Method for measurement of the angles of a 45-deg deflecting (half penta) prism

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Abstract. A simple technique is devised to measure the angles of 45-deg deflecting (half penta) prisms, without using the expensive spectrometers, autocollimators, and angle gauges. [S0091-3286(00)03506-6]

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1 Introduction

The usual practice of comparing the angles of a given prism against a standard angle gauge (or a gauge combination) by using an angle dekkor (autocollimator) is the simplest and most accurate among the several methods used for testing the angles of prisms.[1–5] In this method a suitable angle gauge (or gauge combination) is essential for conducting the experiment. Alternate methods are suggested in Refs. 6 to 10 for the circumstances where an autocollimator and angle gauges are not available. In these methods, the angular deviation from symmetry of two surfaces with respect to a side as baseline is determined from the measurements of the screen distance and the separation of the reflected laser spots on a screen for two positions before and after the rotation of a partially or fully polished optical component by 180 deg.

Since detailed description of the experiments is already given in previous papers,[6–10] here we present only a brief outline of the method for the measurement of the angles of a 45-deg deflecting prism.

2 Principles of the Method

The solid lines of Fig. 1 depict the 45-deg deflecting (half penta) prism. For the purpose of theoretical discussion some of the sides are extended by broken lines to form triangles. The sides of the prism are represented by the symbols S_1, S_2, S_3, and S_4, and the angles by A_1, A_2, A_3, and A_4. In most common uses of the prism it is not necessary for the angle A_1 to be a right angle or for the surface S_1 to be polished. However, for making an initial standard, this method requires a slightly larger prism with all polished sides and a 90-deg angle for A_1. For an ideal prism $A_1=90$ deg, $A_2=A_3=112.5$ deg, $A_4=45$ deg, and the corresponding angles $X=45$ deg and $Y=22.5$ deg. Let the angles of an approximate prism be $A_1=90+\alpha_1$, $A_2=112.5+\alpha_2$, $A_3=112.5+\alpha_3$, and $A_4=45+\alpha_4$, and correspondingly $X=45+\beta$ and $Y=22.5+\gamma$, where α_1, α_2, α_3, α_4, β, and γ are the errors of the angles A_1, A_2, A_3, A_4, X, and Y. The experimentally determined values for α_1, α_2, α_3, α_4, β, and γ can either be positive or negative.

2.1 *Right Angle (90 deg)*

Figure 2 illustrates the principle of measurement of the 90-deg angle of a prism. The detailed description of the experiments can be found in Refs. 6–10. The error in the 90-deg angle is given by

$$\alpha_1=\frac{AB}{4\,OC}. \tag{1}$$

2.2 *Other Angles (45, 112.5, and 22.5 deg)*

Figure 3 illustrates the second part of the experiment. The prism surface S_3 is placed on the optical flat. The angular deviation from symmetry (θ_1) of the surfaces S_4 and S_1 with respect to baseline S_3 (Fig. 1) is given by

$$\theta_1=\frac{LM}{4\,ON}. \tag{2}$$

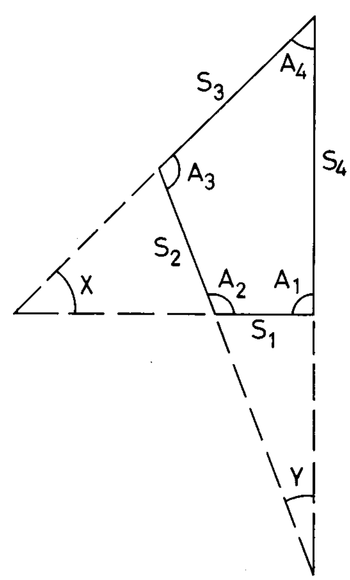

Fig. 1 Schematic diagram of a 45-deg deflecting prism with 22.5-deg corner removed (i.e., a half penta prism). For the purpose of theoretical discussion some of its sides are extended by the broken lines to form triangles.

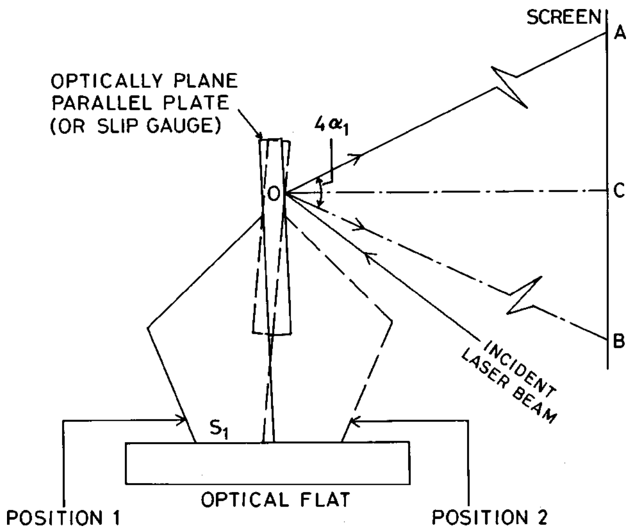

Fig. 2 Schematic diagram showing the principle of testing the 90-deg angle (first part of the experiment). The angle $4\alpha_1$ is greatly exaggerated in this diagram.

