Multichannel optical prism

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Abstract

Currently, many optical tests required the simultaneous measurement values of various technological or metrological parameters. These requirements primarily relate to production and metrological measurements. Examples include optical testing of deformations of parts (e.g., plates) under variable load, shifts of various components of high-precision equipment, and, of course, various metrological measurements of high-precision equipment, such as lithographic machines and different types of measuring and control devices. Simultaneous measurement of one parameter in different parts of the product allows to determine the error (e.g., deformation or alignment error) in object position. Observation and analysis of the position of specific points on the object allows one to judge about deviations both in position and deformation of the measured surface. The proposed multichannel optical prism allows to simultaneously observe several points located on the different parts of the object, as well as monitor their movement in working conditions. The prism must be built into the optical circuit of the measuring device. Some examples of such kind of devices will be discussed below.

Introduction

In order to simultaneously obtain an image of different points of the object, the prism must transform the optical axes of all channels so that they are in the field of view of the sensor or eyepiece. In other words, the use of such a prism allows to simultaneously get multiple images from different parts of the object. The most convenient arrangement of the optical axes at the exit from the prism, which makes it possible to simplify the optical scheme of the subsequent optical system, is telecentric. In object space the optical axes can be at an angle to each other. One of the main features of the proposed prism is that the optical axes of different channels change orientation. The left input optical axis becomes right when light passes through the prism and vice versa. The prism can be located both in front of the optical system and be built into it. The subsequent optical system or optical system with build-in prism must should return the optical axes to their original position so that the image of the left object remains on the left, and the image of the right object is on the right. This requirement determines the structure of the optical system, it must include an inverting system that turns the optical axes after the light passes through the prism and thus observes the correspondence of the relative position of the object and its image.

Multi-channel optical prism description and major relationship between angular parameters

Let's consider at the multi-channel prism system using the example of a three-channel version. The prism has two side channels and one central channel. This mean that in an image plane three objects will be observe simultaneously. The front face of the central channel and the exit face of the prism are parallel to each other, while the front lines of the side channels can be tilted towards the central face. This arrangement of faces allows you to have a symmetrical and one-axis optical system. Figure 1 represents front view of the such kind of prism. As it’s shown on Fig.1 the prism includes three parts: prism A; B and C, where prism C located between prism A and B.

