Optical Pickup Head Alignment using High-speed Aberration Detecting method

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1. Introduction

High-speed and high-accuracy alignment technology for optical pickup heads is necessary to respond the rapid increase of storage density and the rapid expansion of optical-disk market. Threat high-speed and high-accuracy alignment technology for optical heads has been studied. Especially allowable alignment error for DVD-RAM is very small, not only coma aberration (COMA) that is changed by tilt of objective lens but also astigmatism (AS) that is changed by position of collimator lens must be reduced by optical alignment. Conventionally that is aligned by means of spot method.[1] In this method COMA and AS are estimated by shape of optical spot observed in high magnification microscope. This method is difficult to get higher speed or higher accuracy as below. ① Spot position is moved according to lens alignment, therefore spot deflects from field of view and consecutive alignment is difficult. ②COMA and AS affect each other in their detection. ③Defocus affects detecting accuracy. In this report we discuss the prototype alignment system using high-speed aberration detecting method.

2. Theory and system overview

Since long optical path is required for the conventional interferometer, stable measurement is not easy. Besides it needs to collimate the output light from optical head so alignment time for it is not short. Therefore we suggest the shearing interference system shown in fig.1 with short path and without collimation before interference.[2] Output light from optical head is incident on the grating and is diffracted. The 0th and the ±1st order beams are incident to condenser lens overlapping partly each other. Grating pitch p is expressed by eq. (1).

$$p = \lambda / NA \qquad (1)$$

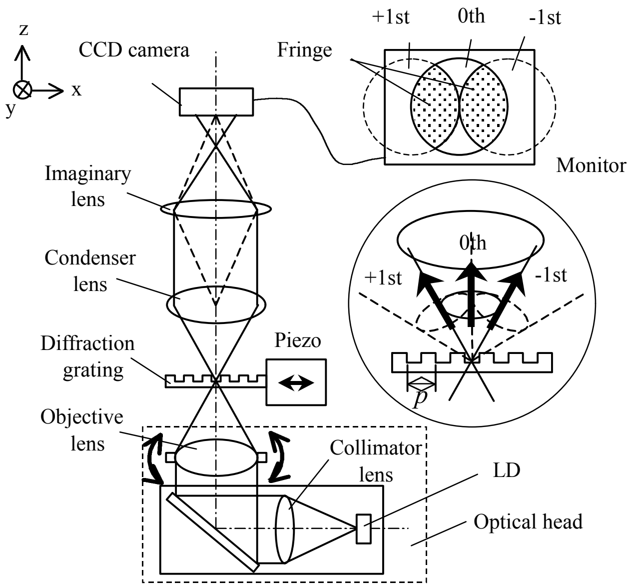
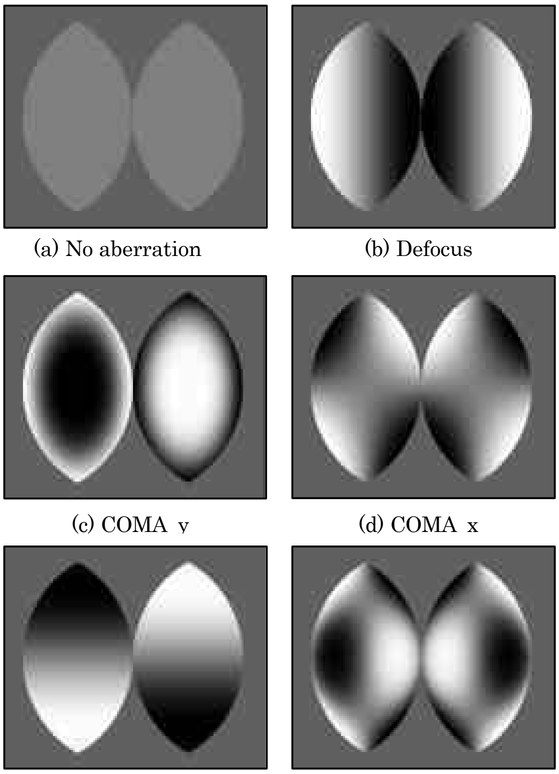


