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고 용량 광 정보 기록 장치를 위한 새로운 접근.

New Approaches for High Capacity Optical Data Storage Systems.

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1. Design aspects of Waveguide Hybrid Advanced MEMS(WHAM)

Three different versions of high numerical aperture (NA =1.9) 0.3° field diffraction limited WHAM lens systems are designed for hi-density data storage by using over-hemi-cylinder surfaces. A prototype WHAM lens with NA=1.23 is also discussed. Detail of unique tolerance issue is presented.

The hybrid recording system proposed by Rauch et al. uses two kinds of fields(1). One is the magnetic field that controls bit length, and the other is an optical beam that controls track width. The optical module uses a fiber-optic input coupler and focuses to a small width in the radial direction on the disk. It is possible to make the optical module, shown schematically in Figure.1, as a waveguide system by using MEMS technology. The use of MEMS technology allows for flexibility to include other opto-mechanical elements into the system. It is very convenient to assemble the whole lens system into one body at the time of production. We call the concept wave-guide hybrid advanced MEMS (WHAM).

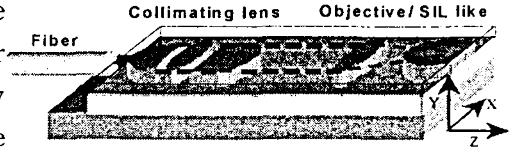


Fig.1. Lay out of the WHAM lens system

The waveguide behaves like a collection of two-dimensional toric optical elements. The mode index is analogous to the refractive index of normal optical elements. The extent of index selection is related to the thickness range of waveguide layers confined by the modes that can be transmitted inside that layer. In case of a SiN material, only two (m=0,1) modes can be transmitted for the thickness variation range 100nm to 400nm. The index changes for the fundamental mode induced by these thickness variations are from 1.75 to 2.05. Consideration of possible manufacturing complexity mandates that we use as few thickness as possible in designing the WHAM system. In this article, we discuss design of the lens system in detail for a two-index system.

Because it is made by MEMS technology, we can control the WHAM shape on the x-z plane and also control the thickness in the y direction, as shown in Figure1. In the y direction, the WHAM structure works only as a waveguide. In the x-z direction, it works as a lens system. Optical performance can be optimized only in the x-z direction. Design constraints contain significant differences between the WHAM lens system and classical lens design. For example, there is no edge or center thickness limitation, and there is no difficulty in aspheric shaping of lens surfaces relative to a sphere. (Of course the surface quality that is related to the tolerance should be analyzed.) Because the index range (1.75 to 2.05) is not large, it is difficult to make a high numerical aperture system with a small number of lens elements. One unique difficulty is that the system performance is extremely sensitive to index changes induced by y thickness variations. Also, the system is sensitive to the alteration of the image position at the last surface. The collimator numerical aperture should be large enough to accept the total fiber beam divergence. The full width -at- $\frac{1}{e^2}$ spot size is $\frac{\lambda}{NA}$. The setup design parameters are shown in Table.1. Three refraction pairs (n_{HIGH}/n_{LOW} =2.05/1.75, 2.05/1.85, 2.05/1.9) are used. Steps in the design process are as follows.

Step1) Divide the total system into 2 modules: front collimating and rear objective parts : ①front part; NA_o=0.2, input layer index no= 1.75,1.8 and 1.9. ②real objective part; NA_i= 1.9,

Step 2) Optimize each module separately.

Step 3) Constitute the boundary conditions : ①control the off axis aberration for the misalignment tolerance ②Any surface can be an aspheric shape in case of necessity2, except the last element (last WHAM lens input surface is circular cylindrical and the output end is flat)

Step 4) Combine modules into the total system and re-optimize.

The total optical system is configured by combining the infinitely conjugated collimator and objective lens, where $1/M \cong 0.105$. Three different kinds of combined WHAM lenses are re-optimized by using the 1st order system data that are displayed in Table.1. The resulting WHAM systems are shown in Figure.2, and their MTF performances are displayed in Figure 4. Vector diffraction theory(2, 3) should be introduced for more detailed understanding and the high NA near field optical system, but in this paper we confine our analysis to geometrical procedures and scalar diffraction .