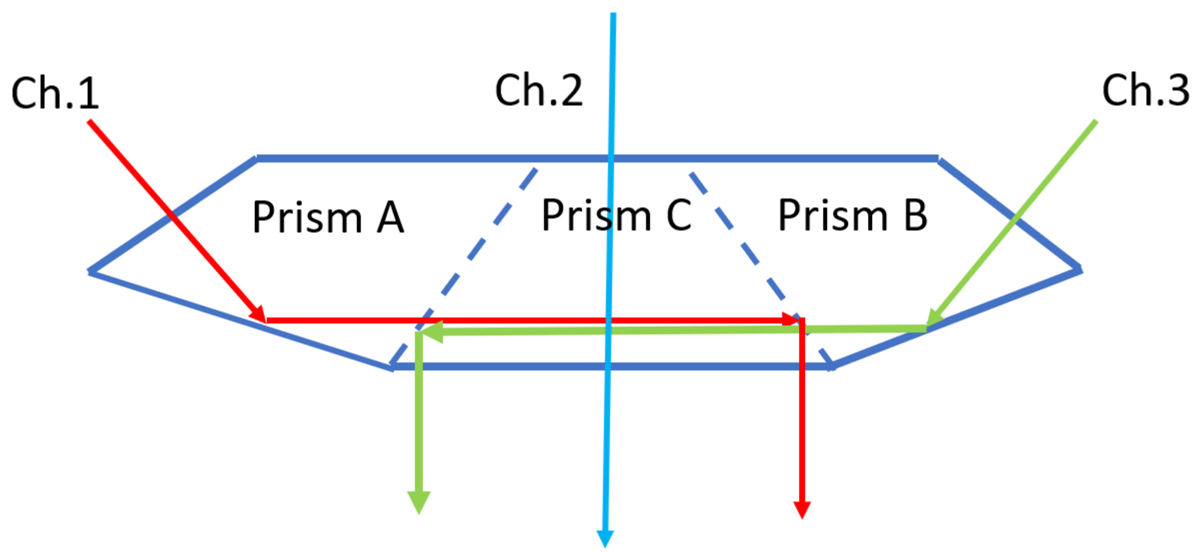

Fig. 1 General view Multi-channel prism

The prisms A and B converts angles of inclination of optical axes and makes all optical axis parallel to each other. This prism required lens wrapping system which returns the optical axes to their normal position, that is, the object on the left side will also be displayed on the left, and the image of the object on the right will also be on the right. Let’s consider the path of the axial rays through the prism system. Figure 2 shows in detail the geometric structure of the prism for general case, where α, β and γ slope angles, Ɵ the angle of inclination of the input face, φ and ψ are help angles needed for a better understanding of the relationship between auxiliary angles and prism angles. Two important special cases should be noted here: if all the optical axes at the entrance of the prism are parallel, then all the reflecting faces of the prism have an angle of inclination equal to 45°, and if the lateral optical axes are perpendicular to the central optical axis, then the prism becomes a set of beam-splitting cubic prisms. If the angle at the top of the prism is within the limits 90°<β<180°, then the measuring base increases, which is an advantage because in this case the dimensions of the optical parts do not increase.

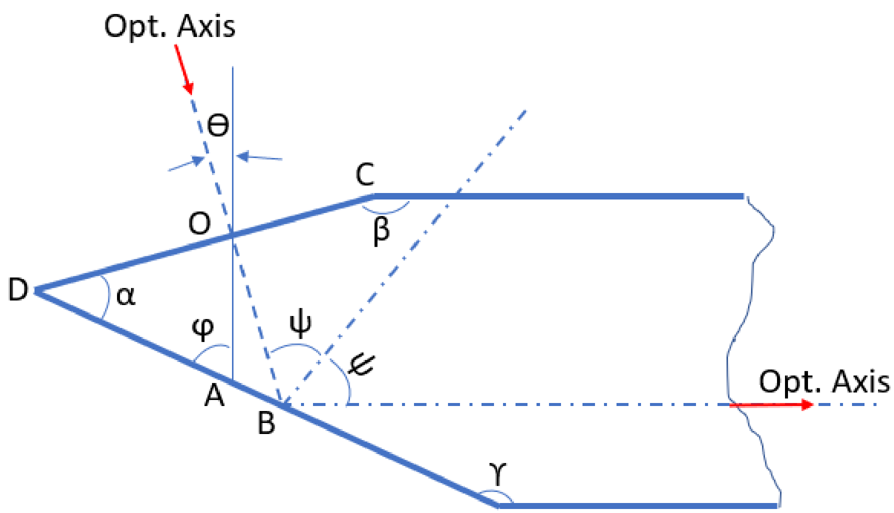

Fig. 2 Prism geometric structure

The following formulas are used to calculate the angles of the prism:

$$\begin{cases} \beta = 180° - \Theta; \ (1) \\ \alpha = 0.5(90° + \Theta); \ (2) \\ \Upsilon = 0.5(270° + \Theta); \ (3) \end{cases}$$

Auxiliary angle φ can be calculate by using next formula: $\varphi = \Theta - \alpha + 90°$, and angle $\psi = \alpha$. The angle of inclination of the optical axis is the main parameter affecting the values of the remaining vertex prism angles and, first of all, the angle of inclination of the input face. Table 1 represents the values of the angles at the vertices of the prism faces as well as the values of the auxiliary angles for different practical cases.

Prism face angles			Optical axis angles		
α	β	ϒ	φ	ψ	ϴ
45°	180°	135°	45°	45°	0°
67.5°	135°	157.5°	67.5°	67.5°	45°
75°	120°	165°	75°	75°	60°
90°	90°	180°	90°	90°	90°

Table 1 Values of prism angles

Multichannel prism implementation in optical devices.

