High Performance Electro-Optic Scanner Based Optical Head Tracking System

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We have used an electro-optic beam scanner as a fine tracking actuator to improve both the ability to perform track following and track-to-track switching. An optical tracking system has been built to demonstrate the elimination of unwanted side effects that can potentially seriously affect the write/read and servo performance of optical drives. We have used this experimental system to demonstrate the potential of high-speed access performance for magneto-optical drives using an electro-optic scanner fine tracking actuator. The results we present demonstrate that the new system has the ability of performing high-speed track switching between nine tracks and has high performance track following with a bandwidth of at least 200 kHz.

Key words: optical drive, fine tracking actuator, electro-optic scanner, optical head, access performance, track following, track-to-track switching

1. Introduction

Shortening the access time is very important for a high performance optical drive. To achieve high speed access, optical beam scanners have been used to improve both the ability to perform track following and track-to-track switching. However, the use of a beam scanner as a fine tracking mechanism can also introduce unwanted side effects which can affect the read/write (R/W) and servo performance of the optical drive. These will also limit the fine-tracking range on the medium. In this paper, we first analyze the cause of these effects in detail. Next we describe a new optical head tracking system using an electro-optic (EO) scanner that eliminates these potential problems. Finally, we present tracking experiments that demonstrate the performance of this new tracking system.

2. Electro-optic Scanner-based Optical Head Tracking System

In a beam scanner-based optical head tracking system (Fig. 1), the fine tracking action can be realized by changing the deflection angle of the laser beam. However, an angular change of the beam incident on the objective lens may also result in a truncation of the collimated beam and optical aberrations, which will affect the R/W performance of the optical drive. This truncation limits the realizable scanning range.

The total fine-tracking range on the medium using a beam scanner is given by,

\[ R_{\text{total}} = 2X_{\text{max}} \cdot f / l \]  

where \( f \) is the focal length of the objective lens, \( l \) is the distance between the deflection pivot plane and the objective lens (OL), and \( X_{\text{max}} \) is the allowed maximum displacement on the objective lens which does not seriously affect the R/W performance. For the EO scanner, all scanned rays when projected back into the scanner appear to originate from a single point we call the pivot. The plane containing the point normal to the direction at propagation of the undeflected beam is called the pivot plane. In an EO scanner-based optical head, the scanner is placed between the collimating lens and the beam splitter. The distance between the EO scanner and the objective lens must be large enough to insert beam splitters for the data/servo channel and a mirror. On the other hand, the maximum displacement should be small to avoid unacceptable R/W performance degradation. Assuming \( l=160\, \text{mm}, \ X_{\text{max}}=100\, \mu \text{m} \), and \( f=4\, \text{mm} \), the track-scanning range is less than 5 \( \mu \text{m} \) (three tracks for 1.6 \( \mu \text{m} \) track-pitch).

Tilting and shifting of the collimated beam with respect to the objective lens will also affect the servo...
performance, since the motion of the spot on the tracking detector will introduce a significant offset error in the push-pull signal. The total tracking error signal (TES) offset depends on the angle of incidence of the beam striking the field lens of the push-pull detectors as well as the shifting of the returning beam with respect to the incident laser beam. The resulting expression for TES offset is,

$$T_{ES}_{offset} = 2k_1R(l/f - 1) + k_2R'f'f$$  \(2\)

where \(l\) is the distance between the objective lens and the deflection pivot plane, \(R\) is the displacement of the focused spot on the medium in the tracking direction, and \(f'\) is the focal length of the field lens. \(k_1\) and \(k_2\) are constants that depend on the exact optical system employed to generate the TES.

Proper design of the optical tracking system can avoid these potential problems. In particular, we would like to keep the effective distance between the pivot plane and the objective lens small by introducing a relay lens system. The TES offset error can be further reduced by minimizing the spot motion on the detector. We have designed a new EO scanner-based optical head configuration using the ZEMAX program to eliminate the unwanted effects on R/W and servo performance (Fig. 2).

