022 Gbits/in² and 1160 Gbits/in², respectively. Energy-assisted PMR (ePMR) is the first implementation of EAMR to scale beyond legacy Perpendicular Magnetic Recording (PMR). ePMR was productized as part of Western Digital's research and characterization of other EAMR technologies such as Microwave-Assisted Magnetic Recording (MAMR).

ePMR

The recording head generates a magnetic field that aligns magnetic elements in the media grains (Figure 3). Aligned media grains represent the individual 1s and 0s of data being written. Higher BPI (and thus higher areal density) is achieved when individual bits of data can be written closer together.



Figure 3: Conventional PMR technology

Figure 4 illustrates the discrepancies in a write signal between ideal and measured. The signal shape of a bit being written can be characterized within the duration of the write current from one direction of saturation to another. The middle of the write signal curve is where the magnetic field is applied to media as the recording head switches from one polarity to another. The recording head does not reach saturation in a consistent manner and provides a variable magnetic field on the media. The variation in the magnetic field can be measured by the different signal outcomes over multiple data writes to the HDD. The distortion in the different waveforms due to write mechanism variability is referred to as "jitter." Jitter comes from the volatility of saturation at the recording head when flipping the write current from one direction to another. Jitter is a significant limiter for linear density improvement bounding BPI.

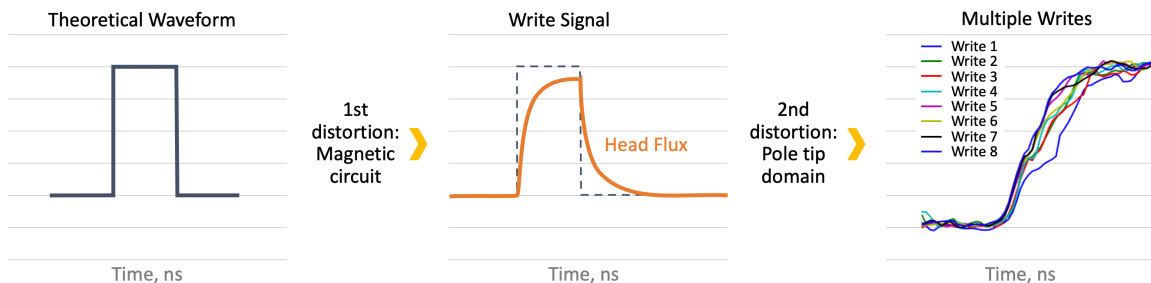


Figure 4: Write signal shape and jitter

ePMR introduces an improvement in head transition consistency that reduces jitter and enables an increase in BPI. ePMR applies an electrical current (Figure 5) to the main pole of the write head throughout the write operation. This current generates an additional magnetic field which creates a preferred path for the magnetization flip of media bits. By applying a preferred magnetic path, every pass of multiple data writes has a more consistent waveform (Figure 6). This, in turn, produces a more consistent write signal, significantly reducing jitter. When jitter is reduced, it is possible to minimize the space between bits written, thus increasing BPI and areal density.

