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Measurement of displacement of optical fiber using Light Intersection Method

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Abstract

Connecting method of optical fibers by V-shaped groove is used in various fields. And in this method, it is important to estimate distortion of a fiber, because a distortion of the optical fiber influences a connection characteristics.

We developed measurement technique of an optical fiber distortion using Light Intersection Method and optimized incidence angle of the laser beam on a sample and developed the algorithm to measure with high accuracy.

By using our method, the repeatability of the measurement of optical fiber distortion is within 1.2μm as 3σ.

1. Introduction

Recently optical fibers are used in various fields such as optical fiber networks, optical fiber sensors and so on. There are several types of optical fiber connection points in these uses. One of the connection method is using a plate with a V-shaped groove on one side which fixes optical fiber. In order to connect each fiber, the optical fiber is pressed against the V-shaped groove. The most important characteristic in optical fiber connection is low light transmission loss. However, the connection loss is influenced by deformation of the optical fiber as the optical fiber is not placed straight in close contact to the V groove. Therefore it is necessary to measure the deformation and to estimate its tolerance. In this paper, we present the measurement technique of the distortion of optical fiber using Light Intersection Method.

2. Light Intersection Method

Figure.1 shows the measurement apparatus. The incident light is radiated from the laser diode through the slit and converged on the sample.

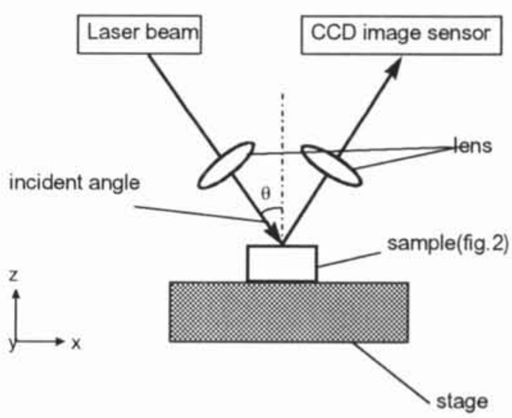

Fig.1 Apparatus of measuring the distortion

The reflected light from the sample passes through the objective lens and is observed on the CCD image sensor.

Figure.2 shows the experimental set up of the measurement sample.

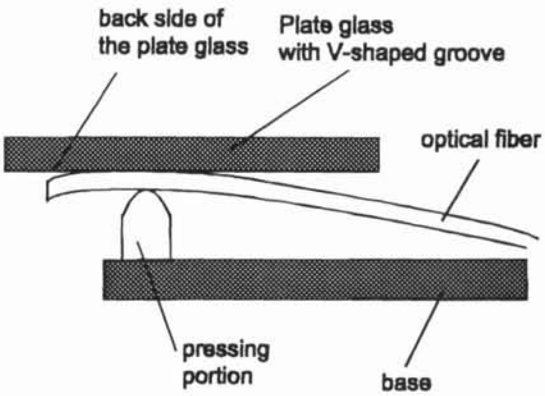

Fig.2 Set up of the measurement sample

It consists of the base which holds the fiber, the plate glass with V groove and the optical fiber. As the optical fiber is not parallel to the plate glass, near the tip, the optical fiber is pressed against the V groove of plate glass. So the optical fiber is curved by pressed force. If the distance between the objective lens and the sample fiber changes as the result of deformation of optical fiber, the position of the reflected light on CCD image sensor also changes. From this image data, it becomes possible to know where the optical fiber locates.

There are some problems in this method for measuring the distortion of the optical fiber. One is that it is impossible to get only the reflected light from the optical fiber surface. The fiber locates under the plate glass and as the reflected light from the back side of the plate glass is much larger than the reflected light from the optical fiber surface, it is difficult to separate the reflected light from the plate glass and the reflected light from the optical fiber. In order to solve this problem, we used an index matching material. The space between the plate glass and the optical fiber is filled with the index matching material which has almost the same refractive index as that of the plate glass. As a result, it becomes possible to reduce the reflected light from the back side of the plate glass and to observe the reflected light of the optical fiber.

To improve the measurement accuracy, it is necessary to increase the measuring points. We developed an automatic measurement system, because it is difficult to measure manually at many points. Figure.3 shows the configuration of the system.

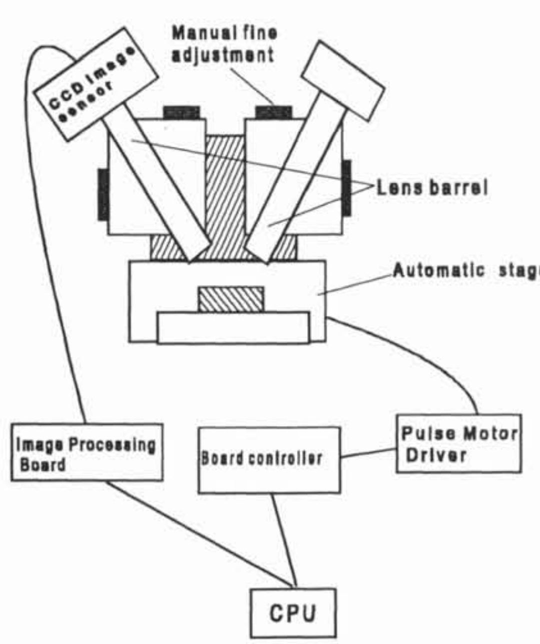

Fig.3 Configuration of the System

Also, it is important to set the incidence angle of the laser beam on the sample to the optimum angle. Generally in Light Intersection Method, as the angle becomes larger, the magnification becomes larger and the measurement accuracy becomes larger. But in this case, as the incidence angle becomes larger, the resolution along the optical fiber axes becomes worse. Several experiments revealed that the preferable incidence angle is around 30 degree.

