SELF-ADJUSTMENT MODULE
FOR PHONE CAMERA LENS ASSEMBLY

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INTRODUCTION

The 1.3-mega-pixel camera cellular phone was first released into the Korea market in October 2003. The major cellular phone companies released 2-mega-pixel camera cellular phone which supports zoom function and 2-mega-pixel camera cellular phone is settled down with the Korea cellular phone market. The table 1 shows that the market share of camera cellular phone was 14.6 % in 2003 and it is expecting that it holds a more than 75 % in 2007.

Table 1 : The world market trend of the cellular phone and the camera cellular phone [1]
(Unit : Million sets, %)

	2003	2004	2005	2006	2007
Cellular Phone	432	478	521	562	618
Rate of Increase	-	10.6%	9.0%	7.87%	9.96%
Camera Cellular Phone	63	135	266	365	464
Market Share	14.6%	28.3%	51%	65%	75%

As the market of a camera cellular phone of which lens module is manufactured by a manual work is getting larger in recent year, the need of automation is increased lately. In this industry, the customer's demand for the variety makes fast model change and the pixel resolution high form VGA to multi-mega pixel. The lens module of a camera cellular phone demands ㎛ order accuracy to be assembled. The assembly system is designed to cope with phone camera model change and make the parts to be assembled arranged precisely. In general it makes the assembly system huge from size of view that the accuracy only depends on the mechanism stiffness. If there is utensil that compensates alignment error naturally, the assembly system can be small and manufactured as is cheap and corresponds easily to the cellular phone model change. In this paper the utensil is proposed and is called Self-Adjustment Module (SAM). The SAM that can compensate the alignment error reduces the tact time and also diminishes the inferior goods. The assembly system that has this SAM is not to have excessive stiffness so that it is designed to be smart and can correspond to the model change easily.

Function of Self-Adjustment Module (SAM)

The lens module consists of a holder, lenses, spacers and shield as shown in Fig. 1. The inside of a holder becomes the reference of assembly, and one after another are assembled lenses, spacers and shield. First a holder is situated at assembly position by a gripper with positioning error. Next a lens is moved to assembly position and then a holder and a lens are assembled with an alignment error. In general this alignment error can be compensated by using vision system.

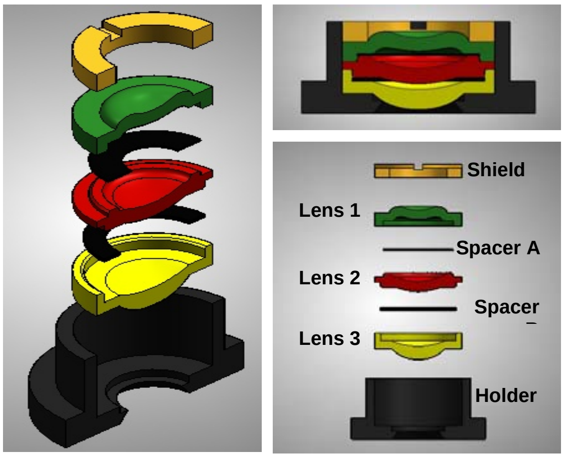

Fig. 1 Lens module of megapixel camera phone

If two parts are assembled and its direction is Z axis, the relative alignment errors has 5 ingredients as shown in Fig. 2. If SAM can make 5 directions free mechanically, two parts are assembled compensating alignment error naturally. Fig. 3 shows the function of SAM schematically when a holder and a lens are assembled.