The multichannel prism can be used in optical devices for measuring various technological quantities, for example, allowances for precise processing of inclined surfaces, elastic deformations of various elements of technological equipment, metrological machines and high-precision products. The main advantage of the optical system, which includes a multichannel prism, lies in the simultaneous measurement of points of the object located in different parts of the object, this allows obtaining reliable information about displacements and deformations in the object of measurement. As an example, we will give the optical scheme of a device for measuring technological quantities [1]. This device was used to measure the grinding allowances for the sloped surfaces of the templates. The template has two inclined lateral planes that are ground with a high degree of dimensional accuracy. In this case, a two-channel prism without a central channel was used. In order not to disorient the meter by a mirror change in the orientation of the optical axes, a lens reversing system was used. Figure 3 shows the location of the optical axes in the space of objects, inside the optical scheme of the device and in the image space.

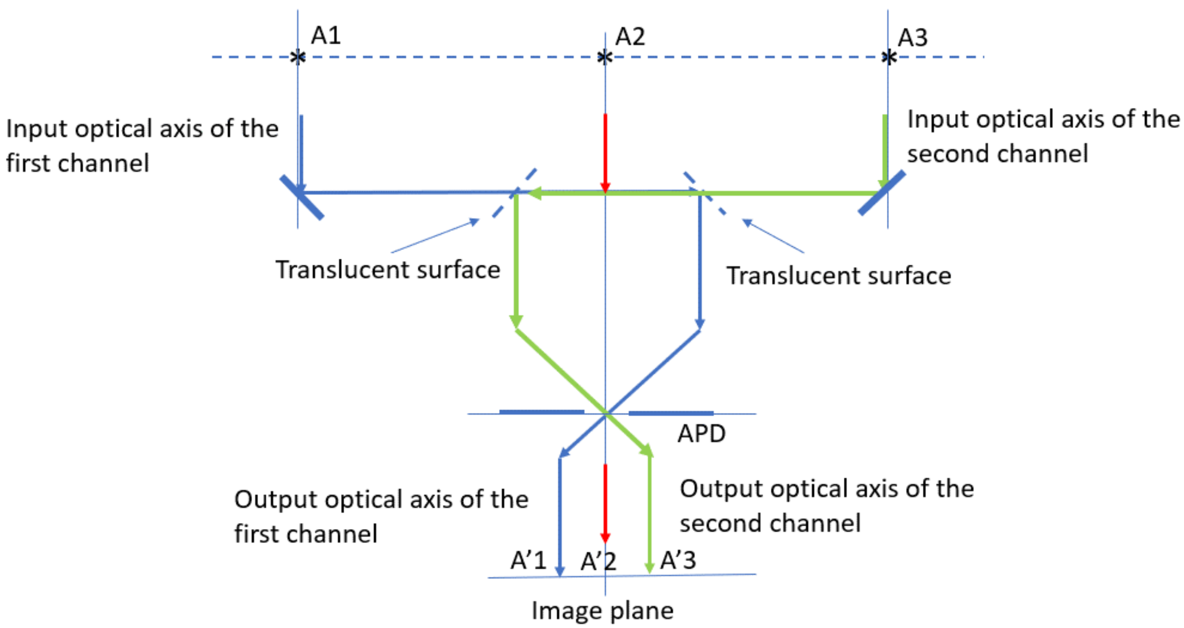

Fig. 3 Optical axis orientation for three-channel prism

Where A1, A2, A3 are measurement objects, and A1', A2', A3' images of measurement objects, APD aperture diaphragm. In our particular case, point A2 is absent since there is no central channel in the system. In this case, point A2 coincides with the central optical axis of the measuring device. Figure 4 shows the optical layout of the measuring device.

