Chapter 6

Conclusion

As enormous storage capacity is required to meet the demand in the rapid progress of computer, high recording density and data transfer rate are the main issues in the optical data storage technology. Moreover, since the pick-up is a key component in the recording system, a high storage efficiency (high data rate) and small-sized optical head is thus essential to make the system more competitive in price and performance. With the objective of a high data transfer rate to large capacity storage device, an improved tracking system with MEMS tracking mirror was proposed. This system combines MEMS high bandwidth tracking actuator with PID feedback control system to realize accurate high-speed tracking system.

(A)Improved tracking system

The tracking characteristics of this improved system discussed below were evaluated through the simulation and experiment.

1: The relation between aberration and mirror's tilt angle has been simulated in Chapter 2. This simulation confirmed the maximum tilt angle of MEMS mirror in the tracking system is 1^{o} which can have allowable optical quality.

2: Dynamic features of mirror were measured by using CCD and DSA in Chapter 3. The spot displacement is measured 1840 um by CCD tester when the MEMS mirror is driven to tilt 1.3^{o}.

3: By using system identification method in MATLAB, the MEMS mirror model was identified and order-reduced as the model of $\frac{3.04*10^7}{s^2+34.2s+6.571*10^7}$, which had -3dB bandwidth at 1.8 kHz.

4: With the PID compensator designed in chapter 4, improved tracking performance was demonstrated that tracking error was suppressed to 17nm at rotation speed 500 rpm by using high bandwidth tracking mirror. Consequently, the tracking mirror showed significantly improved performance compared to a VCM tracking actuator which had 80 nm under the same condition.

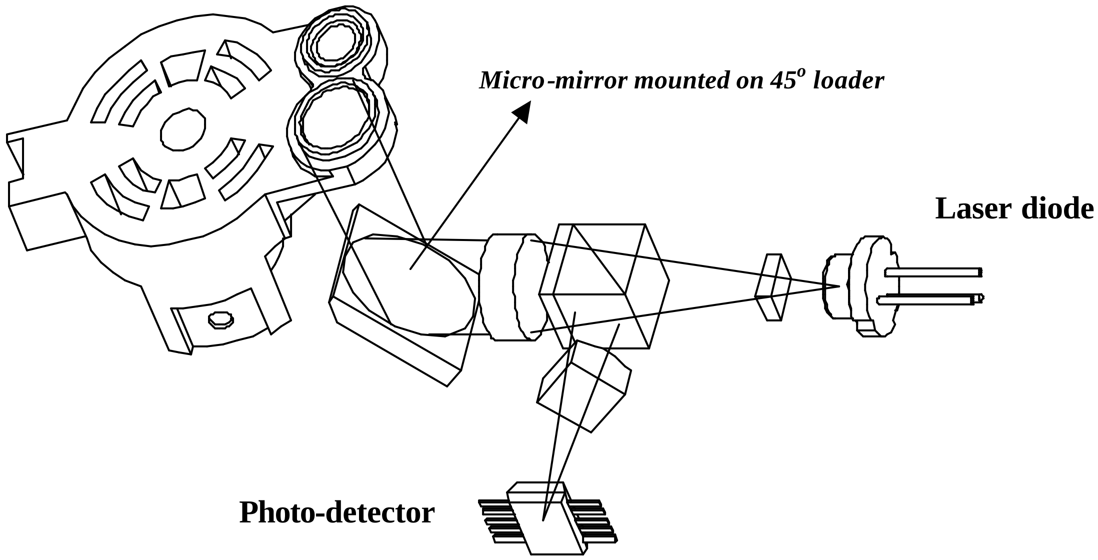
From these results, it can be concluded that the improved tracking system with MEMS mirror is an effective and fast tracking system for high density disks rotating at high speeds.