The EO beam expander (lens \(f_1/f_2\)) is used as a relay lens system to project the deflection pivot point in the EO scanner onto the incident pupil of the objective lens. Similarly, an image of the pivot point is projected on the tracking detector. This design eliminates beam displacement on the objective lens and spot motion on the detector, which prevents the beam truncation and TES offset error discussed above. In this implementation, the realizable scanning range is limited by the deflection angle of EO scanner rather than by the optical head configuration. The beam scanner actuator has the ability to be used as a one-stage fine tracking actuator with this new optical head configuration.

3. Tracking Experiment Using an Electro-optic Beam Scanner

An experimental system was built to demonstrate the improvement in access performance using this new optical head configuration (Fig. 3). The collimated beam input is smaller than 0.4mm to pass through the 0.5mm thick scanner with high efficiency and minimum distortion. The output beam from the EO scanner is enlarged to the aperture size of the objective lens by the beam expander. The beam expander is also used as relay lens to project the deflection pivot plane in the EO scanner onto the incident pupil of the objective lens. The tracking detector is placed on a second image of the pivot plane.

The push-pull TES detection method is used for grooved media. The output signal \(V_{sig}\) from two segments of the split detector (\(S_1 \& S_2\)) are amplified by the pre-amplifier, and the tracking error signal \(V_o\) can be obtained from the difference \((S_1-S_2)\) of the two amplified signals.
The input signal $V_i$ of the EO driver from the signal generator is amplified by 500 times and the output signal $V_{app}$ is applied to the EO scanner. The sampled output signal ($V_{app,samp}=V_{app}/500$) of the EO driver is input to the oscilloscope to observe the driving voltages of the EO scanner. Multi-track scanning experiments can be done by changing the driving voltages to the EO scanner.

Tracking experiments were done using only an EO scanner actuator. Figures 4(a) and (b) illustrate the effects of spot motion on the detector, and the elimination of this motion, respectively. Curve A is the tracking error signal obtained from the split detector. As shown in Fig. 4(a), the signal caused by beam motion on the objective lens and tracking detector is added to the tracking error signal. In contrast, no TES offset is observed with the new improved optical head tracking system as shown in Fig. 4(b).

Application of larger driving voltages to the EO scanner increases the scanning range. Figures 5(a) and (b) illustrate the tracking error signals from four tracks ($V_i=2.0V_{pp}$) and nine tracks ($V_i=4.8V_{pp}$), respectively. The driving frequency was 1kHz.

Curve A is the amplified push-pull tracking error signal (TES) $V_c$ and curve B is the input signal $V_i$ to the electro-optic scanner driver from the signal generator. The results show that the system has the ability to perform track-to-track switching between nine tracks using the current EO scanner. The bandwidth of the EO scanner fine actuator has also been studied for track following performance. Figures 6(a) and (b) illustrate the tracking error signals when scanning within the recorded land at frequencies of 20 kHz and 200 kHz, respectively. The input signal $V_i$ was adjusted to keep the sampled driver voltage constant at $V_{app,samp}=0.18V$ as the frequency was varied. Curve A is the amplified push-pull TES and curve B is the sampled output signal from the EO scanner driver. Figure 7 shows the Bode plot of the scanner-detector system (raw detector output $V_{Sig/scanner}$ input $V_{app,ampl}$) when scanning within the recorded land. The results show the system has a tracking servo bandwidth of 200kHz. This bandwidth is limited by the detector electronics and does not represent a limitation of the EO scanner-based tracking system.
A high performance EO scanner-based optical head tracking system can improve the read/write and servo performance of optical drives and the realizable track scanning range. The tracking experiments have demonstrated the potential for high performance track following and track-to-track switching using an EO fine tracking actuator. The results we present demonstrate that the new EO scanner-based system is capable of performing high-speed track switching between nine tracks and has a bandwidth of at least 200 kHz.

**4. Conclusion**

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**References**