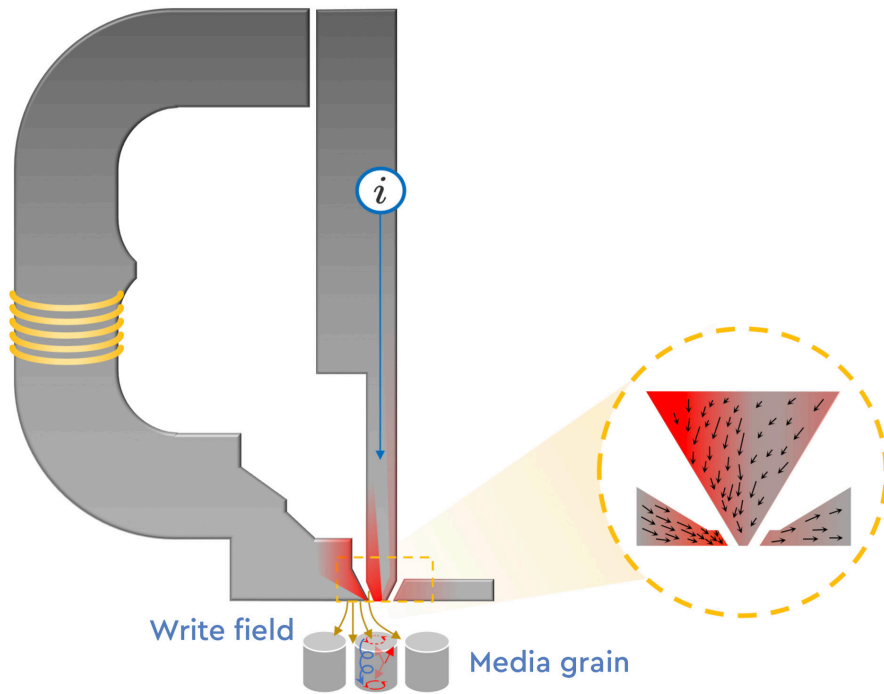


Figure 5: Recording head. Red = relative field coming from ePMR current

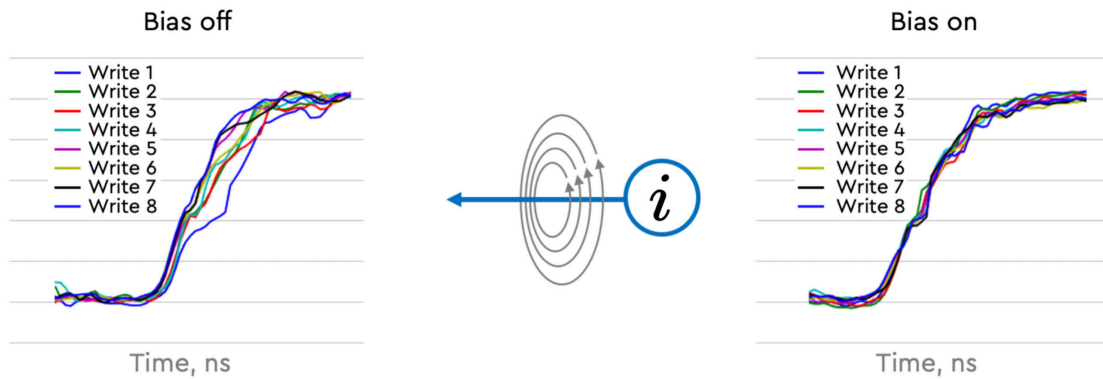


Figure 6: Jitter with and without ePMR

Implementing ePMR is possible with Western Digital's damascene head technology. The process of depositing and etching magnetic and non-magnetic materials provides the ability to create smaller, more complex head structures. The ePMR current is enabled by a metal layer deposited in an ~40nm x 40nm gap between the main pole and trailing shield which forms the necessary electrical circuit (Figure 7).

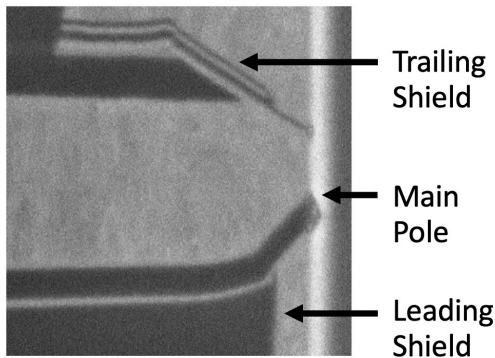


Figure 7a: Conventional PMR write head

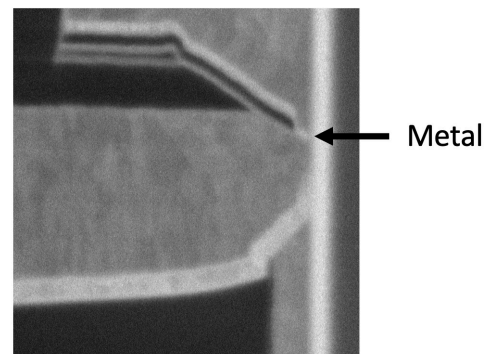


Fig 7b: ePMR write head

Reliability

The value of the ePMR current applied is critical. Higher current will produce less jitter which enables higher areal density (Figure 8). However, this effect must be balanced by reliability concerns with temperature rises in the head.

Western Digital has characterized the optimal bias needed to achieve data center requirements of less than 1 in 10¹⁵ uncorrectable bit error rate (non-recoverable bits read) and 2.5 million hours mean-time between failures (MTBF) (projected). Meeting stringent data center requirements means that Western Digital has complete confidence that reliability is not compromised by the introduction of ePMR.

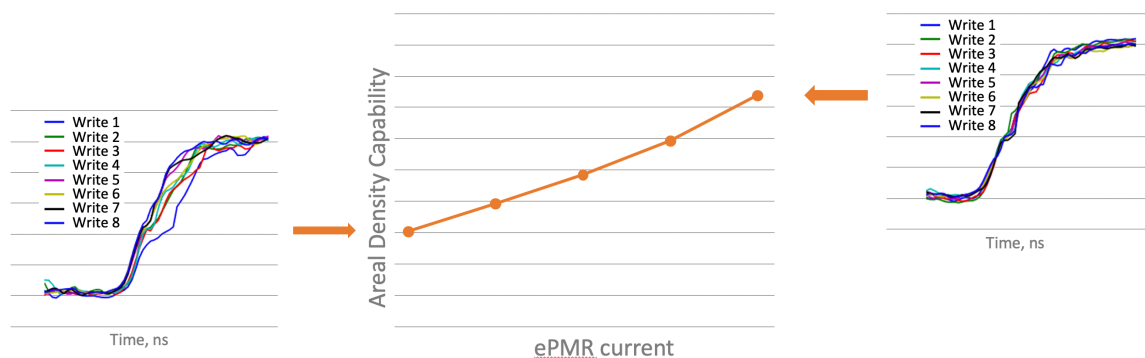


Figure 8: Effect of increasing current on jitter

Summary

Western Digital is committed to investing in HDD innovation and is a leader in EAMR technology. The 20TB Ultrastar DC HC650 host-managed SMR HDDs and 18TB/16TB Ultrastar DC HC550 HDDs are the industry's first commercial implementation of EAMR technology. EAMR is one of several technologies that deliver industry-leading capacities to enable lower TCO for data center customers. EAMR will play an important role in the next generation of high-capacity hard drives. MAMR and HAMR remain technologies that Western Digital continues to invest in with >140 and >500 patents, respectively, issued or pending worldwide.

¹One terabyte (TB) is equal to one trillion bytes. Actual user capacity may be less due to operating environment.