

A Simple and Rapid Data Extraction Method for the Precision Aspheric Optical Surface Height

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Abstract. Nowadays, the application of aspheric optics is becoming more and more popular in the precision optical engineering field. Therefore, it urges the rapid development of the precision machining and measuring technology. Generally, the aspheric optical component is measured by the interferometer. The underlying question is that the figure output by interferometer can't be always recognized by other analysis software or program though the interferometer has its own unique data processing system. In this paper, a robust, rapid and simple method is presented to interpret the surface height data of the precision machined aspheric optical surface. The optical surface is measured by interferometer. The result figure is split into two parts, one of which is the interferogram picture of the whole aspheric optical surface and the other is the colour reference column indicating the height value. The ratios of the red (R), green (G) and blue (B) are analysed based on the middle of the colour reference column, and the corresponding relationship between the colours and surface height is established and looked as a reference data base. Then the interferogram picture of the whole aspheric optical surface is also analysed and divided according to the red (R), green (G) and blue (B) colours. By comparing the ratios and values of RGB colour, the aspheric optical surface height can be extracted approximately. The feasibility of this method was approved by the extraction processing experiment of a polished aspheric optical surface.

1. Introduction

Because of its excellent optical properties, large aspheric surfaces are used in many fields, especially in the astronomical telescope, satellite optical system and laser fusion. The high precision aspheric optics urges the rapid development both of the precision manufacturing and measuring technology. Till now, it is hard to achieve the high precision because of its complex shape and the large size [1-4]. One of the reasons is that it lacks the effective method to evaluate the property of machined optical surface. The machining process of aspheric optics ranges from rough machining, semi-finish machining and finish machining. Each machining process needs their own different measuring method. Generally, polishing is the final procedure to achieve the ultra-precision requirement of the aspheric optics. The polished optical surface has the highest precision degree, and is much close to the theory surface form [5]. Moreover, the aspheric optics is basically transparent, which results the ultra-precision of the polished optical surface needs a specific measuring technique. The optimum equipment to measure the polished aspheric surface is the laser interferometer. The laser interferometer is a type of noncontact measuring method and has its own unique data processing system. But the output result of the laser interferometer is often a colour figure expressed by red, green



and blue, which indicates its surface height. In general, researchers can analyse the surface condition by the output colour figure. But unfortunately, the figure output by interferometer can't be always recognized by other analysis software or program, which brings inconvenience to the researcher who doesn't have the interferometer equipment. On the other hand, the analysis with the interferometer is also time consuming and is expensive. Then it is apparently that a data extraction method is necessary to the analysis of polished aspheric optics, by which the surface height can be extracted and dealt as a data base. In this paper, a robust, simple and rapid method is presented to interpret the surface height data of the precision machined aspheric optical surface.

2. Theory of the Surface Height Data Extraction Method

The data processing procedure always runs within the *MATLAB*, which was developed by Math Works Corporation in 1984. *MATLAB* has many merits in data processing, such as the powerful capability in the matrix calculation, friendly viewing interface, high programming efficiency, opening property and fruitful figure processing function. Now, *MATLAB* has become the mainstream in the data and figure analysis field. *MATLAB* is suitable for the figure processing operation. The basic research content of *MATLAB* includes the figure transformation, figure strengthening, figure analysis and figure condensing. In this paper, the figure processing research is performed based on the *MATLAB* software. A figure in *MATLAB* may be expressed as a data matrix or a mapping matrix with colour. Based on the matching relationship between the data matrix and the index of figure pixel value, a figure in *MATLAB* can be sorted as four types, which are indexing figure, gray figure, binary figure and RGB figure.

The indexing figure deals with the pixel value as the bottom index of RGB colour palette. In *MATLAB*, indexing figure includes a data matrix and a colour mapping matrix named as colour palette. The data matrix may be unit 8 and unit 16 or double precision. The colour mapping table is a $m \times 3m \times 3$ data matrix, and the elements values are double precision floating point data type data and ranges from 0 to 1. Each row of the mapping matrix denotes the colour fraction values of red, green and blue. The indexing figure can map the pixel value to the value of colour palette. The value of each pixel can be achieved by using the value of data matrix's bottom index. For example, value of 1 can be set as the indicator pointing to the first row of the mapping matrix and value of 2 to the second row, and so on. The grey figure only contains the intensity information without the colour fraction information. The grey figure in *MATLAB* is also a data matrix. Each element represents a pixel point. The data matrix of grey figure can be double precision and its elements vary from 0 to 1. The data matrix of grey figure can also be the unit 8 type and its value ranges from 0 to 255. The value of 0 of both cases denotes the colour of black, and the 1 of double precision type and 255 of [in unit 8 which 0](#)~~in unit 8 which 0~~ means the colour of white. The binary figure can be looked as either a special grey figure that only contains black and white colours or an indexing figure including two different colours. The matrix of binary figure contains only 0 and 1. The matrix can be saved as data arrays of double precision type or unit 8 type. *RGB* figure is also called as the true colour figure. Liking the indexing figure, it is expressed with three different colours (red, green and blue), which are red (*R*), green (*G*) and blue (*B*) and is called as the *RGB* figure. The data of *RGB* figure matrix can be either double precision floating type, unit 8 or unit 16. The combination of three colours can get any forms of colours. Different ratio of three colours denotes different surface height.