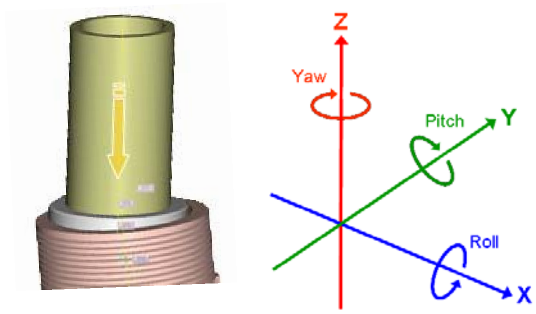

Fig. 2 Five alignment errors when assembly direction is Z axis

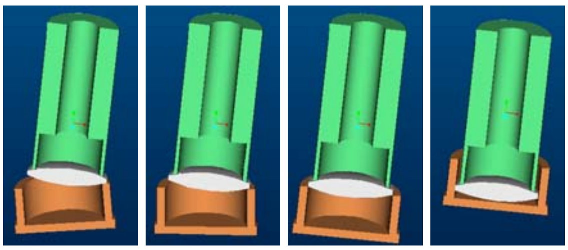

Fig. 3 Function of Self-Adjustment Module

Self-Adjustment Module (SAM) Design

The SAM only takes the stiffness in assemble direction and can be moved freely in the other direction so that it can make the parts assembled with the reference to the inside of a holder. Several types of SAM are proposed in the previous research [2][3]. This investigation suggests new two types of the SAM that can adjust one part to the inside of holder automatically and shows performance evaluation of SAM.

The first type is using hemisphere air bearing as shown in Fig. 4. This type consists of base that has five holes and hemisphere that has one hole. The pressure air that is supplied through center hole of base passes hole in hemisphere and make the holder housing floating freely. This function makes as holder housing has X, Y, Yaw 3 degree of freedoms. The other small holes in the base make the hemisphere floating on the base freely. This function makes as holder housing has Roll, Pitch 2 degree of freedoms. As a result, this device makes 5 degreed of freedoms free only with stiffness to Z axis direction.

The second type SAM consists of the porous air bearing that give three-degree of freedom free and the coil spring that give two-degree of freedom free as shown in Fig. 5. The air bearing can make a part moved without mechanical friction in X, Y direction and yaw motion and the coil spring also is able to get a part moved smoothly in roll and pitch motion.

