Ultra compact zoom lens unit which uses glass-mold lenses

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Abstract.

Recently, mobile camera phones are spreading rapidly. Therefore, the demand for miniaturization of zoom lens unit is very intense. We have developed an ultra compact zoom lens unit suitable for mobile camera phones. We have succeeded in designing a very small zoom lens system with robust sensitivity to assembly errors using plural glass-mold lenses. We have also introduced a compact piezoelectric linear actuator called SIDM (Smooth Impact Drive Mechanism) to reduce the overall size of the zoom lens unit. With our lens design method and the SIDM, an ultra compact zoom lens unit which is mass producible can be achieved.

1. Introduction

In digital camera unit for mobile phone, mega pixel and auto-focus have been achieved.[1] Now, zoom lens unit is desired for mobile phones. The following two technologies are necessary to achieve a very small zoom lens unit. The one is optical lens design method which can control the lens sensitivity to assembly errors. The other is a very small zooming actuator. We have introduced a usage of plural aspherical surfaces and glass-mold lenses into our lens design, which results in small lens sensitivity to assembly errors, reduction of the number of the lenses, and reduction of the size of the optical system. We have also introduced a compact piezoelectric linear actuator called SIDM (Smooth Impact Drive Mechanism) to reduce the overall size of the zoom lens unit. Konica Minolta Opto Inc., has been manufacturing the SIDMs for auto-focus camera modules. We have developed a new SIDM with long driving stroke suitable for moving zoom lens units.

2. Minimizing the optical system by the lens design method

One of the main issues in minimizing the optical system is the degradation of the image quality due to manufacturing errors. General approach to reduce the size of the optical system is to increase the optical power of the lens elements, which results in the reduction of the zooming strokes and the lens-to-lens distances. However, increasing the optical power of the lens elements also leads the increasing the refraction angles at the lens surfaces, which results in larger assembling errors. We have succeeded in overcoming this contradiction by utilizing plural aspherical surfaces and glass-mold lenses.

2. 1. Controlling the lens decentering sensitivity utilizing plural aspherical surfaces

We explain that the lens sensitivity to the assembling errors can be controlled by the usage of the aspherical lenses. Fig. 1 shows the ultra compact zooming system which consists of the negative-optical-power first lens group, the positive second lens group, and the positive third lens group. The first lens group is the zooming compensator and the second is the zooming variator. The third lens group is fixed during the zooming operation. We have succeeded in designing almost 3-time zoom lens system with only 5 lens elements and plural aspherical surfaces. We have designed the following two types of the zoom lens systems.

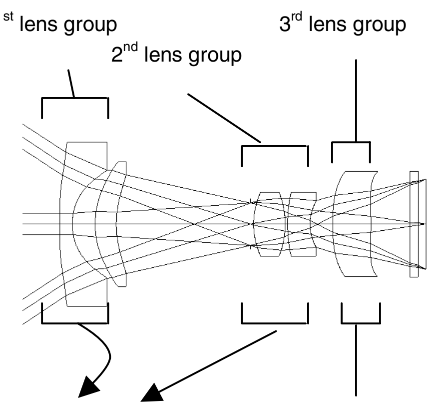

***Figure 1**. A schematic view of the three-time zoom lens*

Type A: A sensitivity controlled zoom lens system utilizing glass-mold lenses

Type B: A sensitivity uncontrolled zoom lens system utilizing glass-mold lenses

Fig. 2 shows the second lens group of Type A and B. Fig. 3 shows the MTF field tilt sensitivity to the decentering of both types.