By comparing the characteristics of figure types mentioned above, it can be found the *RGB* figure is more appropriate to the expression of surface height. If a colour figure can be identified in terms of different colours' element fraction, the mapping relationship between the surface height and colour element fraction can be achieved. Therefore, the *RGB* figure was chosen as the researching object to extract the surface height of polished aspheric optical component. The proposed extraction method of surface height can be described as follows,

2.1 To Read the RGB Interferogram Figure of Polished Aspheric Optics into MATLAB

The format of function calling of *RGB* figure in *MATLAB* is
`x=imread ('filename').`

2.2 To Split the Figure into Two Parts

One is the interferogram picture of the whole aspheric optical surface, and the other is the colour reference column indicating the height value. The format of figure trimming is

'imcrop ('filename')'.

Then the split figure is read separately into the *MATLAB* with the format of 'imread (*)'. Generally, the size of the read whole aspheric optical surface figure is $426 \times 437 \times 3$, which means that the figure contains 426×437 pixels. Each pixel's color is expressed with the color of red, green and red stored in the third column. The value of RGB ranges from 0 to 255. While the size of color reference column is $365 \times 27 \times 3$, which means that it contains 365×27 pixels. The colour of each pixel is expressed with the color of red, green and red stored in the third column.

2.3 To Build the Reference Data Base

The RGB values of the middle line of the reference column is extracted and stored in a matrix, whose size is 365×1 and its elements ranges from 0 to 255. The reference data is extracted from the middle line of the colour reference column. Through the analysis of the middle line, the fraction of different colours mixed in each pixel can be calculated. The weight component of different colour in each pixel is fitted with polynomials in *MATLAB*. In this paper, the red component is fitted with a quadratic polynomial. The green one is fitted with 12 times polynomial and the blue one is fitted with fourteen times polynomial.

In this paper, an assumption is made that the surface height of middle line of the reference column is proportional with the numbers of the combination of different colours. Then the reference data base that maps the surface height of middle line and the numbers of pixel of different colours can be built up.

2.4. To Extract the Surface Height of Aspheric Optical Component

In order to get the surface height of the aspheric optical component, a comparison method is adopted as depicted in Figure. 1. The fraction of different colours in each pixel is firstly calculated, which denote as R_i, G_i, B_i . Then R_i, G_i, B_i are compared with R, G, B stored in the reference data base, by which the deviation errors between, R_i, G_i, B_i and R, G, B are evaluated. The R, G, B with the minimal errors will be thought as the value of R_i, G_i, B_i , and so does the height corresponding to the value of R, G, B . With this method, the surface height of the whole aspheric surface can be achieved.

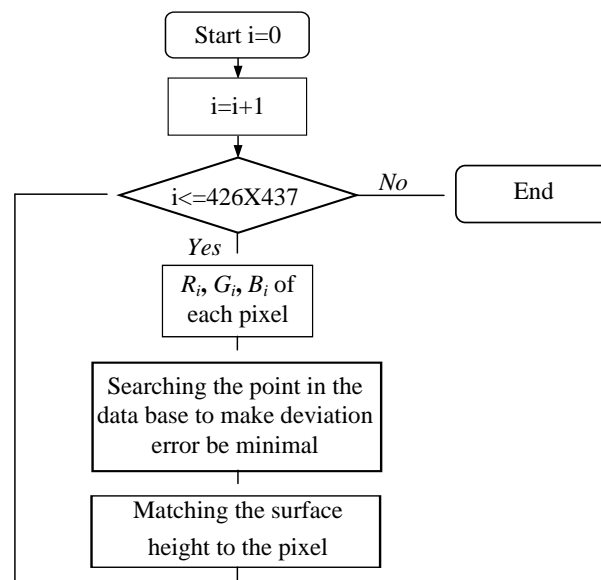


Figure. 1 Flowchart to extract the surface height by comparison

3. Verification of the Surface Height Data Extraction Method

In order to verify the feasibility of the proposed method, the extraction procedure was performed on one polished aspheric optical component. A polished aspheric optical component, of which the diameter is 100mm, was chosen as the research object. Figure. 2 is the interferogram picture of the polished surface output by the interferometer. The interferogram picture was read into *MATLAB* and shown in Figure. 3.

