# OPTICAL PICK-UP FOR DVD

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***ABSTRACT***

*The optical pick-up for DVD with CD (Compact Disc) compatibility is discussed. The difference of the substrate thickness between DVD and CD causes the different spherical aberration and prevents the laser beam from being focused into a diffraction limit spot size with only one objective lens. Several methods of reducing this aberration and possessing the compatibility with CD are proposed. The twin lens type optical pick-up is one solution of overcoming this problem. It incorporates objective lenses for both DVD and CD. Each lens results in an optimum focused spot without the extra spherical aberration for each type of disc.*

## 1. INTRODUCTION

The emerging multimedia system must be able to process a huge volume of visual data such as still pictures and full-motion videos. The developers involved are enthusiastic about the commercialization of DVD. This technology is expected to become a core medium in the multimedia market.

Aiming at penetration of DVD into the current CD-dominated market, DVD players or DVD -ROM drives have been earnestly required to possess the compatibility with CD. However, the specification of DVD differs from the one of CD with respect to many items. Table 1 shows the specification of DVD and CD. The track pitch and the minimum pit length of DVD are almost half of those of CD. Therefore a focused spot tiny enough for reproducing DVD is required. To realize the tiny spot, a high NA (numerical aperture) of 0.6 objective lens and a red laser diode of 635 or 650 nm are employed. From the point of view of the compatibility with CD, the most serious problem is the difference of substrate thickness between DVD and CD.

In this paper, first, we introduce several ways to realize the compatibility with CD, and then, we describe the twin lens type optical pick-up using two objective lenses which we proposed and developed.

Table 1. Specifications of DVD and CD.

| | DVD | CD |
|---|---|---|
| Diameter | 120 mm | 120 mm |
| Substrate thickness | 0.6 mm | 1.2 mm |
| Track pitch | 0.74 μm | 1.6 μm |
| Minimum pit length | 0.40 μm | 0.834 μm |
| Wavelength | 635 / 650 nm | 780 nm |
| Numerical aperture of objective lens | 0.60 | 0.45 |
| Data capacity | 4.7 GB | 0.65 GB |

## 2. METHOD OF COMPATIBILITY WITH CD

The laser beam transmitted through the transparent substrate of disc must be focused into a diffraction limit spot size in optical disc systems. As for the general pick-ups, aberration correction is given to the objective lens so that the spherical aberration is reduced to a minimum for each disc. Therefore as shown in Fig. 1, the laser beam cannot be completely focused if the thickness of the disc to be played is different from the one of that the objective lens can

Manuscript received June 10, 1996

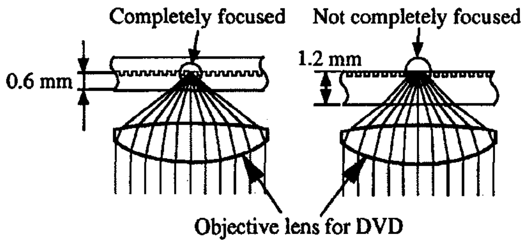


Fig. 1. Spherical aberration caused by substrate.

correct spherical aberration.

To avoid such a problem, several methods to reduce the spherical aberration and possess the compatibility with CD are proposed by several manufactures as follows:

(1) two optical pick-ups; one is for DVD and the other for CD,

(2) two objective lenses in one lens actuator as shown in Fig. 2 (A),

(3) two focal points using a holographic optical element as shown in Fig. 2 (B) [1],

(4) aberration reduction by decreasing numerical aperture during CD reproduction as shown in Fig. 2 (C).

In method (2), objective lenses for DVD and CD compensate the spherical aberration caused by the substrate thickness of DVD and CD respectively. Therefore each lens results in an optimum focused spot without the extra spherical aberration for each type of disc. In method (3), the holographic surface generates the zeroth order diffracted laser beam for DVD reproduction and the +1st order diffracted laser beam for CD reproduction. In addition, the holographic surface is designed so that the spherical aberration of the +1st order diffracted laser beam through the objective lens and a CD substrate is a minimum. In method (4), a liquid crystal plate (LCP) is used as a laser beam shutter. In CD reproduction a marginal part of the laser beam is cut by the LCP. Therefore the NA of the objective lens decreases effectively and the spherical aberration becomes small enough to reproduce CD.

