A Novel Dual Focus Objective Lens for DVD/CD Pick-up Head

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Abstract — **A new dual focus objective lens of combinig aspherical surfaces of DVD and CD for DVD/CD pick-up head was designed. Numerical analysis based on the diffraction model were studied to trade off the spot size, side lobe, and energy ratio of DVD and CD. The hybrid aspherical surfaces of DVD and CD are optimized for low aberration. The spot size of full wave half maximum (FWHM) are 0.553 and 0.88μm for DVD and CD, respectively, measured from thus constructed double rings lens.**

I. Introduction

Digital versatile disks (DVD) have been viewed as the most promising product of new generation optical storage. High numerical aperture (NA) of 0.6 and short wavelength of 635/650nm are used to increase the data density. However, aberration of coma induced by the tilt of disk substrate is proportional to NA^3 and the thickness of disk substrate. Thus, the thickness of DVD disk substrate is decreased to 0.6mm in order to have enough tolerance of disk tilt. Since different disk substrates are used in DVD and CD, the high spherical aberration will degrade the focus spot while using the DVD objective lens to read the CD disks. Therefore, several approaches, such as twin lens[1], hologram lens[2], liquid crystal shutter[3], and annular mask lens[4] were used to read both the DVD and CD disks. In order to reduce the shperical aberration, most of these designs mask the marginal rays of the high NA lens to reduce the effective NA. In this paper, a novel dual focus objective lens having hybrid aspherical surfaces for suppressing the marginal rays is proposed for DVD/CD pick-up heads.

II. Principle

The spherical aberration (W_{40}) of a pick-up head in reading an optical disk can be written as

$$W_{40} = \frac{d}{8}\frac{n^2-1}{n^3}(NA)^4 \qquad (1)$$

Where d, n are the thickness and refractive index of disk substrate, respectively.

The spherical aberration increases as the incident ray height is increased. The aberration can be reduced by using an aspherical lens. The CD substrate, whose thickness is twice of DVD, still results in large spherical aberration. Using the separated objective lens is the most simple and direct way in reducing aberration at the expense of the complex actuator and the increased cost of optical head. On the other hand, by reducing the effective NA to compensate the spherical aberration due to different substrate thicknesses of is another approach. Therefore, a new dual focus objective lens which combines aspherical surfaces of both CD and DVD into a hybrid surface presents a feasible solution.

The dual focus objective lens, whose entrance surface combines two aspherical surfaces: the CD aspherical surface located in the central circle area, and the DVD aspherical

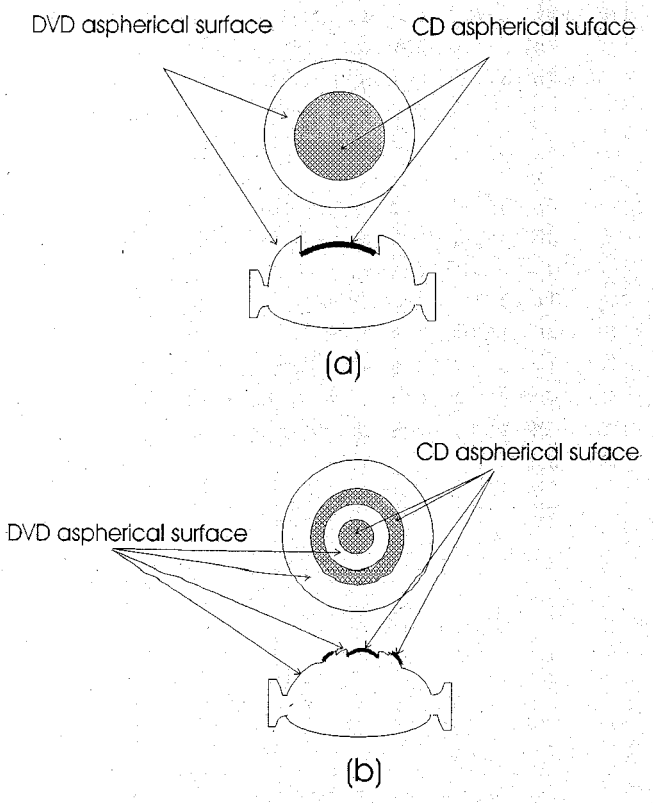

Fig.1. Schematics of (a) the single-ring and (b) the double-ring dual focus lens.

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surface located in the outward ring area, as shown in Fig. 1(a), is proposed. The exit surface is an aspherical surface which is designed to match both the DVD and CD entrance aspherical surfaces. Thus, the objective lens for both CD and DVD can be made into a single lens. However, the lens used in DVD shown in this scheme possesses an obvious sidelobe of the focusing spot due to the ring lens.

A multi-ring scheme is thus adopted to reduce the sidelobe of the DVD spot. The entrance surface still combines both CD and DVD aspherical surfaces, as illustrated in Fig.1(b), and the exit surface uses the same aspherical exit surface as shown in Fig. 1(a). Nevertheless, CD aspherical surface portion of the entrance surface is composed of the central circle area and the middle ring area, where the inner and outward ring areas form an aspherical surface for DVD lens.