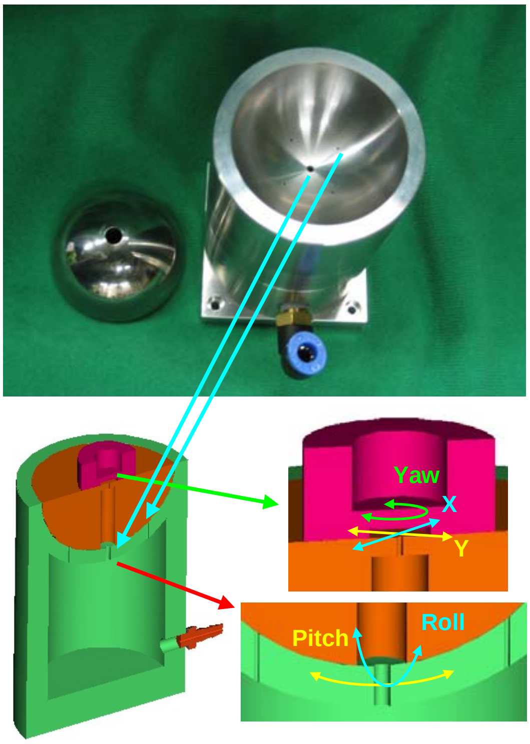

Fig. 4 Type 1 SAM using air bearing

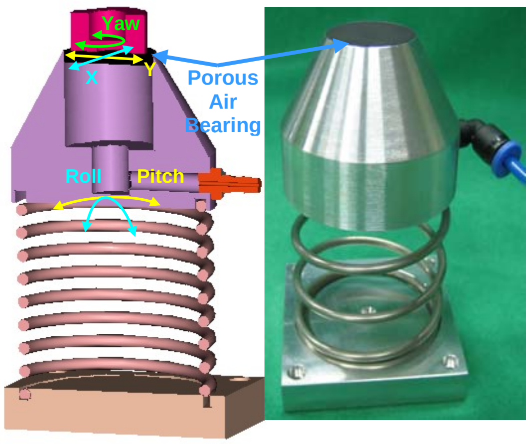

Fig. 5 Type 2 SAM using spring and air bearing

EXPERIMENTAL SETUP

Experiment has micro stage that can occur pitch, roll, X, Y direction alignment error independently as shown in Fig. 6. Also it has two gap sensors that can measurement X1, Y1 direction displacement of holder housing and two-dimensional PSD (Position Sensitive Detector) sensor that can measurement pitch, roll of holder housing. The angle between gap sensor and micro stage is 45 ° mechanically, so the displacement of holder housing was expressed by X1, Y1. The gap sensors hold generating power 10 ㎷ per 1 ㎛ displacement. It tunes out that 1 ㎛ displacement of laser spot on the PSD results in output voltage of 1 ㎷. Pitch and roll is calculated in geometric relation from PSD displacement.

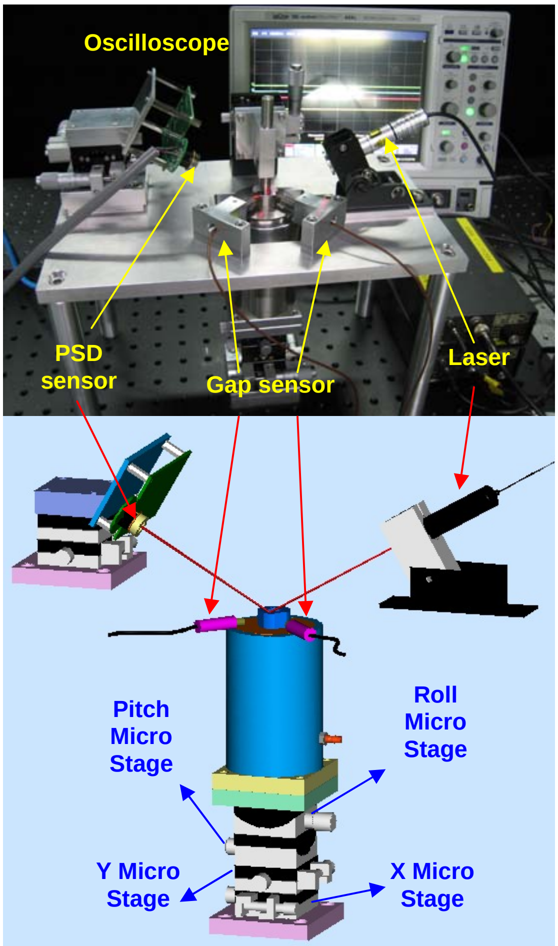

Fig. 6 Experimental setup

EXPERIMENTAL RESULTS

The experiment each type was carried out on 4 conditions.

First : X position error generated when pitch error was 0.3°, the other error is zero.

Second : Y position error generated when pitch error was 0.3°, the other error is zero.

Third : X position error generated when roll error was 0.3°, the other error is zero.

Fourth : Y position error generated when roll error was 0.3°, the other error is zero.

Because the center of micro stage that breed pitch, roll motion and that of holder housing differ, the micro stage can not move holder housing independently. If micro stage that breeds pitch, roll motion is moved, the position of the holder housing changes with X, Y, Z motion at the same time. In this research, the difference value in starting point was measured and calculated because the deviation is important. In general maximum alignment error is smaller than 0.1 ㎜ and 0.1°, so experimental condition is that displacement error is 0.5 ㎜ and angle error is 0.3°.

