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The Development of a three dimensional displacement platform

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ABSTRACT

This paper presents a novel precision three-dimensional platform based on vertical scanning that has practical application in surface topography measurement. The three-dimensional precision platform is composed of a two-dimensional platform with metrology system and a vertical scanning platform. When the work piece is measured, the closed loop control system controls the two-dimensional platform. Meanwhile, the Z direction servo motor and the piezoelectric actuator drive the vertical scanning platform to move vertically to realize the fine displacement. The diffraction grating displacement sensor detects the vertical relative displacement of the vertical scanning platform.

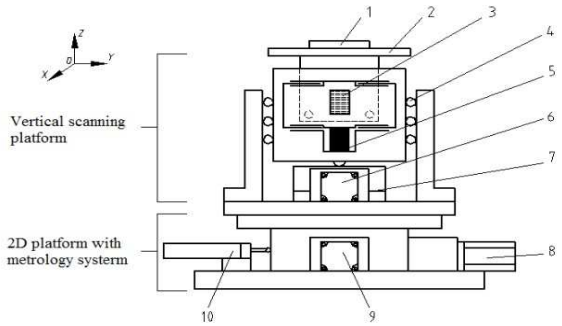
INTRODUCTION

With fast development of precision processing and measure skill, the issue of fine displacement becomes crucial part[1,2] In order to study surface appearance and function, the evaluation of surface topography measurement evolves from two-dimension into three-dimension and scale develop from micron to nanometer, plus measuring range turns from small areas to much bigger range. Meanwhile, micro-processing, micro-operating and micro-storage are also expected to enlarge their ranges and precision to enhance the function and efficiency of the equipment. Hence mass of precise-location platform becomes imperative for advanced science.

This paper presents a three-dimensional precision platform which can be widely implemented in surface topography measurement, precise and super-precise processing and semiconductor ray-carve areas, etc. In compared with traditional two or three dimensional platform, it has the advantages of high precision and bigger measurement range. It adopts rough fit location system and metrology including the closed loop control. The platform achieves mass of full range scanning vertically (Z axes) and precise-location horizontally) (from X-Y axes).

ISTUCTURE AND PRINCIPLE OF PLATFORM

System whole structure and work principle. The structure of three-dimensional platform with metrology system is shown in Fig 1.



1 Work piece, 2 Objective table, 3 Diffraction grating displacement sensor,4 Linear rolling Guide, 5 Piezoelectric actuator 6 Z direction servo motor,7 Inclined Guide, 8 Y direction motor, 9 X direction motor, 10 Metrology grating displacement Sensor

Fig.1 The structure of three-dimensional displacement platform

The platform is composed with vertical scanning platform and two-dimensional X-Y platform. The vertical scanning platform is put above the two-dimensional X-Y platform, which shown as Fig 2**.**

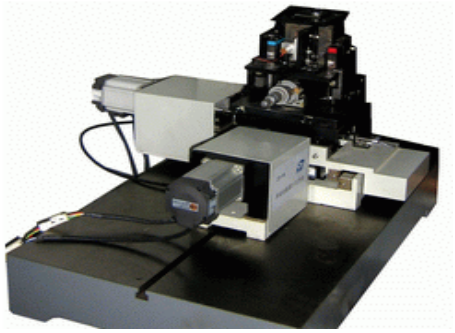


Fig.2 Real photo of three-dimensional platform

Vertical scanning platform. As showed in Fig 1, measurement vertical scanning platform is composed by rough and precise drive. The precise drive is carried out by piezoelectric actuator 5 and the rough drive is carried out by servo motor 6 on and inclined guide structure 7 on Z axes. The movement of both driving is systematically measured by diffraction grating displacement sensor [3].

Fig 3 shows the illustrative diagram which diffraction grating measures systematic optics. The laser launches ray which reflects on diffraction grating then diffracts rank +1 and -1 two diffraction lights. The lights pass through right-angle prisms positioned aside and reflect back to one spot on diffraction grating. After the second diffraction, diffraction lights (+1, +1) and (-1,-1) will form interference fringe on op to-electrical inductor that is perpendicular to X axes. As diffraction grating moves, interference fringe moves to reflect the object movement by observing fringe's change. Diffraction grating system adopts the measuring diffraction gratings with 1200 grooves/mm and the final resolution can reach up to 5nm by two diffractions and signal subdivision of 20.

