OPTICAL REVIEW Vol. 21, No. 5 (2014) 576–577

Short Note

Advanced Optimization Method for Spherical Aberration and Focus Offset for Optical Disc Drive

Tomo KISHIGAMI, Yusuke KANATAKE, and Nobuo TAKESHITA

Advanced Technology R&D Center, Mitsubishi Electric Corporation, Nagaokakyo, Kyoto 617-8550, Japan

(Received November 28, 2013; Accepted May 15, 2014)

We developed an optimization method for spherical aberration and focus offset for an optical disc drive using an elliptical approximation. This method measures the small number of points that are located at specific positions. Furthermore, it approximates a characteristic distribution to an ellipse and calculates the center of the ellipse as the optimal point. The effectiveness of this method is experimentally confirmed using Blu-ray discs with three types of protective layer of various thicknesses.

Keywords: focus offset, beam expander, spherical aberration

For high-capacity optical discs (for example, Blu-ray Disc™), it is necessary to optimize the spherical aberration that varies depending on the thickness of the protective layer disposed on the information reading surface of the optical discs.[1] Furthermore, in order to ensure the playback quality of the optical discs, it is necessary to optimize the spot diameter of the laser light irradiated to the information reading surface.

Figure 1 shows a schematic of the optical head and disc. To correct the spherical aberration, the beam expander (BEX) moves the collimator lens in the optical axis direction using the stepping motor. To optimize the spot diameter of the laser light, it is necessary to adjust the focus offset (FO) to determine the offset position of the objective lens.

Since both of the BEX and FO are mutually affected by the movement of the lens position in the direction of the optical axis, they cannot be adjusted independently. Therefore, the conventional adjustment method must be optimized by changing both parameters alternately. In one example of using this method, the optimal point is determined by changing the BEX and FO simultaneously.[2] In this method, it takes a long time to adjust the BEX and FO since there are a large number of changes in the BEX. Such adjustment is a time-consuming process in an initial adjustment of the optical drive. Thus, the adjustment time must be shortened.

In the case that the FO and BEX are ellipsoidally distributed, a method of adjusting the optimal point in a short time with a small number of measurement points has been proposed.[3] In this method, the axis of the ellipse characteristic distribution is assumed to be parallel to both axes of the FO and BEX. Therefore, if the characteristic distribution is inclined, there is a possibility for an incorrect adjustment.

We previously proposed the advanced method that can optimally adjust the BEX and FO in a short time even if the characteristic distribution is inclined.[4] In this study, we evaluated this method using discs with different types of protective layer of various thicknesses and confirmed its effectiveness.

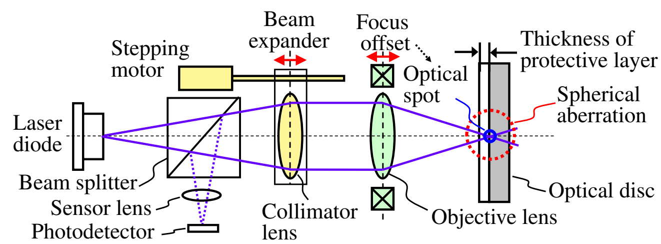

Fig. 1. (Color online) Schematic of optical head and disc.

Figure 2 shows the relationship between the characteristic distribution of RF signal amplitude and the adjustment method. The characteristic distribution is indicated as the grayscale intensity. In Fig. 2, one step of the BEX corresponds to a protective layer thickness of approximately 0.6 μm, and FO (%) is the percentage of the focus error signal amplitude. Figure 2(a) shows an example of the measurement points of the advanced optimization method. Here, the measurement points are indicated by circles and the arrow shows the order to change the measurement point. For elliptical approximation, 4 measurement points are required on each of the 3 lines (Lines A, B, C) to make quadratic approximation. The 12 measurement points can be reduced to 9 by sharing with a different line as shown in Fig. 2(a). The measurement point is changed in the order shown by the arrow from the initial position, and RF signal amplitude is measured at each point. To reduce the adjustment time, the number of changes in the BEX is minimized. Playback signal quality (e.g., jitter) can be used instead of the RF signal, the push–pull signal is difficult to be used because of its different characteristics.

Figure 2(b) shows an example of elliptical approximation. After measuring the RF signal amplitude at each measurement point, the estimation points are calculated and indicated by squares. The estimation points are calculated by estimating the positions of the BEX and FO to obtain the same RF signal amplitude level. Next, ellipse coefficients of Eq. (1) are calculated using the estimation points.