Type 1 SAM Result

X axis move, Y axis 0 ㎜, Pitch : 0.3° , Roll : 0.0°

X (㎜)	-0.5	-0.25	0	0.25	0.5
X1 (㎛)	4.9	-0.5	0	3.9	-1.3
Y1 (㎛)	10.6	7.5	0	0.5	-7.0
θ1 (arcsec)	18.1	19.7	0	-0.5	-11.0
θ2 (arcsec)	6.5	5.1	0	1.3	2.8

X axis 0 ㎜, Y axis move, Pitch : 0.3° , Roll : 0.0°

Y (㎜)	-0.5	-0.25	0	0.25	0.5
X1 (㎛)	-17.9	-6.0	0	-0.5	-1.5
Y1 (㎛)	8.2	6.0	0	10.6	13.3
θ1 (arcsec)	-5.9	-0.5	0	10.6	13.3
θ2 (arcsec)	19.7	17.3	0	-14.5	-14.5

X axis move, Y axis 0 ㎜, Pitch : 0.0° , Roll : 0.3°

X (㎜)	-0.5	-0.25	0	0.25	0.5
X1 (㎛)	13.3	2.8	0	-5.1	-18.4
Y1 (㎛)	13.4	18.1	0	-1.5	-4.9
θ1 (arcsec)	16.4	11.2	0	-9.6	-12.9
θ2 (arcsec)	6.0	1.3	0	7.3	-6.5

X axis 0 ㎜, Y axis move, Pitch : 0.0° , Roll : 0.3°

Y (㎜)	-0.5	-0.25	0	0.25	0.5
X1 (㎛)	-17.3	-10.6	0.0	5.3	18.4
Y1 (㎛)	5.1	15.8	0.0	-1.5	-4.9
θ1 (arcsec)	13.6	-5.9	0.0	4.9	7.7
θ2 (arcsec)	17.2	4.9	0.0	0.5	-11.0

Type 2 SAM Result

X axis move, Y axis 0 ㎜, Pitch : 0.3° , Roll : 0.0°

X (㎜)	-0.5	-0.25	0	0.25	0.5
X1 (㎛)	3.1	0.2	0	0.5	0.8
Y1 (㎛)	2.8	1.5	0	-1.2	-1.9
θ1 (arcsec)	7.9	6.1	0	1.2	-5.2
θ2 (arcsec)	2.1	2.7	0	-0.6	1.8

X axis 0 ㎜, Y axis move, Pitch : 0.3° , Roll : 0.0°

Y (㎜)	-0.5	-0.25	0	0.25	0.5
X1 (㎛)	-6.9	-3.5	0	0.2	-1.6
Y1 (㎛)	3.9	2.2	0	2.8	3.4
θ1 (arcsec)	-2.3	1.2	0	2.8	3.4
θ2 (arcsec)	6.1	5.1	0	-4.7	-4.7

X axis move, Y axis 0 ㎜, Pitch : 0.0° , Roll : 0.3°

X (㎜)	-0.5	-0.25	0	0.25	0.5
X1 (㎛)	3.4	1.8	0	-2.7	-5.3
Y1 (㎛)	4.0	9.3	0	-1.6	-3.1
θ1 (arcsec)	6.4	5.4	0	-4.1	-4.5
θ2 (arcsec)	3.5	-0.6	0	1.7	-2.1

X axis 0 ㎜, Y axis move, Pitch : 0.0° , Roll : 0.3°

Y (㎜)	-0.5	-0.25	0	0.25	0.5
X1 (㎛)	-5.1	-2.8	0	3.3	6.7
Y1 (㎛)	2.7	8.4	0	-1.6	-3.1
θ1 (arcsec)	3.6	-2.3	0	2.9	2.4
θ2 (arcsec)	7.3	2.9	0	-1.2	-5.2

CONCLUSIONS

In case of type 1 SAM, maximum displacement deviation is more than 35 ㎛ and maximum angle deviation is more than 34 arcsec. It is considered that the large deviation is caused by impertinent air bearing design, so air flow is unstable.

In case of type 2 SAM, maximum displacement deviation is smaller than 10 ㎛ and maximum angle deviation is smaller than 15 arcsec. The performance of type 2 SAM is improved little more, it is applicable in lens module assembly.

We confirmed that SMA compensated alignment error in some degree through this study.

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