Chapter 1

Introduction

Optical data storage industries are continually growing with rapid progress of computer, multimedia, and network markets. In this trend, technologies capable of higher recording density and faster access thus become increasingly demanded. Among the components in an optical data storage system, the optical pickup plays an important role. The traditional optical pickups are composed of discrete components, whose accuracy is limited during the manual assembly. Meanwhile, the high weight and large volume hinder its further application as well. Miniaturization technologies, by which all the optical components are monolithically integrated on the same substrate, provide a possible route to overcome the above issues. Until now, four schemes has been proposed to realize the miniature pickup system: Waveguide with focusing grating [1], planar approach [2], stacked optical module [3], and free-space optical bench by surface micromachining techniques [4] .

1.1 Introduction of miniature pickup head

S. Ura *et al.* employed a focusing grating coupler (FGC) as a pickup in recording/reading mechanism [5-7]. A FGC is a kind of diffractive waveguide which has chirped and curved grating pattern to couple a guided wave from laser diode to focus in the free space, as shown in Fig. 1-1. In spite of robustness, this method suffers from high coupling and propagation loss.

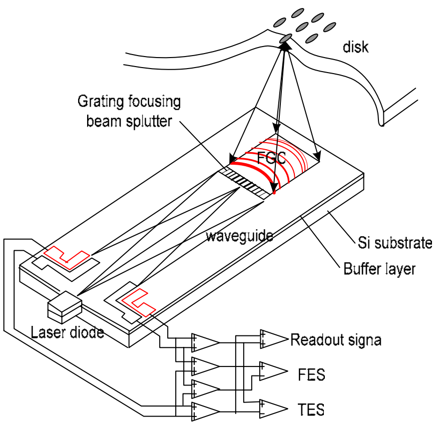

Fig.1-1 Schematic of the integrated optic disk pickup (IODPU). The curved and chirped grating incorporates the input/output coupling and the focusing by the wavefront conversion based on holography principle.

Compared with FGC, planar optics proposed by T. Shiono *et al* allows a double-side diffractive structure to modulate the optical propagation. The glass substrate is used as a light guide in which the beam follows a zigzag optical path, as shown in Fig. 1-2. However, the off-axis aberrations such as coma and astigmatism significantly deteriorate the overall performance. In addition, alinment error on both sides of the substrate can easily lead to a large amount of stray rays, which potentially casue enormous crosstalk during the reading process.

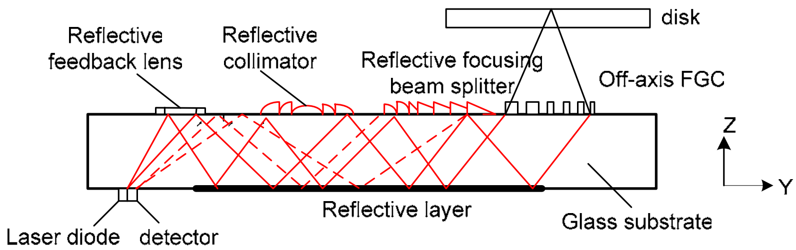

Fig. 1-2 The side view of the planar optical disk pickup

Chang *et al.* proposed a stacked silicon-based micro-optical pickup in 2005[8]. The optical pickup system was composed of optical elements fabricated on a SiN membrane, as shown in Fig. 1-3. The designed elements were stacked by chip bonding technology. The method can simplify the process flow, however, the performance is highly limited by its low utilizing efficiency.

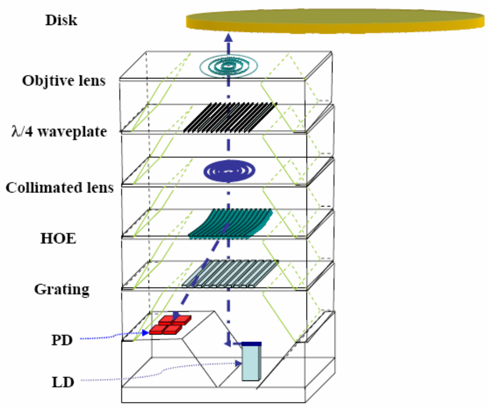

Fig. 1.3 Schematic of the optical disk pickup by silicon-based stacked micro optical system.

