Phase-change Recording Characteristics Based on 1.84 NA

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ABSTRACT

Recording and readout characteristics were studied on phase-change discs with a Near-Field optics of 1.84 NA. The performance of the Near-Field optics is primarily determined by the characteristics of the objective lens, i.e. the solid immersion lens (SIL). We controlled the quality of the SIL by checking the wave front aberration during its assembling process. Even though the performance of the SIL is well controlled, the fluctuation of the gap distance could degrade the recording power tolerances. This is because the coupling efficiency of the evanescent field is quite sensitive to the gap distance. Bearing this point in minds, we evaluated the recording power tolerances on different groove geometries with different track pitches. We reached the conclusion that the effect of the gap fluctuation was negligible in the surface recording process. We will discuss the highest practical recording density by studying various combinations between the track pitch and the linear recording density.

Key words: Near-Field, NA, high density, power tolerance

1. INTRODUCTION

The Near-Field recording method is the surest technology for increasing the recording density of the optical disc in that we can store and retrieve digitalized information even at the recording capacities of 100 GB or more on a 120 mm-diameter disc [1]. The gap distance, which must be in the order of a tenth of the wavelength of the laser, is precisely controlled in our Near-Field optical disc system. Owing to this precision, a large coupling efficiency of the evanescent field is stably realized in it [2]. Thus the two key technologies supporting the system are the high NA objective lens and the high accuracy control method of the gap distance. We have already proposed a two-element objective lens of 1.84 NA including a super-hemisphere shaped solid immersion lens (SIL) [3] and the gap control method for which a total reflection is utilized [2]. In the next step we have to evaluate the true ability of these technologies paying attention to the performance they show on recording and retrieving the data.

The main objective of this paper is to discuss the recording and readout performance of our Near-Field optical disc system. We formed a conventional phase-change recording stack on DC groove substrates that were prepared thorough the PTM mastering process [4]. We tried to find the optimum groove geometry by changing the track pitch and the groove duty. We will discuss lastly the maximum practical recording density determined by our high NA objective lens.

2. PREPARATION OF THE SIL

The 2-element lens of 1.84 NA consists of a super-hemisphere lens (SHL) and an aspherical molded lens of 0.42 NA as shown in Fig.1. The super-hemisphere lens is made of high index glass S-LAH79 (n=2.07, OHARA INC.). The thickness of this lens Z_T must be optimized for minimizing the spherical aberration in connection with media structure. The total wave front aberration of the optical disc system as a whole is determined finally by the parameter Z_H. The order of the design tolerance of these parameters ranges from sub-microns to microns. A 5-axis goniometer shown in Fig. 2 was used for adjusting the parameter Z_H and for aligning the optical axes of the two lenses during the assembling process of the 2-element lens. Figure 3 shows an interference fringe pattern observed by use of the CCD camera in Fig. 2. From this result the imaging performance of the two-element lens, i.e. the wave front aberration, was estimated by fast Fourier transform. We compared the wave front aberration of the two-element lens and the quality of the readout signal. A 1-7 pp random signal was recorded on phase change discs with 160 nm track pitches that had three different land duties respectively. The linear velocity and the channel clock were set to 2.46 m/s and 66 MHz respectively.

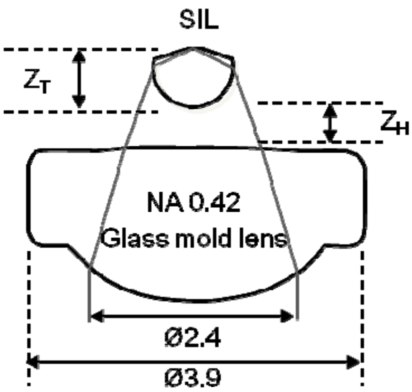

Fig. 1 A cross section of the the-element lens with important parameters.

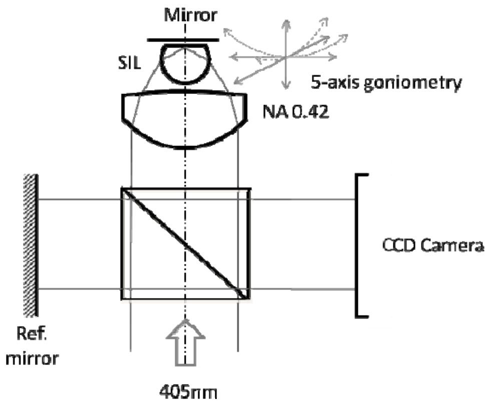

Fig. 2 Schematic drawing of the interferometer for assembling the two-element lens.