## 3. TWIN LENS TYPE OPTICAL PICK-UP

### 3.1 Background of Twin Lens Actuator

An optical pick-up generally incorporates an objective lens actuator to keep the disc rotating in the right position without disc-face runout or off-track. The actuator controls movement of the objective lens both in the focusing and tracking directions. We developed the sliding and rotary type objective lens actuator as shown in Fig. 3 and applied it to various kinds of optical pick-ups so far [2]. For focusing control, upward-downward sliding is made along the shaft, and for tracking control, rotation is made around the shaft.

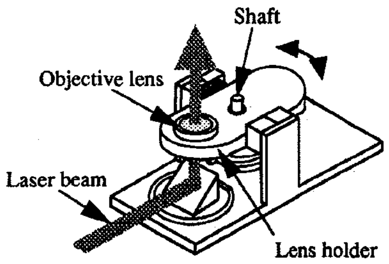


Fig. 3. Sliding and rotary type objective lens actuator.

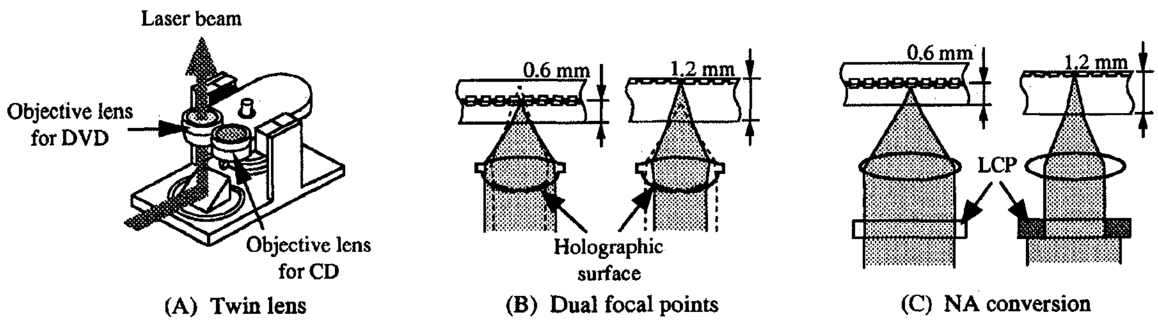


Fig. 2. Methods for possessing the compatibility with CD.

This technique of the sliding and rotary type lens actuator is easily utilized to realize a construction which allows the lens holder including two objective lenses to rotate around the shaft to select the applicable lens. The objective lens switching motion is achieved by sending a pulsed current to the tracking coils. Therefore this construction is an improved version of the existing sliding and rotary type actuator.

### 3.2 General specifications

We employed the method of using two objective lenses in one lens actuator for the compatibility with CD. Table 2 shows the specifications of the newly developed optical pick-up named "Twin lens type optical pick-up". Figure 4 shows the newly developed objective lens actuator and optical path layout. Figure 5 shows the external view of the twin lens type optical pick-up.

Table 2. Specifications of the twin lens type optical pick-up.

| Items | | Specifications | |
|---|---|---|---|
| Laser diode | Wavelength | 635 / 650 nm | |
| Objective lens | NA for DVD | 0.60 | |
| | NA for CD | 0.38 | |
| Error detection | Focusing | Astigmatism method | |
| | Tracking | Differential phase detection | |
| | | 3 beam method | |
| Photo diode | | with pre-amplifier | |
| Actuator type | | Sliding and rotary | |
| | | Focusing | Tracking |
| Sensitivity at 200 Hz | | 0.028 mm / V | 0.022 mm / V |
| Fundamental resonance | | 14 Hz | 30 Hz |
| First natural resonance | | ≥ ± 25 kHz | ≥ ± 25 kHz |

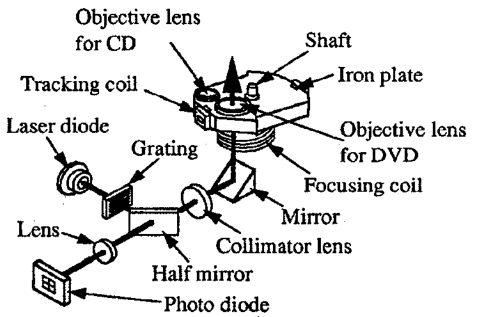


Fig. 4. Twin lens actuator and optical path layout.

