High precision manufacturing of small aperture double aspheric shaping element

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Small-aperture aspherical optical components that significantly enhance imaging quality and improve the optical performance of instruments when employed in optical systems, The manufacturing of small-aperture aspherical optics still faces issues related to processing efficiency and accuracy, due to the relatively limited processing space for such components. In order to produce high precision small aperture aspherical optical components, The ultrasonic vibration assisted cutting and the high precision grinding and polishing technology were used for the processing. The surface accuracy was less than 200nm measured with a profiler, and the roughness was smaller than 20nm with the help of the white light interferometer.

1. Introduction

It is well known that the uniform of high intensity distribution was highly desirable for many practical applications such as laser processing, lithograph, optical storage and high-power laser coherent synthesis[1-3], And various design methods have been developed to design integrated shaping elements [4-6], In order to reduce the number of optical components, simplify the instrument structure, lighten the instrument weight, and lower production costs, the demand for small-aperture aspherical optical components has grown dramatically[7-8]. The surface quality of small-aperture aspherical optics demands not only a nanometer-level surface roughness but also sub-micrometer-level shape accuracy and minimal subsurface damage[9-10]. Although the technology of manufacturing has made great progress in recent years, it is still a challenge to get small scale high-precision aspherical surfaces for the glass material .

In this paper, a single-lens beam shaper element that contains two high-order aspherical surfaces was implementation. The ultrasonic vibration assisted cutting and high-precision grinding-polishing technology were employed for the beam shaper element machining. The surface accuracy and roughness of the element was measured by profiler and white light interferometer.

2. The Optical Manufacture and Testing

2.1 Manufacture

It is essential to realize the beam shaping that the optical manufacturing and testing of shaper component. The parameters of the fused quartz were shown in table 1. As is the typical hard and brittle material, traditional machining methods are difficult to achieve high-precision surface for fused quartz. Therefore, innovative processing method of ultrasonic vibration assisted cutting and high-precision grinding-polishing are explored in this paper.

Table.1 The parameters of the fused quartz

Parameters	Value
Refractivity	1.46@1064nm
Abbe number	63.96
Knoop hardness HK 100(kg/m^2)	610
Young's modulus E(Gpa)	73
Density(g/cm^3)	2.19
Thermal expansion coefficient(W/mK)	0.5 × 10 ^ -6

According to the analysis above, the surface shape accuracy and roughness are equally important for the beam shaper. The processing flow is shown in fig.1. After the rough forming machining, the beam shaper was cutting with ultrasonic vibration assisted method to obtain high surface shape accuracy. And the high precision profile detecting was used to evaluate the RMS. Then the high precision grinding and polishing were used to improve the surface roughness of Ra, and the scanning white light interferometer are used to testing the Ra.

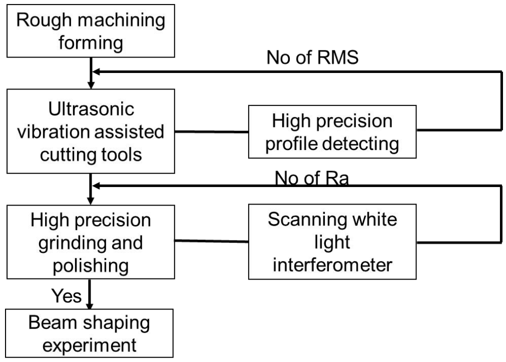

Fig.1. Processing and testing flow chart

The ultrasonic vibration assisted cutting was shown in fig.2 with two steps of rough machining and precision machining. Th e machining parameters were shown in table 2, the tool with 0. 5mm corner radius, -25°tool rake angle and 10°tool clearance w as chosen to generate high-pressure phase transition of fused q uartz. Firstly, the rough cutting was performed with the rotating speed of 3000 r/min, 1300 mm/r feeding rate and the cutting d epth 0.03mm. And the ultrasonic vibration voltage is 56V, the fr equency is 100kHz with 970nm amplitude. The selection of para meters for low voltage, low frequency and large amplitude were mainly aimed at improving material removal and laying the fo undation for surface shape in precision machining. Then the fine cutting was performed with a rotating speed 5000 r/min, 1000 mm/r feeding rate and the cutting depth of 0.003mm. The ultras onic vibration voltage is 65V, the frequency is 125kHz with 600 nm amplitude. The purpose of increasing voltage and frequency and reducing amplitude was to improve surface shape accuracy