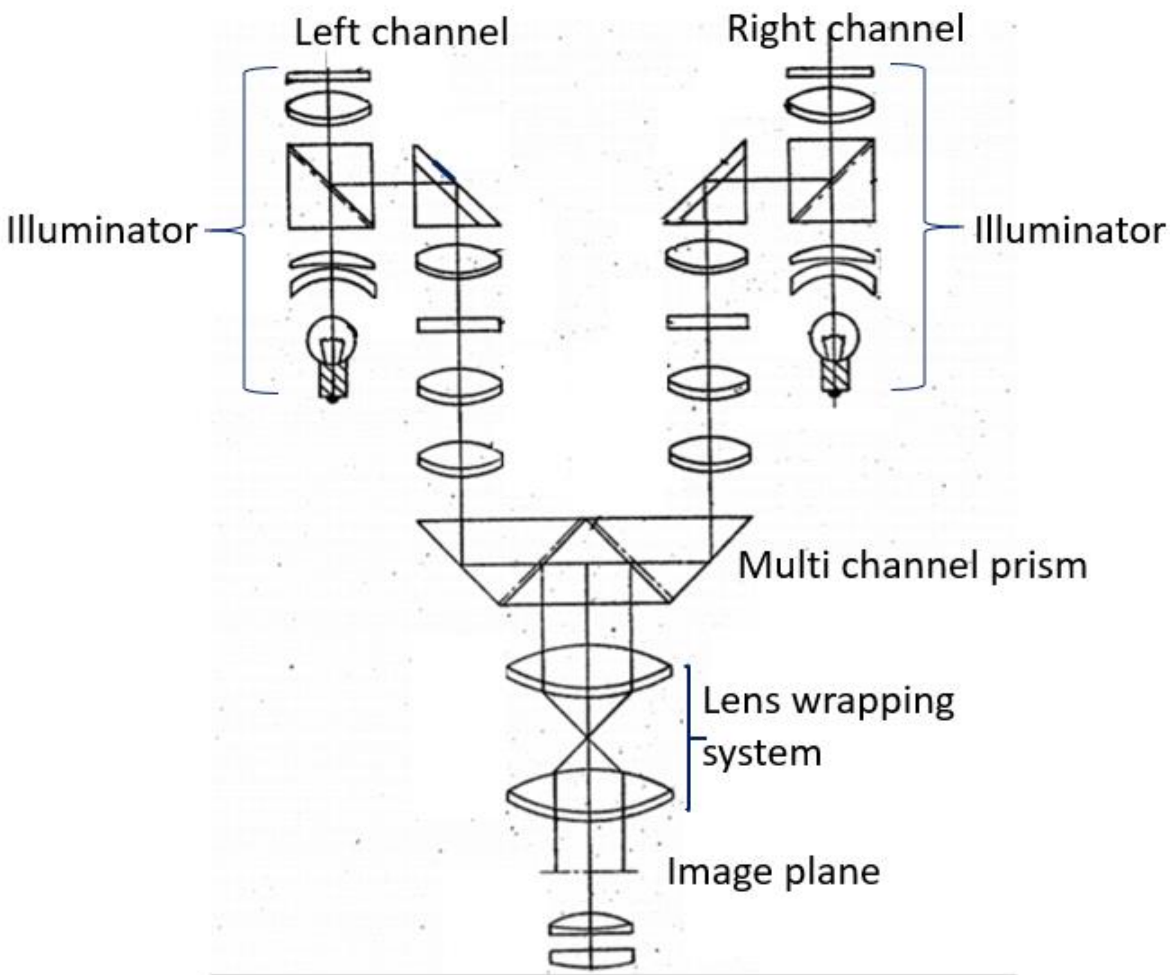

Fig. 4 Optical scheme two-channel measuring device with build-in prism

As you can see from Figure 4, the device consists of two input and one output channels. Each channel includes an illuminator and a head part consisting of a lens, a focusing lens and a grid onto which the intermediate image is focused. Further, this image is projected to infinity with the help of a two-component lens system and, after passing through a multichannel prism, is focused using a lens relay (lens wrapping system) into the image plane. This system is described in more detail in the patent [1]. A similar two-channel three-channel prism was used in an optical device for measuring elastic deformations of plates under variable load [2]. Here, the central channel was also involved, which measured the elastic deformation in the center of the deflection plate (object). The measurement scheme is shown in Figure 5.

