Plastic Objective Lenses for Blue LD Optical Pick-up

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Abstract

Plastic objective lenses are also promising in the Blue-LD optical pick-up, since temperature dependency can be compensated by distribution of power or using movable element.

1 Introduction

Plastic objective lenses have played an important part in spreading optical disc systems since the CD was invented. Take molds, for instance; molds for glass lenses are no longer usable after 10 thousand uses. On the other hand, molds for plastic lenses are able to hold out over 1 million uses. So, plastic lenses are essential to mass production of optical disc drives.

Recently, new high density optical disc systems employing Blue-LD have been proposed. One of them is the HD-DVD system that adopts an objective lens, of which the NA and the cover layer thickness are the same as on the DVD. Another is the Blu-ray system adopting an objective lens, of which the NA is 0.85 and the cover layer thickness is 0.1mm. Is it still possible to use plastic objective lenses, especially for such a high NA system as Blu-ray?

In this paper, we introduce some examples of plastic objective lenses and discuss technical issues concerning their application.

2 Technical issues for application of Hi-NA plastic objective lenses

Table 1 Specifications of plastic singlets of NA0.85

	A	B	C
Focal length(mm)	1.76	0.9	0.59
Entrance Pupil Diameter(mm)	3.0	1.53	1.0
Working Distance(mm)	0.5	0.22	0.12
Wavefront error (λrms) at 25 ℃	0.0	0.0	0.0
Wavefront error (λrms) at 55 ℃	0.12	0.06	0.03

Plastic singlets for Blu-ray can be designed as shown in **Fig. 1** . The specifications of these singlets are listed in **Table 1 .**

It's a well-known fact that the refractive index of plastic changes with temperature, and the refractive index change causes spherical aberration in a plastic singlet. If the NA is not so high, however, the spherical aberration caused by temperature change (hereafter, called "temperature aberration" for short) is negligible.

The spherical aberration increases in proportion to the 4th power of NA. So in the case of Blu-ray, temperature aberration is a critical issue except with small size lenses.

We proposed two ways to correct the temperature aberration 1) 2). The first solution is a doublet that combines two positive lenses. **Fig. 2** is a schematic diagram showing how to correct temperature aberration. Spheri-

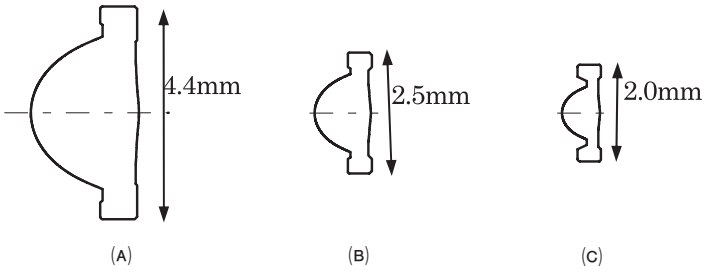

Fig.1 Plastic singlets for Blu-ray

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cal aberration changes the opposite way when the temperature of only one of the two lenses increases. And when the magnification of the 2nd lens is chosen appropriately, temperature aberration can be corrected well by itself.

The second solution is the optical system that consists of a plastic objective and a movable collimator or a movable beam expander with an actuator.

Fig. 3 shows one of the configurations.

Movable plastic collimator works together a plasticobjective singlet. The temperature aberration is corrected by the collimator's shift along the optical axis.

Additionally, if the diffractive structure applies to one of the surfaces of the collimator, the chromatic aberration of the objective lens can be compensated for.

Fig. 4 shows residual wavefront error after compensation by the collimator shift. This will be the simplest of all the optical systems for Blu-ray if the spherical aberration can be detected.

