White paper
Blu-ray Disc Format

4. Key Technologies

August 2004

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4. The key technologies for Blu-ray

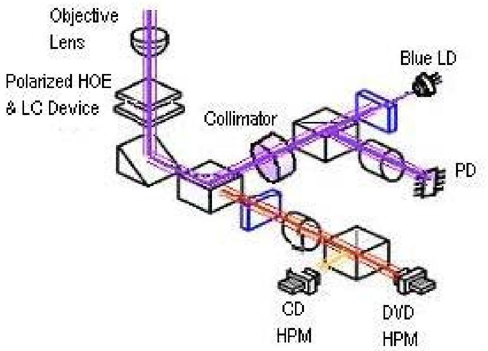
4.2 Pick up

4.2.5 BD/DVD/CD Compatibility with Polarized HOE

There is a thin 0.1mm cover layer in Blu-ray Disc which enables sufficient tilt margin. CD and DVD discs are difficult to reproduce by an optical pick-up used only for BD because of the spherical aberration caused by the difference of cover layer thickness and wavelength between BD, DVD and CD.

LG Electronics has developed the compatibility technology to reproduce DVD and CD with an optical BD pick-up. To achieve compatibility between these discs that have different transparent substrate thickness, there are three functions to be implemented in the optical pick-up. One is to keep sufficient free working distance of the objective lens. The second is to have a means to compensate for spherical aberration and the third is to control the numerical aperture for each disc format.

To satisfy the need for backward compatibility, LGE has developed a BD/DVD/CD compatible pick-up with a single aspherical objective lens having a working distance of 0.54mm with NA 0.85, and a new polarized HOE (Holographic Optical Element) device (Fig. 4.2.5.1).



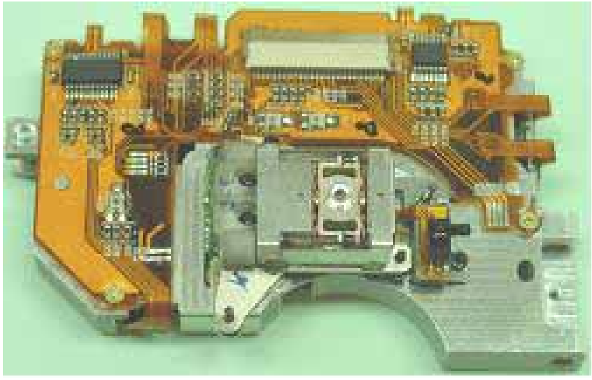


Fig. 4.2.5.1 BD/DVD/CD compatible pick-up, Polarized HOE and LC device are located under the objective lens.

To make the HOE device, a birefringent material is used. This material is sandwiched between two substrates and has the same refractive index as the bonding material for a certain polarization direction, but has a different refractive index for a perpendicular polarizing direction compared to the first polarizing direction. The HOE is designed not to affect the wavefront of BD wavelength 405nm, but at wavelengths of DVD 650nm and CD 780nm, when their polarization direction is perpendicular to that of 405nm, there must be some phase distributions for both 650nm and 780nm wavelength beams due to the index difference $\triangle n$ between the birefringent and bonding materials. This HOE also has a width variation of pitch in the radial direction and a depth d in the surface of one substrate so as to control the phase distribution of the incident beam in the entrance pupil diameter for both DVD and CD. It also compensates for the spherical aberration generated by the thickness difference of the DVD and CD .[9)] To control the numerical aperture of DVD and CD, an aperture filter using an optical filter or diffraction type filter could be adopted in the HOE device to prevent the diffracted noise beam outside the effective diameter for both DVD and CD, even though its effect on the signal is not so critical (Fig. 4.2.5.2).

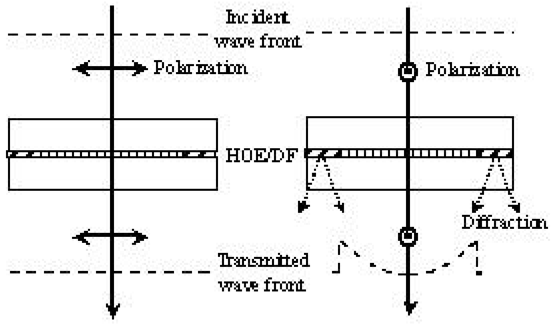


Fig. 4.2.5.2 HOE structure and operating principle

The part of oblique lines in this figure is the diffraction type filter to control NA.

