going into Overdrive

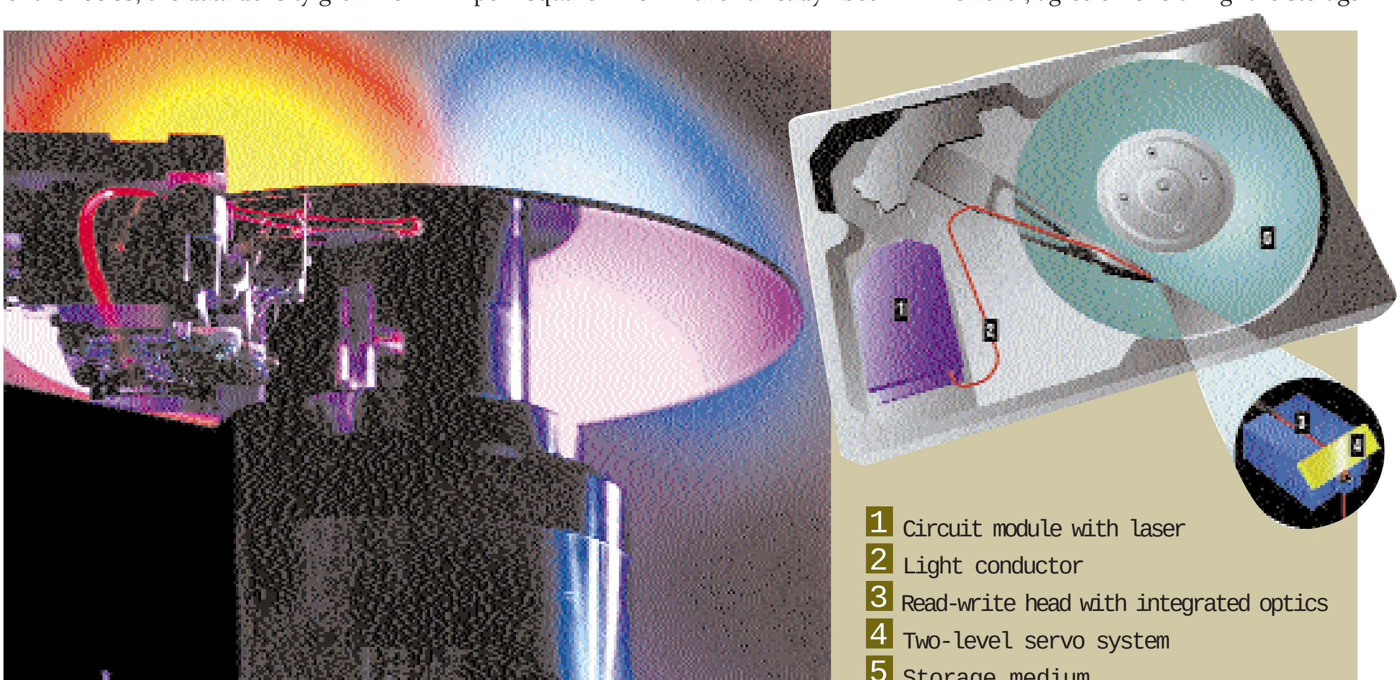
Does the development of new storage technologies such as holograms spell the end of the road for conventional magnetic storage devices?

Bill Gates, while launching the first PC in 1981, is credited with having said that 640 KB should be enough for anybody. At that time Seagate had already brought out a hard drive that could store a whopping 5 MB. But neither Microsoft nor Seagate could have foreseen that the subsequent growth of hard drives would be so rapid.

From the early 1970s till the beginning of the 1990s, the data density grew from 10 Megabits per square inch to 1000 Megabits per square inch. In recent years the progress has been even more rapid—it currently stands at 60 percent per year and this pace will be maintained for a few years more.

Today, hard disks with a storage capacity of 4 Gigabits per square inch are commonly available. At the IBM Research Labs, storage densities of over 10 Gigabits per square inch have already been achieved, and hard disks with this storage density should be commercially available soon. According to IBM's predictions, a density of 40 Gigabits per square inch should be common by the year 2004.