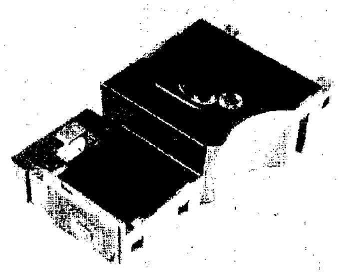

Fig. 5. External view of the twin lens type optical pick-up.

### 3.3 Objective Lens Actuator

The objective lens actuator we newly developed is an improved version of the existing sliding and rotary type actuator, so its construction and function is almost the same as the conventional single lens type actuator. The lens positioning mechanism using magnetism for the lens switching motion and the tracking motion is newly employed in this actuator. This mechanism consists of four tracking magnets, two tracking coils, and two iron plates as shown in Fig. 6. When DVD or CD is reproduced, one pair of tracking magnets opposing to the tracking coils is used for the tracking motion. The iron plates are provided within the lens holder located opposing to the tracking magnets. The lens switching motion is achieved by sending a pulsed current to the tracking coils. After the switching motion the other pair of tracking magnets opposing to the tracking coils

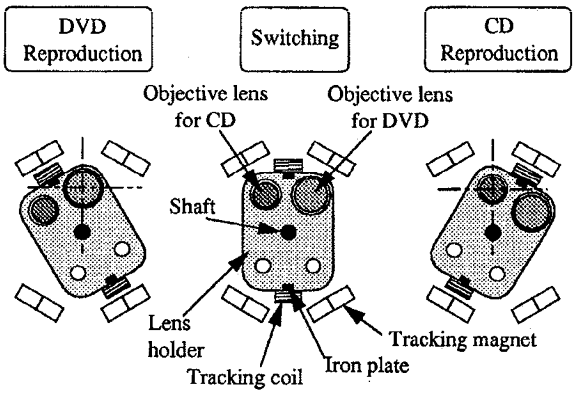


Fig. 6. Construction of twin lens actuator and mechanism of lens switching motion.

is used for the tracking motion. The magnetic supporting mechanism using the iron plates also acts for the focusing direction.

We evaluated the frequency characteristics of this twin lens actuator and obtained the results that higher order resonance frequencies are greater than 25 kHz for both the focusing and the tracking direction as shown in Fig. 7. No differences regarding the objective lens between DVD and CD appeared in the frequency characteristics. In addition, force constants for both direction are so high to be applicable for CD 8X.

The construction of the lens actuator can make its tilt angles initially adjustable for the tangential and the radial direction of discs, so that the focused spot can maintain the high quality in spite of using the high NA objective lens.

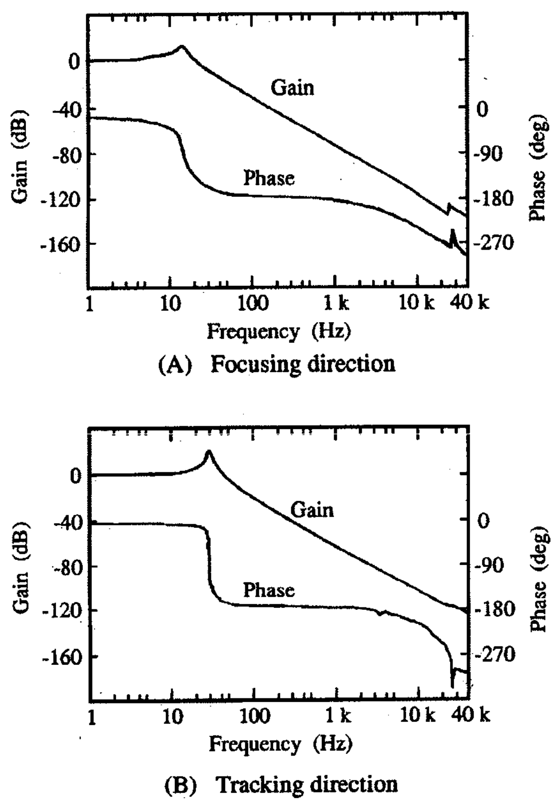


Fig. 7. Frequency characteristics of twin lens actuator.

