Chapter 1 Introduction

As the coming of tetra-era, the demand for data storage capacity grows with each passing day and inspires researchers to increase the storage density as high as possible. In this chapter, the choke points of current storage mechanisms are overviewed and the objectives of this thesis will be resolved accordingly.

1.1 Motivation

Optical disks such as compact disks (CDs) and digital video disks (DVDs) are considerably popular, and the oncoming blue-ray disk, of which the data capacity is up to 20 GB, is anticipating for multitudes. Their mechanism is to utilize a far-field laser stylus for data reading and writing. To increase of data capacity primarily depends on the reduction of spot size; therefore, far-field diffraction limit is the most crucial criterion and also an imperative bottleneck to overcome.

Hard disks (HDs) are the major storage device today so that many investigators aspire after making the storage density of HD up to 1 Tb/in^2. In order to reach such density, hybrid recording (heat-assisted magnetic recording) is necessarily introduced; as a result, not only the diminution of the grain size in the recording medium is required but the reduction of the optical spot is indispensable.

Regardless of which mechanism for data reading or writing, confining the optical spot to a tiny size, which infers to break through far-field diffraction limit, is a necessary work evidently. Therefore, two methods associated with near-field optics come with the tide of fashion and are described as follows.

The first branch is a solid immersion lens (SIL), which was incipiently introduced by Mansfield and Kino [1]. As plotted in Fig. 1.1-1, an SIL is a hemispherical lens placed with its flat side in proximity to the recording layers, and thus, light of which the incident angle is smaller than the critical angle passes into the gap and propagates as a homogeneous wave. While the incident angle surpasses the critical angle θ_c, the light suffers total internal reflection (TIR) at the interface between the SIL and the gap; notwithstanding, some light still penetrates through the gap evanescently, decaying exponentially with the increased air gap Δz. On account of the gathering of evanescent energy, the NA of an SIL can exceed that of an ordinary objective lenses and a small optical spot that unlikely appears in a far-field optical system is obtained accordingly.

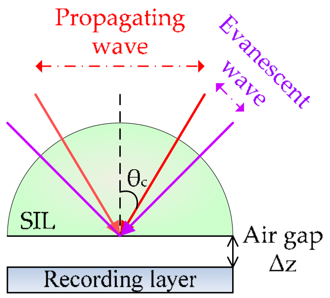

Fig. 1.1-1 Layout of an SIL

An SIL-based flying head is plotted in Fig. 1.1-2, where an SIL is mounted in a slider similar to those used for magnetic hard drives. The motion of the disk under the SIL generates an air gap that separates the SIL from the recording layers. Such a module, however, confronts three momentous issues for practical application: heaviness, alignment and difficult fabrication.

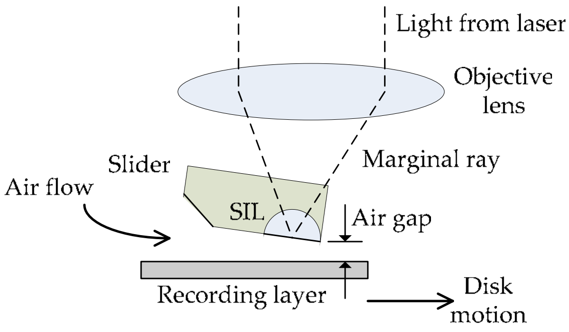

Fig. 1.1-2 An SIL-based flying pick-up

The other approach of breaking through far-field diffraction limit is to employ a nano-aperture in an opaque mask, which was firstly demonstrated in scanning aperture-type near-field microscopy by Betzig [2], whose experimental results are shown in Fig. 1.1-3. Although a subwavelength spot size was successfully achieved, the extremely low transmittance of 10^{-5}~10^{-6} is a fatal barrier for pragmatic applications, especially for dynamic optical storage systems because the dwell time will vastly increase until adequate energy is acquired for an effective singal-noise ratio (SNR), and consequently, the data reading and writing rates will be encumbered.

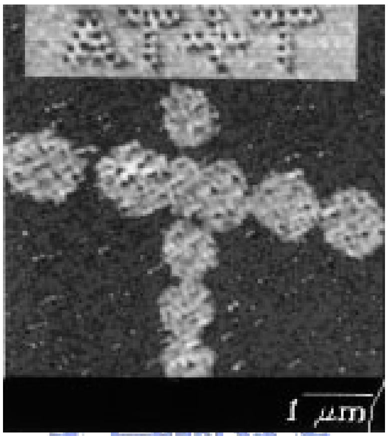

Fig. 1.1-3 Betzig's experiment results with resolution ~ 60 nm, the upper section is made by a near-field probe and the lower section is reading image of the mark

1.2 Objectives

Taking aforementioned concerns into account, a fiber-based light delivery module is proposed in this thesis in order to surmount those issues in an SIL-based one. The primary model is a single mode fiber (SMF) spliced by a coreless fiber which is used to focus light, as depicted in Fig. 1.2-1. At its focal plane, a nano-aperture is located in a metal film to further reduce the spot size. Due to the utilization of the fiber, this module is much lighter than the SIL-based one; moreover, focused ion beam (FIB) allows the fabrication of a nano-aperture to be simpler than that of an SIL.

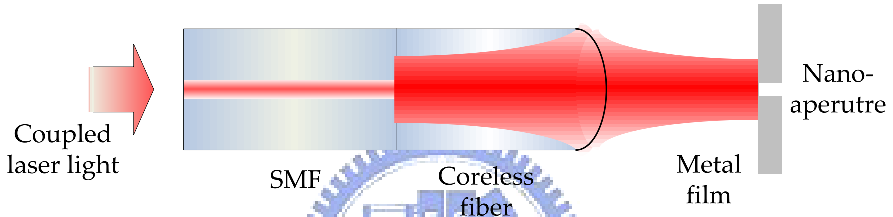

Fig. 1.2-1 Primary model of fiber-based light delivery module

Because this model still has some restrictions such as alignment, hard integration and energy loss owing to the freestanding metal film, an improved and simpler model is propounded, as shown in Fig. 1.2-2. To avoid the misalignment and to diminish the loss between the coreless fiber and the nano-aperture, the metal film is immediately deposited on the end face of the GRIN fiber and a nano-aperture is subsequently perforated; thereby, the light delivery module becomes more compact and effective.

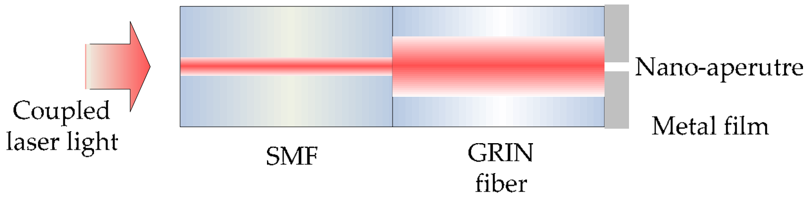

Fig. 1.2-2 Improved model of fiber-based light delivery module

1.3 Organization

Based on these two models, the objective of this thesis is to design a novel nano-aperture that can provide adequate transmittance for practicability. Simulation will be carried out firstly for optimization and analyses; then, experiments will be implemented to confirm the calculations and demonstrate the feasibility. This thesis is organized to review the basic theories and previous literatures in Chapter 2. Simulation analyses are described in Chapter 3 and Chapter 4, followed by experiments in Chapter 5 and conclusion in Chapter 6.