Practical plasmonics

Magnetic hard disk technology is approaching its limits. *Nature Photonics* spoke to William Challener, Ed Gage and Mark Re from Seagate about their demonstration of heat-assisted magnetic recording.

What are the current approaches for recording data?

When considering rotating media, hard disk drives and optical disk drives are the standard. Magnetic hard drives are approaching their technological limit and optical drives are stuck at the diffraction limit (roughly half the wavelength).

What are the limitations of the current magnetic and optical approaches?

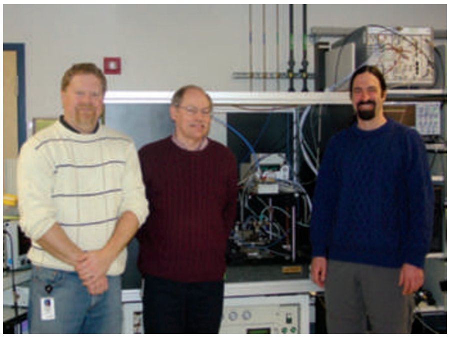
The problem is that as areal density increases the magnetic grain has to keep getting smaller to maintain the signal-to-noise ratio. However, the stability of the grain's magnetic state is proportional to the volume. As the grains get smaller, they become much less stable until finally just the kT — the thermal energy — can randomly reverse the magnetic state of the grain. It is a little bit uncertain, but projections for the ultimate limit for magnetic hard drives are of the order of a terabit per square inch.

Far-field optical approaches have diffraction-limited spot sizes. Blu-ray optical disks use a far-field approach at a short wavelength of 405 nm with a large numerical aperture of 0.85. That gives you a spot size of the order of 240 nm. To get to Tb in^{-2} densities you need to record marks with an area of $(25\ \text{nm})^2$, which would require optical spot sizes about 50 nm in diameter (or much less than that), well below the diffraction limit and beyond the capability of Blu-ray. The biggest challenge is to transfer optical energy into the recording medium in a sub-diffraction-limited spot, efficiently.

What is HAMR?

HAMR is an acronym that we invented here for heat-assisted magnetic recording. The process is similar to conventional magneto-optic recording in that we are using a laser beam to heat a magnetic layer to record information on it in a high-temperature state which then becomes stable when it cools back down.

HAMR combines optical storage technology with conventional magnetic technology, but there are important distinctions. Magneto-optic recording is done by using a larger unconfined external magnetic field and modulating the focused laser at the data rate to store information, whereas in HAMR the laser is constantly on and we modulate the high magnetic field near the optical spot. We fly a transducer just 15 nm above a recording medium at 2,700 r.p.m. In our case, we confine our spot to below 50 nm. If our light spills over, it begins to heat the neighbouring tracks and erase previously recorded information. Also, in read back, in magneto-optic approaches that is done optically by looking at the polarization state of the reflected light, but we have a magnetic sensor on the recording head measuring the magnetic state of the recorded track. HAMR should be able to go an order of magnitude higher in density than the products now on the market, but nobody knows yet how far we can go.



SEAGATE

Edward Gage (left), William Challener (centre) and Mark Re (right) at Seagate, in Pittsburgh.

What is important when designing the actual recording head?

The head had to be compatible with the standard fabrication processes in the hard disk drive industry: lithography and thin-film type techniques. A near-field transducer that could be easily fabricated by lithography in the wafer processing stage, not in a subsequent stage after the wafer had been diced, was crucial. The more processing you have to do at later stages, the more expensive it becomes.

What sets your work apart from previous HAMR studies?

Other groups have done HAMR but with a static head which uses piezo systems to scan the head. The systems are not integrated. The biggest difference here is that we have a completely integrated head — flying over the rotating recording medium — with recording pole, reader and optics. We have also done static testing and we know the challenges in going to a real flying head. The other big step was going to materials that have the potential to be used in real HAMR products. Previous attempts had used materials that were convenient for demonstrations but not really capable of high-density data storage.

What data density did you achieve in your proof-of-principle work?

We use light at a wavelength of 830 nm and have a track width of less than 80 nm, which is less than one-tenth of a wavelength. With a 15 dB signal-to-noise ratio, we achieved an areal density of the order of 350 Tb m^{-2} (0.2 Tb in^{-2}). This is a higher density than we were able to achieve without a near-field plasmonics transducer using blue-wavelength light.

What are the remaining challenges before commercialization?

What we have done is demonstrated the proof-of-principle. There are still lots of engineering challenges that have to be addressed. For example, one thing we didn't really go into in the paper is a practical way to deliver the light to the recording head. That could be through an optical fibre or placing a laser directly onto the recording head; these types of issues still have to be figured out. The recording medium itself currently would not allow a small enough head-to-medium spacing to get to the Tb in^{-2} areal data density. The surface smoothness and grain size need to be improved. There are certainly thermal issues too. We need to look into the repeated heating and cooling of the head and those kinds of things.

We are expecting HAMR not to change the cost of a drive significantly and to reduce the cost per gigabyte. The only additional component is the laser diode, which is similar to those used in today's inexpensive CD recorders. Those drives cost significantly less than our hard drives today.

INTERVIEW BY DAVID PILE.

William Challener and his team have a Letter on heat-assisted magnetic recording on *page 220 of this issue.*