As mentioned above, when the non-diffracted beam for BD and the diffracted beams for DVD and CD are used, it is possible to optimize and improve the optical efficiency for both DVD and CD system without any influence on BD system. This HOE device is only available with linearly polarized light. But a new hybrid HOE device is now under development to make the incident beam on the disc side circularly polarized. This would remove the linearly polarized beam effect on the recording layer of Blu-ray disc by combining the polarized HOE with the wave plates.[10)]

In our pick-up, we have removed the beam shaping device for BD and used a liquid crystal device to compensate for the cover layer thickness difference between single and dual layer BD. So we put both the HOE and the liquid crystal device in the actuator.

23.3GB BD-RE disc, DVD and CD-ROM disc are reproduced by the newly developed BD/DVD/CD compatible pick-up and their eye-patterns are shown. The data-to-clock jitter values are 8.5%, 7.8% and 15nsec after conventional EQ, respectively (Fig. 4.2.5.3).[11)]

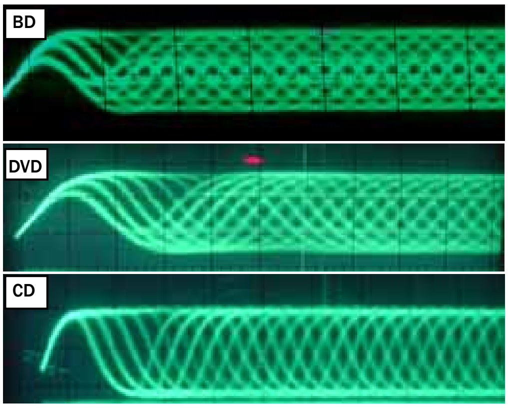


Fig. 4.2.5.3 Eye-patterns of readout signal

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4.2.8 Compatible Objective Lens for Blu-Ray Disc and DVD

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The Blu-ray Disc (BD) system uses blue light and a high numerical aperture (NA) of 0.85. A cover layer thickness of 0.1 mm is chosen to secure the disk tilt margin. DVD recorders are so popular that BD recorders are expected to be backward-compatible and allow reading and recording of DVDs, despite the fact that their optical parameters are very different. The cover layer thickness, the light wavelength and the NA of DVD are 0.6 mm, 650 nm and 0.6 respectively.

Chromatic aberration is also an important issue in a BD system, since focal depth is smaller and dispersion of lens material is larger at shorter wavelengths.

It is well known that the chromatic aberration of a refractive positive lens can be corrected using a diffractive optical element (DOE) that acts as a positive lens.1) In a BD and DVD-compatible pickup, red light for DVD also passes through the DOE. To realizing recoding, higher light power efficiency is needed for the optical system. Figure 1 shows diffraction efficiency of blazed gratings calculated by scalar analysis. If the first order diffractions of blue and red light are utilized, diffraction efficiencies are lower than 80%. In contrast, diffraction efficiency higher than 90% can be achieved when the second order diffraction of blue light and the first order diffraction of red light are utilized. In this way sufficient light energy for BD and DVD writing can be obtained. 2)

Spherical aberration caused by the difference in thickness can be eliminated utilizing the difference in wavefront curvature between incident blue and red rays. 2) This difference in wavefront curvature, however, causes coma aberration with lens movement of the tracking servo, and requires individual photodetectors for BD and DVD.

A BD-DVD compatible lens able to converge parallel blue and red rays is needed to stabilize tracking servo control and to enable the use of a common photodetector for detecting signals from both types of disc. The third order spherical aberrations (SA3) caused by the difference in cover layer thickness between BD and DVD can be corrected by utilizing the diffraction angle difference of the red and the blue light. 3) This SA3 of DOE, however, causes incorrect SA3 cancellation when the wavelength of the blue light deviates from the designed standard wavelength.4)

To address this, we utilize phase-steps to correct the chromatic SA3. The unit height of the steps makes the optical length equal to five standard blue wavelengths and three standard red wavelengths.

