A large ion beam figuring plant used for manufacturing astronomical telescope

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ABSTRACT

A large ion beam figuring plant which can process up to 1.5m mirror in diameter has been developed. The plant adopts five axes scanning mode. The mirror with which the five axes scanning system is set face to face is placed vertically when working that can reduce the adverse effect of the flour dust to the mirror and the ion source. The mirror and the five axes scanning system are installed on two doors respectively. The open-close type of the door is a hanging bridge type. And the door will be horizontal when completely opening that will be convenient for installing the mirror and maintaining the system. Two software which are used for calculating the dwell-time and controlling the five axes system are programmed. The five axes system will always keep normal direction following when working.

Keywords: ion beam figuring plant, five axes controlling, mirror figuring

1. INTRODUCTION

At the beginning of this century, some domestic and international astronomer have put forward several design proposals of overlarge foundation astronomical telescope. Now two projects have been started: one is E-ELT of Europe, which caliber is 42m; the other one is TMT of the USA, which caliber is 30m. These overlarge telescopes are built up of several hundred or thousands of sub-mirrors. And each of the sub-mirrors is off-axis aspherical mirror. It is very hard that these mirrors are processed by conventional method.
Ion beam figuring is the key technology which is used for precision polishing the mirrors of 30m-100m overlarge telescope.
We carry out the work of developing a large ion beam figuring plant, which is sponsored by National Natural Science Foundation of China. The goal of the project is developing a plant which can process 1.5m mirror.

2. STRUCTURE OF THE PLANT

Figure 1 is the working principle diagram of ion beam figuring plant. The upward side is the mirror to be processed. The ion source which produces ion beam is set on a five-axis coordinate system. The five-axis system will always keep normal direction following when working. And distance between the mirror and the ion source will keep unchanged.

6th International Symposium on Advanced Optical Manufacturing and Testing Technologies: Advanced Optical Manufacturing Technologies, edited by Li Yang, Eric Ruch, Shengyi Li, Proc. of SPIE Vol. 8416, 841607

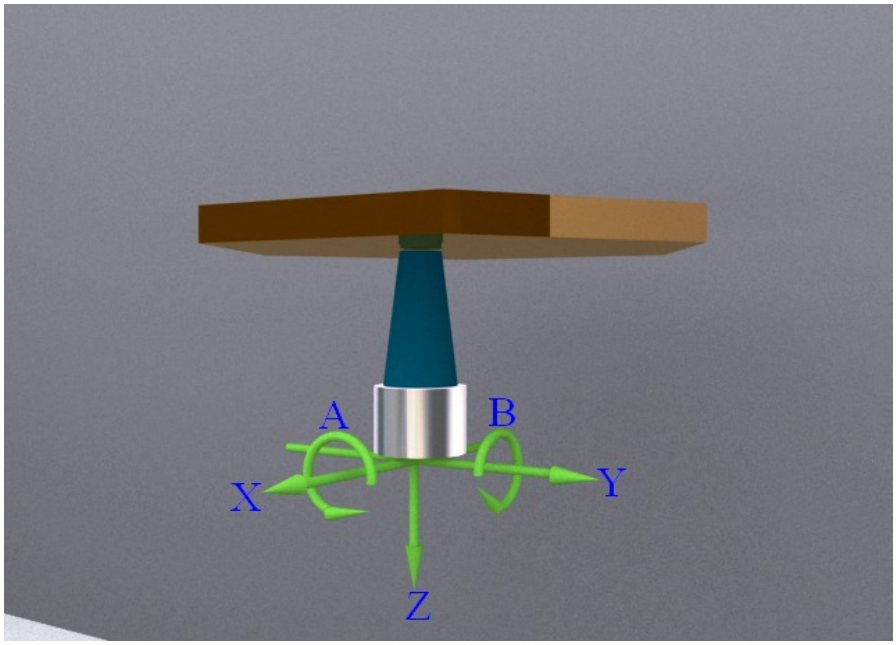

Figure 1: the working principle diagram of ion beam figuring

The mirror and the ion source is upper and lower positioned in Figure 1. The early ion beam figuring plant adopted this method. Practices indicate the material bombarded from mirror will contaminate the ion source. So we adopt the method of face to face vertically positioned.