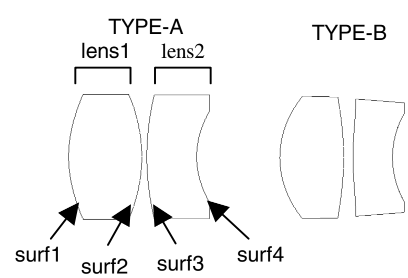

***Figure 2**. 2nd lens group of type-A and type-B zoom lens*

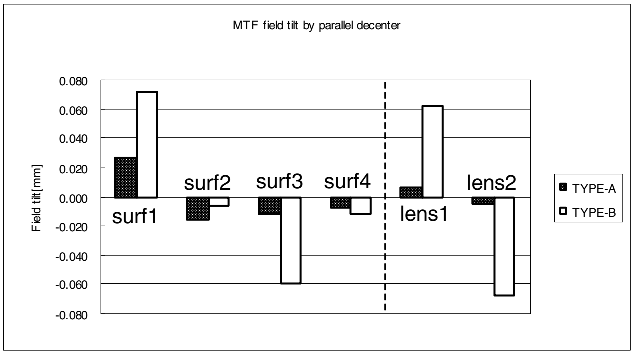

***Figure 3**. The MTF field tilt sensitivity to the decentering; 0.01mm shift perpendicular to the optical axis at the telephoto-end.*

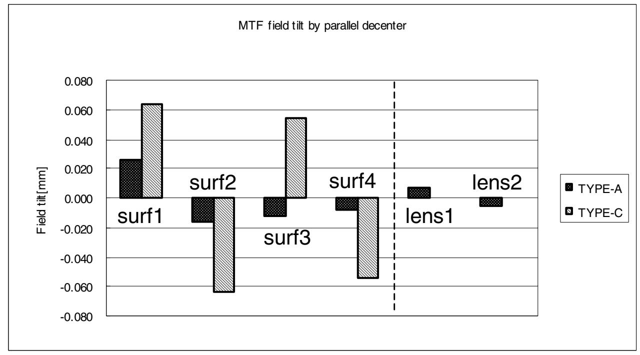

***Figure 5**. The MTF field tilt sensitivity to the decentering; 0.01mm shift perpendicular to the optical axis at the telephoto-end.*

As seen in Fig. 2, the lens shape of the second lens group does not differ between type A and B. However, there is a huge difference of the lens sensitivity between type A and B (See fig. 3). Generally, the sensitivity of the lens block should be smaller than the sensitivity of the lens surfaces because of the difference of the assembling errors. The second lens group of Type A is suitable for mass production since the lens block and the lens surface sensitivity of Type A are much smaller than those of Type B.

2. 2. Effect of glass-mold lenses

Materials of the aspherical lenses are usually glass or plastic. The distribution of refractive index and the dispersion of the glass-mold materials are much wider than those of the plastic-mold materials. The refractive index of the plastic-mold material is small and the dispersion is located in the middle-range. We have designed the following two types of the zoom lens systems to see the effect of glass-mold lenses.

Type A: A sensitivity controlled zoom lens system utilizing glass-mold lenses

Type C: A sensitivity controlled zoom lens system utilizing plastic-mold lenses

Fig. 4 shows the second lens group of Type A and C. Fig. 5 shows the lens decentering sensitivity of Type A and C.

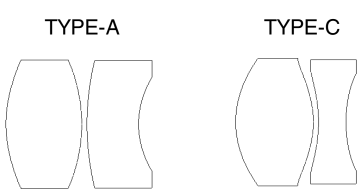

***Figure 4**. 2^{nd} lens group of type-A and type-C zoom lens*

As seen in Fig. 5, both of the lens and block sensitivity of Type A is well constrained while the lens surface sensitivity of Type C is large. We could design a mass producible optical system when we used glass-mold lenses. In Type A, the Abbe number difference between the positive and the negative lens is large thus the optical power of the each lens should not be too large in order to compensate the color aberrations. The high refractive index of the glass-mold lens also contributes to the reduction of the curvature of the lens surfaces which results in the lower lens sensitivity. An ultra compact optical system which is suitable for mass production is achieved by the usage of plural glass-mold aspherical lenses.

3. Minimizing the size of a zoom module utilizing the very small zooming actuator

3. 1. Driving mechanism of the SIDM

The driving principle of the SIDM is shown in Fig.6. One end of a piezoelectric element is attached to a fixed body and the other end is attached to a friction shaft. A movable body is coupled with a friction shaft with an appropriate frictional force. When the piezoelectric element expands slowly, the movable body moves together with the friction shaft because of the frictional force. When the piezoelectric element contracts quickly, the movable body slips on the friction shaft because of the inertia, and stays at almost the same position. (See Fig. 6. (2)). The movable body moves along the friction shaft with the repetition of slow expansion and quick contraction of the piezoelectric element. The movable body can also move in the opposite direction by the repetition of quick expansion and slow contraction of the piezoelectric element.