Therefore, from Ref. 10,

$$X=45-\frac{\alpha_1}{2}\pm\theta_1, \tag{3}$$

$$A_4=45-\frac{\alpha_1}{2}\mp\theta_1. \tag{4}$$

The errors of the angles X and A_4 are given by

$$\beta=-\frac{\alpha_1}{2}\pm\theta_1, \tag{5}$$

$$\alpha_4=-\frac{\alpha_1}{2}\mp\theta_1. \tag{6}$$

Figure 4 illustrates the third part of the experiment. The experiment is conducted, as above for the surfaces S_1 and S_3, by placing S_2 on the optical flat. We now have by the preceding discussion

$$\theta_2=\frac{PQ}{4\,OR}, \tag{7}$$

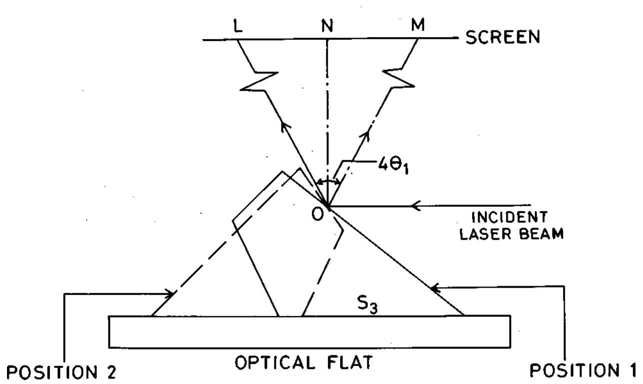

Fig. 3 Schematic diagram showing the principle of testing the 45-deg angles A_4 and X of Fig. 1 (second part of the experiment). The angle $4\theta_1$ is greatly exaggerated in this diagram.

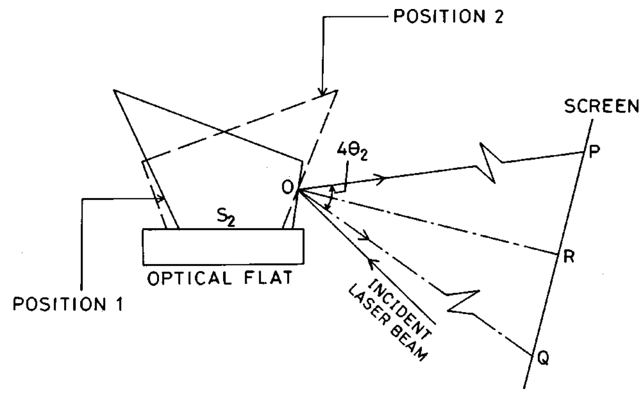

Fig. 4 Schematic diagram showing the principle of testing the 112.5-deg angles (third part of the experiment). The angle $4\theta_2$ is greatly exaggerated in this diagram.

$$\alpha_2=\frac{\beta}{2}\mp\theta_2, \tag{8}$$

$$\alpha_3=\frac{\beta}{2}\pm\theta_2. \tag{9}$$

The error γ of the angle Y (Fig. 1) is given by

$$\gamma=-(\alpha_3+\alpha_4). \tag{10}$$

The details about the measurement of the angles α_1, θ_1, θ_2, etc., can be found in Refs. 6–10.

Experiments are conducted to measure the angles by the proposed method and also by using a micrometer angle dekkor (autocollimator). The results are given in Table 1.

The angular deviations from symmetry (α_1, θ_1, and θ_2) can also be measured by using an autocollimator instead of using a laser beam. The only difference is that we get $2\alpha_1$, $2\theta_1$, and $2\theta_2$ from the autocollimator rather than $4\alpha_1$, $4\theta_1$, and $4\theta_2$ as shown in Figs. 2, 3, and 4 (since the autocollimator graticules and micrometer screws are designed to read half of the actual angles). Thus the technique can also be extended for carrying out measurements with an autocollimator when a suitable angle-gauge combination is not available.

The accuracy of the measurements depends upon the distances (*OC*, *ON*, and *OR* of Figs. 2, 3, and 4) of the screen from the point of incidence of the laser beam on the optical component. For this case $OC=ON=OR=5$ m. These distances are measured to an accuracy of 1 mm. A

Table 1 Experimental results for a 45-deg deflecting (half penta) prism.

Name of the angle	Error (arcsec) By the proposed method	Error (arcsec) By autocollimator and angle gauges
A_1	−48.16	−48.0
A_2	15.14	15.5
A_3	−9.00	−9.5
A_4	42.02	42.5
Y	−33.02	−33.0

method of increasing the screen distance is given in Ref. 8. The distances *AB*, *LM*, and *PQ* are measured to an accuracy of 0.01 mm.

From the error analysis (which is identical to that given in Ref. 10), the accuracy in the measurement of angles is 1/3 arcsec, whereas with the micrometer angle dekkor it ranges from 0.5 to 2 arcsec, depending on the performance of the micrometer screw.

3 Conclusions

The proposed method does not require precision spectrometers, autocollimators, and standard angle gauges. It is a simple, accurate, and relatively inexpensive method.

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