LASER BASED ASPHERE AND FREEFORM MEASUREMENT TECHNOLOGY BY UA3P

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Abstract:

Recently the demand of the metrology for large asphere and freeform optics are increasing for digital camera and other area. We have developed new technology having the accuracy is less 0.1um and scanning speed is 30mm/s using the linear motor and the air bearing system based on the He-Ne stabilized frequency laser coordinate measurement system. By using this technology, we developed form measurement machine UA3P-650H, having larger measurement area XY 500mm and Z 120mm for asphere and freeform surfaces.

When we think about asphere and freeform measurement, the form accuracy is needed not only the deviation from bestfit radius form but also the absolute radius form, by reason of the focal length is depending on the absolute dimension of surface form. In this case, it's suitable to use He-Ne frequency stabilized laser which has the traceability to the international length standard.]

And we will introduce how to measure freeform surfaces and the off axis asphere by using this technology.

For the increasing demand for the measurement of mobile and smart phone aspherical lenses, we have developed automatic measurement function additionally conventional UA3P series. And we have developed special unit and function for this machine to measure 4,000 lenses on the single wafer.

Keywords: Measurement, Laser, Tactile, Aspherical, Freeform

1. INTRODUCTION

Recently the demand of the metrology for large asphere and freeform are increasing. Ultrahigh Accurate 3-D Profilometer (UA3P)[1],[2],[3] having Atomic Force Probe (AFP), high accurate axes measurement system and software can measure not only the symmetrical aspherical but also free form surface by using the user created sub design formula, as the difference form between the measured data and designed form and is used in the industry area to measure the aspherical and freeform surface.

But the demand for the more accurate measurement accuracy and improved efficiency in the large asphere or freeform is increasing for industry optics and other devices.

To respond these request, we developed the air stage system and linear motor system, so we can get the faster measurement speed 30mm/s and the accuracy less 0.1um.

And for the wafer level optics, we developed the wafer chuck, measurement process and the software including wafer alignment system which realize the whole of the wafer lens measurement about 4,000 lenses on the wafer.

2. MEASUREMENT TECHNOLOGY AND APPLICATIONS

2.1 Construction of measurement machine and tracebility

The measurement principle of UA3P is controlled to be constant the force between the probe which detect the surface and the measured surface, and keeping this condition, the probe is scanned to XY direction by numerically and probe XYZ position is measured by the stabilized He-Ne laser interferometer system.
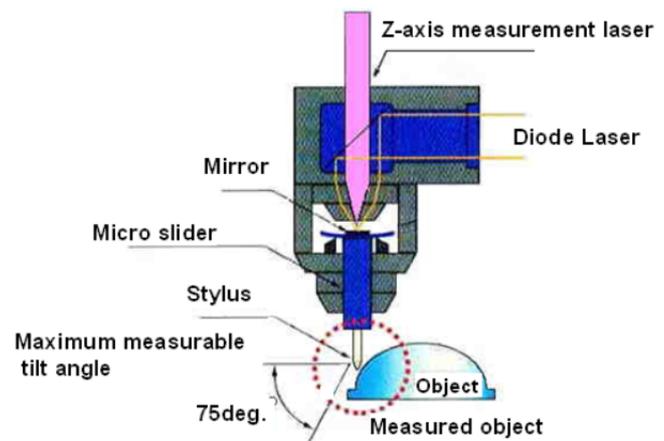

Fig. 1: Probe structure

Fig. 1 shows the structure of probe system. The stylus which is made of ruby or diamond is supported by the micro air bearing. The micro mirror and micro spring is put on the opposite side of the stylus. Diode laser is used to detect the force between the sample surface and the stylus. At the same time, the frequency stabilized He-Ne laser is used to measure the displacement between the micro mirror and the Z direction reference mirror.

Controlling the force between the stylus and the sample surface to be constant by moving the whole of the probe system to Z direction, the surface position is measured by the Z direction laser interferometer. By this controlling method, measured surface is scanned to any direction and the maximum inclined surface angle is up to 75 degree.

The stylus radius is calibrated by measuring the standard sphere which roundness is less than 50nm.

