

# Near-Field Optics: A New Tool for Data Storage

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*Invited Paper*

*Evanescence energy can be used to produce extremely small optical spots. Two practical implementations that use evanescent energy are aperture probes and solid immersion lenses (SILs). For data storage, the optical near field is defined in terms of evanescent coupling between the system used to read data and the recording layer. Because of the small spot size, near-field techniques are applied to optical data storage systems in order to increase recording density. Both aperture-type systems and SIL systems show good promise of achieving densities of more than 150 Gb/in<sup>2</sup>. The characteristics and performance of several systems are compared, and future near-field technologies are discussed.*

**Keywords**—Evanescence energy, near-field optics, optical data storage, solid immersion lens.

## I. INTRODUCTION

Optical disks, in particular read-only compact discs (CDs) and digital versatile disks (DVDs), are popular for software, music, and video distribution, where large amounts of digital information are mass replicated in an inexpensive removable format. Optical disks are also popular as write-once devices in the compact-disc-recordable (CD-R) format. Other formats, including erasable optical disks, are just beginning to make a significant penetration into the marketplace for computer applications.

As optical disks evolve, their data capacity increases.<sup>1</sup> For example, the data capacity of a single-layer DVD (4.7 GB) is a factor of 7.3 more than the data capacity of a CD (0.64 GB). The next member of the CD/DVD family is the digital video recorder (DVR), which promises over 20 GB per layer [1]. The CD, DVD, and DVR devices use the mechanism of *far-field* recording. This paper addresses a mechanism called *near-field recording* that can extend the capacity

of optical disks well beyond what is found in CD, DVD, and DVR.

A typical arrangement for optical disks is shown in Fig. 1. Light from a laser passes through a beam splitter and is focused onto a recording layer by an objective lens. The recording layer is on a disk that spins under the objective lens. The recording layer contains spiral tracks of mark patterns that differ in reflectivity from the area between marks. As the focused laser beam passes over a mark, the reflected light level changes. Changes in the reflected light level are sensed by using the beam splitter to direct a portion of the reflected light onto a silicon detector. The detector current, which is a representation of the mark pattern, is decoded to produce digital information. The fidelity of the detector signal determines the amount of data per unit length of track that can be decoded with high reliability.

The change in reflected light level as the spot traverses the mark is due to the scattering of light away from the objective lens in CD media where the marks are physical depressions called *pits* in the surface of the recording layer. Alternatively, the medium can be made of phase change (PC) material, where the marks are one material phase, say, amorphous, and the area between marks is another material phase, like crystalline. The crystalline and amorphous phases exhibit different refractive indexes and, hence, different reflection coefficients. PC material can be erasable. That is, the material phase can be reversed and overwritten many times. Erasable PC material is the basis of CD-RW and DVD-RAM products. Marks can also be formed in erasable magneto-optic (MO) material, where the polarization of the reflected light is changed upon reflection from the recording layers [2]. With MO media, the detection optics are more complicated due to the addition of polarization elements. Also, two detectors must be used to form a difference signal that reduces common-mode noise. MO media is not used in CD, DVD, or DVR products but is commercially available in other formats.

There are several factors that influence the fidelity of the detector signal. The most important factor for closely spaced marks is the focused spot size  $s$ , as illustrated in Fig. 2. Large

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<sup>1</sup>Density and capacity are calculated throughout this paper in the following way. Density =  $c/a/b \cdot 0.645$  Gb/in<sup>2</sup>, where  $a$  = minimum mark length ( $\mu$ m),  $b$  = track spacing, and  $c$  = channel bit multiplier. Total capacity on a 120-mm single-surface disk = Density  $\cdot$  1.69 GB. Table 1 lists many parameters from the text