Magnetic Super Resolution

Enabling Technology for the Next Generation of Removable Storage

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Until recently, one of the most significant issues associated with optical recording technology has been the question of how to increase capacity while maintaining backward compatibility. Doubling the capacity, while maintaining backward compatibility with lower density disks, has posed a formidable challenge for storage engineers. The process not only requires the ability to record significantly smaller marks on the disk, but also the capability to read them back with an extremely high level of accuracy. Accurate recording and playback of these smaller marks has usually necessitated changes to laser wavelength, optics or recording methodology, and, consequently, sacrificing backward compatibility, an important feature for end-users.

Recently, however, Fujitsu and Sony have developed a new magneto-optical (MO) disk that enables very small recorded marks to be read reliably using a technology called Magnetic Super Resolution (MSR). With MSR, advancements in disk materials combine with precise recording techniques to enable writing and reading of data onto a magneto-optical disk at bit densities smaller than the spot size of a laser. This paper describes how Magnetic Super Resolution is achieved using advanced recording and masking techniques.

Conventional MO Recording

Recording magnetic marks on a conventional MO Disk

Recording information on a MO disk involves heating the MO material with a focused laser beam to its Curie temperature -- the temperature at which the MO material will not retain a magnetic polarity. As the MO material cools, it retains any magnetic polarity that is present during the cooling process.

A 680nm red laser is focused on a spot on the disk approx. 0.7 microns in diameter. This is called the laser spot size. The laser has two power levels, a high power setting for heating the disk during writing, and a low power setting used for reading the disk. When the laser is focused on the disk, the magneto-optical material under the laser spot begins to heat. The laser power is precisely controlled so the MO material heats to its Curie temperature (approximately 200 ^{o} C), but does not cause any change to the actual structure of the material. This is one of the reasons for the high rewritability quotient of magneto-optical recording.
While the material is hot, a stationary magnet below the MO material creates a magnetic field through the disk (see figure 1). Once the material is heated to its Curie temperature, the spinning disk moves the heated spot away from the laser. As this spot cools, the magnetic polarity from the stationary magnet is "captured" by the spot, allowing the drive to write magnetic "bits" on the disk.

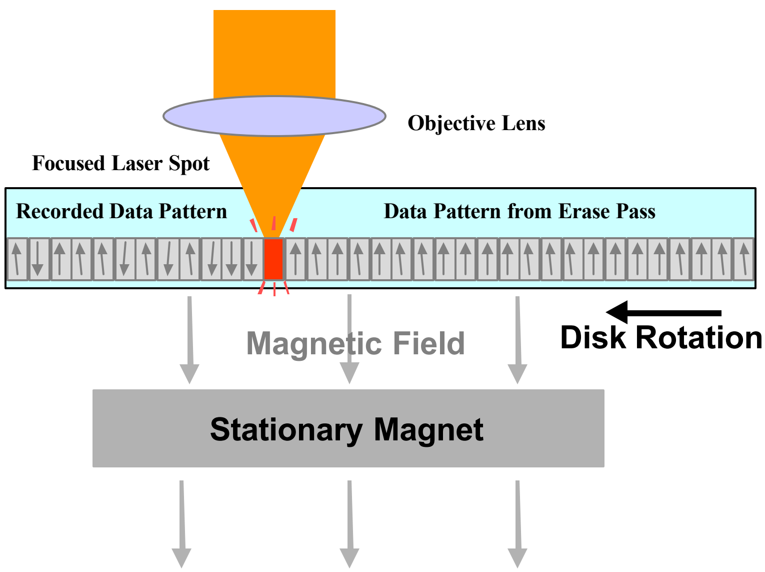

Figure 1.

Conventional MO recording requires at least two rotations (or passes) of the disk. The first pass, called the "erase pass", causes all of the bits on the recorded track to have the same polarity. During the second pass, or the "write pass", the magnetic field of the stationary magnet is reversed. Data written in the write pass will create magnetic bits in the opposite direction of the erase pass. The laser is pulsed at proper intervals, allowing the drive to create a recorded data pattern (essentially 1's and 0's), where required on the disk. Often a third pass, called a "verify pass", is performed to re-read the data recorded on the disk and verify that it is correct.

Reading a magnetic mark using a laser beam

When a polarized laser is reflected off a magnetic material, the polarity of the reflected beam is tilted because of an effect called Kerr rotation. Similarly, if a laser is shined onto the recorded data pattern on the disk surface (shown in Figure 2), the polarity of the reflected beam is tilted slightly, either positively or negatively, depending on the magnetic bit that was recorded. Using sensitive optics, the MO drive can detect this change in polarity and determine if the recorded data bit is a “1” or a “0” with very high accuracy. Since the drive is only detecting the reflected laser beam, and no heating is required, a low power laser setting is used.