As a result of that, the image data of the optical fiber is taken as a small circle image and it becomes possible to measure the position of the optical fiber accurately.

3. Image processing algorithm

The algorithm of the image processing is as follows. First step is to pick up only the image data by the reflected light. Figure.4 shows an example of the image by the slit light.

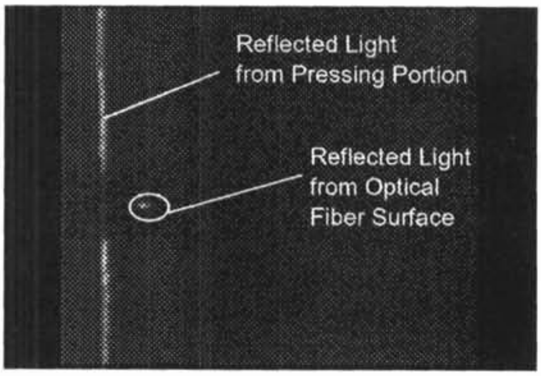

Fig.4 Example of the image by the slit light

In this case, the image data includes those of both the optical fiber and the pressing portion. The image of the pressing portion is observed as two lines which is divided by the optical fiber and the image of the reflected light from the optical fiber is a circle and is smaller than that from the pressing portion. By subtracting the image data from the pressing portion, it becomes possible to take only the optical fiber data.

Second step is to search a pixel which has the maximum intensity in the image data from the optical fiber.

Third step is to calculate the real optical fiber surface position from an intensity distribution and a pixel position which has the maximum intensity. The approximate fitting curve of the intensity distribution of the image data is calculated from the maximum intensity and the intensity of adjacent pixels. Finally, the optical fiber surface position is calculated. The distortion of the optical fiber is measured by moving the stage along the direction of optical fiber axis.

Figure.5 shows the procedures of the image processing algorithm.

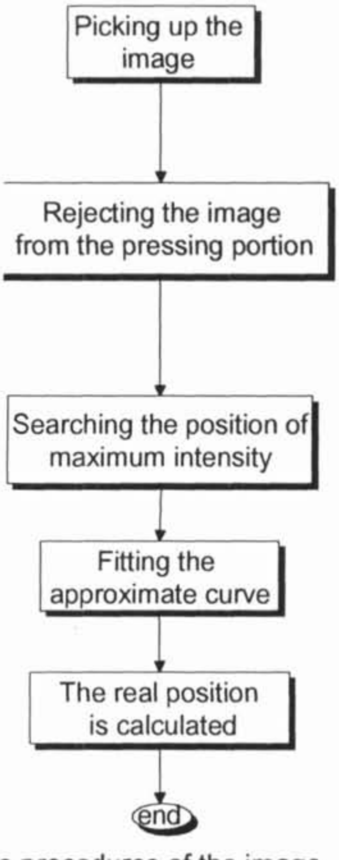

Fig5. The procedures of the image processing algorithm

4. Experimental Results

Figure.6 shows an example of the result of the measurement.

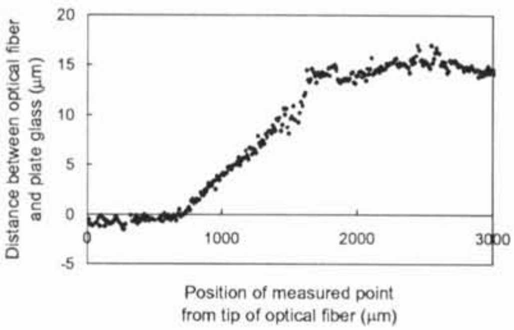

Fig.6 Example of the result of the measurement

Fig.7 shows the repeatability of measurement of the deviation of optical fiber from the V-groove using the above mentioned techniques.

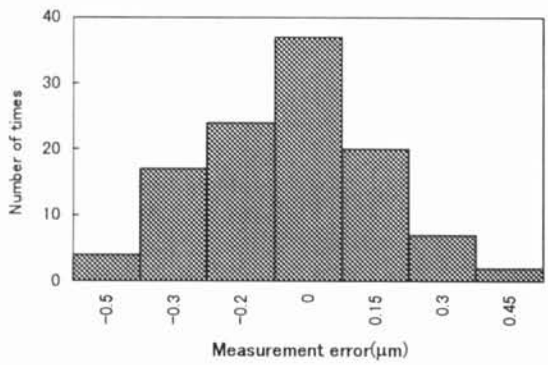

Fig.7 Error of distance measurement between plate glass and optical fiber surface

The repeatability of the measured data is within 1.2μm as 3σ.

5. Conclusion

We developed an automated visual inspection system of the optical fiber distortion by using Light Intersection Method. It was very difficult to measure the distortion of the optical fiber because the light intensity reflected from the back side of the plate glass is large.

To overcome this problem, we used the index matching material between the plate glass and the optical fiber to reduce the reflected light from the back side of the plate. And we separated the reflected light from the pressing portion and the one from the fiber by using the above mentioned algorithm.

As the result of that ,the repeatability of the measurement of the optical fiber distortion is improved within 1.2μm as 3σ.

REFERENCE

(1) Mikio Takagi, Haruhisa Shimoda.,"HANDBOOK OF IMAGE ANALYSIS", University of Tokyo Press, Jan. 1991