Objective lens design for multiple-layer optical data storage

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Abstract. A number of aberration compensation systems are investigated for use with multiple-layer optical data storage. A Burch-type objective lens in conjunction with a Galilean telescope is found to be a compact, simple and effective optical system for spherical aberration compensation.
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Subject terms: multiple-layer disk; aspheric objective lens; optical data storage; aberration compensation; spherical aberration.

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1 Introduction

Single-layer optical disk systems are the most popular medium for optical data storage. These systems consist of a laser source, focusing objective lens, rotating disk, beamsplitter and detectors, as shown in Fig. 1. The laser diode provides a beam of light that passes through the beamsplitter and is focused onto the recording layer by the objective lens. The light is focused through the substrate that protects the recording layer from contamination. The objective lens is usually mounted in an actuator that controls the fine position of the focused spot on the recording layer. Light reflected by the substrate is directed by the beamsplitter onto a detector array that provides data and servo signals. The objective lens must compensate for the spherical aberration introduced by the substrate so that micrometer-sized laser spots are realized at the recording layer.

The recording layer consists of micrometer and submicrometer-sized features that alter properties of the reflected light. The features can be pits, reflective marks, or magneto-optic domains. Features are arranged in spiral tracks. Modulation of the reflected light at the detectors indicates the data pattern as the focused spot scans along a track.

The fidelity of the data signal at the detectors depends on the relative size of the focused spot and the data features on the recording layer. If the spot size is too large with respect to the features, contrast in the data signal is poor. In most systems, the smallest feature is 30 to 60% of the $1/e^2$ diameter spot size, which is approximately equal to λ/NA, where NA is the numerical aperture of the focused beam, and λ is the wavelength air. The density of the features on the recording layer varies between 0.3 and 1.6 $\mu\mathrm{m}^{-2}$, depending on the λ, NA and track pitch used by the system. The raw capacity of a single-layer system is given by the product of the useable area on the recording layer and the average feature density.

Multiple-layer optical storage disks are currently being investigated[1] as extensions to single-layer systems. These systems can have five or more storage layers on which optical data are stored, as shown in Fig. 2. The capacity of each layer of a multiple-layer system is nearly the same as a single-layer system. However, the total capacity is N times greater, where N is the number of layers. Data from layer N is read by focusing light through the substrate and intervening $N-1$ storage layers.

With a multiple-layer system, there is the possibility that information from more than one data layer can be simultaneously detected. This phenomenon is known as interlayer crosstalk, and complicates the readout process. To minimize crosstalk, each layer is separated by $d \geqslant 50\ \mu\mathrm{m}$ and is read individually. The focused spot size on each layer must be as small as possible to maximize capacity.

Spot size can increase due to spherical aberration. The thickness t_n affects the amount of spherical aberration introduced. Figure 3 displays the variation in spherical aberration introduced by a $\lambda = 550$ nm, NA$=0.6$ beam focused through substrate thicknesses from $t = 0.4$ mm to $t = 1.2$ mm, where the system is compensated at $t = 1.2$ mm. Spherical aberration varies linearly with the coverplate thickness. The objective lens used for multiple layer data storage must compensate for varying amounts of spherical aberration and maintain a high NA over the entire multiple-layer thickness range. In addition, multiple-layer data storage at the blue and red wavelengths is also pos-

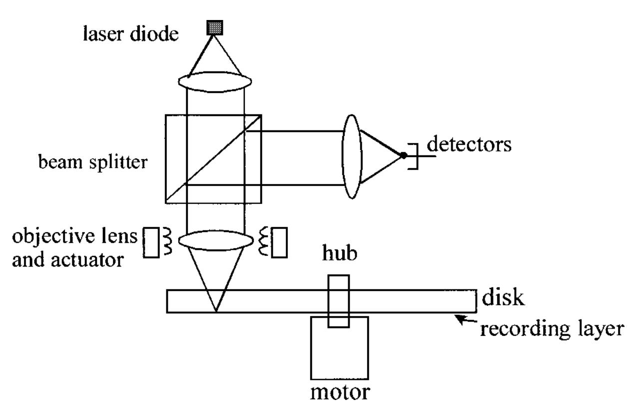

Fig. 1 Typical single-layer optical data storage device.