Advances in magnetic storage, especially improved read-write heads with new technologies, have ensured that physical barriers continue to be broken. Scientists, however, agree on one thing—the storage



Hard disk with laser support: The Optical Assisted Winchester (OAW) drive.
To write data even in the smallest structures on the hard disk, the storage medium is briefly heated at the current position. The light conducting fibre directs a laser ray on the read-write head and from there, on the disk. Seagate has already backed this tech-

density on magnetic disks cannot be increased indefinitely. Nobody can predict the limit or when it will be reached.

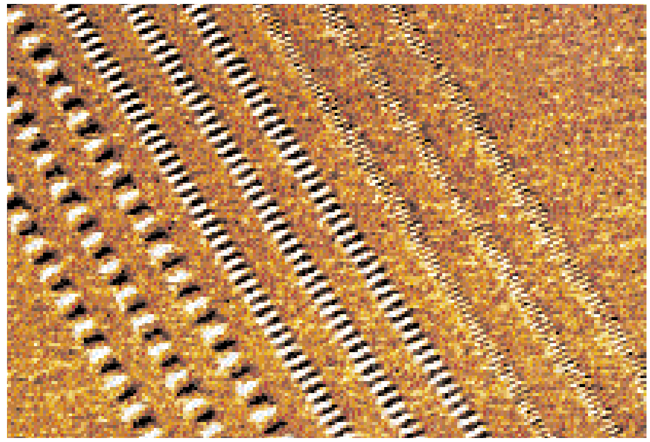
The emergence of the so-called super-paramagnetic forces should define the limits. These super-paramagnetic forces appear when the magnetic particles become too small. The energy required to change the magnetisation of these small particles is not much greater than the heat energy at room temperature, making them impractical for storing data.

Sense and sensitivity

IBM made substantial contribution to the swift growth of storage media with its MR (magneto-resistive) and GMR (giant magneto-resistive) head technologies. In both cases, writing to the disk is a magnetic process, while reading is measured by the changes in resistance.

The biggest functional difference between MR and GMR sensors is sensitivity. GMR heads are able to read and write magnetic data bits that have been more closely packed, enabling more data to be stored on each square inch of the disk—they are typically twice as sensitive. GMR uses further resistance changes based on electron quantum effects. Both types of heads provide separate read and write elements that can be optimised independently of each other.

The magnetic induction is based on the write-and-read principle. The inductive write head records bits, whereby it magnetises tiny areas on the disk along the concentric tracks. While reading, these bits cause a change in the magnetic orientation in the MR or GMR sensor. This in turn changes the resistance in the sensor, which is measured as a signal and can be amplified. This device is known as the pre-amplifier, which is present in the arm of the hard disk drive or as part of the drive electronics. Compared with read-write units available until now, the new heads are much more compact.



How dense can you get? The data tracks of a hard disk under a special micro-scope. 10 billion bits per square inch (right), 5 billion (middle), 1.6 billion (left)

Storage density on magnetic disks cannot be increased indefinitely. However, nobody can predict the limit or when it will be reached

Spin Doctors

Quantum, in alliance with TeraStor, is working on a technology different from that of IBM: Near Field Recording (NFR) technology. Here they use a read-write head that combines magnetic and optical recording methods.

The core of this recording process is the Solid Immersion Lens (SIL). It is integrated in the head, floating over the hard disk, and enables a reduction in the size of the magnetic bit-cells through the precise management of the head movement. Subsequently, it offers a higher recording density than the current hard disks. In addition, the new process helps itself to the so-called First Surface Recordings, where the bits are placed in the outermost magnetic disk layer lying immediately next to the head.

TeraStor's NFR technology delivers dramatically higher capacity random access removable products at a lower overall cost than existing hard disk drives, tape and magneto-optical based solutions. TeraStor's first NFR product family will support 10-GB and 20-GB capacities and is designed for enterprise online backup, archiving and automated library solutions, as well as for high-capacity digital applications in the professional market.