The main part of new plant is a large vacuum chamber in Figure 2. The cylindrical vacuum chamber is placed horizontally. The two ends of the vacuum chamber are two spherical shell-shaped doors. The hinge of the door is not on the side but in the bottom of the vacuum chamber in contrast with general vacuum equipment. The door is controlled by hydraulic system. The door will be horizontal when it falls down. The workpiece plate used for setting mirror and five-axis coordinate system are installed in two doors respectively.


Figure 2: the picture of ion beam figuring plant

From the situation we have known, this kind of structure has never been saw on the similar equipments at home and abroad. But its advantages are quiet obvious.
(1)When ion beam figuring is processing, some very fine dust will be produced. It is not good that the dust fall on the mirror or ion source. But the dust will fall vertically under the influence of gravity in vertical and opposite case. That will greatly reduce the influence on the mirror and ion source.
(2)The workpiece plate and five-axis coordinate system are installed directly in two doors respectively. So the material and the space will be saved. The door will lie above the ground when the door opens. It is very convenient to install samples and maintain the ion source. At the same time, this kind of plan will produce that the structure is compact; the interior volume of vacuum chamber is the smallest; a higher vacuum degree will be obtained by a smaller vacuum pump.
(3)The plant can arbitrarily choose polar coordinate or Cartesian coordinate when ion beam figuring is needed. For example, generic mirror can be processed by polar coordinate. Off-axis aspheric mirror can be processed by Cartesian coordinate.
(4)Small magnetron sputtering source can be installed in the location of ion source. Then technological test of coating filling figuring can be carried out.

3.MATHEMATICAL MODEL AND CONTROL SOFTWARE

The description of ion beam figuring is a convolution formula:

$$E(x,y) = \iint_{path} R(x,y) \cdot D(x-\xi, y-\eta) d\xi d\eta + Q(x,y)$$

E(x,y) is defined as the error distribution of the mirror;
R(x,y) is defined as the material distribution function which is bombarded by ion beam per unit time;
D(x,y) is defined as the dwell time of the ion beam everywhere on the surface of mirror. It is called dwell-time function;
Q(x,y) is defined as the residual error, after processing.

We establish the computer mathematical model according to this formula. Our goal is to solve the dwell-time function *D(x,y)*, which is the time the ion beam should stay in each point of the mirror.
In mathematical modeling we enter into in-depth discussions. Finally we establish a method of optimized dwell-time calculating. We can quickly get accurate dwell-time table without negative time value. The calculating process simulates the figuring process. The dwell-time of the high place will be gradually implemented by tentative removing the high place on the mirror surface. we can quickly complete the calculating so long as the the error distribution of the mirror *E(x,y)*, the material distribution function *R(x,y)* and the dwell-time function *D(x,y)* are saved in the computer.
How to get a precise removal function *R(x,y)* of ion beam is also very important. But the details have never been introduced in the literature. We have successfully established a method of accurately extracting the removal function of ion beam.
There are three main software that are programed for the plant:
1. Calculating (mathematical simulating) software
The dwell-time matrix will be produced by calculating according to the mirror error to be processed.
2. Coordinate system controlling data generating software
The motion parameters of five-axis movement will be calculated according to the size and shape of the mirror in order to realize normal direction following when working.
3. Five-axis coordinate moving controlling software
Five-axis moving will be realized by implementing the data files produced by before-mentioned two software.
In addition there is a vacuum system monitoring software on the plant. The software can control the vacuum pumps and automatically display the real-time vacuum degree of various parts in the vacuum system. The file will be automatically saved and recorded.

4. CONCLUSIONS

We develop this large ion beam figuring plant according to our understanding of ion beam figuring technology. In order to facilitate work, there are some new considerations that will be convenient to use and maintain. Now the plant is

basically functioning properly. Figure 3 and Figure 4 are the measurement data before and after ion beam figuring. RMS value has reached 6nm, better than 1/100 wavelength; PV value has reached 39nm,better than 1/16 wavelength.