In the Fig. 2, when the probe is scanning on the sample surface, the laser interferometer system measure the XYZ

position on the same axis of probe center position to the each XYZ reference mirror. By using this method, the measured data can be acquired more accurately without affected from X or Y stage undulation.
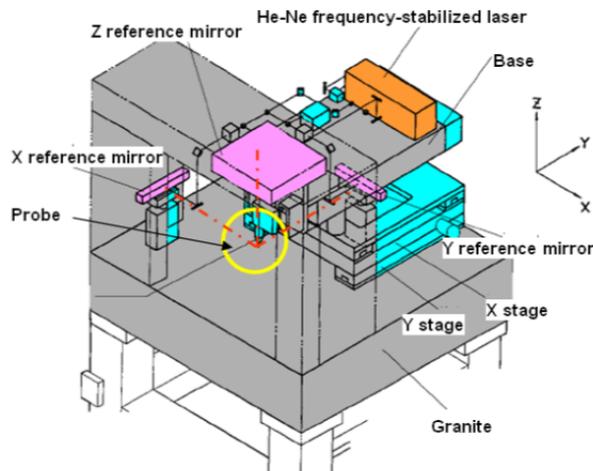

Fig. 2:   Axes measurement system

To set the sample to the center position with no error less nanometer level and having no tilt is impossible. So to evaluate the sample surface, first calculate the displacement and orientation between the measured data group and the designed form group to be minimum the sum of the root mean square of the difference, and second rotate and shift the measured data group to be parallel and overlapped, and third the difference between the rotated and shifted measured data and the designed form is displayed and enlarged to the Z direction. We named this sequence as the alignment.
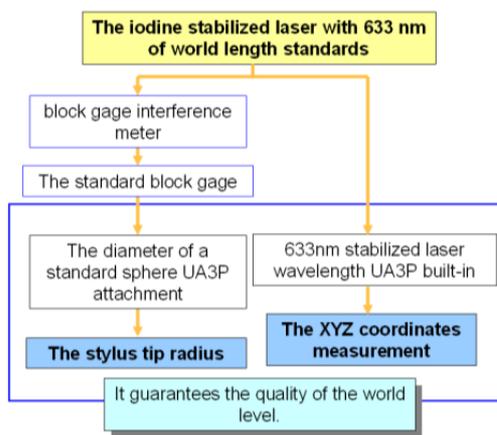

Fig. 3:   Traceability system of UA3P

Fig. 3 shows the traceability system of UA3P. The scale for the displacement measurement is used frequency stabilized He-Ne laser which is calibrated by the frequency stabilized He-Ne laser having the traceability to the ISO traceability system. The standard sphere which calibrate the radius of stylus, is calibrated by measuring the difference the gauge block and standard sphere diameter. So the

measurement and calculated result like the lens best fit radius and so on has the traceability.

2.2 New measurement technology

In the conventional configuration of UA3P having the ball bearing and ball screw, when the probe or sample is scanned fast to X or Y direction, the vibration noise is caused by those devices, and this vibration change the distance of the metrology frame between the laser interferometer and the probe, as the result measurement nose is caused.

To reduce the measurement noise, it's important to reduce those vibration noise. By using non contact air bearing system and linear motor system, the scanning noise when the stage is moving can be reduced. And we can get the improved measurement accuracy and the higher measurement speed.

Fig. 4:   Overview of the UA3P-650H/700H

Fig 4. shows the UA3P-650H/700H which XY stage stroke is XY 500mm and Z 120mm. Basically XY and Z stage systems is same in both UA3P-650H and 700H.

