

Design and Fabrication of Fiberlenses for Optical Recording Applications

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The novel design and fabrication of a microlens on the front end of a single-mode fiber is described. The beam quality and spot size for optical recording applications are analyzed. A hyperbolic-shaped microlens on a single-mode fiber with focused spot of $1/e^2 = 0.82 \mu\text{m}$ (x -direction) and $0.89 \mu\text{m}$ (y -direction) at $\sim 145 \mu\text{m}$ working distance was achieved by a simple fabrication procedure. [DOI: 10.1143/JJAP.41.1834]

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1. Introduction

Optical disk systems are being developed with higher speed and density. Due to this trend, conventional lenses and their mountings with substantial mass will face difficulty regarding fast access motion. Moreover, tight tolerance in the optical path requirement limits the development of near-field optics using flying head systems.

Optical fibers have the advantages of low weight and high flexibility when used as light-guiding media. Fibers can overcome the tight tolerances found in high numerical aperture (NA) optical paths and can reduce the number of components, therefore reducing the cost and weight. Thus, fiber systems are a good choice for high-speed access that is to be applied in next-generation dynamic flying head systems in optical data storage.

Microlenses formed on the end of single-mode fibers (SMFs) are widely used for optoelectronic passive elements to facilitate laser-to-fiber coupling for optical communication systems. The objective of the coupling scheme is to (1) maximize the coupling efficiency and (2) minimize the optical feedback due to Fresnel reflection from fiber to laser. Several authors have proposed techniques for producing such end-of-fiber lenses as laser-to-fiber coupling elements.^{1–6} These techniques include photolithography,³ chemical etching,⁴ mechanical polishing,⁵ and thermal melting.⁶ The lenses are minute in size, where the radius of curvature is only a few micrometers, and they have a short working distance of less than $10 \mu\text{m}$.

Though these microlenses show fine performance, they are not adequate for use in optical scanning systems. First, these lenses require relatively cumbersome fabrication processes to ensure small microlens radius of curvature. Second, the minute working distance less than $10 \mu\text{m}$ can easily allow contact between the front edge of the microlens and the spinning disk. Finally, the short working distance between microlens and medium will result in high optical feedback due to Fresnel reflection from the lens front end, which will degrade the readout signal.

In this paper, we present a design and analyses of a fiber-front-end microlens used as a pick-up for optical data recording applications. The objective of our scheme is to achieve the smallest possible spot at a reasonable working distance.⁷ The

size of the focused spot for a thermal writing mechanism is directly related to the size of marks recorded on the medium. Also, the spot size determines the resolution of the system in the readout. A reasonable working distance is designed to avoid mechanical contact between the front end of microlens and the spinning disk.

2. Analyses

We designed a fiberlens with a large radius R compared to other published works.^{1–6} The distance between the SMF and the microlens is filled with a pure silica rod of the same diameter and same refractive index as the core of the SMF to avoid reflection, as shown in Fig. 1. The mode field radius W_0 is computed by the following formula.⁸

$$\frac{W_0}{a} = 0.65 + \frac{1.619}{V^{3/2}} + \frac{2.879}{V^6}, \quad (1)$$

where a is the core radius of the step-index fiber, and V is the normalized frequency $V = \frac{2\pi a}{\lambda_0} \sqrt{n_1^2 - n_2^2}$ (n_1 and n_2 are the refractive indexes of core and cladding, respectively). The mode field diameter $2W_0$ at wavelength $\lambda_0 = 0.6328 \mu\text{m}$ is about $4.3 \mu\text{m}$.

A hemispherical microlens at the front end is used as the focusing element. The length of the pure silica rod d is designed to control the focused beam waist W_i , which is defined as half-width at $1/e^2$ maximum intensity, and position Z_i , which is defined as the distance from the beam waist position to the lens front end. The relationships of W_i and Z_i as a function of propagation distance $g = d + R$, where R is the radius of the hemispherical lens, are shown in Fig. 2 under the

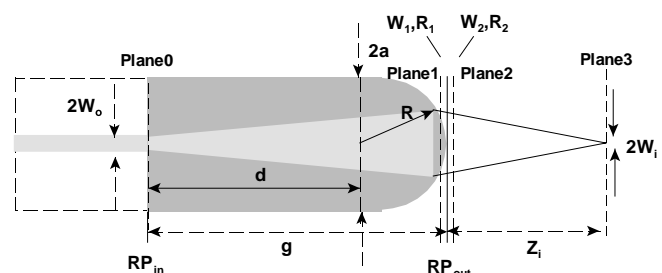


Fig. 1. Illustrated schematics of the microlens on the end face of the SMF (Refractive index of pure silica rod $n = 1.55$, cladding diameter $2a = 125 \mu\text{m}$, mode field diameter $2W_0 = 4.3 \mu\text{m}$ of single-mode fiber at wavelength $\lambda_0 = 0.6328 \mu\text{m}$).

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