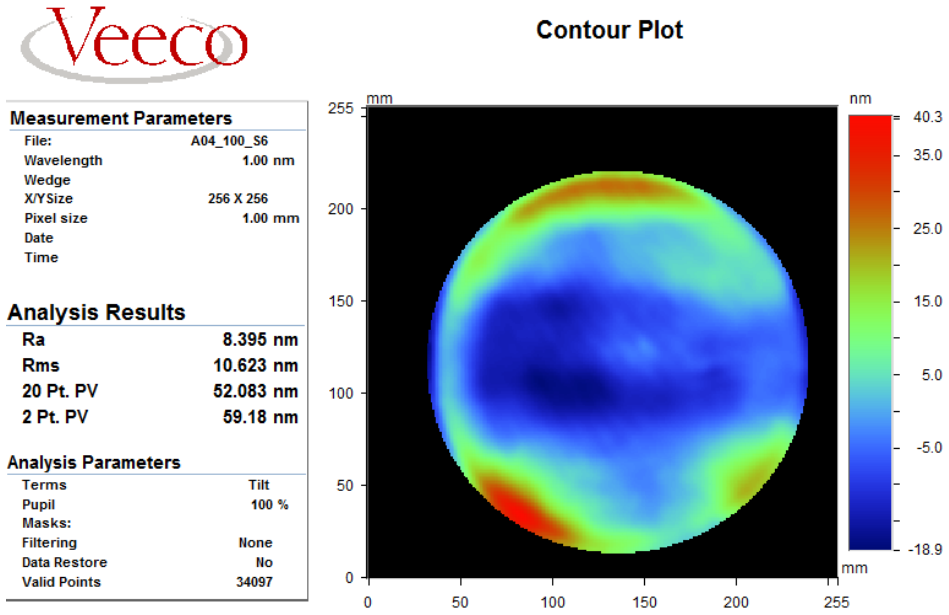

Figure 3: before ion beam figuring

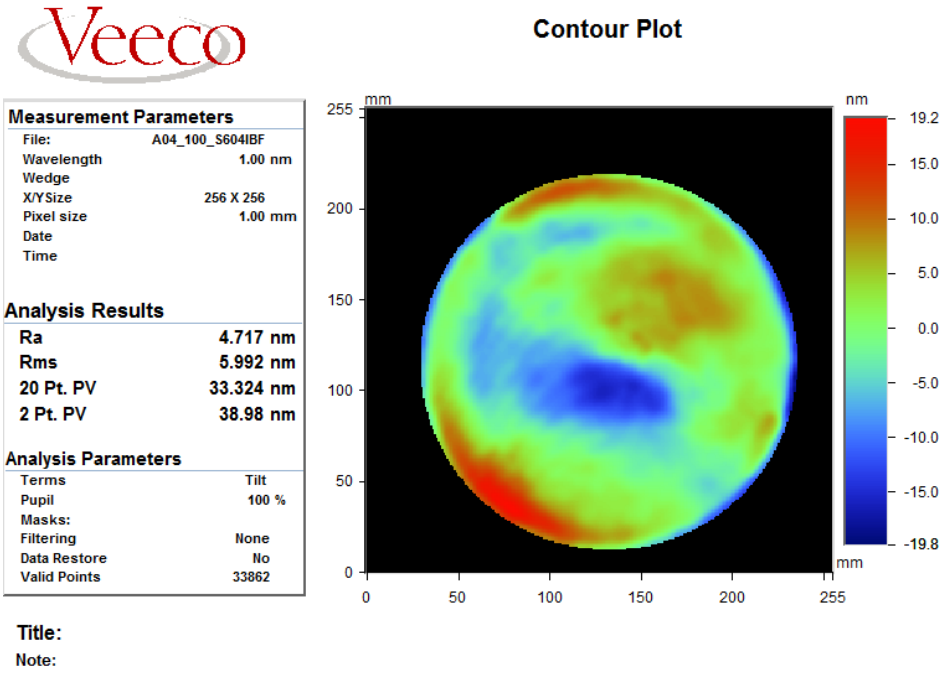

Figure 4: after ion beam figuring

5. ACKNOWLEDGEMENT

This project is supported by National Natural Science Foundation of China. The foundation number is 10827302. We appreciate their trust and support.

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