TeraStor Corporation publicly demonstrated their first functional NFR disk drives in April 1999 at NAB '99, the annual convention of the National Association of Broadcasters, held in Las Vegas, Nevada, USA. TeraStor anticipates that the first commercial NFR products will be available by the end of this year.

Laser-powered Winchesters?

A promising technology yet to penetrate the Terabyte range in hard disks is OAW (Optically Assisted Winchester). Hard disks have been working with Winchester technology since the 1970s.

If the magnetic fields lie too close to each other, they will begin to affect each other during the read and write processes. The magnetic signature of the opposing polarised bits changes and can even get lost under certain circumstances. The industry has accepted 20 Gigabits per square inch as critical density limit for a reliable storage-and-read process in keeping with conventional technology. This could move on to a maximum hard disk capacity of about 500 Gigabytes for 3.5-inch drives.

Quinta, the American company (now part of Seagate), intends to break through this 20 Gigabit barrier. With their OAW technology, they believe they can stretch the limit to more than ten times the present one. They are aiming for a 250 Gigabit per square inch storage density. In practice, this means a possible hard disk capacity of up to 5 Terabytes, which is 500 Gigabytes.

An OAW drive is basically constructed on the same principles as a conventional hard disk. The essential difference is, however, a laser ray that influences the read and write process respectively. The concentrated light ray is produced with a module in the disk casing and directed to the read-write head through a 350 micrometer thin light-conducting fibre. Motorised silicon mirrors, the size of pinheads, ensure that the laser ray finds its path to the disk surface.

When data is read from or written to the hard disk, the laser heats up an appropriate area for about two-billionths of a second. With this, the polarity of the storage medium is more easily influenced and a stable magnetic field is achieved. At room temperature, the magnetisation is difficult to manage, as it is very easy to mutually influence adjacent zones. When heated, the operation is simpler—adjacent fields are not affected.

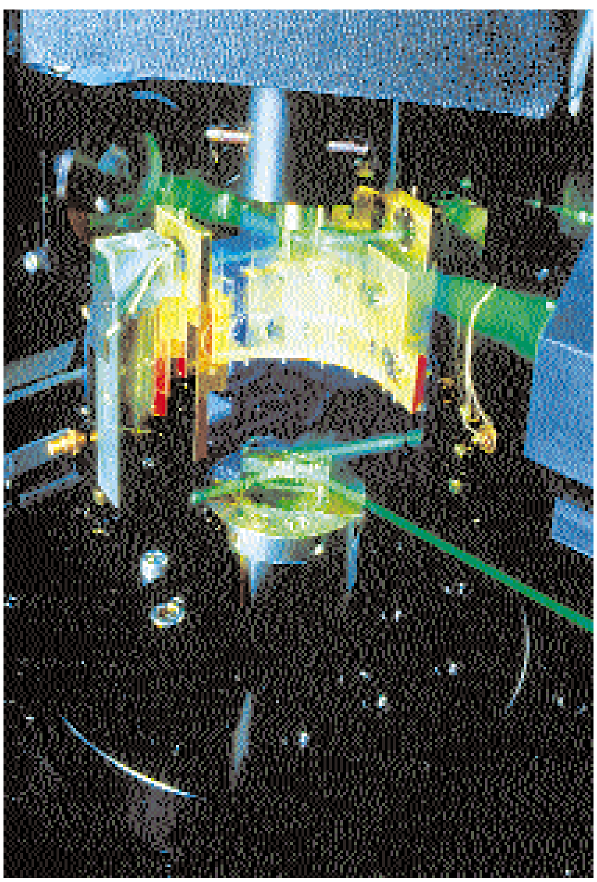
According to Quinta, the interaction of laser and motorised mirrors promises further advantages. To equip bits with a magnetic signature, the entire hard disk arm need not be necessarily moved. Normally, it is easy to position the laser by adjusting the mirrors correctly. As a result, working with the hard disk becomes more effective and precise. In addition, the structure of the components allows a greater distance between the plate and the read-write head. The disks exhibit a distinctly longer life span because of a lower wear effect.