SPECIFICATION DA			
WAVE LENGTH (nm)	780		
INDICES PAIR	2.05/1.75	2.05/1.08	2.05/1.9
NA	1.89	1.9	1.9
INFINITE COJUGATE			
EFL(mm)	0.7653	2.4828	3.7549
APERTURE STOPE(mm)	0.989	0.977	0.982
AT USED CONJUGATE			
MAGNIFICATION	-0.105	-0.1049	-0.1057
TOTAL LENGTH(mm)	5.53	5.98	6.6
FIBER INOUT TOLERANCES(Xaxis)			
ALIGN HEIGHT(mm)	0.015	0.02	0.012
FIELD ANGLE(deg)	0.2	0.25	0.3

Table 1. First order WHAM data

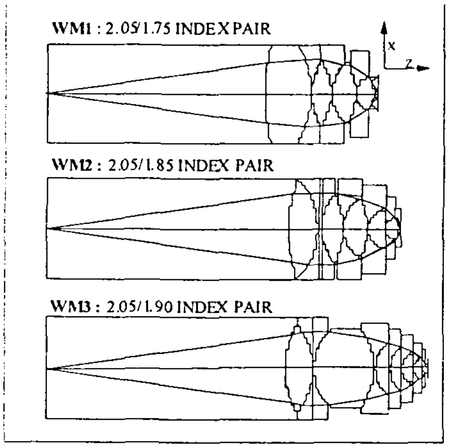


Figure 3. Total WHAM system layout

2.Advanced Lens Design for the two-photon bit-wise 3D memories.

Two different types (high-NA and low-NA) of objective lens for the multi-layer data storage system are designed. For the low-NA system, Galilean telescope spherical aberration(SA)(4) compensator combined with Geltech lens is designed and its focus performance for allowable depth range in the recording medium is analyzed. For the high-NA system, near-field SIL system without compensation is investigated. Optimum SIL system design for the high NA application is achieved by considering hyper-hemi spherical SIL and hemi-spherical SIL system. Extended allowable defocus range is obtained by using the optimum SIL system design.

2-1. Low NA (Far-Field) SA Compensation System

Using a Galilean Telescope system as a compensator and Geltech 350340 aspheric lens as a characteristic objective lens precedes a custom low NA optical system design. A Galilean telescope is selected because of several merits listed below.

1) Overall length is small, but compensation range is relatively large.

2) It provides a simple SA control mechanism. By slightly changing the optical conjugate, the system can provide opposite sign of SA generation.

3) A relatively small number of elements are needed to setup the compensator

A magnification 2 Galilean telescope and Geltech aspheric lens are combined together and optimized to get the diffraction limited performance at NA=0.6. The layout diagram is shown in Fig.3. OAL is 11mm and field angle is 0.2. After changing T_F for moving focus position T_M through the depth direction inside media, T_Z distance is changed for compensation. Focus performance is checked at the every specific focus depth position and presented in the Table.2, which shows 2mm allowable focus changing depth range within 90% Strehl ratio and 0.05wave RMS wave-front aberration error. The amount of W_{040} and $SA_{longitudinal}$ at t=2mm, NA=0.6, n=1.5 and =0.685 is 17.5 waves and 0.13mm relatively.

T_{MEDIA}	T_{ZOOM}	T_{FOCUS}	$WAVE_{ERROR}$	Strehl(%)
0.1mm	1.145	2.394	0.048	91
0.4	1.075	2.232	0.025	98
0.8	1.012	2.070	0.007	100
$1.2_{nominal}$	1.533	1.668	0.002	100
1.6	2.435	1.224	0.014	99
2.0	3.735	0.771	0.035	96
2.4	4.536	0.458	0.128	52

Table.2. Focus performance data for NA=0.6 Galilean Compensator.

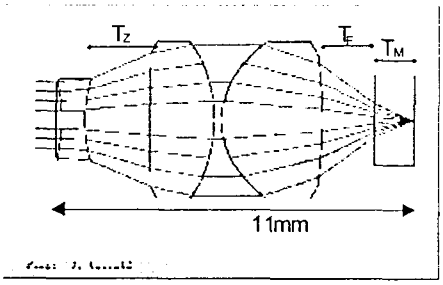
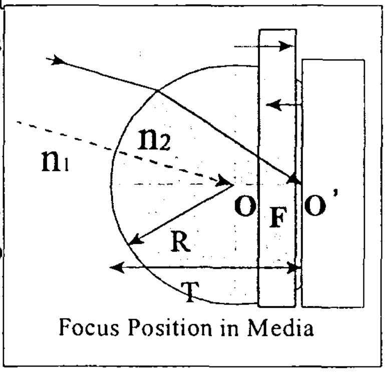


Fig.13 Layout of a low NA, SA compensation system
Check the focus performance at the different TM position by changing TF and TZ combination.