Table 1 Specification of UA3P-650H and 700H

Model		UA3P-650H	UA3P-7000H
Meaurement range (X,Y,Z)		ϕ500x120mm 400x400x120mm	500x500x120mm
Scale		He-Ne Frequency stabilized Laser	
Probe		Atomic force probe Ruby : Tip curvature radius 0.5mm Diamond : Tip curvature radius 2 μm	
Probe measurement accuracy			
●Ruby stylus	Up to 30°	0.01〜0.05 μm	
Surface incline angle	Up to 45°	〜0.08 μm	
	Up to 60°	〜0.1 μm	
	Up to 70°	〜0.15 μm(Downward)	
Measurement error of coordinates (Measurement range of XY coordinate axes)		(Up to 100mm) : Within 0.05 μm (Up to 200mm) : Within 0.1 μm (Up to 400mm) : Within 0.2 μm (Up to 500mm) : Within 0.3 μm (Repeatability within 0.05 μm)	
Measuring speed (Valiable in multiple steps)		0.01〜30mm/s	

Table 1 shows the specifiation of UA3P-650H and 700H. These machines can measure less 0.1um accuracy up to 60 degree inclined surface. UA3P-700H can measure XY:500x500mm area. UA3P-650H is used the smaller size

Z reference mirror to reduce the machine cost so UA3P-650H is reduced the measurement area than UA3P-700H. UA3P-650H can measure the both XY:400x400mm area and XY: ϕ 500mm area.
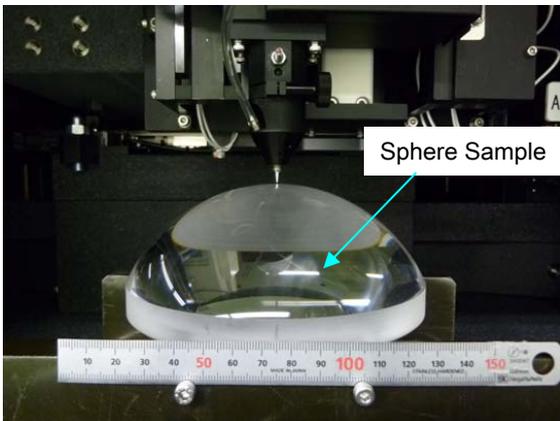

Fig. 5:   R80mm sphere sample example

Fig. 5 shows R80mm sphere sample example. Diameter is 145mm. Maximum inclined angle is 60 degree.

Fig. 6 shows R80mm sphere measurement result which measurement speed is 20mm/s and measured area is +/-70mm in each X or Y direction and the surface inclined angle is 60 degree. The horizontal direction is X or Y distance form center. The vertical direction is the difference between the measured data and designed form. This data shows that the measurement accuracy is less than 0.1um.
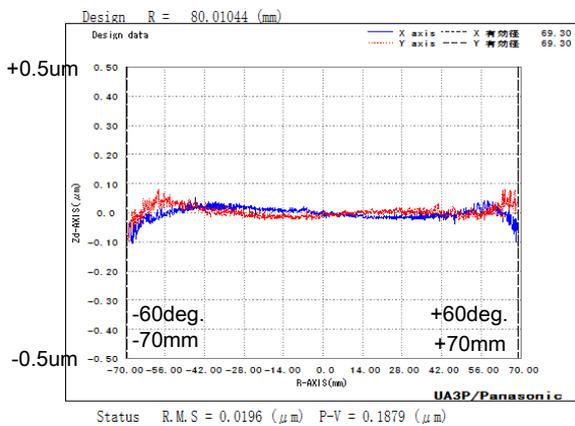
Fig. 6:   R80 sphere measurement data

2.3 Freeform measurement of UA3P

Controlling the force between the stylus and the sample surface to be constant by moving the whole of the probe system to Z direction, there is no need to make NC program including Z information like surface height and inclined angle. When probe is scanning, only the XY direction scanning path is needed. By using this scanning method, not only the symmetrical aspherical but also freeform surface can be scanned to the XY direction and measured with nanometer accuracy.

It's impossible to prepare every freeform equation in the measurement machine. In the UA3P, when the user programs the equations in C++ language, after compiling the source file, this program is attached to the UA3P main program, and the freeform surface can be measured and aligned.
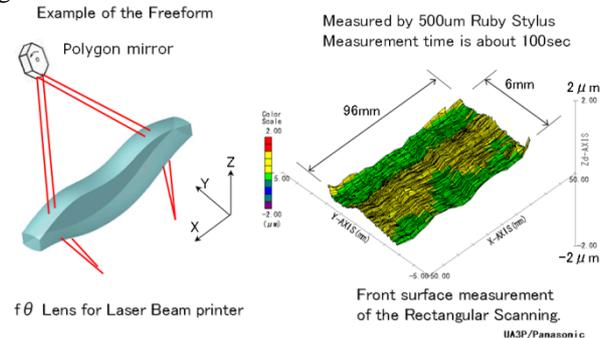

Fig. 7:   Measurement example of f-theta lens

Fig. 7 shows the measurement example of f-theta lens used for laser beam printer.