The modified disk material also plays an important role in the reliable functioning of an OAW drive. Quinta has mentioned an 'aluminium construction' that is supposed to record and determine the magnetic loads faster than the materials used till now.

Need for Speed

Seagate Technology has announced faster and higher-capacity versions of the fastest disk drive on spindles. The company recently introduced new versions of its 10,000-rpm Cheetah drive, currently the storage device of choice for the most disk-intensive, multithreaded PC applications on network servers, Web servers and graphics and financial workstations. The new Cheetahs are available in 9 GB, 18 GB and 36 GB capacities.

Seagate also has four new versions of its 7200-rpm Barracuda drive, a more affordable SCSI alternative for desktop PC applications. These drives ship in 9 GB, 18 GB and 36 GB capacities, with a 50 GB drive expected to be available soon.



Laser beam with hologram cube

The crystal in this trial arrangement at the IBM Research Centre in Almaden is smaller than a cubic centimetre in volume, but can store several Gigabytes of data.

The object ray and the reference ray meet in the crystal and produce an interference pattern that contains the information.

The reference ray alone is enough to read the data. If a search pattern is modulated on it, it reproduces the accompanying picture ray. The detectors at the rear of this structure record it.

IBM's Deskstar 22GXP is a 7200-rpm, DMA-66, 22 GB speedster that for everyday tasks claims to outperform even a 10,000-rpm Ultra2 SCSI Seagate Cheetah. Despite its monstrous 22 GB capacity, the Deskstar is the same external size as any other desktop hard drive. The drive also features SMART (Self Monitoring And Reporting Technique) data protection, which allows for background re-assignment of potentially defective sectors—helping to ensure that you don't lose information.

IBM, in its latest generation of disk drives, has taken a giant step forward in ending confusion about trouble-shooting hard drives. Instead of relying on the operating system or diagnostic applications to pinpoint a problem, the company has built a diagnostic program directly into its hard drives that can run regardless of whether the OS will boot or not.

The new Drive Fitness Test is useful for end users because it will allow them to check whether a hard drive has been damaged when, say, a notebook computer is dropped. It is also significant for resellers, who will be able to remotely check hard drives on their customers' computers to pinpoint problems. But the biggest beneficiary of all is expected to be IBM, because the technology will reduce the number of people who insist on returning problem-free drives.

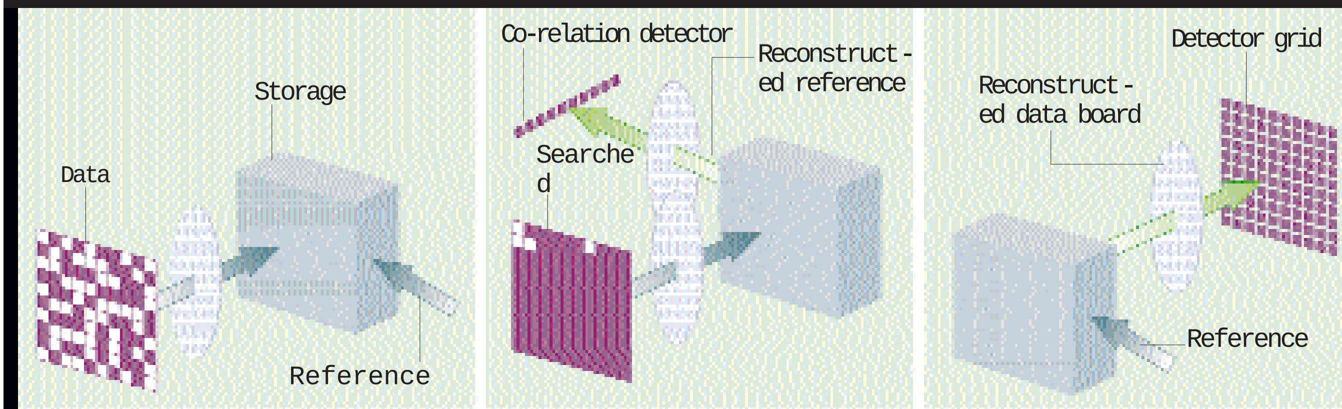
A hard look at alternative devices

The search for alternatives to the hard disk has already begun. At the IBM Research Centre, Almaden, California, scientists are studying the suitability of holographic recording methods for data storage. Incidentally, the hard disk was developed here over 40 years ago and even the MR and GMR techniques are IBM developments.

