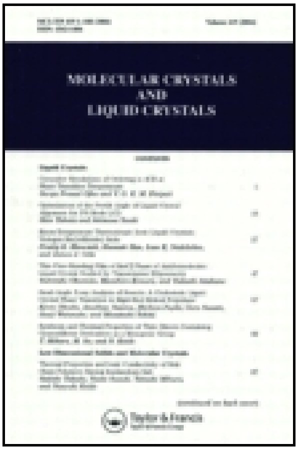

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An Advanced Active Optical Pickup with Crossed-Stripe Liquid Crystal Device for Compensation of Spherical Aberration

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An Advanced Active Optical Pickup with Crossed-Stripe Liquid Crystal Device for Compensation of Spherical Aberration

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To increase recording density in an optical disk system, increasing the numerical aperture (NA) is one effective method. But when NA becomes larger, the spherical aberration due to disk thickness error increases. We propose an optical pickup with a spherical aberration compensator using nematic liquid crystal (LC). Our LC device is composed of two LC cells each of which has X and Y stripe electrodes, respectively. We have actually fabricated the device and have confirmed that the desired property was achieved. We have also confirmed that the laser beam was modulated by the LC and was successfully focused.

Keywords: optical disk; numerical aperture; compensation; aberration

1. INTRODUCTION

The spot size of a laser beam is approximately proportional to λ/NA because of the diffractive effect, where λ and NA are wavelength and numerical aperture,

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respectively. Therefore, increasing the NA is one effective method to increase the recording density of an optical disk[1-4].

A large NA optical pickup, however, has an important problems, that is spherical aberration due to a disk thickness error. Figure1 shows the wave-front aberration as a function of the disk thickness error. This error in the present fabrication system is -50 to +50 μm, and the tolerance of the wave-front aberration is 0.07 rms λ as shown in Fig.1. It is seen from this figure that the aberration is just within the tolerance when *NA*=0.6, but in the case of *NA*=0.85, the tolerance of aberration is not satisfied. For a large NA system it is necessary to reduce this aberration by active devices.

For such a device, we propose an optical pickup using a crossed-stripe liquid crystal (LC) device.

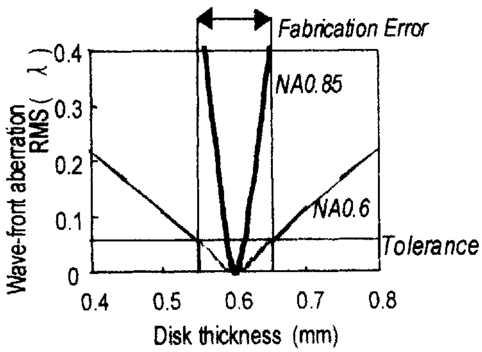


Fig.1 Wave-front aberration as a function of the disk thickness error (Standard thickness is 0.6mm)

2. REQUIREMENT FOR LC DEVICE

Our goals for the LC device are as follows.

(1) Alignment free in assembly.

(2) No-use of TFT-matrix because its fabrication process is very complex.

(3) Compatibility of the spherical compensation and the uniform deformation of LC alignment.

Then, we have considered a novel crossed stripe LC device as mentioned in the next section. The spherical aberration is rotationally symmetric and therefore the most suitable alignment of LC to compensate the aberration must be also rotationally symmetric, while such LC cell distorts the laser polarization.

The disk thickness can be compensated by phase distribution of two LC cells, whose phase transfer functions are $\phi=C_1x^2$ for X direction and $\phi=C_2y^2$ for Y direction, respectively. In the case of the disk thickness error of ± 50 μm and NA-number of 0.85, for example, C_1 and C_2 must be changed in the range of -2.0×10^{-3} to 2.0×10^{-3}.

3. CONSTRUCTION OF THE CROSSED-STRIPE LC DEVICE

The cross-stripe LC device consists of two LC cells and 1/2 wave plate as shown in Fig.2. Each LC cell is composed of glass substrates with X and Y stripe electrode and a planer electrode, respectively. The alignment of LC is homogenous and is perpendicular to the stripe electrode. A pitch of the stripe electrode is 10 μm. The device is placed in front of an objective lens to modulate laser beam. The LC alignments applicable to this LC cell are vertical alignment or bend alignment besides the homogenous alignment as not to change polarization state of the laser beam. According to the elastic continuum theory, the thickness of the LC cell is estimated more than 12 μm for bend alignment and more than 5 μm for homogenous alignment for LC material with birefringence Δn of 0.15.