Not only the surface defined by the single equation, but also the surface which is defined multiple equations like lens array or hologram on the surface can be measured, if those equations can be programmed by C++ language.
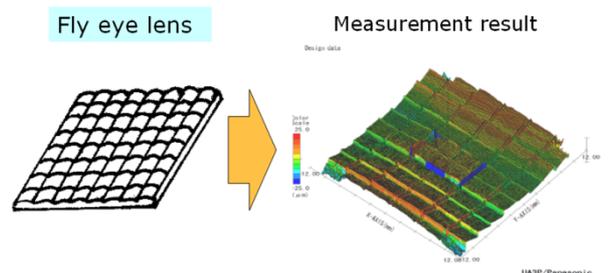

Fig. 8:   Measurement example of lens array

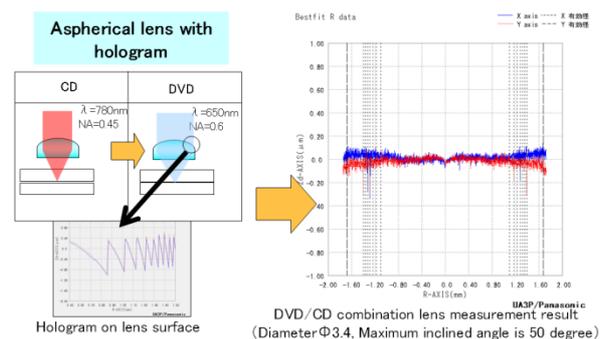Fig. 8 shows the measurement example of lens array.

Fig. 9:   Measurement example of lens with hologram

Fig. 9 shows the measurement example of lens with hologram.

In case of off axis surface measurement, unlike symmetrical surface having the center of convex or concave form, it's not easy to define the measurement start point. In this case, first measure the reduced area of the sample surface, second align the measurement data, third adjust the measurement start point XY direction. From this alignment

result, if the tilt value is large, adjust the tilt stage under the measurement sample. Fourth measure the whole of the surface and align the measurement data. Then we can get the accurate measurement result.

Fig. 10 shows the measurement example of parabola mirror.

In case of the measurement of freeform, it's not reasonable to estimate whole of the surface only from X and Y cross section data, because freeform processing technology is much different from symmetrical aspherical. So to measure the free form, we need to get larger measurement area data, and the scanning speed is more important.
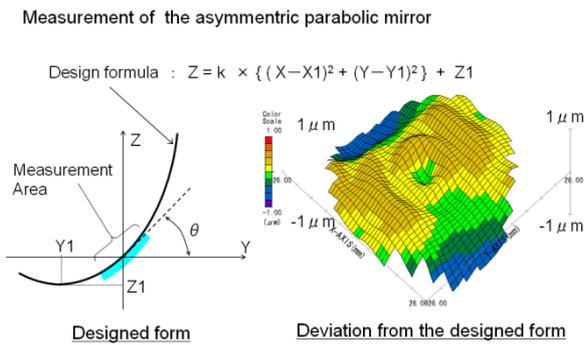
Fig. 10:   Measurement example of parabola mirror

To evaluate the off axis optics, we evaluated the off axis data which divided from rotational symmetric asphere data.