$$ax^2 + bxy + cy^2 + dx + ey + 1 = 0. \quad (1)$$

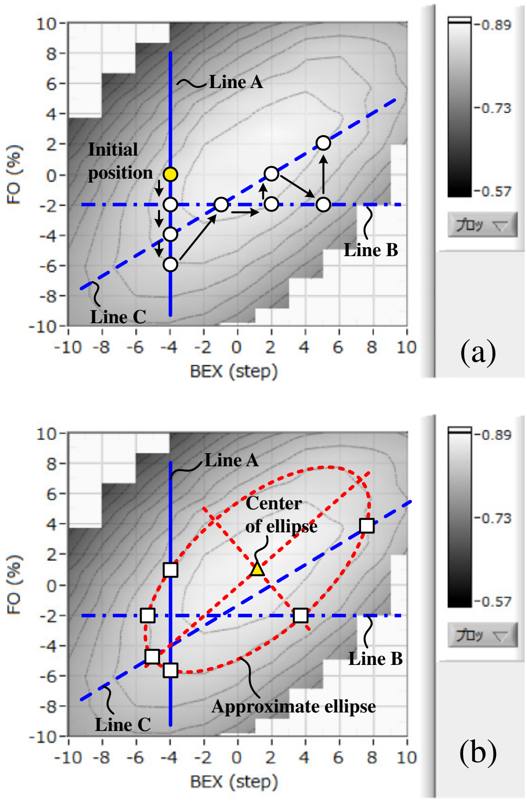

Fig. 2. (Color online) Distribution of RF signal amplitude and the adjustment method: (a) measurement points and (b) elliptical approximation.

Table 1. Experimental conditions.

Disc	Three types of disc (BD-ROM SL) (A: thin/B: typical/C: thick)
Number of trials	20 (each disc)
Initial position	Result of coarse adjustment of optical drive

Then, the center of the ellipse is calculated from ellipse coefficients and Eq. (2) as the best point (RF signal amplitude maximum point).

$$2ax_c + by_c = -d, \quad bx_c + 2y_c = -e. \tag{2}$$

As described above, the BEX and FO can be adjusted to the optimal point in a short time by the elliptical approximation.

Table 1 shows the experimental conditions for evaluating the adjustment accuracy of our method and Fig. 3 shows the distribution of adjustment results. In this figure, Discs A, B, and C have thin, typical, and thick protective layers, respectively. Moreover, Discs A and C correspond to the upper and lower limits of the BD standard.[5] Furthermore, the contour RF signal amplitude is 96% of the maximum value, which is indicated by a solid line. The optimal point (RF amplitude maximum point), initial positions, and adjustment results are indicated by a rhombus, crosses, and squares, respectively. As shown in Fig. 3, it was confirmed that all adjustment results were located near the optimal point without depending on the thickness of the protective layer and the initial position.

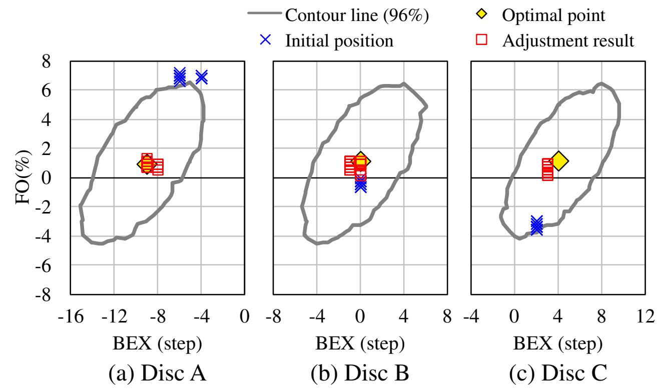

Fig. 3. (Color online) Experimental results (distributions): (a) thin, (b) typical, and (c) thick protective layer discs.

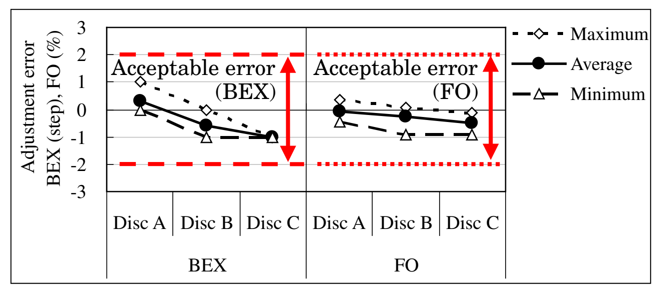

Fig. 4. (Color online) Experimental results (adjustment errors).

Figure 4 shows the adjustment errors (differences between the adjustment results and the optimal point) of the BEX and FO. As shown in Fig. 4, the adjustment error of BEX was within plus or minus 1 step and that of FO was within plus or minus 1%. Here, the acceptable adjustment errors of the BEX and FO are within plus or minus 2 steps and plus or minus 2%, respectively. In addition, it was confirmed that the BEX and FO can be adjusted in less than 0.7 s in all trials.

In conclusion, we developed an advanced optimization method for optimizing the spherical aberration and FO, and confirmed the adjustment variation using discs with different protective layers of various thicknesses. As a result, it was confirmed that the BEX and FO can be adjusted to a position near the optimal point for different protective layer thicknesses. Furthermore, the adjustment time could be shortened by reducing the number of changes in the BEX.

References

1) N. Ogata, Y. Kanazawa, M. Horiyama, S. Nishioka, T. Miyake, Y. Nakata, and Y. Kurata: Jpn. J. Appl. Phys. **45** (2006) 5807.
2) S. Horinouchi, S. Yumita, and T. Matsuo: Panasonic Tech. J. **54** (2008) 15 [in Japanese].
3) Y. Kanatake, T. Matozaki, and N. Takeshita: Proc. IEEE Int. Conf. Consumer Electronics, 2013, p. 296.
4) T. Kishigami, Y. Kanatake, and N. Takeshita: ISOM Tech. Dig., 2013, p. 194.
5) Blu-ray Disc Association: White Paper Blu-ray Disc™ Format 1.C Physical Format Specifications for BD-ROM (2012) p. 10.