III. Numerical Analyses and Experiment

The quality of focus spot of the objective lens thus designed is a function of the width and position of these rings. Numerical calculation based on the scalar diffraction model is made to trade off the quality of spots and the energy ratio between DVD and CD lens. Theoretically, the focus spot of DVD and CD can be calculated independently when the focus lengths of DVD and CD are different. Therefore, to calculate the focus spot of DVD, the region of CD is viewed as a mask, and vice versa, to calculate the focus spot of CD.

The focus spots quality of the lens was then measured. Several masks were made to put on the individual DVD or CD lens, where the NAs of DVD and CD are 0.6 and 0.38, respectively. The experimental results were compared with the numerical results to fine tune a suitable dual focus lens design. Then, the DVD and CD aspherical are optimized by CODE_V^{TM} . Finally, the dual focus lens is carved by a diamond turning machine. PMMA with refractive index of 1.49 is used to form this dual focus lens.

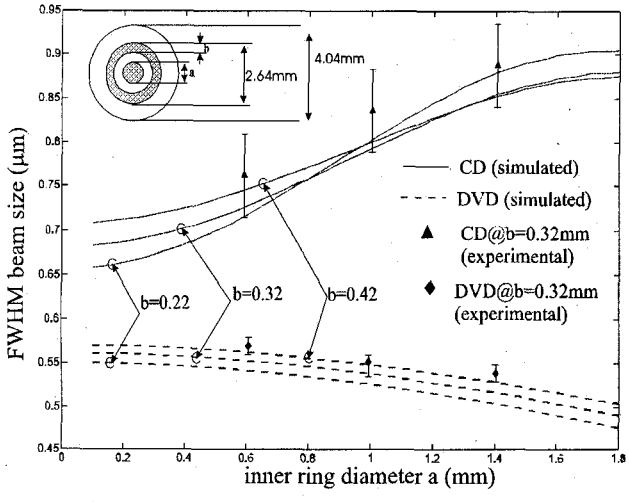

Fig. 2 The FWHM spot size of DVD/CD as a function of the structure of dual focus lens

IV. Results and Discussion

The DVD and CD spot size and sidelobe as a function of ring structure are shown in Fig.2 and Fig.3, respectively. Super resolution optical spots of DVD and CD lens can been seen in Fig. 2. The FWHM spot size for DVD lens decreases as the width of inner ring is narrower or shrinks inward, while the spot size for CD lens increases inversely. Although the sidelobe usually is an inherent drawback of the super resolution, the sidelobes of both DVD and CD lens here ranges from 10 to 0.3% , as the ring structure is changed. A compromised structure is to have the inner ring diameter in the range of 1.0 to 1.4 mm, which results in 5% less sidelobe for both DVD and CD lens, as shown in Figs. 2 and 3.

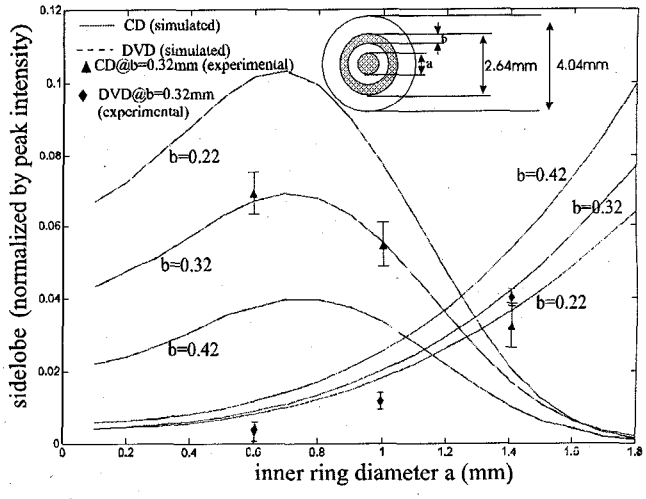

Fig. 3 The sidelobe of spot size of DVD/CD as a function of the structure of dual focus lens.

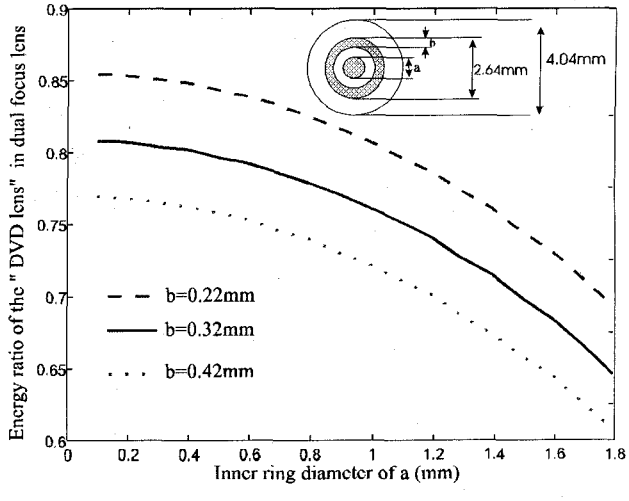

Fig. 4 The energy ratio of the "DVD lens" in hybrid dual docus lens

Energy ratio of DVD and CD is another factor to be considered. The energy ratio of the "DVD lens" in the dual focus lens is shown in Fig. 4. An reasonable value of the ratio is about 60 to 80%. Consequently, to trade off the spot size, sidelobe, and energy ratio of both DVD and CD lens, we chose the ring structure having an inner ring diameter **a** 1.1mm and the width of the ring **b** 0.32mm.

