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Measurement of the Absorption of Light by Polaroid Sheet

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Nomenclature

a = absorptance of the polarizer material
I = detector beam intensity (all polarizations)
I_H = detected horizontally polarized beam
I_v = detected vertically polarized beam intensity
I_0 = incident beam intensity
ε = relative alignment of an incident beam polarization and the axis of a polarizer

Introduction

VARIOUS publications involving the scatter of a linearly polarized laser beam at 90 deg by spherical particles in distilled water have been directed at presenting the resulting lobe-shaped scatter pattern.[1–4] When the incident laser beam is essentially circularly polarized, the detected variation in the scatter at 90 deg as a function of angle is very different.[5] An interesting offshoot of this study has been the development of a method to estimate the absorption of light by a linear polarizing sheet. This uncomplicated method is based on the general concepts of geometric optics.

Analysis

In an effort to describe the estimate, consider Fig. 1. This figure is the depiction of a linearly polarized beam of light of intensity I_0 incident upon a polarizer sheet. In traversing this sheet, the beam experiences two mechanisms that act to extinguish the beam. The first is the extinction of that portion of the beam whose polarization is not aligned with the axis of the polarizer sheet. The elimination of this component produces a linearly polarized beam whose axis is parallel to the axis of the polarizer. The second mechanism could be classified as standard absorption. This mechanism acts to eliminate a portion of the incident beam even if a linearly polarized incident beam is aligned with the polarizers. Without this second mechanism, a completely unpolarized incident beam I_0 would produce an output linearly polarized beam of intensity approximately $I_0/2$. That is, when the incident beam polarization and the polarizer axis are aligned, the beam passes through unscathed in terms of the polarized component being absorbed: there will be an absorption of the correctly aligned polarization component. A fraction a of the beam (aligned

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Table 1 Computed absorption coefficient of polaroid from linearly polarized incident light data of Ref. 5

Concentration, %	Detector depth, cm	Average particle size, μm 1.240	0.494	0.360	0.123	0.065
0.005	0.0	0.3168	0.3427	0.3137	0.3314	0.3500
	1.5	0.4273	0.3784	0.3248	0.2629	0.3035
	3.0	0.3609	0.3598	0.3249	0.2670	0.2849
0.0025	0.0	0.3274	0.3931	0.3007	0.2840	0.2884
	1.5	0.3216	0.2993	0.3014	0.2948	0.3191
	3.0	0.3410	0.3174	0.3018	0.2540	0.2587

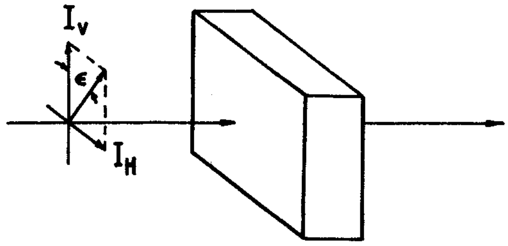

Fig. 1 Schematic of a nonaligned incident beam and polarizer.

with the polarizer) will be absorbed. Thus the detected intensity in this case is

$$I = (1 - a)I_0 \tag{1}$$

A nonaligned beam and polarizer would require two measurements (one for each component), i.e.

$$I_v = (1 - a)I_0 \cos \varepsilon \tag{2}$$

$$I_H = (1 - a)I_0 \sin \varepsilon \tag{3}$$

Thus

$$\tan \varepsilon = I_H/I_v \tag{4}$$

$$a = 1 - [(I_v^2 + I_H^2)/I_0^2]^{1/2} \tag{5}$$

Results

Equation (5) is particularly convenient as a basis for the computation of the absorption (the second mechanism) of the linearly polarizing element of an experiment considering the data reported in Ref. 5; total polarization I_0, horizontal polarization I_H, and vertical polarization I_v were measured. This absorption analyses was applied to all of the data reported in Ref. 5. The results are presented as Table 1. It may be noted that the polarization of the incident beam should not effect the absorption a; it does effect the angle ε. Thus, detector depth and particle size and concentration are not active parameters and do not effect the absorptance of the polarizing medium. The data in this table produce an average absorptance of $\bar{a} = 0.3184$. If a small sample statistic is used, the mean deviation and standard deviation are

$$\mathrm{MD} = \frac{1}{n}\sum_{i=1}^{n} |a_i - \bar{a}| = 0.0286$$

$$\mathrm{SD} = \left[\sum_{i=1}^{n} (a_i - \bar{a})^2/(n - 1)\right]^{1/2} = 0.0397$$

While these results are not ideal, they do represent the method and agree with the accepted absorptance of the standard HN 32 polaroid material of approximately 32% at a wavelength of 0.6328 μm (He Ne laser).[6]

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