The step causes a 0.14λ phase shift when the wavelength shift from the standard wavelength of blue light is 5 nm. The SA3 caused by 5 nm wavelength deviation is reduced from 100 m lambda (rms) to 5 m lambda in NA of 0.62.

The DOE pattern and refractive lens surfaces are divided into inner and outer regions (Fig. 3). The inner regions are designed to focus the second-order diffracted parallel blue ray through the 0.1 mm cover layer and the first-order diffracted parallel red ray through the 0.6 mm cover layer. The DOE corrects the SA3 caused by the difference in cover layer thickness by utilizing the wavelength and the diffraction-order difference. The outer regions are designed only for BDs. Consequently, there are large aberrations for DVDs and the NA is automatically reduced without the need for a dichroic aperture.

Focus power components are distributed to the lens and DOE to correct longitudinal chromatic aberrations in both regions.

The designed compatible lens features a diffractive-refractive hybrid configuration and comprises two elements. 4)

The light power distributions of focused spots of red and blue parallel rays using the assembled compatible lens were observed. The spot sizes of red light through a 0.6 mm substrate were 0.56 micron x 0.58 micron by full width at half maximum (FWHM) and those of blue light through a 0.1 mm substrate were 0.27 micron x 0.28 micron by FWHM, demonstrating that a compatible lens can converge both red and blue parallel rays.

The readout signal patterns for a read only memory DVD (DVD-ROM) and a ROM disk having a 0.1 mm thick substrate and a 25 GB capacity are successfully obtained, demonstrating that the compatible lens can read out data from both BD and DVD format discs.

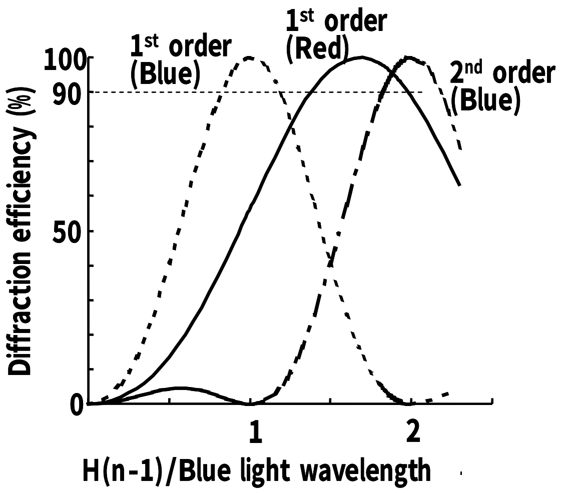

Figure 1. Diffraction efficiencies and normalized grating depth.

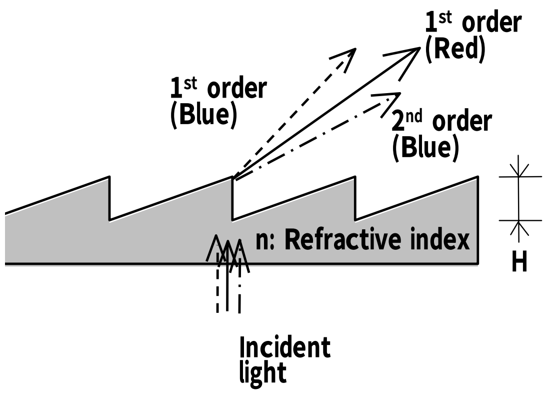

Figure 2. Diffraction angles variation dependent on wavelength and diffraction order.

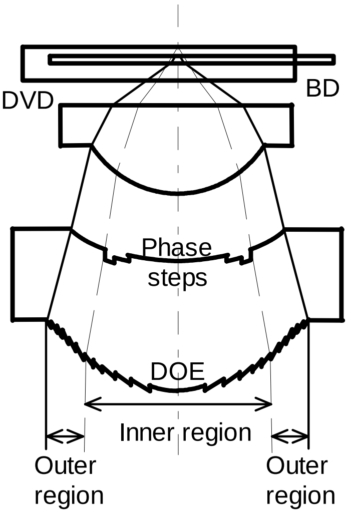

Figure 3. Configuration of compatible objective lens

References

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3) Y. Tanaka, Y. Komma, Y. Shimizu1, T. Shimazaki, J. Murata1and S. Mizuno: Tech. Dig. ISOM2003, Nara, Th-G-04 (2003) 222.
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4.2.9 Blu-ray Disc, DVD and CD compatible, 3-wavelength recording/playback Optical Head

Sony Corporation

A single 3-wavelength recording/playback optical head, capable of recording and playing-back 3 formats, Blu-ray Disc (BD), in addition to DVD, CD has been developed.