The root mean square (RMS) wavefront aberrations of a dual focus lens and a single DVD lens as a function of the image height are calculated, as illustrated in Fig. 5. The single DVD lens has an aberration larger than 0.07λ in reading CD disks, while the dual focus lens has an aberration less than 0.07λ as the image height is less than 80 and 170μm, for DVD and CD, respectively, implying that the tolerance of disk tilt will increase when the hybrid dual focus lens is used for CD readout.

The FWHM spot size of the proposed and constructed hybrid dual focus lens measured by a spot scanner is 0.553 and 0.88μm for DVD and CD, respectively, as shown in Fig. 6. The spot size and quality are adequete for the DVD pick-up to read both CD and DVD disks.

V. Conclusion

The dual focus lens is a low cost approach to implement the optical pick-up head to read both DVD and CD disks. The hybrid dual focus lens is an effective scheme to reduce aberration when disk substrates of different thicknesses are used. Moreover, the spot quality of optical super resolution with low sidelobe will improve the readout signal. From numerical calculation and experiment, the optimized hybrid dual focus lens shows that the FWHM spot size of 0.553 and 0.88μm for DVD and CD disk substrates, respectively, shall be adequete for DVD pick-up applications in reading both DVD and CD disks.

References

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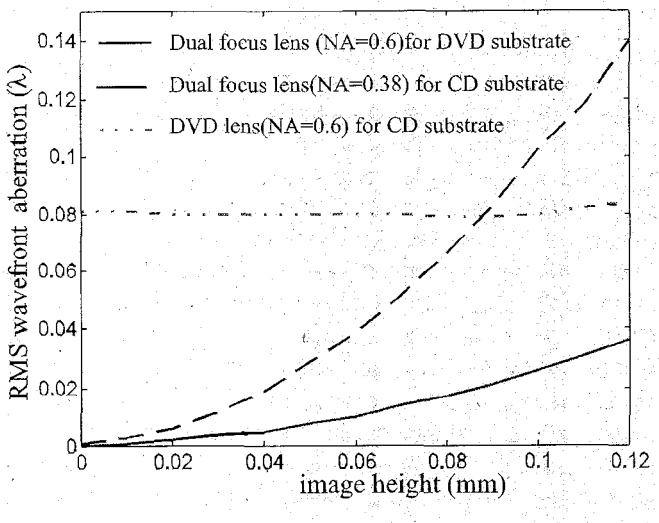
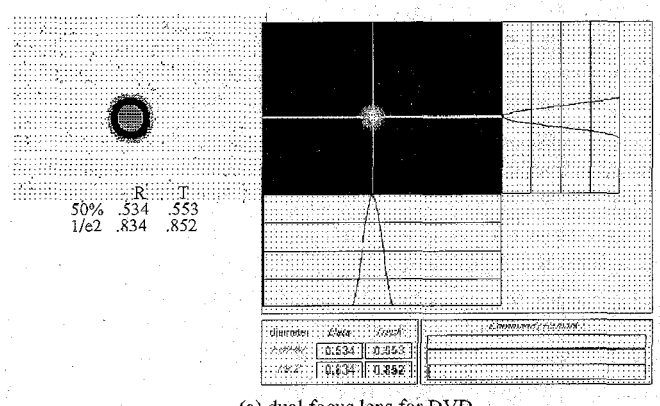
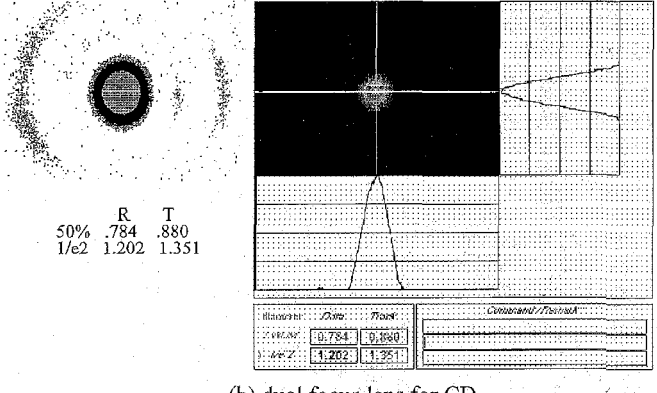


Fig. 5. The RMS wavefront aberration as a function of image height.



(a) dual focus lens for DVD



(b) dual focus lens for CD

Fig. 6 The focus spot profiles measured for (a)DVD and (b)CD disks using the hybrid aspherical dual focus lens