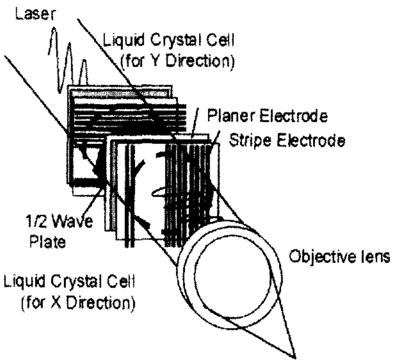


Fig.2 Structure of cross-stripe LC device

4. EXPERIMENT AND DISCUSSION

Modulation of the wave-front of laser beam is performed by the LC device with phase transfer functions of $\phi=C_1x^2$ and $\phi=C_2y^2$, respectively. These properties are obtained by applying suitable voltages to 640 electrodes individually. We tested the modulation by observing the fringes of interference of the ordinary and the extra-ordinary lights. Figure3 shows an example of the fringes. Considering the disk thickness error, C_1 and C_2 must be changed in the range of -2.0×10^{-3} to 2.0×10^{-3} as mentioned previously. Then, we took the following four conditions as typical examples.

$$\phi = (0.5 \times 10^{-3})(x^2 + y^2) \cdots (a)$$

$$\phi = (1.0 \times 10^{-3})(x^2 + y^2) \cdots (b)$$

$$\phi = (2.0 \times 10^{-3})(x^2 + y^2) \cdots (c)$$

$$\phi = (3.0 \times 10^{-3})(x^2 + y^2) \cdots (d)$$

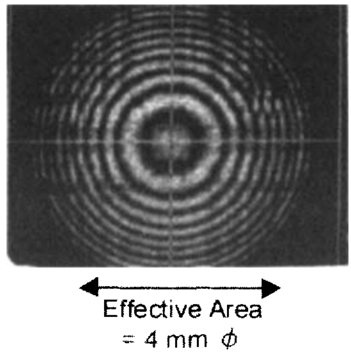


Fig.3 Fringe obtained by the LC device

Figure 4 shows results of calculation and experiment of the phase distributions for these examples. It is seen from this figure that the calculation and experiment agree very well. We also measured the profile of the beam spot. Figure 5 shows the experimental results of focussing. These are images on CCD when voltage control inputs a suitable voltage date. Compensation off, Y direction only and compensation on are compared. From these result we

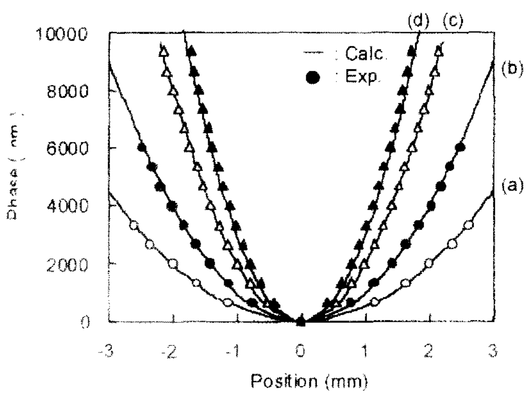
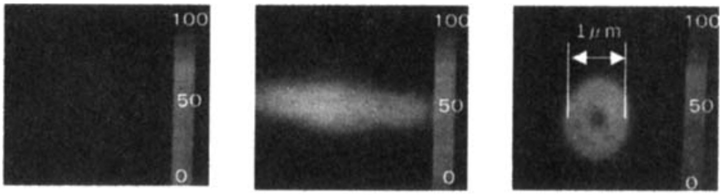


Fig.4 Phase distributions modulated by the cross-stripe LC device

confirmed that the laser is sufficiently focused by the objective lens and the crossed-stripe LC device.



(a) (b) (c)

Fig.5 Experimental results of focussing (a) compensation off, (b) Y direction only and (c) compensation on.

5. CONCLUSIONS

We proposed crossed-stripe LC device for a large-NA optical pickup and fabricated this device.

We have confirmed that the modulation of the laser beam was successfully made by our device. By using this device, ±50 μm disk thickness error in NA 0.85 optical system was compensated. We also tested the profile of the laser spot, and confirmed that the laser is focused sufficiently.

Our LC device has the advantage of both simplicity in pattern electrode structure and flexibility in the active matrix electrode structure. This compensation method is useful for multi-layer recording.

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