The BD market is expected to expand in the coming era as high-quality content becomes mainstream. However, it is desirable for the BD recorder to record and playback DVD-R and CD-R. In order to cope with this, a 3-wavelength recording/playback optical head is required.

To achieve a 3-wavelength recording and playback optical head with most simple structure, a single unit 3-wavelength laser and also an objective lens corresponding to the 3 wavelengths have been developed. Utilizing the laser and the objective lens, a prototype optical head was made to realize a common optical path for the 3 wavelengths. A picture of the prototype is shown in Figure 4.9.1. The prototype is 82 mm in height, 50 mm in width and 32 mm in depth.

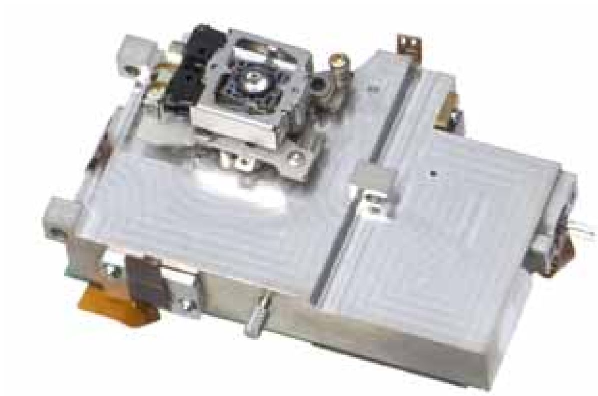


Figure 4.2.9.1 3-wavelength recording/playback Optical Head (Prototype)

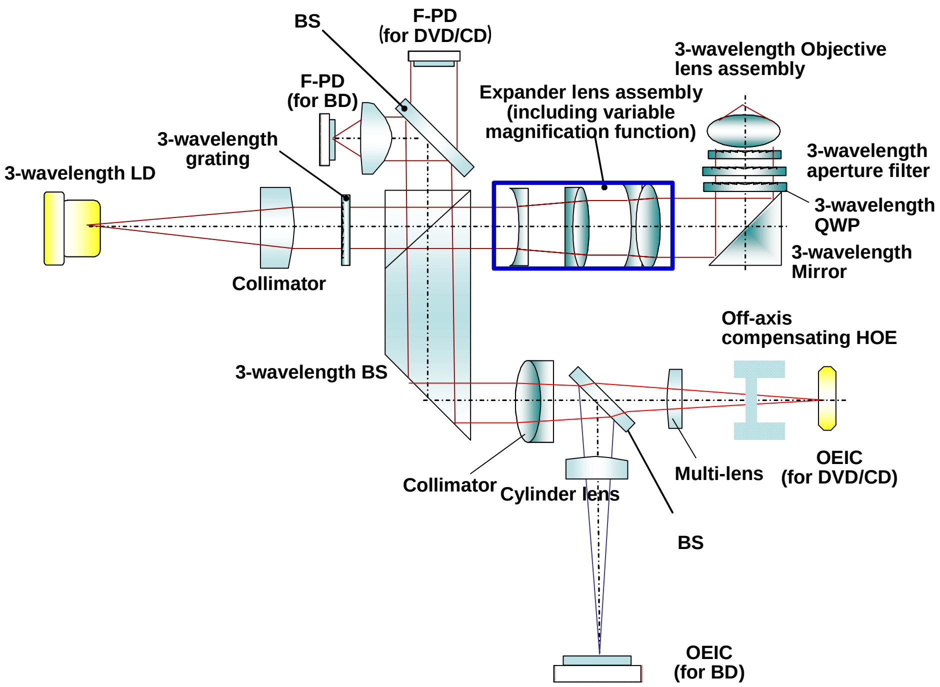
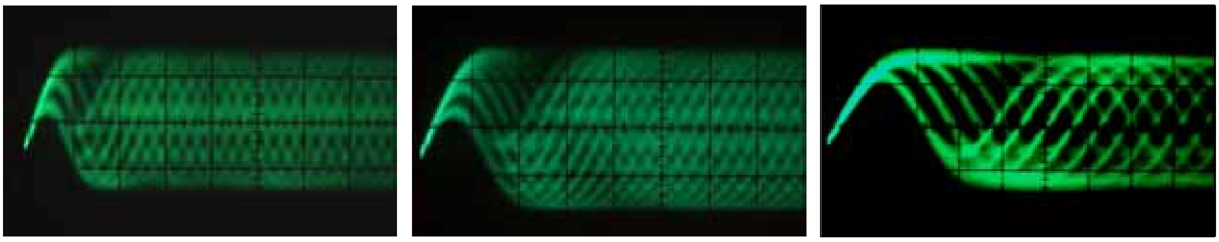