Fig. 1 Schematic of optical system

COMA and AS are estimated from fringe patterns generated at pupil plane of the condenser lens and focused onto the CCD. Simulated fringe patterns by each aberration are shown in fig.2. Wavefront aberration is applied by Zernike polynomials in a unit circle and sheared. Generally, since aberrations are compounded complexly and fringe patterns become complicated. Many algorithms to extract



(a) No aberration (b) Defocus

(c) COMA_y (d) COMA_x

(e) AS (f) SA3

Fig. 2 Simulated fringe patterns

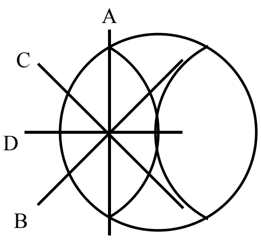


Fig. 3 Line areas for processing

aberration from differential interference pattern with relatively large shear ratio using 2-dimensional data and 2-axis shearing are suggested.[3] As shown in fig.3, we make a suggestion of using 1-dimensional data on certain lines and basically 1-axis shearing for high-speed detection of only COMA and AS. Basic 3rd and under order aberrations (COMA, AS, Defocus and spherical aberration (SA3)) are treated here. Phase distribution on these lines is expressed as below by Zernike polynomials.[4] Y-axis is line A, x-axis is line D, distance between two aperture is 2α. ϕ is the phase of wavefront and S is quantity of each aberration in wavelength unit. Line A is equal to $x=0$, on line A

$$\phi_{Defocus}(x,y)=\phi_{COMA\_x}(x,y)=\phi_{SA3}(x,y)=0$$
$$\phi_{AS}(x,y)=S_{AS}(x,y)\times 4\alpha y \qquad (2)$$
$$\phi_{COMA\_y}(x,y)=S_{COMA\_y}(x,y)\times(3y^2+6\alpha^3-4\alpha)$$

Line B is equal to $y=x$, on line B

$$\phi_{Defocus}(x,y)=S_{Defocus}(x,y)\times 8\alpha x$$
$$\phi_{AS}(x,y)=S_{AS}(x,y)\times 4\alpha x \qquad (3)$$
$$\phi_{COMA\_y}(x,y)=S_{COMA\_y}(x,y)\times(24\alpha x^2+6\alpha^3-4\alpha)$$
$$\phi_{COMA\_x}(x,y)=S_{COMA\_x}(x,y)\times 12\alpha x^2$$
$$\phi_{SA3}(x,y)=\phi_{SA3}(x,y)\times(96\alpha x^3+48\alpha^3 x-24\alpha x)$$

Line C is equal to $y=-x$, on line C

$$\phi_{Defocus}(x,y)=S_{Defocus}(x,y)\times 8\alpha x$$
$$\phi_{AS}(x,y)=S_{AS}(x,y)\times(-4\alpha x) \qquad (4)$$
$$\phi_{COMA\_y}(x,y)=S_{COMA\_y}(x,y)\times(24\alpha x^2+6\alpha^3-4\alpha)$$
$$\phi_{COMA\_x}(x,y)=S_{COMA\_x}(x,y)\times(-12\alpha x^2)$$
$$\phi_{SA3}(x,y)=\phi_{SA3}(x,y)\times(96\alpha x^3+48\alpha^3 x-24\alpha x)$$

Line D is equal to $y=0$, on line D

$$\phi_{Defocus}(x,y)=S_{Defocus}(x,y)\times 8\alpha x$$
$$\phi_{AS}(x,y)=\phi_{COMA\_x}(x,y)=0 \qquad (5)$$
$$\phi_{COMA\_y}(x,y)=S_{COMA\_y}(x,y)\times(18\alpha x^2+6\alpha^3-4\alpha)$$
$$\phi_{SA3}(x,y)=S_{SA3}(x,y)\times(48\alpha x^3+48\alpha^3 x-24\alpha x)$$

Thus COMA_y is estimated by the value of the 2nd order coefficient of phase distribution on line A. The other aberration doesn't have the 2nd order component on it. COMA_x is estimated by the value of difference on the 2nd order coefficient between line B and C. AS is estimated by the value of the 1st order coefficient on line A. This algorithm estimates COMA and AS independently of Defocus and SA3. The 1st order coefficient on line D estimates Defocus. This algorithm overcomes the spot method's problems as below. ① High-powered microscope is not necessary and field of view is wide. ②COMA and AS are estimated independently. ③Defocus does not affect COMA and AS detection.