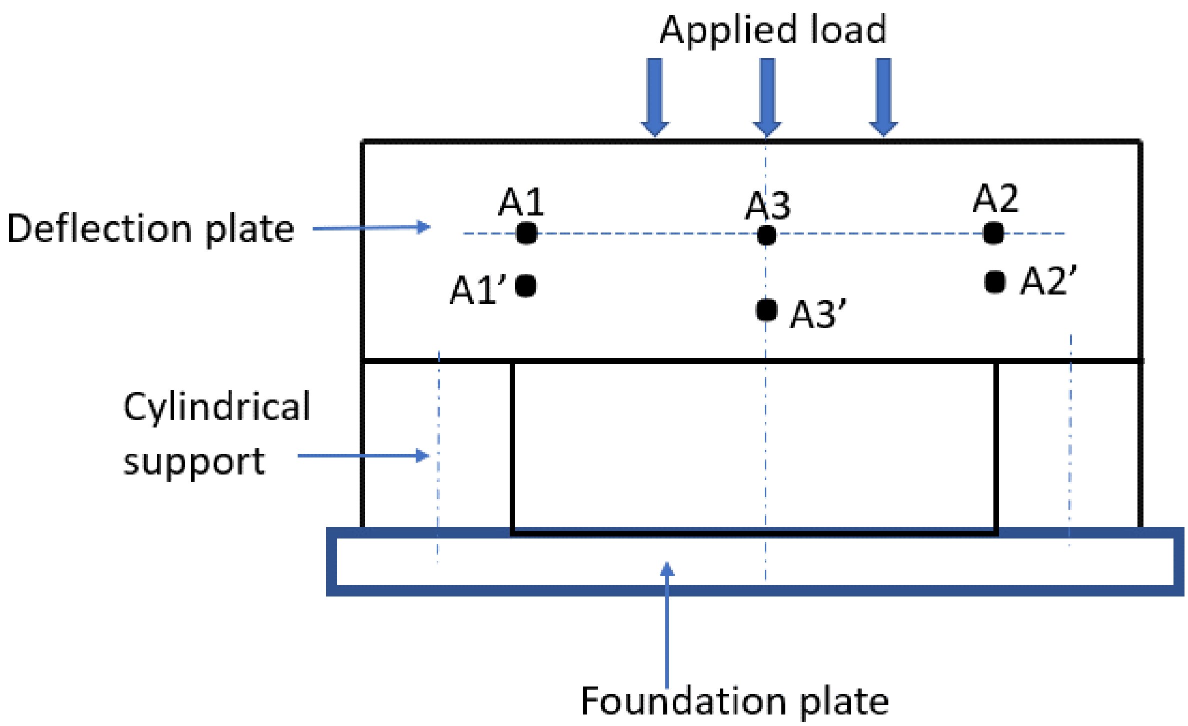

Fig. 5 Scheme of measuring plate elastic deformation

The test plate is connected to the base using cylindrical supports. When a load is applied to the upper surface of the slab, its elastic deformation occurs, the real value of which is (A3'-A3) - (A1'-A1) or (A3'-A3) - (A2'-A2). All three points A1, A2 and A3 are simultaneously in the field of view of the optical device. After applying the load, they move to new positions defined by points A1 ', A2' and A3'. These displacements of points determine the deflection deformation of the slab.

Conclusion

The optical multichannel prism capable of orienting optical axes for simultaneous acquisition of several images in the field of view of the device is considered. This prism allows simultaneously determine the movement of various points located on the observation object and measure various technological parameters such as: allowances for machining of inclined surfaces, elastic deformations and other quantities whose values are important in processing precision parts, metrological measurements and setting up various equipment. The prism can be built into the optical circuit of a multichannel device, as well as placed in front of a standard single-channel optical device. The article provides analytical expressions for the angles between the edges of the prism and auxiliary ones, which allows to determine the values of the angles for each specific case, and also gives the numerical values of the angles for the most common options. An example of the optical scheme of the device is also given, including the proposed prism system. The use of multichannel optical prisms will simplify and speed up the process of measuring various quantities and parameters that directly affect the quality of production.

REFERENCES.

[1] L. Ryzhikov , D. Pismennyj . Limited Patent SU 823853 (1981);

[2] L. Ryzhikov . Limited Patent SU 706691(1978).