(B)Future work

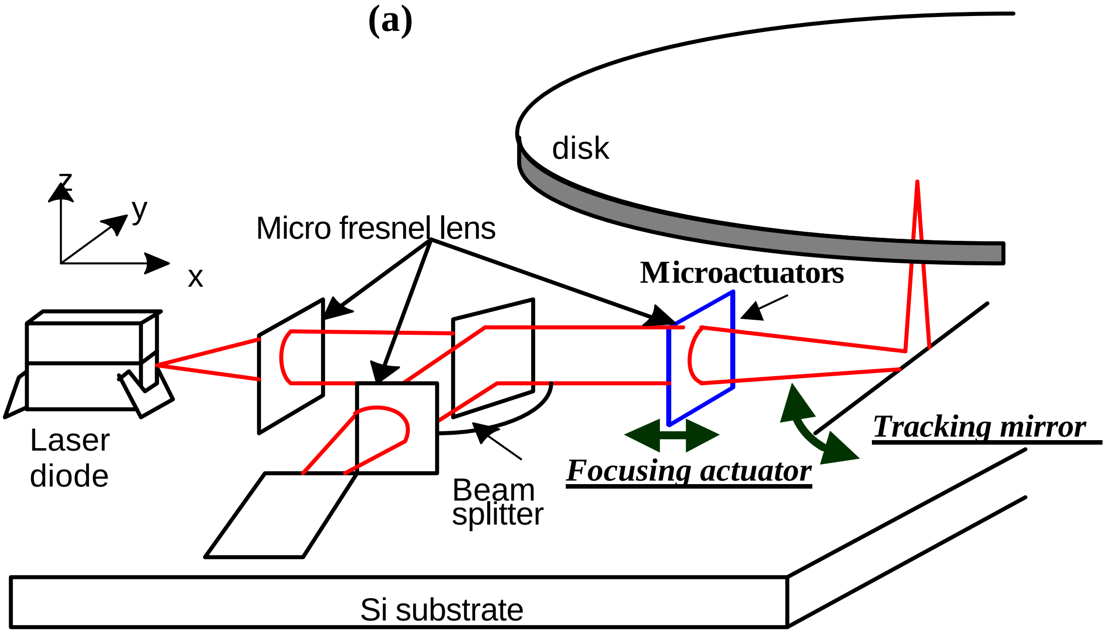
In this thesis, the basic functions of MEMS mirror-based optical system have been analyzed and examined. The tracking performance can be improved to yield a high-speed and high-accuracy tracking system at high data transfer rates and large storage capacity condition, which are the requirements for future storage system. But the test system is implemented in the disk tester, which has large distance between optical devices compared to real pick-up. For the practical usage of MEMS mirror-based approach, two methods discussed below can be used to implement it. As a result, the optical and tracking performance can be improved as the micro-mirror is integrated to pick-up as a tracking actuator in future.

(1) A MEMS tracking mirror functioning as a fine actuator is mounted on the 45 degree loader in traditional pick-up, as shown in Fig. 6-1(a). **[30]**

(2) By using silicon surface micromachining, a Si-substrate serves as a micro-optical bench on which three dimensional optical elements, for example, micro-actuator and micro-mirror are monolithically fabricated. A micro-mirror functioning as a tracking actuator in pick-up is mounted on the Si-substrate to replace the fixed folding mirror, as shown in Fig. 6-1(b). [31-33]



(a)



(b)

Fig 6-1 (a) Micro-mirror mounted in traditional pick-up, and (b) Micro-mirror fabricated with other optical device by surface micromachining

References

[1] S. M. Mansfield, W. R. Studenmund, G. S. Kino and K. Osata: Opt. Lett. **18**, 305 (1993).

[2] A. B. Marchant: *Optical recording: a technical overview*, Addison-Wesley, Massachusetts (1990).

[3] H. D. Joseph: *Focus servo performance optimization for an optical disk data storage device* (1990).

[4] M. Masuripur: *The Physical Principle of Magneto-optical Recording*, Cambridge University Press, New York (1995).