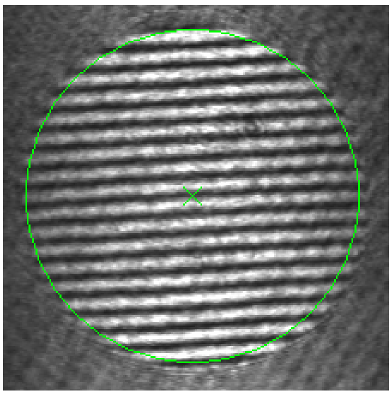

Fig. 3 The interference fringe pattern generated by the two-element lens.

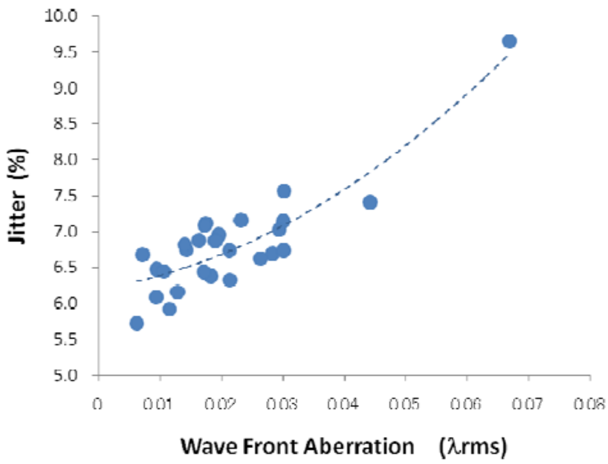

Fig. 4 Correlation between the jitter value and the wave front aberration.

In Fig. 4 the jitter value through the limit equalizer is plotted with respect to the corresponding aberration value of the two–element lens. We see from this figure that the aberration value of 0.03 λrms or less is small enough for obtaining satisfactorily small jitter value of 7.0 % or less. We used a two-element lens with a wave front aberration of 0.03 λrms for all the following signal evaluation.

3. EVALUATION OF POWER TOLERANCE

Because the gap distance has a crucial effect on the coupling efficiency of the evanescent field, fluctuation of the gap distance could bring about instability of the laser power intensity in the media. Actually different gap distances resulted in different recording sensitivities of the phase change media. Generally in a near-field optical disc system, therefore, the gap distance must be controlled with the accuracy in the order of nanometers. In figure 5 the laser power at which C/N of the 9T signal reaches 5dB is plotted against the corresponding gap distance employed.

The bottom power was fixed at 0.1 mW. We first found out the tilt angle (***d***) which brings the SIL tip contact with the media surface, varying the gap control voltage. The absolute gap distance (***G***) was calibrated using the radius of SIL tip (***D***) according to the equation, ***G=D·sin(d).*** From this result we can estimate the ratio of the laser power fluctuation to the gap distance fluctuation to be 1.3 [%/nm]. The residual focus error of our gap servo is 5 nm at 3000 rpm, on the other hand [5]. Therefore we have to take account of a laser power fluctuation of 6.5 % for evaluating the recording power tolerances.

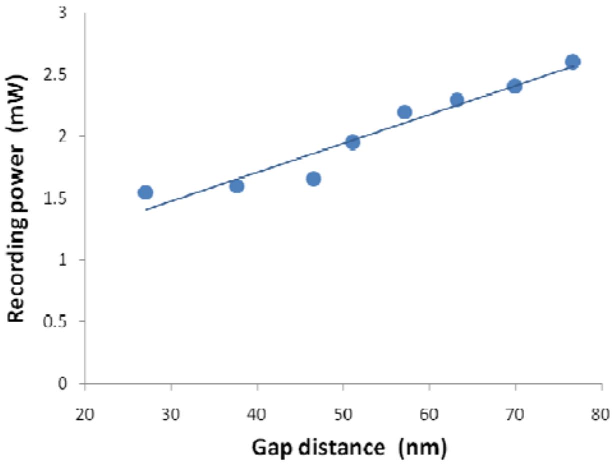

Fig. 5 The fluctuation of power coupling efficiency as a function of gap distance between SIL and media surface.