In the approach of silicon surface micromachining proposed by M. C. Wu *et al.*, a Si substrate serves as a micro-optical bench on which three dimensional optical elements are monolithically fabricated. The schematic drawing of the pickup is shown in Fig. 1-4. Because the system is based on the MEMS technology, it is easy to integrate with active devices. Nevertheless, the optical pattern is made of polysilicon which is not transparent in the visible spectrum; hence, the efficiency is not high enough to be used in the optical pickup operated at visible spectrum yet.

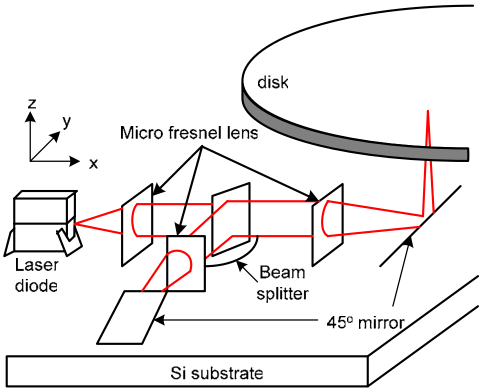

Fig. 1-4 Scheme of free-space system.

A comparison of the four approaches for integrated-optic pickup device is presented in Table 1-1. Among the proposed miniature pickups, the free-space type possesses more possibility to integrate with actuators. Integration with actuators can further reduce the fabrication and packaging cost. Unfortunately, the previous proposed free-space type was developed for 780 nm technologies, and not compatible with the current 633 nm and 405 nm technology. In the following section, a micro optical pickup configuration compatible with 633 nm and 405 nm will be proposed.

Table 1-1 Pros and Cons of four integrated optic disk pickups (IODPU).

Pros	Cons
Waveguide with focusing grating [1]	
1. Integration well	1. High coupling loss 2. Hard implementation of high NA lens by the focusing grating
Diffractive optical element (DOE) planar approach [2]	
1. High coupling efficiency 2. High performance in planar micro-optical components	1. Requirement of precise alignment on both sides of the substrate
Stacked optical pickup scheme [3]	
1.self-aligment 2.simple fabrication process	1.Easily broken membrane
Free-space optical bench using surface-micromachining technique [4]	
1.Three dimension dynamical calibration 2. Free space can perform optical imaging and generate diffraction-limited focused spot	1. Cumbersome fabrication process

1.2 The frame of our micro-optical system

The miniature free-space optical pickup system was composed of fiber lens, grating, PBS, collimators, 45° mirrors and quarter wave plane. As shown in Fig. 1-5, the light from the fiber is directed towards the grating. After grating, the light is divided into three beams for tracking. After passing through the PBS, the light is split into two orthogonally polarized components, the transverse electric (TE) and transverse magnetic(TM) modes. The TM mode is for reading and writing the data in the disk; while the initial TE mode is used for monitoring the light intensity. After collimated by a collimator, the polarization state of the light is changed from the linear to the elliptical by the quarter wave plate. The light is then reflected by the 45° mirror. The objective lens is designed for focusing the light on the disk. After reading data from the optical disk, the elliptically polarized light passes through the quarter wave plate again and changes its polarization into linear polarization orthogonal to the original one. The reflected TE mode with data information is then reflected by the PBS and detected by the photodiode array. The advantage of using polarized light for data-reading is that it can improve the light efficiency. Consequently, the objective of the thesis is to produce a micro PBS for a free-space micro optical system operated at visible spectrum, 633 nm and 405 nm.