[5] H. Ukita, Y. Katagiri and S. Fujimora: Appl. Opt. **28**, 4360 (1989).

[6] S. Yamaguchi, K. Yasukawa, D. Iguchi, K. Sumiya, A. Murakami, H. Goto and K. Ueyanagi: Proc. SPIE **1248**, 96 (1990).

[7] W. Odajima, F. Tawa, N. Aoyama, M. HOkari, M. Shibano and S. Hasegawa: ISOM/ODS Technical Digest ThB-3 389 (2002).

[8] R. Katayama, Y. Komatsu and Y. Yamanaka: ODS Technical Digest TuB-1 97 (2001).

[9] J. Y. Kim, S. W. Suh and K. C. Park: ODS Technical Digest TuD-2 136 (2001).

[10] L.Y. Lin, J. L. Shen, S. S. Lee, and M. C. Wu: Opt. Lett. **21**, 155 (1996).

[11] G. Bouwhuis, J. Braat, A. Huijser, J. Pasman, G. vanRosmalen and K.S. Immink: *Principles of Optical Disc systems*, Adam Hilger Press, Bristol (1985). T. W. McDaniel: Handbook of Magneto-Optical Data Recording, Noyes publications, New Jersey (1996).

[12] T. Teruyuki, S. Masayuki, W. Kanji: *High-speed access mechanism for 90mm*

1-inch-high optical disk drive, (1993)

[13] S. Tetsuo, K. B. Allen, A. Alan: *Interactions between servo loops of an optical disk drive* IBM Tokyo Research Laboratory, (1996)

[14] Z. Jinhui, H. Yuhong, S. Steve, W. Messner: *High bandwidth Electro-optic scanner for optical data storage*, Jpn.J.Appl.Phys. Feb. (2000).

[15]W. Ichiro, I. Yoshiaki, K. Takayuki: *Precise track-following control using a micro-electromechanical-system tracking mirror in high-density optical disk drives*, J.J. Appl Phys (2003).

[16]http://www.opticalmems.com/, OPTICAL MEMS Company

[17]Y. T. Cheng: *The study of laser scanning micro-mirror device for 2D display*, June. (2000)

[18] http://www.sony.com/, SONY Corporation of America.

[19] Altera Device Data Book, (2000)

[20] *LABVIEW for printer port communication*, National Instruments Company.

[21] W. Feei, A. Daniel, F. Gene: *A method for verifying measurements and models of linear and nolinear systems*, June. (1993).

[22] T.C. Hsia: *System identification- least squares methods*, Lexington books, (1987)

[23] Lennart Liung: *System identification toolbox- for use with MATLAB*, The Math works Inc., (1995).

[24] X.P. Hu, T.S. Low, B.M. Chen: *Dual stage actuator modeling and control in a CD-ROM drive*, IEEE, (1998)

[25] Ken C. Pohlmann: *The compact disc handbook*, Oxford University Press, (1992)

[26] G.F. Franklin, J.D. Powell, E.N. Abbas: *Feedback control of dynamic systems*, (1998)

[27] *NI PCI-6014 AD/DA card with LABVIEW*, National Instruments Company.

[28] G.F. Franklin, J.D. Powell, W. Michael: *Digital control of dynamic systems*, (1998)

[29] Z. Jinhui, H. Yuhong, S. Steve, W. Messner: *High bandwidth Electro-optic scanner for optical data storage*, Jpn.J.Appl.Phys. Feb. (2000).

[30] W. Jeroen, D. Jadranko, J.N. Arnold, Rieck Marcel: *Fast-access optical drive*, Jpn.J.Appl.Phys., Feb. (2000).

[31] T. Suhara, H. Nishihara and J. Koyama: Opt. Commun., **19**, 353 (1976).

[32] M. Miler and M. Skalsky: Opt. Commun., **33**, 13 (1980).

[33] D. Heitmann and C. Ortiz: IEEE J. Quantum Electron., **QE-17**, 1257 (1981)