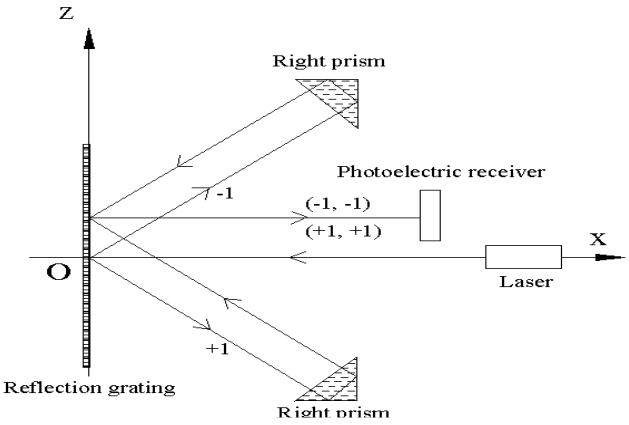


Fig.3 The principle of the diffraction grating displacement sensor

This system implements type WTDS0810025 retractable piezoelectric actuator from China Electrical Technology Group. Co, Ltd. high voltage driven power is self-manufactured.

Piezoelectric actuator power normally can be separated into voltage-controlled type and electricity-controlled type. There are two forms of voltage-controlled power: one is based on DC converter switch which has the traits of low power usage, high efficiency and small volume, however has weak points of big power output ripples and narrow range of frequency response. Another one is DC amplifier which has broader range of frequency response but it is contradictory to output precision. However from the view of development, this kind of power has bright future.

Electricity-controlled power can improve piezoelectric ceramic's sluggishness and deformation. Since piezoelectric ceramic carries big internal resistance, it suits for static state or low frequency response condition due to its characteristics of low electric current charging and long response time. According to the system's need, DC amplifier is implemented and Fig 4 shows how the circuit works.

It implies that this particular drive circuit has higher resolution than millivolt when the alternating component shows less than 1mV in condition of stable high voltage output after using multimeter in millivolt switch. It can be reached to a very high resolution using piezoelectric actuator to measure precision.

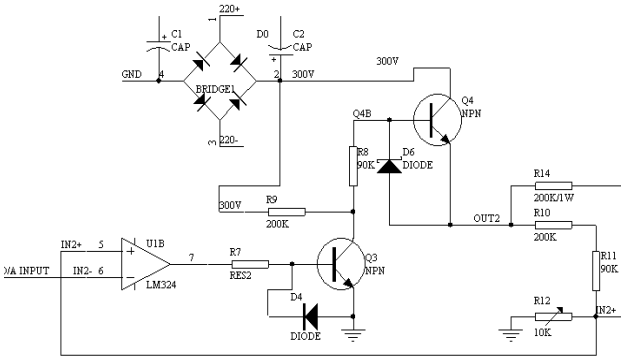


Fig.4 Circuit principle of high voltage driver

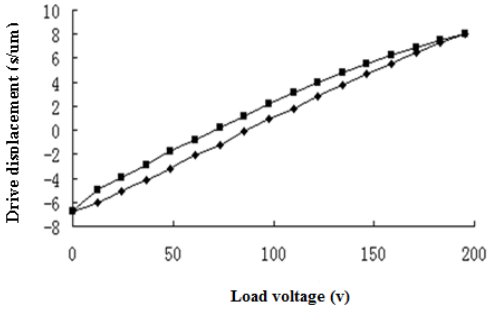


Fig.5 The static characteristic curve of PZT

Type WTDS piezoelectric actuator is formed by several layers of ceramics. In no-load condition, when voltage increases from 0 to 200V, there is 20um of displacement increased. Fig 5 shows drive displacement curve of the micro platform for this system. The method of voltage loading is to load up or load down 12.5V and stabilify for 10 seconds each time from 0 to 200V. The upper curve is 0 to 200V and the lower curve is 200 to 0V. The inductive displacement sensor can catch the movement with precision and high voltage driver provides the loading. The Fig 5 shows in observed the measuring range of piezoelectric actuator is 16um and it appears to have hysteresis curve with wider margin.

Calculated from simple the simple equation, the theoretical value of displacement resolution is 16μm/32000=0.5nm on condition of 16 digital chip and within 20um.

X-Y two- dimensional platform. As showed in Fig 6, the X-Y two-dimensional control system [4]. On X axes X-Y platform, servo motor drives guide screw spinning through sleeve pipe then the platform begins to move. Meanwhile on the other side of the platform, displacement sensor receives target's movement signal then circuit makes subdivision of the output signals and finally processes position and calculation. After calculation of platform's actual movement by software, the machine makes comparison of actual movement and target movement and controls precise position of stepping motor with the difference value. It is the same story for Y axes drive on X-Y platform.