We measured the recording power tolerance setting the minimum bit length to 55 nm (2.46 m/s, 66.0 MHz). This condition corresponds to a recording capacity of around 100 GB when the track pitch is 160 nm. We have to classify the recorded track into the following three types. The data on an isolated track can be readout without the effect of crosstalk or cross-overwrite and will indicate the intrinsic S/N of the media. The data that is recorded on a track between two previously recorded tracks will be affected by the crosstalk. The data on the central track will be affected by the crosstalk and cross-write if recording is performed on the adjacent tracks afterwards. Figure 6 shows a typical eye pattern retrieved from the 100 GB signal on an isolated track, i.e. without crosstalk or cross-write. The optimum recording power was estimated based on the single carrier characteristics. The ratio of the peak power to the bottom power was fixed through the measurements.

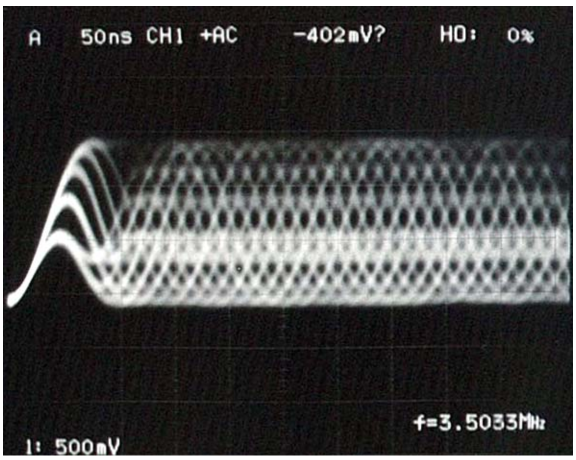

Fig. 6 The retrieved eye pattern from the 100 GB signal. The minimum bit length is 55 nm and the track pitch is 160 nm.

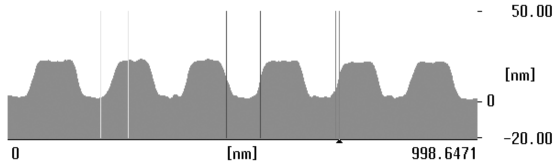

Fig. 7 A cross section of the groove with 160 nm track pitch fabricated by the PTM process.

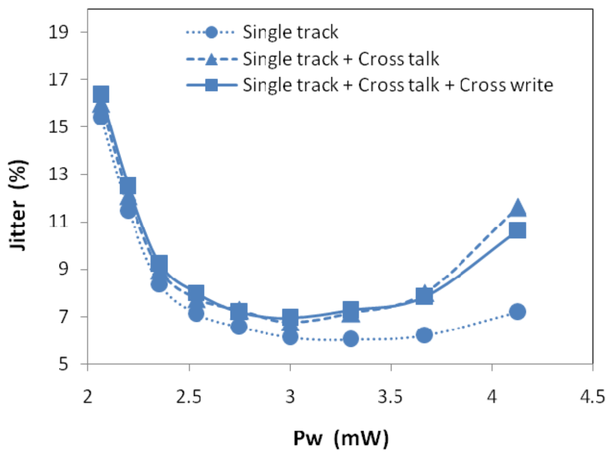

Fig. 8 The recording power tolerances at 160nm track pitch at a minimum bit length of 55 nm.

We prepared the substrates through the phase transition mastering (PTM) process [4]. The groove conditions of these substrates together with the recording performances are summarized in table 1. We made three different substrates with different land duty both for 160 nm track pitch and 146 nm track pitches respectively, as indicated in table 1. A cross section image of one of the substrates with 160 nm track pitch (No. 160-2) taken by AFM is shown in Fig. 7. Figure 8 shows the recording power tolerance on this substrate. Three curves correspond to different track types mentioned previously. We can see that the power tolerance is large enough and the influence of crosstalk or cross-write is very small. We can estimate the power tolerance to be ±32.3 % with a jitter criterion of 13 %. We can see that the crosstalk is dominant in this case because the influence of the data on the adjacent tracks is almost the same even if the recording sequence is changed. Fig. 9 and Fig. 10 are the corresponding results we obtained for 146nm track pitch. Although the influence of cross-write turned out to be clearly dominant at this track pitch, the recording power tolerances were about 20%, which was still satisfactrily large. We can also see the bottom jitter increased by around 1.5 % as the track pitch decreased from 160nm to 146nm. We consider that this was caused by the small land width indicated in Fig. 10 and is one of the future challenges.