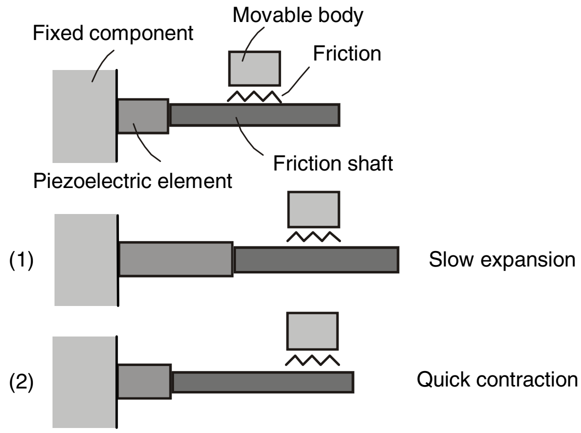

***Figure 6**. The SIDM driving principle from Yoshida et.al.[2]*

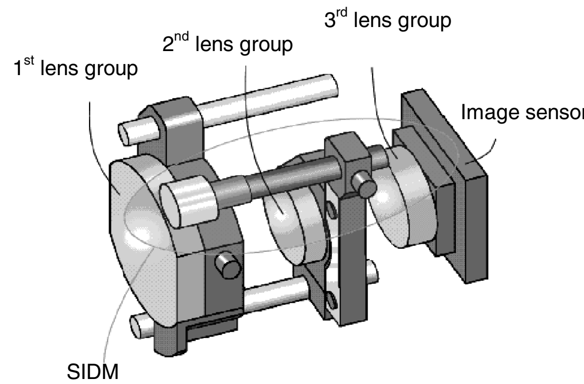

***Figure 8**. Schematic view of a zoom lens module using SIDM from Yoshida et.al.[2]*

3. 2. Ultra compact zoom lens module using the new SIDM

We have already completed the developing SIDMs for auto-focus lens unit. We have developed a new SIDM with long driving stroke for zoom lens unit. Fig. 7 shows the picture of the new SIDM. The upper one is for moving the first lens group and the lower one is for the second lens group. The driving stroke of the new SIDM is about 7mm and the total length of the SIDM is about 17mm. The moving lens group is directly connected with the SIDM's friction shaft. The SIDM is very simple and compact actuator.

Fig. 8 shows the schematic view of the zoom lens unit using the SIDM. The second lens group is directly coupled with the SIDM and moves linearly during the zooming operation. Rotary actuators such as stepping motors require the mechanism which translates a rotational movement into a linear motion while the SIDM doesn't require such a mechanism. It follows that the zoom lens unit using the SIDM is much smaller than that of using stepping motor. Moreover, because the moving lens group is directly attached to a SIDM's friction shaft with a friction force, the moving lens group is precisely held. Hence the assemble error of the moving lens group is well suppressed.

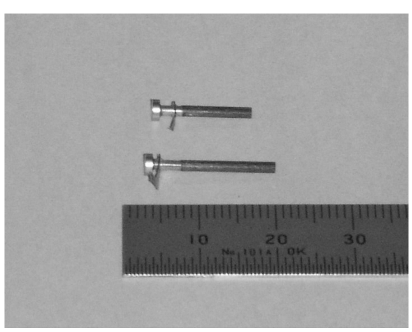

***Figure 7**. Picture of the SIDM*
Top: SIDM for the 1st lens group
Bottom: SIDM for the 2nd lens group

4. Conclusion

We have succeeded in designing an ultra compact zoom lens system with robust sensitivity to assembly errors using plural aspherical glass-mold lenses. We have also developed the compact SIDM for zoom lens module. We have developed an ultra compact zoom lens unit suitable for mobile camera phones. We are pursuing more compact and smaller lens unit by developing low-cost and high-precision glass-mold process and precise lens assembling process.

References

[1] For example, http://www.nokiausa.com/phones/N90/
[2] R.Yoshida,Y.Okamoto and H.Okada,"Development of Smooth Impact Drive Mechanism (2nd Report)-Optimization of waveform of driving voltate-,"J.Jpn.Soc.Precis.Eng.,vol.68,No.4,pp.536-541,2002

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