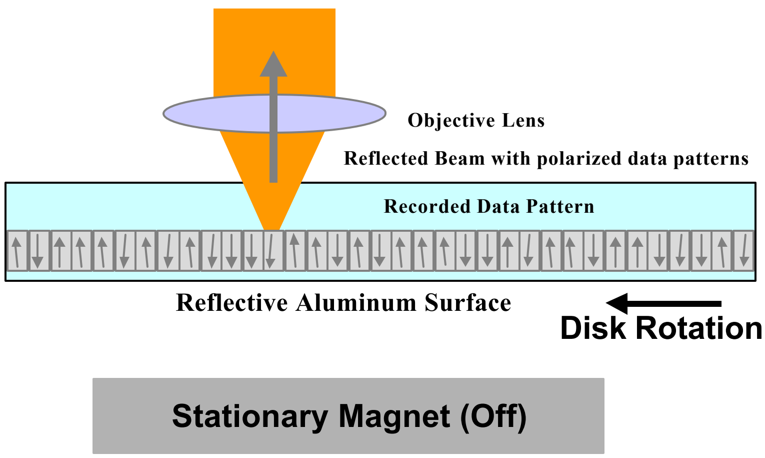

Figure 2.

Advanced recording techniques

Recording a mark smaller than the laser spot size

By precisely controlling the laser power, it is possible to cause only the hot center of the magneto-optical material to reach its Curie temperature as shown in figure 3.

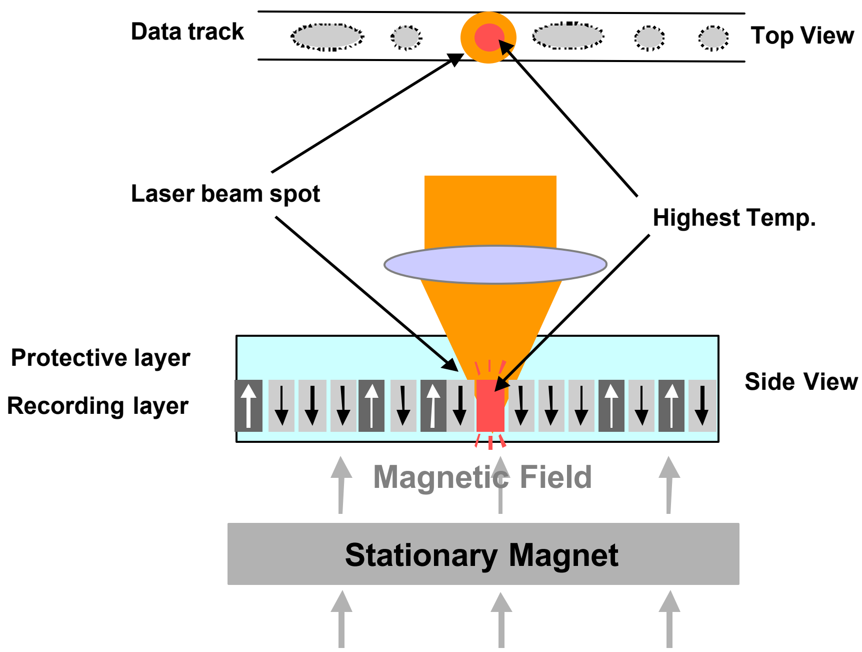

Figure 3.

The magnetic mark, or bit, is only recorded in the high temperature area. The size of the magnetic mark is only about 0.4 um in diameter, but is created from a laser beam with a 0.7 um spot size.

Reading a mark smaller than the laser spot size

Once the mark has been recorded, it must be read by the drive using the same laser spot. Unfortunately, it is not possible to read a small mark with a large laser spot using conventional methods.

Magnetic Super Resolution

Because magneto-optical drives read a magnetic mark, it is possible to use the physics of magnetism to “trick” the laser into seeing a single magnetic mark with the larger laser spot. This technique, called a thermal mask, is accomplished by using a multi-layer disk and combining the magnetic properties of both rare earth and transition metals. The thermal mask allows the drive to read the individual small recorded marks without interference from other recorded marks. This process, called “Double Mask, Magnetic Super Resolution,” is employed by Fujitsu’s 1.3 GB MO drive. This is the first commercial storage product to implement this revolutionary technology.

The Low Temperature Mask

By applying a weak external magnetic field to the disk, the magnetization of the Intermediate layer aligns with the external field at room temperature. The magnetism of the Readout layer opposes the Intermediate layer because of an effect called exchange coupling. All of the magnetic bits in the Readout layer align in the same direction. This creates an effect called the “Low Temperature Mask”.