Fig. 11 shows the data from rotational symmetric asphere data.
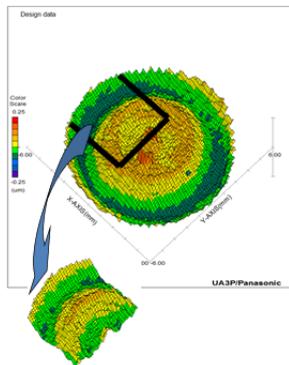
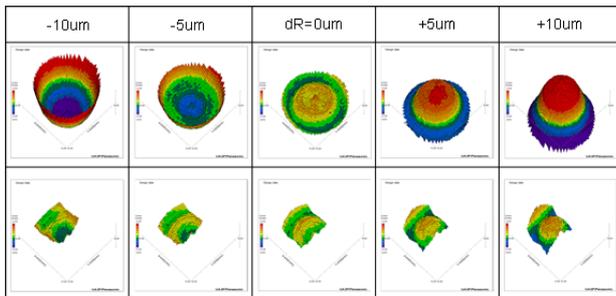Fig. 11:   Off axis data example divided from asphre

Fig. 12:   Bestfit form deviation change

Fig. 12 shows the bestfit form deviation change correspond to the design radius change. From this figure,

when we evaluate the off axis form, only watching the figure, it is difficult the bestfit radius. But when we plot the rms change correspond to the design radius change, we can find out the best fit radius on off axis optics. Fig. 13 shows the example of rms change according to design radius change.
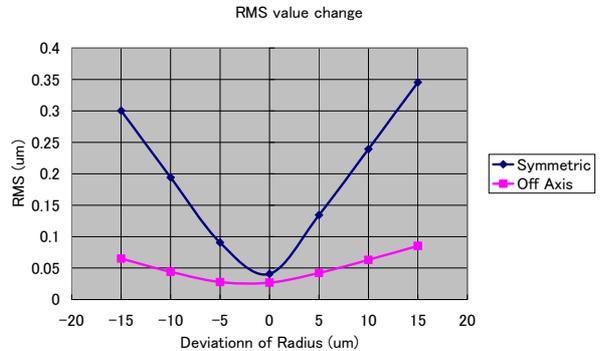

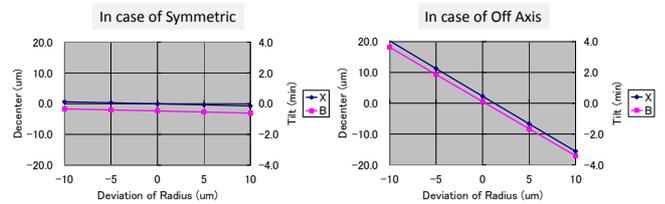Fig. 13:   rms change according to design radius change

Fig. 14:   Center position and Tit change

Fig. 14 shows the center position and tilt change according to the design radius change. This shows the off axis optics center position and angle can be evaluated by using this technology.

Totally by using the merit to use UA3P measurement technology for the off axis optics is the following.

1) Easy to change the designed form for analysis
2) To get the best fit radius
3) To get the actual designed center position

2.4 Automatic measurement for asphere measurement

Increasing the number of camera for mobile devices, automatic measurement technology is needed.

We developed the automatic measurement software. This software can measure the multiple lenses on the lens tray, inputting the lens formula parameter, measurement area, scanning speed, data sampling pitch and so on as the recipe file. When this software is used, the measurement result doesn't depend on the operator's skill.

In the Fig. 15, if the samples are scanned and have some particle on the surface, probe detect the focus error signal and scanning is suspended to avoid the damage to the stylus and the probe. In this case, this software can switch another process to measure continually as the preprogrammed error processing by the user. After scanning the lens, measured data can be aligned and saved as CSV file and JPEG data automatically.
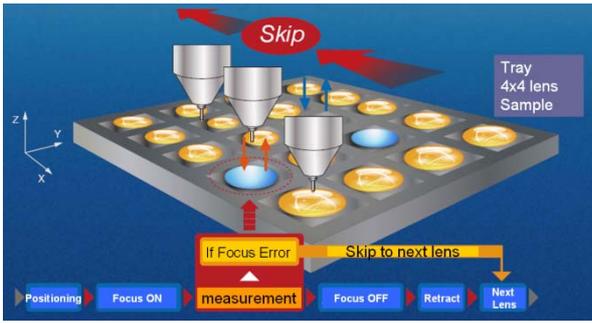
Fig. 15: Automatic measurement sequence

To reduce the processing cost of the lens for mobile area, 4,000 lenses on the 200mm wafer processing technology has developed as the 'Wafer level lens (WLL)'. And the this wafer is stacked multiple layer to construct camera lens unit.