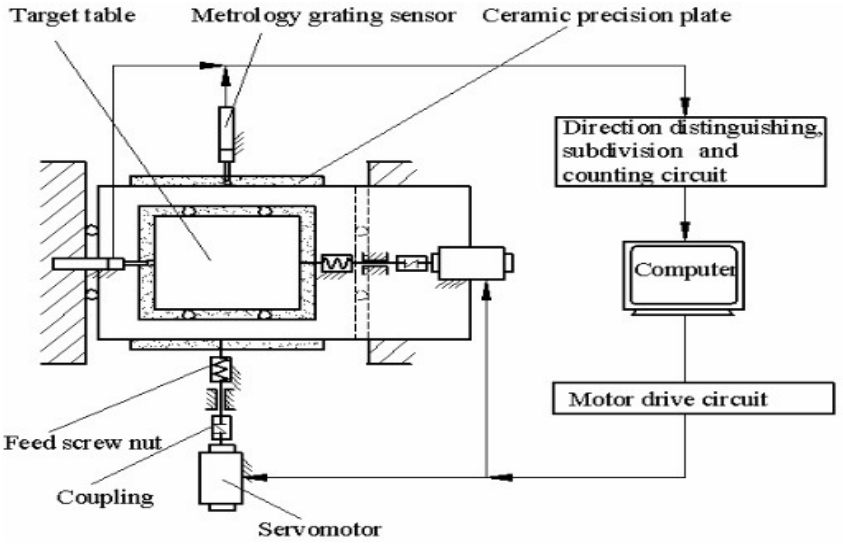
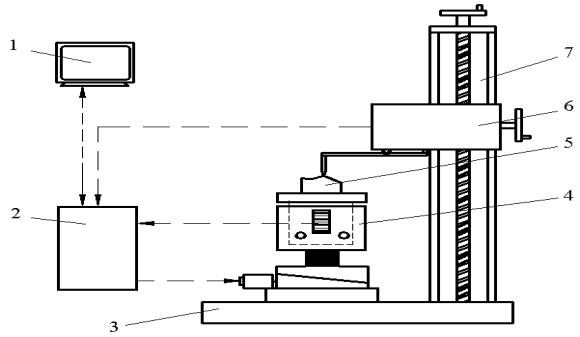


Fig.6 The control system of the 2D platform
With metrology system

The platform uses conjunct base level design. It bears object moving forward to X and Y axes on platform and always sticks on precise ceramic surface to move which leads to high-precise movement surface.
Adopted raster's (the displacement sensor) measurement range is 0 to 50mm and cascade spacing is 20μm. Its quadruple frequency pulse resolution is 5um.

The application of platform and experimental results

This subject has already successfully introduced three-dimensional precision platform which applies for three-dimnsional surface topography measurement. The evaluation leads to good measurement effect. Traditional profiler has the shortcomings like low precision and limited measurement range. However using three-dimensional precision platform can effectively gain much higher precision and reduce measuring force.



1 Computer, 2 Measurement and control circuit, 3 Base,
4 Vertical scanning work table, 5 Work piece,
6 Inductive sensor, 7 pillar

Fig.7 Application of three-dimensional Precision instrument
on three-dimensional precision platform

When measures an object, servo motor and the piezoelectric actuator drive the vertical scanning platform to move vertically to realize the fine displacement according to the displacement sensor calculates the zero shift value and also make sure measuring level keeps in balanced position. In this way, it avoids nonlinear difference coming from the leverage rotation of traditional profiler and

increases measuring precision. At the same time, the diffraction grating displacement sensor detects the vertical relative displacement of the vertical scanning platform and sends the information back to relevant circuit and computer for processing. Final results can be obtained from assessment software. Due to two-dimensional platform's accurate positioning in X-Y direction, this instrument can perform three-dimensional surface topography measurement. As showed in Fig 8 and Fig 9 is original surface topography contour curve and measuring results separately.

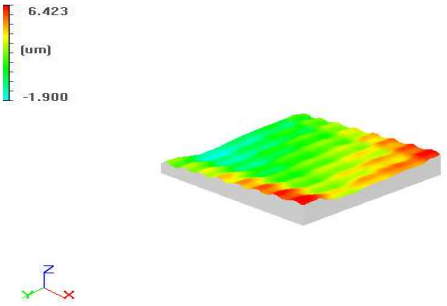


Fig.8 The original 3D surface topography

Sq	1.04um
Sz	1.46um
Ssk	1.04
Sku	2.23
Sds	235.69 peak/mm²
Str	0.09

Fig.9 The 3D measurement result

CONCLUSION

Vertical scanning platform uses the diffraction grating displacement system for measurement and resolution response can reach 5nm. Meanwhile X-Y two-dimensional platform uses raster size system and its quadruple resolution response is 5um. Therefore this three-dimensional platform which is formed by vertical scanning platform and X-Y two-dimensional platform has the traits of high precision and big measurement range. It has special value for three-dimensional surface topography measurement and assessment field.

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