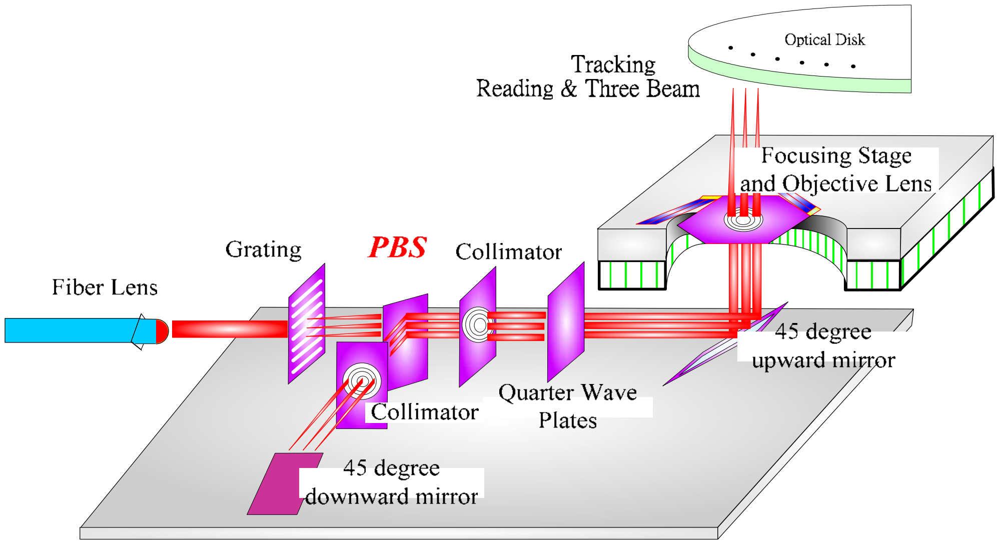

Fig. 1-5 The scheme of our novel optical bench

1.3 Introduction of micro polarization beam splitter (PBS)

The micro polarization beam splitter (micro PBS) is required in micro optical system for sensing and signal processing when polarization state is a concern. There are several principles to produce polarizers, including the Brewster angle effect, birefringence of crystal materials, light interference in optical thin films, and differential light absorption. The commercial polarizers and PBS are summarized by Li *et al* in 2000 [9]. It shows that the performance of the conventional PBS based on birefringence is better than others. Unfortunately, a birefringent crystal is too bulky to integrate in the micro system. On the contrary, although narrow bandwidth is the main issue for thin film PBS, it is suitable to be used in the miniature optical pickup for it possesses the advantage of compatible with the micro-electro-mechanical system (MEMS) technology.

1.4 Current researches of micro thin-film PBS

In 1998, Chuan Pu et al. proposed a monolithographically integrated free-space PBS using polysilicon surface micromachining process (MUMPS) for the first time. [10]. The PBS has been realized on a single Si chip and is lifted up perpendicular to the substrate. Nevertheless, the optical pattern is made of polysilicon which is excessively lossy for visible light, thus, the low efficiency.

Kishan Gupta et al. proposed a novel PBS with excellent performance by replacing the polysilicon with low stress SiN in 2003 [11]. The insertion loss can be reduced to 3%, while the extinction ratios for reflected and transmitted light can reach upon 21 and 10 dB. However, the bulk micromachining technology they mentioned is not suitable for the surface micromachining based micro free-space optical pickup.

1.5 Motivation and Objective of this thesis

Miniaturizing the optical pickup to enhance the data-transfer rate and cost is a consequential trend. However, there is neither thin nor compact PBS that can efficiently produce polarized light and integrate with the miniature system. Therefore, the objective is to design and fabricate a micro thin film PBS which can satisfy the requests. Two types of micro-PBS will be introduced. One is for operating at 633 nm wavelength; the other is for operating at 405 nm wavelength.

1.6 Organization of this Thesis

The thesis is organized as following: The principle of thin film polarization beam splitter is presented in **Chapter 2**. In **Chapter 3**, the design and simulation of micro-PBS for 633 and 405 nm wavelength systems are presented. The processes to fabricate thin film PBS are described in **Chapter 4**. The experimental results, including fabricating thin film micro PBS, will be shown in **Chapter 5**. Finally, the conclusion of this thesis will be presented in **Chapter 6**.