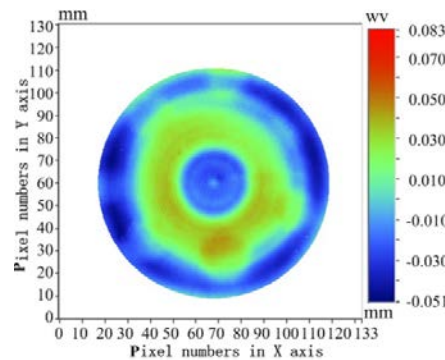


Figure. 2 The interferogram of polished surface

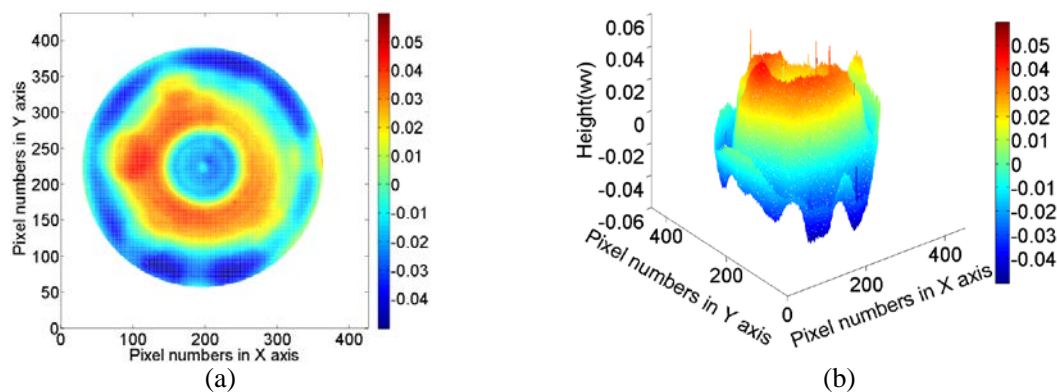


Figure. 3 Original RGB picture of surface height in *MATLAB*

According to the proposed method, the interferogram figure was split firstly into two parts. One is the interferogram picture of the whole aspheric optical surface, which is shown in Figure. 4(a). The other is the color reference column indicating the height value shown in Figure. 4(b).

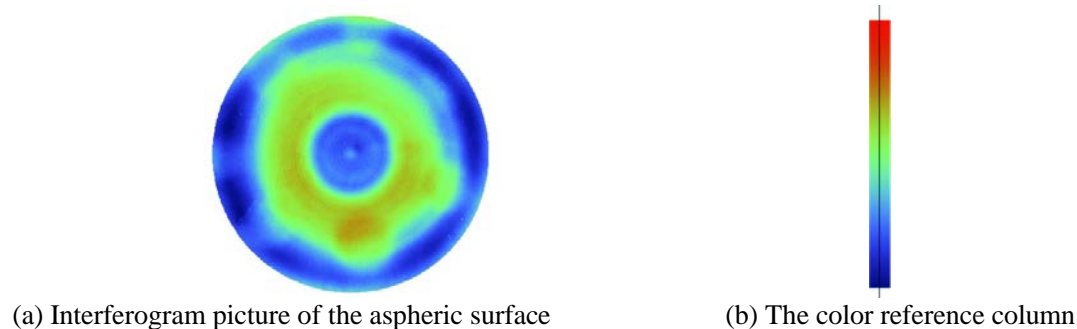


Figure. 4 The trimming figure of the interferogram

Secondly, the R , G , B values of each pixel lying in the middle line of the reference column were fitted with polynomials. Here, in order to improve the accuracy, nine interpolation points were inserted between two neighbouring surface height point to calculate the values of R , G , B of each pixel. Then the reference data base that matching the surface height and the R , G , B value of each pixel was built, which is a 3641×1 matrix. Fig. 5 (a) shows the R , G , B value of middle line and Fig. 5 (b) is the fitted values. By comparing the R , G , B value, the residual error could be calculated and was shown in Figure. 5 (c). It can be found that the biggest error is 4.3296, which means that the fitting method is feasible.