3. Prototype system and experiment

Aberration detecting part is shown in fig.1. The diffraction grating is driven by x-axis piezo stage and intensity distribution of fringe pattern is transferred in phase distribution by fringe scanning method.[5] The optical heads are adjusted by detected value of aberration. Total processed data number is about 1 000 whereas conventional reconstruction method processes several 10000 and above. Axial displacement between the grating and optical spot appears in fringe patterns as defocus. The grating and the piezo stage are located on z-axis stage and controlled by detected value of defocus, although defocus does not affect COMA and AS detection.

One example of fringe patterns generated in this system is shown in fig.4. The 0th order beam and the ±1st order beams are overlapping partly each other and two rugby-ball-shaped fringe areas are formed.

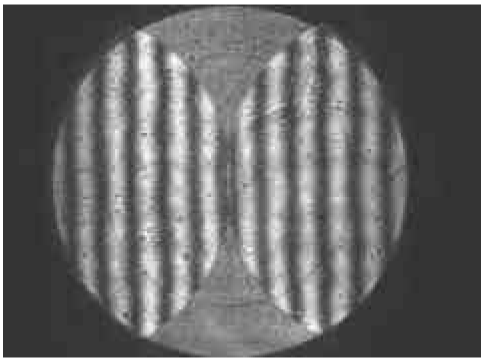


Fig.4 Generated pattern

Requiring time for aberration detection is 0.33 s consisting of image importing time of 0.14 s, auto-focus-control time of 0.1 s and processing time of 0.09s.

Detection accuracy is estimated and results are shown in fig.5 and table 1. AS in optical heads has been reduced by this prototype system or the spot system and has measured by conventional interferometer. COMA in these optical heads has been measured by this prototype system and the spot system, and conventional interferometer as a standard. Difference between values detected