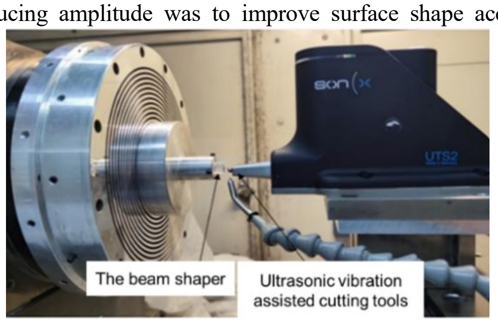

Fig.2. Processing with ultrasonic vibration assisted cutting tools

Table 2. The parameters of ultrasonic vibration assisted cutting

Parameters		Rough	Fine
Cutting	rotating speed（r/min）	3000	5000
	feed rate（mm/min）	1300	1000
	cutting depth（μm）	0.03	0.003
Tool	corner radius（mm）	0.5	
	tool rake angle（°）	-25	
	tool clearance（°）	10	
Ultrasonic vi bration	voltage（V）	56	65
	frequency（kHz）	100	125
	amplitude（nm）	970	600

The high precision grinding and polishing were shown in fi g.3 with the parameters in table 3, the 6mm grinding head dia meter and 2000# abrasive size tools were selected, and the rotat ing speed was set as 20000 r/min with 1500 mm/r feeding rate and the cutting depth was 0.004mm.

Fig.3. High precision grinding and polishing

Table 3. The parameters of high precision grinding and polishin g

Parameters		Value
Cutting	rotating speed（r/min）	20000
	feed rate（mm/r）	1500
	cutting depth（mm）	0.004
Tool	Grinding head diameter (mm)	6
	Abrasive grit size	2000#

2.2 Testing

After high-precision grinding and polishing, the sample of beam shaper was shown in fig.4, the concave surface S1 and the convex surface S2 could be clearly seen. And the surface accuracy profile detecting was put into effect as fig.5, The detec ting results were shown in fig.6 and fig.7. The RMS shape erro r of S1 and S2 were 196.92nm and 178.40nm just as fig.6(a) a nd fig.6(b), both of them met the indicator requirements less tha n 200nm. The Ra of S1 and S2 were 17.83nm and 16.81nm ju st as fig.7(a) and fig.7(b), both of them met the indicator requir ements less than 20nm.

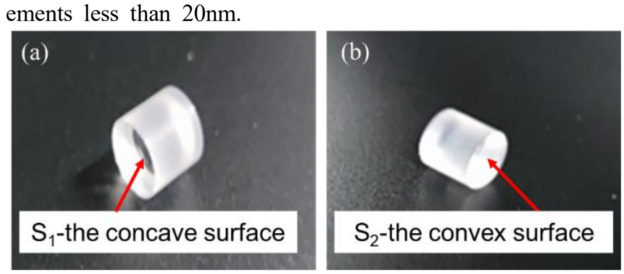

Fig.4. The sample of the shaper

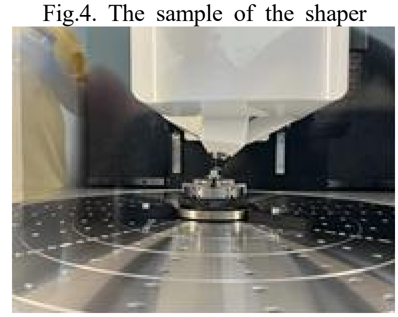

Fig.5. Surface accuracy profile detecting

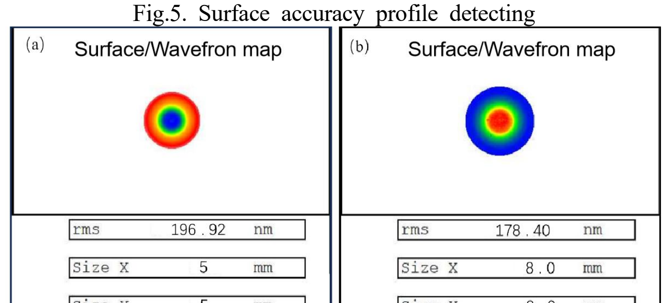

Fig.6. (a) RMS of S_1 (b) RMS of S_2

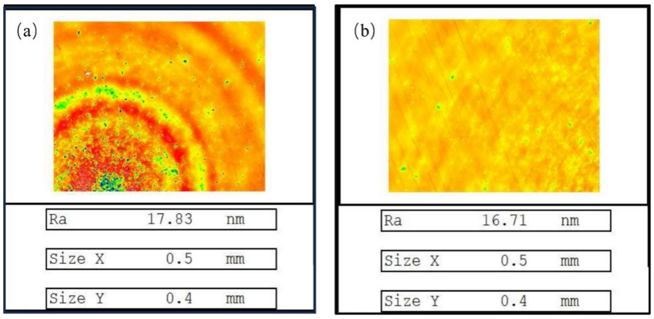

Fig.7. (a) Ra of S_1 (b) Ra of S_2

3. Conclusions

In this paper, the ultrasonic vibration assisted cutting and high precision griding and polishing were used to process small aperture double aspheric shaping element, taking the measurements results into consideration, the RMS is within 200nm and the Ra is within 20nm, which can meet with the need of the beam shaper. In addition, such a beam shaper simplifies the overall structure in comparison with the traditional one and it is easy in alignment and reduction of cost. The results showing tremendous potential in the field of laser processing. So, this kind of beam shaper has the potential to be mass produced.

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