So to estimate the WLL, the lenses on the wafer is needed to evaluate not only the form PV, rms also need the lens center position based on the alignment mark on the wafer.

We developed the wafer chuck and camera system to align the wafer to be parallel to UA3P XY axes.
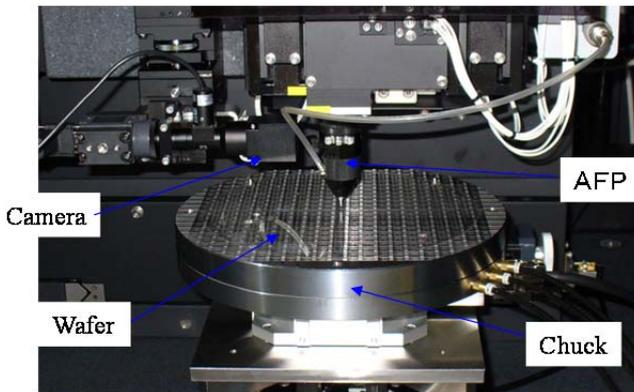
Fig. 16: Wafer chuck and camera system

By using this chuck unit, we scan the whole of the wafer lenses continuously. So we can reduce the measurement time than measure the lens step by step.
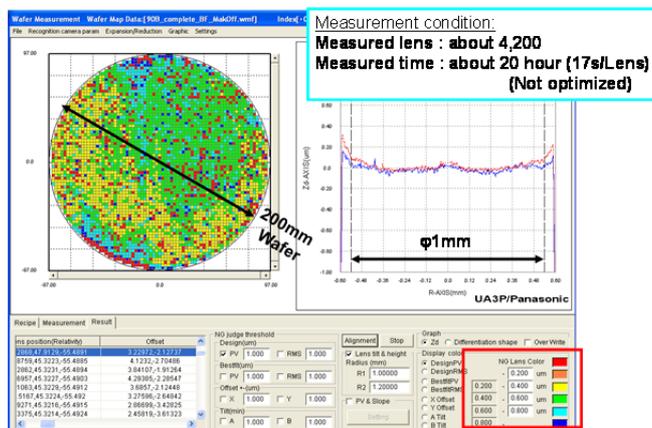

Fig. 17: PV distribution map on the wafer lens

In the Fig. 17, we measured the 4,200 lenses on the wafer and measurement time is 17s/lens.
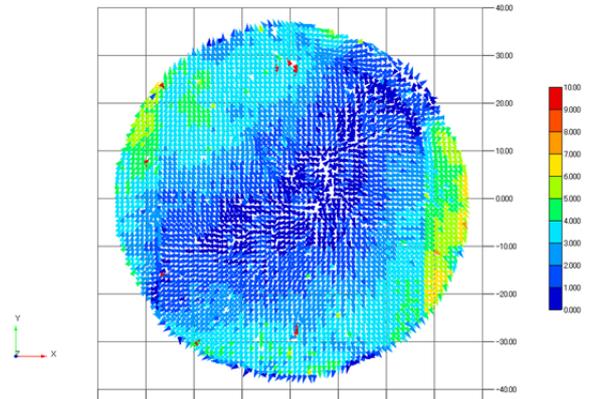

Fig. 18: Lens center deviation from the designed position

UA3P has the laser interferometer system in not only XY but also Z direction. To evaluate the deviation of lens center, first each lens center position is calculated by each XY direction scanned measurement data, and second compare the lattice of each lens designed center position. After that, we can evaluate the lens center deviation on the wafer.

In the Fig. 18, lens center deviation from the designed position is calculated from measured data.

2.5 Decenter and tilt measurement for asphere

In case of both side asphere lens decenter measurement, the decenter and tilt can distinguish by on XY axes measurement result if the XY direction measurement data can be get on the same measurement axes.