Figure 4.2.9.2 Diagram of prototype optical head

A diagram of the prototype is shown in Figure 4.2.9.2. In addition to the 3-wavelenght laser and objective lens, a variable magnification function is key to realize the 3-wavelength optical head. The function was realized by introducing expander lens assemblies whose magnifications were different for corresponding objective lens apertures for BD, DVD and CD. With this function, the efficiency from each laser to BD, DVD and CD can be maximized, enabling high speed recording for each format.

As shown in figure 4.2.9.3, excellent eye patterns from BD, DVD and CD were obtained by the prototype optical head.



from BD from DVD from CD

Figure 4.2.9.3 Eye patterns from BD, DVD and CD reproduced by the prototype optical head

As for the 3-wavelength laser (hybrid-type), a red laser diode (max 150 mW pulse) and a infrared laser diode (max 200 mW pulse) were precisely mounted on a blue laser diode (max 120 mW pulse), whose heat conductivity is as good as a conventional heat sink (figure 4.2.9.4, figure 4.2.9.5).

As for the object lens, introduction of aspherical glass and hologram lens to achieve spherical aberration correction corresponding to each wavelength enables one optical system to deal with 3 wavelengths.

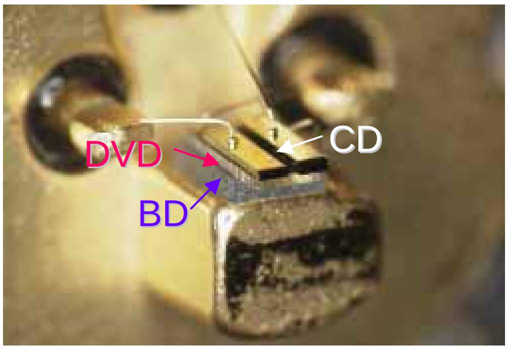


Figure 4.2.9.4 Structure of a single unit 3-wavelength laser

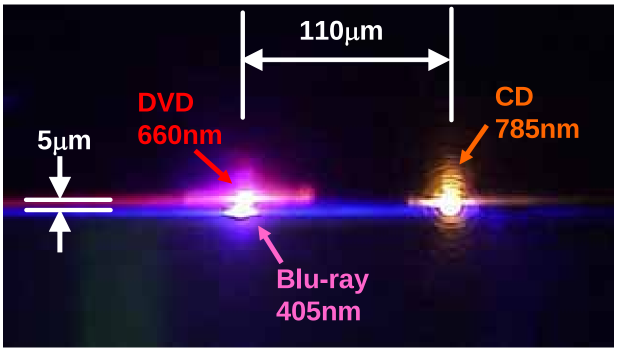


Figure 4.2.9.5 Laser emission from a single unit 3-wavelength laser prototype

* The 3 lasers will not be emitted at the same time when the unit is in actual use.

In the future, the number of parts and size of the prototype optical head can be reduced by combining, for example, OEIC and so on. We believe a single 3-wavelength recording/playback optical head is key to the expansion of BD markets.