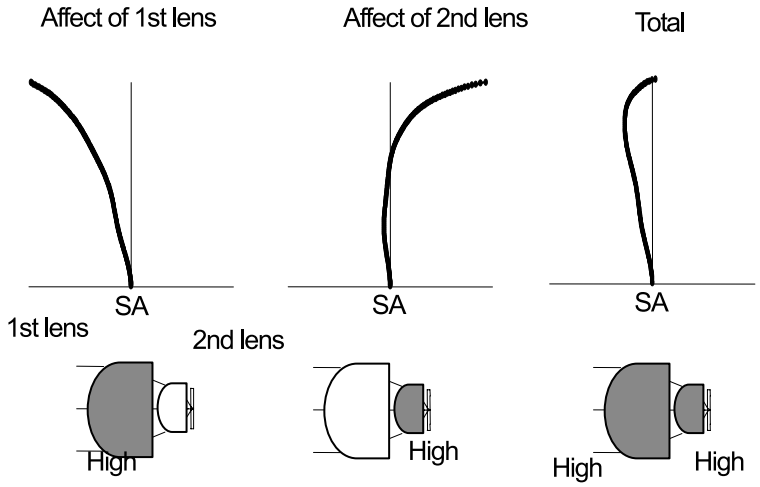

Fig.2 Schematic diagram for correcting temperature aberration

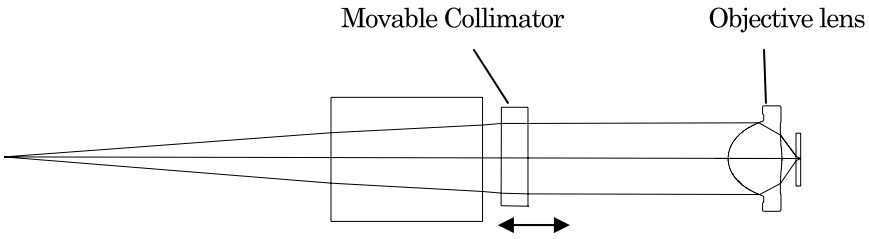

Fig.3 Plastic singlet and movable collimator

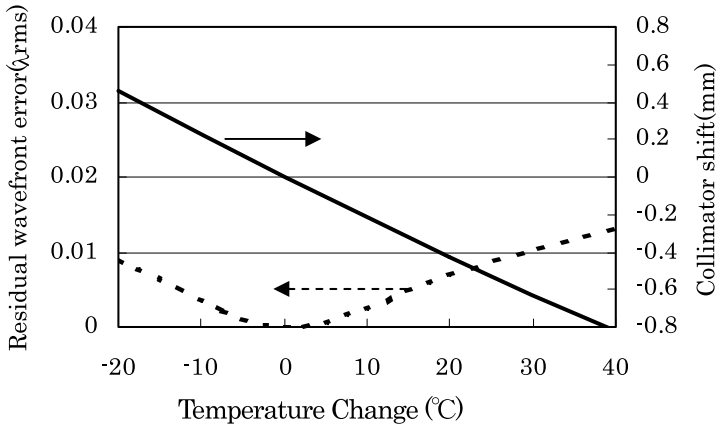

Fig.4 Residual wavefront error

3 Compatibility

Compatibility is desired and various approaches have been proposed.3-5) Blu-ray/ DVD compatible objective lens assembly using a singlet made of glass and a plastic phase plate has been developed recently. 6) The plastic phase plate has a wave selective diffractive structure (WSE) that compensates for spherical aberration due to the different thickness of the cover layer.

The cross section view of this lens is shown in **Fig. 5** and its specifications are listed in **Table 2**.

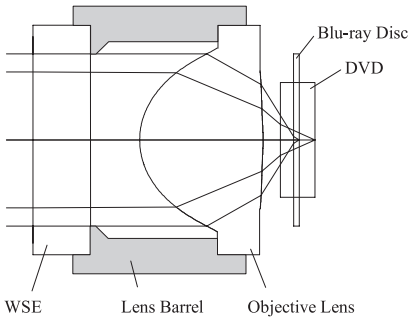

Fig.5 Schematic view of the objective lens assembly

Table 2 Specifications of a compatible objective lens

	Blu-ray Disc	DVD
Wavelength	405nm	650nm
Numerical Aperture	0.85	0.65
Focal Length	1.765mm	1.819mm
Working Distance	0.53mm	0.30mm
Cover Layer	0.1mm	0.6mm

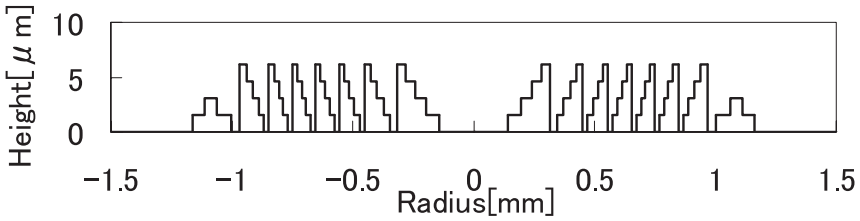

Fig.6 Cross sectional view of the WSE

The wavelength selective diffractive structure is drawn in **Fig. 6**. It has steps, height (h) of which is as follows;

$$h = 2\lambda_1/(n_1 - 1)$$

where λ_1 is wavelength of 405nm, and n1 is refractive index of the phase plate for 405nm. Therefore, the wavefront of 405nm gets through without phase change. On the other hand, in the case of 655nm, certain amounts of phase shift remain and then this periodic structure affects the wavefront as diffraction gratings. The divergent power of the diffractive lens corrects the spherical aberration due to the difference of cover layer thickness. Needless to say, this means can be adopted also for a plastic objective lens.

4 Fabrication results

As an example of fabrication, we are now getting ready for mass production of the first solution of plastic objective lens for Blu-ray shown in **Fig. 1**. The diameter of entrance pupil is 3mm and the working distance is 0.24mm. It is assembled automatically combining their flanges directly. As shown in **Fig. 7**, it can be handled like a singlet. **Fig. 8** shows its interferogram. The wave front errors are stably below 0.04 λrms in preproduction.

5 Conclusion

We proposed a few ways to compensate the temperature aberration of Hi-NA plastic objectives and have demonstrated a compatible objective lens using a plastic WSE. Plastic objective lenses have a disadvantage regarding temperature dependency but at the same time, they possess huge advantages regarding mass production and flexibility to achieve compatibility. It would be necessary to make good use of plastic objectives in order to

achieve a low-cost and high-density optical disk system. Plastic objective lenses will play an important part in the optical pick-up systems using Blue-LD including Hi-NA objective lenses and compatible objective lenses.

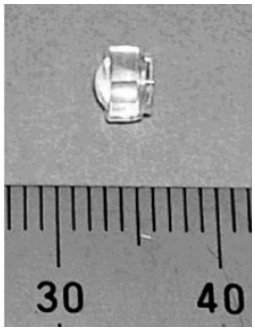

Fig.7 Plastic doublet

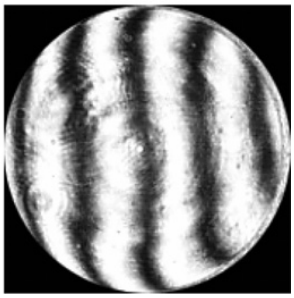

Fig.8 Interferogram of plastic doublet

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