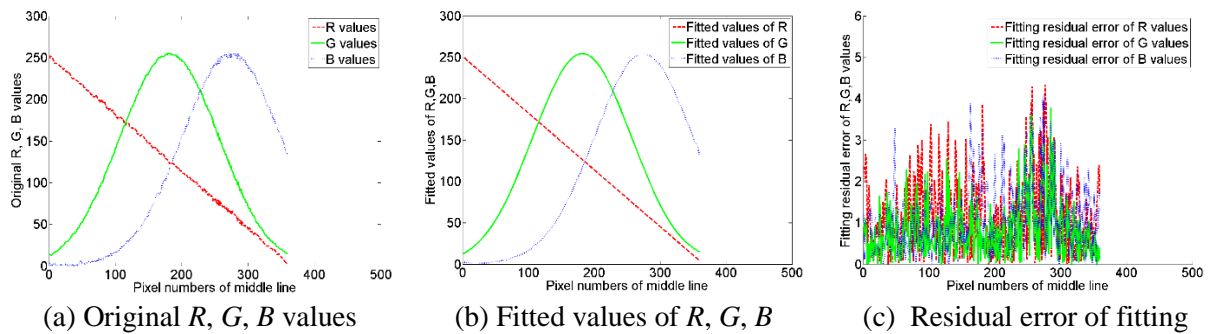


Figure. 5 Fitting R , G , B values of the middle line

With the comparison method, the surface height of the whole aspheric surface height was approximated. Figure. 6 shows the approximated surface height in *MATLAB*. It can be found that the original one is very similar to the approximated picture. Furthermore, the approximated deviation error of surface height was calculated as shown in Figure. 7. It is found that the deviation errors are very small compared to the surface height value. The biggest deviation error is 0.0059315 times of wave length, which is almost an order of magnitude less than the original surface height. Hence, the feasibility of proposed method in this paper has been approved and can be used in the approximated analysis of the polished aspheric optical surface.

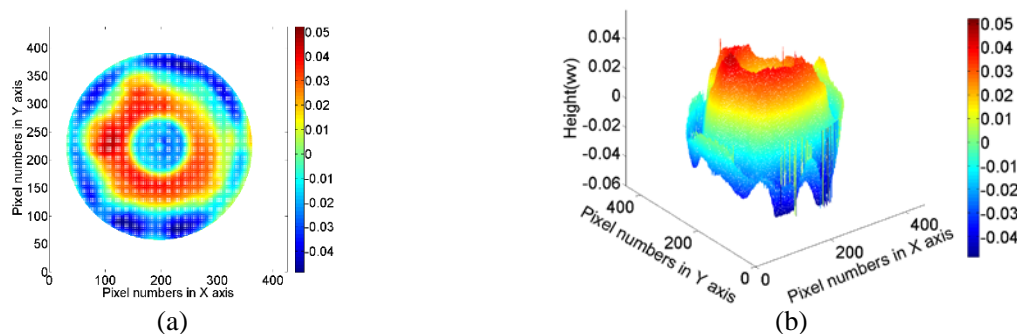


Figure. 6 RGB picture approximated in *MATLAB*

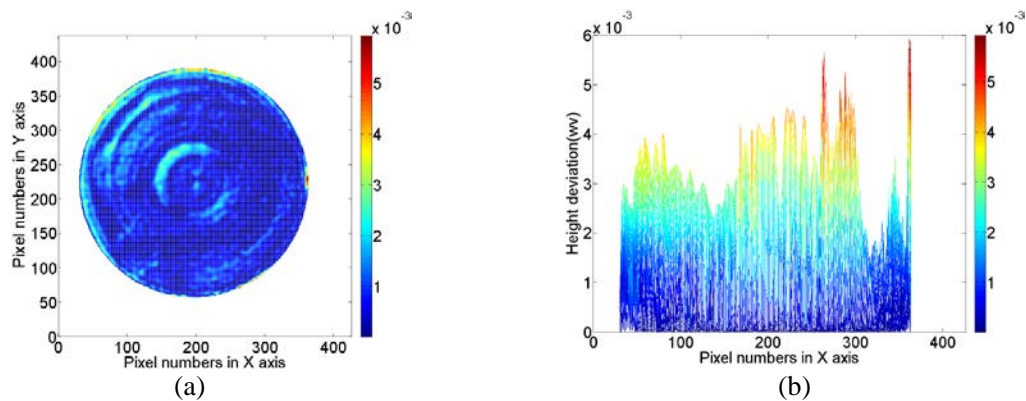


Figure. 7 Deviation error between the approximated value and true value of the surface height

4. Conclusions

The analysis of aspheric optical surface always needs a simple and rapid data extraction of the surface height. In this paper, a novel method was proposed base on the *MATLAB*. The interferogram picture of the aspheric surface was expressed in the *RGB* form and the ratios of red, green and blue were evaluated in each pixel. Then the different contents of RGB ratios were mapping to the surface height of the polished aspheric surface, with which the surface height can be extracted approximately. The processing procedure was done based on an aspheric surface. The result shows that the method proposed in this paper is feasible in dealing with the data extraction of surface height.

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6. References

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