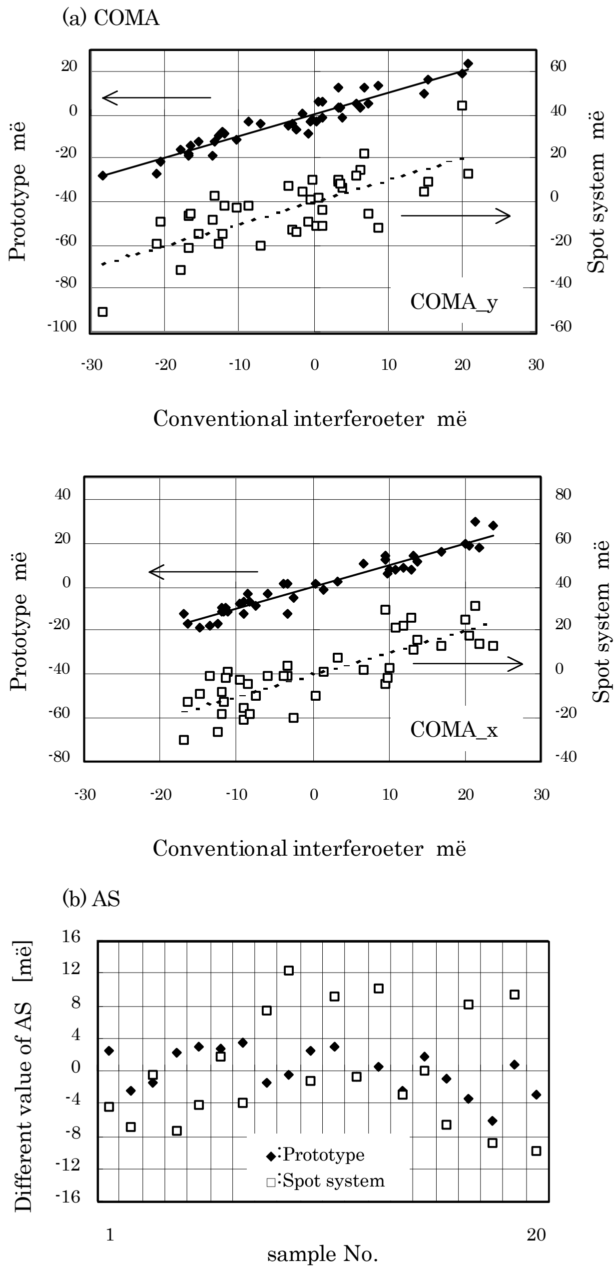


Fig.5 Detection accuracy of COMA and AS

by this prototype and by the interferometer are 3.7mλ for COMA and 2.7mλ for AS at 1σ, smaller than that between by the interferometer and by the spot system in both COMA and AS. Thus this prototype system has higher aberration detecting accuracy than the spot system.

Change of detected value by ±100 μm misalignment in optical axis between this system and optical heads is as small as repeatability of 1.5mλ at 1σ shown in table 1. Allowable

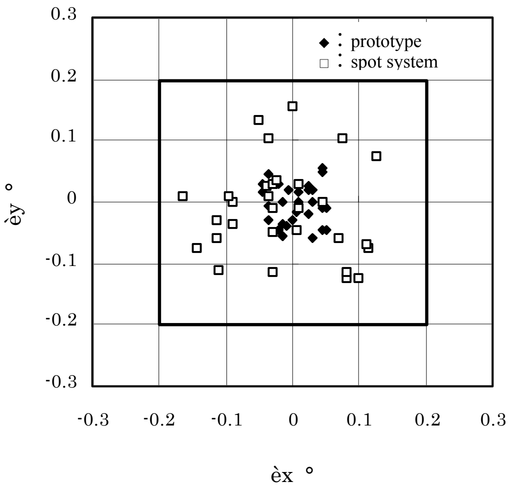


Fig.6 Residual tilt

Table 1 Comparison with conventional system

		Spot system	Prototype system
Repeatability of measurement (σ)		3mλ	1.5mλ
Accuracy of aberration detection (σ)	COMA	10mλ	3.7mλ
	AS	7mλ	2.7mλ
Misalignment of tilt (3σ)	x-dir.	0.25 °	0.09 °
	y-dir.	0.23 °	0.1 °
Aberration detecting time		several sec	0.33sec
Alignment time	COMA	45sec	20sec
	AS	45sec	10sec

misalignment is about ±100μm, that is larger than conventional interferometer method stated above in tenfold and above.

Alignment accuracy and alignment time are shown in fig.6 and table 1. Optical heads have been adjusted by this prototype system or the spot system. Signal jitter of that adjusted by this prototype system has been smaller than that by spot system. Residual tilt, that is tilt amount of optical head required to get minimum jitter, is shown in fig.6. In this prototype system that value is under 0.1deg at 3σ and smaller than 0.2deg required for DVD-RAM optical heads and smaller than that of spot system. Besides this prototype system has realized 1/3 alignment time of it.

4. Conclusion

For high-speed of alignment process on optical heads, an optical system based on shearing interference by grating has been applied and an algorithm that extracts aberrations from fringe patterns using 1-dimensional data on certain lines and basically 1-axis shearing has been devised. Thus the DVD-RAM optical-heads alignment system has been developed. This prototype system has realized 2 times and above as high-accuracy as the conventional spot system, attaining 1/3 alignment time of it. This technology can be applied easily to higher-NA type optical-heads for the next generation. Besides this can be applied to alignment of group-type lens with higher NA.

References

1) K.Ishijima and H.Kase, Optics alliance, 5, 6 (1994) 34.
2) K.Takada, M.Nakajo, K.Nishii, K.Kasazumi, Ext. Abst. (Kansai Meet. 2000); Japan Society for Precision Engineering, B12.
3) G. Harbers, P. K. Kunst and G. W. R. Leibbrandt, Appl. Opt., 35, 31 (1996) 6162.
4) K.Takada, H.Mochizuki, M.Nakajo and K.Nishii, submitted to J. Jpn. Soc. Prec. Eng.
5) P.D.Groot, Appl. Opt., 34, 22 (1995) 4723.