We define the decenter and tilt of the both side asphere lens in the Fig. 19.
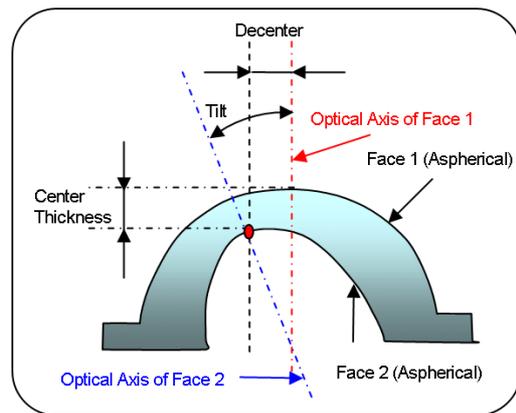

Fig. 19: Definition of the decenter and tilt

To measure the decenter and tilt between the front side and back side of the lens, we set the lens to the jig which have 3 balls sphere which round ness is less 50nm.

And first measure the front side of lens surface to XY direction and measure the 3 balls. Second, rotate the jig 180 degree and measure the back side of lens surface to XY direction and measure the 3 balls.

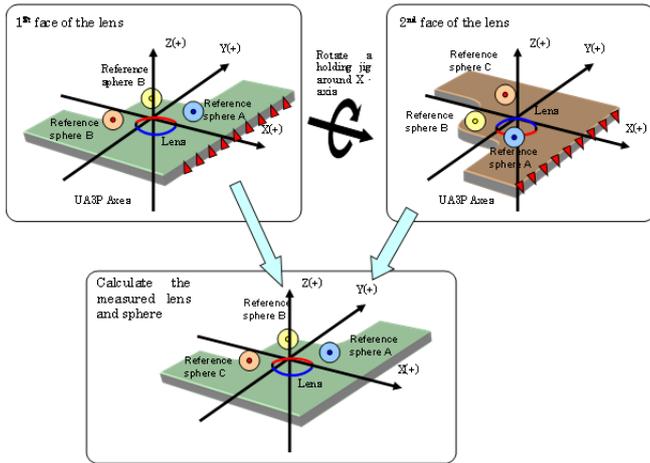In the Fig. 20, we show the measurement procedure.

Fig. 20: Measurement procedure of decenter and tilt

After we measured, both side data is combined to the 3 ball center to be same position, and shift the combined data to be parallel to front side or back side by your choice. So we can get the both side asphere lens decenter and tilt in Fig. 21.
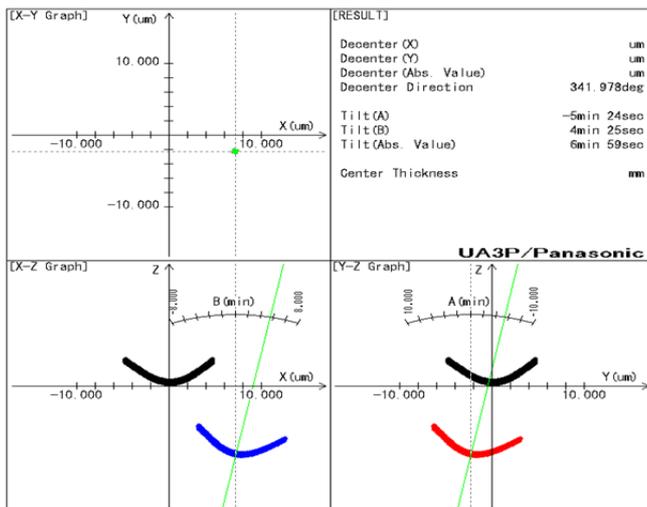

Fig. 21: Decenter and tilt measurement result

3. CONCLUSION

We developed non contact air bearing system and linear motor system. UA3P-650H/700H get the accuracy less than 0.1 um of R80mm sphere measurement result which surface inclined angle is 60 degree and get the scanning speed in actual measurement up to 30mm/s.

And we introduced the freeform measurement and automatic measurement system for conventional asphere and wafer level lens and the decenter measurement of asphere.

ACKNOWLEDGEMENTS

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