2-2. High NA (Near-Field) Optimum SIL System

A starting point for the optimum design condition of a high NA SIL system can be obtained from the results of hemi-spherical SIL(HMS) system and hyper-hemi spherical SIL(HYS) system. HMS shows that better performance is obtained more inside (thicker media layer) from the SIL center point (O in Fig.4.), and HMS shows better performance direction outside (thinner media layer) from the hyper spherical aplanatic point (O'in Fig.4.). So, the best stable condition and large allowable defocus range can be realized at the region of F in Fig.4. That range correctly coincides with the neighborhood of a stable focus position D in Fig.5. (SA graph of the perfect focus move inside a ball lens)$^{(5,6)}$



Focus Position in Media

Fig.4. Optimum focus condition for SIL system

In the optimum design, the nominal focus position is near the center point of allowable defocus depth range and is focused at the stable focus position. D in Fig.5. Optical performance at the nominal focus point has a small amount of residual aberration.

Allowable defocus range can be maximized by uniformly distributing optical potential of the optimum SIL system to the other focus positions (thinner or thicker focus position). Layout diagram of an optimum SIL system is shown in Fig.6. and its performance is diffraction limited. EFL=1.15mm, NA= 1.2, OAL=12mm. Off-axis field angle of this system is optimized at 0.5. Focus position 'SIL+d' can be moved in the longitudinal direction by changing the negative lens position 'Tz'. Focus performance data is checked as a function of the media thickness in Table.3, which shows 0.2mm allowable focus changing depth range within 80% Strehl ratio and 0.07waveRMS wave-front aberration error. The amount of W_{040} and $SA_{longitudinal}$ at t=0.2mm, NA=1.2, n=1.5 and =0.780 is 24.6 waves and 0.053mm respectively. Deep inside focus performance is better than thin media focus. SA generated by increasing media thickness is positive (Fig.7). By moving the negative lens closer to the positive power lens positive SA is also produced (Fig.8), but SA generated by moving the focus from the nominal 'D'in Fig.5. position to the inside media direction is negative. These SA components compensate each other and the total SA can be minimized in that region.

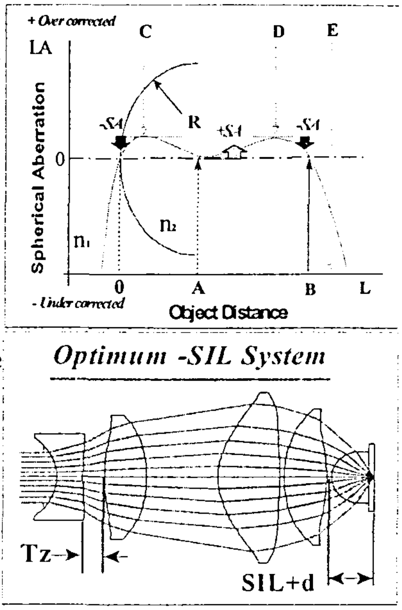


Fig.6. Layout of the optimum SIL system
NA=1.2, OAL=12mm. Check the focus performance at the different image position (SIL+d) according to Tz chanange.

ΔT (mm)	ΔSIL+d (μ)	ΔWave front	Strehl (%)
0.31	-70	0.08	79/76
0.22	-50	0.07	82/81
0.00	0	0.07	85/83
-0.20	45	0.07	82/81
-0.44	100	0.06	88/86
-0.56	130	0.06	91/82

Table.3. Focus performance data for optimum SIL

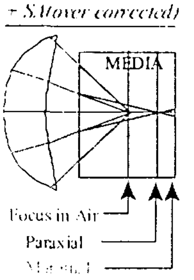


Fig. 7. SA in the Medium
Media moves inside from the focus in Air position

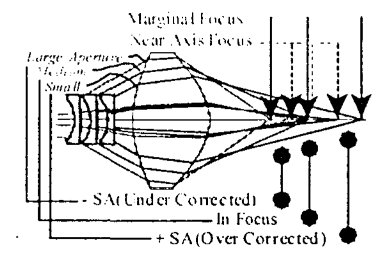


Fig. 48.SA from the Positive and Negative lens Combination

3.REFERENC

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