Though hardly a new technology in itself, there is still a long way to go before holographic mass storage becomes common. However, some spectacular success has already been made, and preliminary trial structures in the darkened Hologram Lab in Almaden have proved encouraging.

The holographic process promises advantages that make it worthwhile for research efforts. The first advantage is the immense storage volume that holograms can offer. In a suitable optical material

ASSOCIATIVE RETRIEVAL: SPECIFIC DATA SEARCH IN THE HOLOGRAM CUBE



The object ray with the data and the reference ray produce an interference pattern that is stored in a light-sensitive crystal (left).
During the search (middle), the reference ray that can be used to produce the pictures and that can best match the

(typically crystals), lasers store electronic samples as boards. Millions of bits can be placed on one board and, on a medium that is not much larger than a small coin, you can fit thousands of such boards. In all, one can store trillions of bytes on a very small area—this is the Terabyte range.

The possibilities for accessing information placed in this fashion are even more interesting. Simultaneous saving and reading is possible and this results in data transfer rates of at least 1-Gigabit per second. At the same time, the access time is well below one millisecond. Because every stored bit is distributed over a larger volume, in principle, holograms are more tolerant of defects than are conventional storage media.

In order to store data in a medium, two coherent laser rays are required. A light modulator—for example, an LCD grid—directs one of the two rays (called object ray). At the same time, it receives the information to be stored. Finally it falls on an optically sensitive medium. Then, a second laser ray (the reference ray) is superimposed on it. The interference sample produced by both rays is stored as spatial modulation of the refractive index in the medium. This is a hologram.

If the reference ray alone lights up the medium, it gets scattered because of modulation, and produces a copy of the original object ray. When it is directed to a grid of photo-detectors, it delivers the stored information.

The search for the ideal storage medium continues. At the moment, laboratories are experimenting with Lithium Niobate (LiNbO3). In fact, unlike conventional hard disks, holograms cannot be used as mass storage media yet. On the one hand the stored data pictures are light-sensitive and, even in the dark, are constant only for a limited period. On the other hand, delete and rewrite are possible without much problem. Of course, if a wrong procedure is used, all the data is in danger.

Red for read, green for write

IBM has found a solution to this problem, namely a two-colour process. In this process, the data is written and fixed with a green laser ray, while a cheaper red laser is enough for reading. The advantage here is that that the data is no longer disturbed while reading.

IBM crossed another important hurdle with its process for finding specific stored information. Only with effective search mechanisms can holograms actually be considered as a substitute for storage media such as hard disks. IBM calls this process of retrieving specific data on a medium 'associate retrieval'.

As opposed to the process normally employed in holograms, the reference ray is not used for reconstructing the entire hologram. Instead, a new object ray containing the search information—for example, files with specific letters of the alphabet—is directed to the medium only once. For this purpose, a reference ray is sought, with which one can successfully achieve the largest match. As a result, all files beginning with those specific letters are fished out of the three-dimensional medium. The search for the suitable reference ray is done mechanically.

Nobody can yet say what the first holographic mass storage devices will look like. One can well imagine storage chips that resemble the current DRAMS in appearance, with a storage volume of 25 Gigabytes per chip. Or disks in the form of the current hard disk that come with capacities in the Terabyte range. Anyway, one is already talking of Petabytes (millions of Gigabytes) in holographic racks for servers and mainframes.

One thing is assured—because hardware is expensive and storage media cheap, the larger the storage the more favourable the costs per Gigabyte will be. And that certainly holds promise.

MANFRED FLOHR, WOLFGANG GRÜNER and HARIKRISHNAN MENON

SITES TO VISIT

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