### 3.4 Optics

A red laser diode with a wavelength of 635 nm or 650 nm is employed in this optical pick-up. As for CD, we employed the objective lens with a NA of 0.38 which is smaller than the conventional one of 0.45, since the wavelength is shorter than that of conventional CD pick-ups of 780 nm. The focused spot diameters of 0.9 μm (at $e^{-2}$) using the objective lens for DVD and 1.3 μm using the lens for CD are obtained.

Two types of tracking error detection are available. The three beam method is used for CD reproduction. The differential phase detection is used for not only DVD reproduction but also CD reproduction. The astigmatism method is used as the focusing detection for both discs.

In order to secure the reproduced signal quality, we employed the photo-diode with pre-amplifiers whose cut-off frequency is larger than 15 MHz.

### 3.5 Reproduced Signals

Figure 8 shows the eye-pattern signals reproduced from DVD and CD. Figure 9 shows the jitter characteristics of DVD against disc tilt angles. The bottom jitter is 8 %, and the tilt margins are about ± 0.8° for the radial direction and about ± 0.65° for the tangential direction.

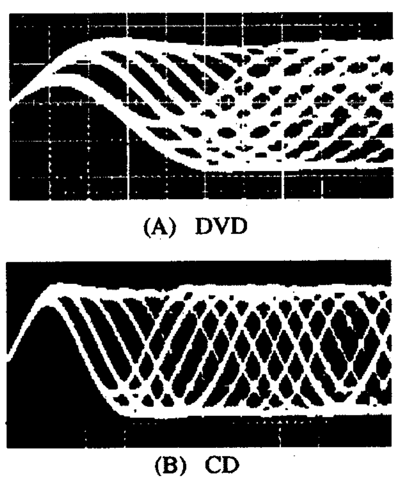


Fig. 8. Eye-pattern signals reproduced from DVD and CD.

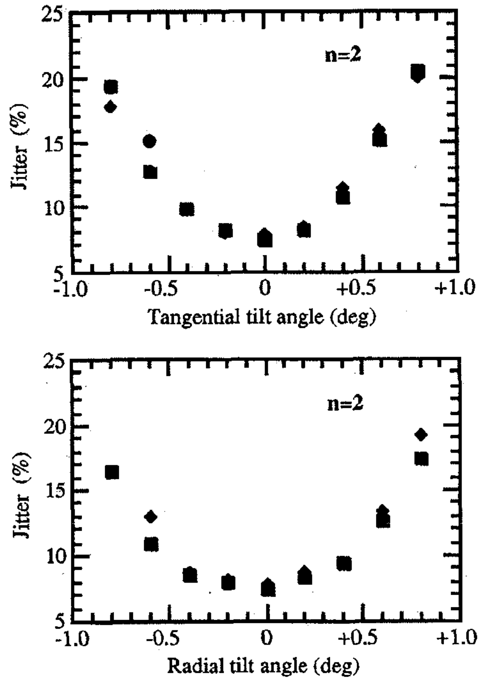


Fig. 9. Jitter characteristics of DVD against disc tilt angles.

## 4. CONCLUSION

We introduced the methods of CD compatibility proposed so far in optical pick-ups for DVD. In our model, we employed the twin lens type optical pick-up. This pick-up incorporates the sliding and rotary type objective lens actuator, on which two objective lenses are mounted. Each objective lens resulted in an optimum focused spot for each type of disc, as well as clear eye patterns in the reproduced signals.

**References**

[1] Y. Komma, S. Nishino, and S. Mizuno; OPTICAL REVIEW vol. 1, No. 1(1994) 27

[2] K. Kime, H. Hashimoto, N. Egusa, and S. Sakabe; Bull. Japan Soc. of Prec. Engg. vol.22, No. 2(1988) 133

## BIOGRAPHY

**Masahisa Shinoda** received his B. S. and M. S. degrees in physics from Osaka University in 1979 and 1981, respectively. He then joined Mitsubishi Electric Corporation, where he is currently engaged in development on optical design for optical disk memories. He is a member of the Japan Society of Applied Physics, the Optical Society of Japan, and the Institute of Electronics, Information and Communication Engineers of Japan.

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