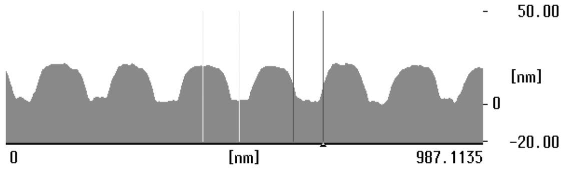

Fig. 9 A cross section of the groove with 146 nm track pitch fabricated by the PTM process.

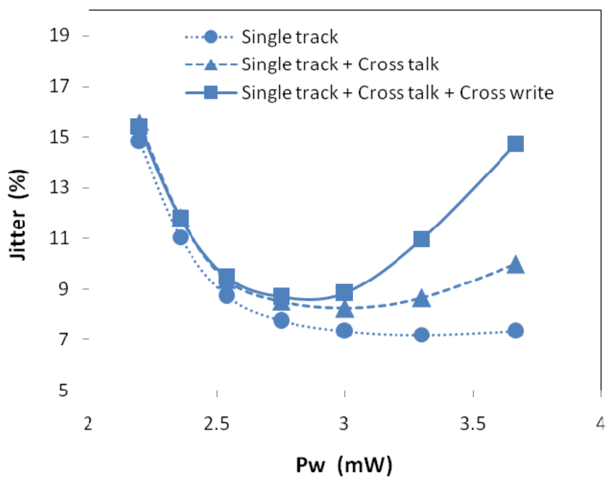

Fig. 10 The recording power tolerances at 146nm track pitch at a minimum bit length of 55 nm.

Table 1 The recording power tolerances at 146nm track pitch at a minimum bit length of 55 nm.

Substrate No.	Track pitch	Land duty	Bottom Jitter	Power Margin
160-1	160 nm	63.5 %	6.9 %	± 30.4 %
160-2	160 nm	54.9 %	6.8 %	± 32.3 %
160-3	160 nm	45.3 %	7.9 %	± 30.8 %
146-1	146 nm	57.5 %	8.7 %	± 20.7 %
146-2	146 nm	52.7 %	9.7 %	± 20.0 %
146-3	146 nm	48.6 %	10.7 %	± 13.8 %

4. CHALLENGE OF LARGER CAPACITY

In order to explore the possibility of recording larger capacity data, we decreased the minimum bit length from 55 nm to 45 nm by decreasing the linear velocity keeping the channel clock at 66 MHz. The bit error rate was measured through a PR121 processor for the data on a track including the effect of crosstalk and cross-write. The channel bit error rate as a function of the recording capacity is shown in Fig. 11. We obtained a reasonably small bit error rate of 5×10^{-4} even at the recording capacity of 120 GB. Note that the results obtained for the substrates with 146 nm and 160nm track pitches approximately are on the same line. Judging from this result, we anticipate room for higher track densities, i.e. higher capacities.

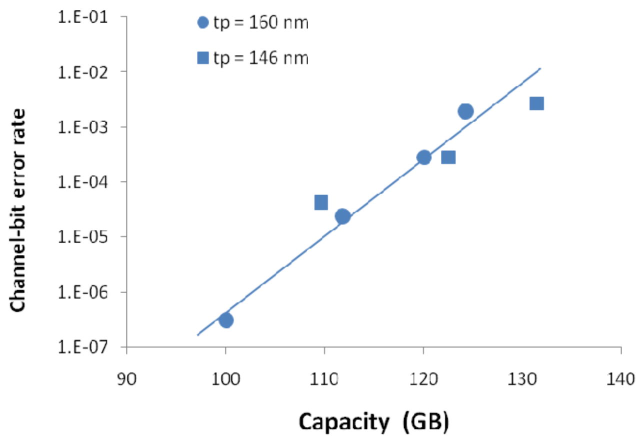

Fig. 11 The bit error rate as a function of the recording capacity with a minimum bit length of 45 nm/bit for 160nm and 146nm track pitches.

4. CONCLUSION

The recording characteristics were studied on phase-change discs with Near-Field optics of NA 1.84. We examined the signal properties on two track pitches, 160 nm and the 146 nm, varying the land duty. For 160 nm track pitch, we obtained a sufficiently large power tolerance of more than ±30 % at the recording capacity of 100 GB. Even for 146 nm track pitch, a large recording power tolerance of ±20 % was obtained. It is concluded that the gap fluctuation involved in our Near-Field optical disc system did not cause any serious problem during the recording and readout process. We recorded and retrieved the data whose capacity corresponded to 120 GB per 120 mm diameter disc, with a bit error rate of 5×10^{-4}.

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I was born on 5 September in 1960 at Toyama prefecture of Japan.

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