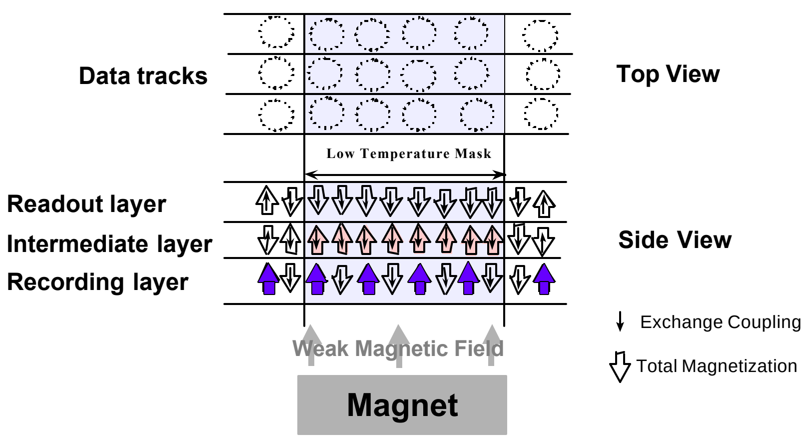

Figure 4.

The High Temperature Mask

When a medium power laser is directed onto the disk, the disk material under the laser spot begins to heat. Because the disk is moving, the temperature is higher in the rear area of the beam spot than in the front and the center area. As the Intermediate layer begins to heat (the medium temperature region shown in Figure 5), it couples with the Recording layer, and the magnetic direction of the Recording layer is transferred to the Intermediate layer. The Intermediate layer then couples with the Readout layer. At this temperature, the magnetic bit in the Recorded layer is essentially "transferred" to the Readout layer (Figure 5).

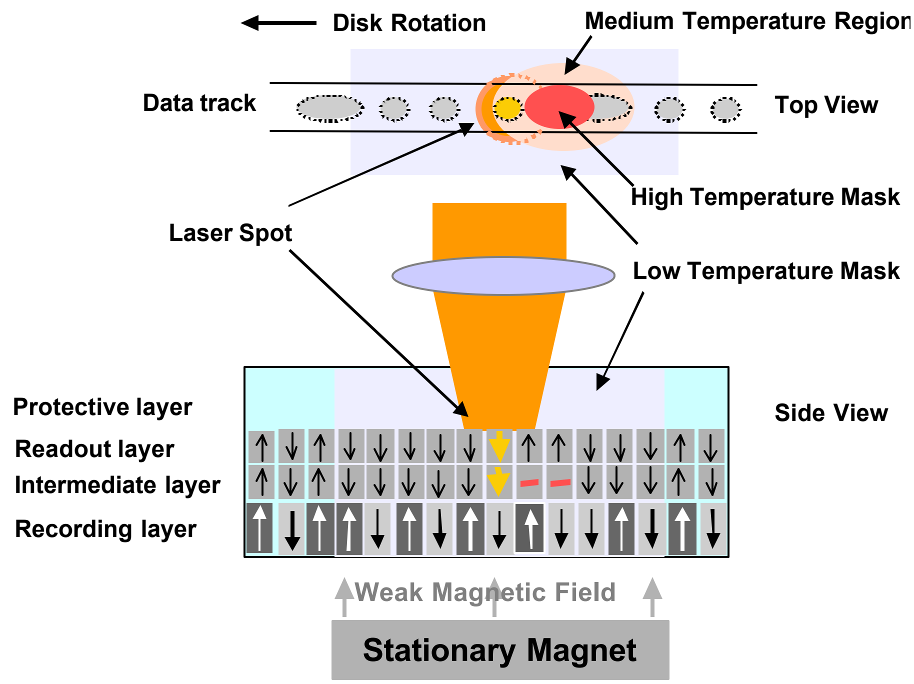

Figure 5.

As the Intermediate layer continues to heat, it reaches its Curie temperature, the point at which its magnetization disappears. This is the called the "High Temperature Mask". Without magnetization, the Intermediate layer cannot couple with the Readout layer. The Readout layer then aligns with the external Weak Magnetic Field. The reflected laser shows the magnetic effect (Kerr rotation) of only the mark in the medium temperature area. This allows the sensitive photo detector of the drive to easily distinguish the magnetic mark in the medium temperature region from information in the masked region.

Note: The medium power laser used in this operation will not effect data in the Recorded layer because the Curie temperature for the Recorded layer is much higher than the Curie temperature of the Intermediate layer.

Conclusion

Magnetic Super Resolution (MSR) provides the key to reading marks smaller than the laser spot size, and enables double capacity recording on magneto-optical disks without sacrificing backward compatibility. Because MSR does not depend on changing optics or reducing the laser spot size to increase capacity, it is far superior to other recording technologies, such as phase change recording.

MSR ensures that magneto-optical recording will continue to be a viable technology for many years to come, providing consumers with the most reliable solution available for meeting the rapidly expanding storage demands of the information age.

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Biography

Dan Dalton joined Fujitsu in 1996 and has been involved in magneto-optical drive development since 1989. Dan earned a Bachelor of Science degree in electrical engineering from Northern Arizona University and had spent 16 years in computer peripheral development. He is a frequently requested speaker at optical disk forums.