Journal of ASTM International, Vol. 7, No. 10
Paper ID JAI102826
Available online at www.astm.org

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Polarizing Filters in Ski Sports*

ABSTRACT: Polarizing filters are suitable, e.g., for driving/motoring. They also have great advantages for sailing or angling. But are they useful in alpine skiing? A natural source for at least partly polarized light is not only the scattered light in the sky but also the reflected light on special materials. The reflected light on snow might be partly polarized, especially for compressed snow (traces in the snow) or ice patches. Depending on the direction of the polarization of a filter, the amount of information might be reduced in a skiing area because these polarized icy patches might become invisible.

KEYWORDS: contrast perception, polarized skiing goggles, safety in Winter sports, alpine skiing

Introduction

Vision has an influence on performance in alpine skiing [1–5]. Vision has further accident and injury prevention implications, particularly in view of the fact that fall-related injuries often mean longer periods of absence from the sport (primarily in the professional ski circus) or unemployability (e.g., on leisure-time skiers) due to the gravity of the injuries sustained [6].

During the last decades, contrast enhancing filters for ski sports were developed to a nearly perfect level [7]. But what else can be done to go beyond that? A manufacturer detected the polarized light for alpine skiing goggles. Starting in the last five years, there are a growing market and, meanwhile, an inestimable offer on polarized skiing goggles. Following the advertising that seeing has improved, contrasts are more emphasized, and, of course, potential danger spots on the slope, like ice plates/sections, are exceptionally noticeable.

To understand why that—in alpine skiing—is really not the case, it is necessary to review the physics on polarized light.

Physics of Polarized Light

Light can be described as an electromagnetic transversal wave. The electric field vector vibrates perpendicular to the direction of propagation. If this vibration is restricted to a plane, then the light is called *polarized*. The blue light of the sky is partly polarized, depending on the location of the sun. If the sun, the point in the sky you are looking at, and you, the observer, form a kind of rectangular triangle, then the effect is strongest (Fig. 1). In most practical cases, the direction of the polarization is vertical as indicated in Fig. 1. The conclusion is that the illumination of the snow is partly polarized.

With a spectral photometer (Minolta CS-S1w), we measured not only the spectra of snow but also the spectra by using a polarizing filter in front of the measuring device. The spectra differ with the direction of polarization of the filter. It turned out that the vertical component of the light coming back from the snow is usually stronger than the horizontal. Therefore, in most cases, snow is slightly vertical polarized.

Reflected light from a surface, like glass or water, might be polarized under special conditions. It was Augustin Jean Fresnel (1788–1827) who brought light into the mystery of polarized reflected light. First, he defined the incidental plane given by the incident ray and the normal on the incidental point on the

Manuscript received November 2, 2009; accepted for publication September 11, 2010; published online October 2010.
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* In memoriam our research partner Dr. Walter H. Ehrenstein (1950—2009), a wayfarer in the field of perceptual neuroscience, in thankfulness and friendship and on the occasion of his 60th birthday.

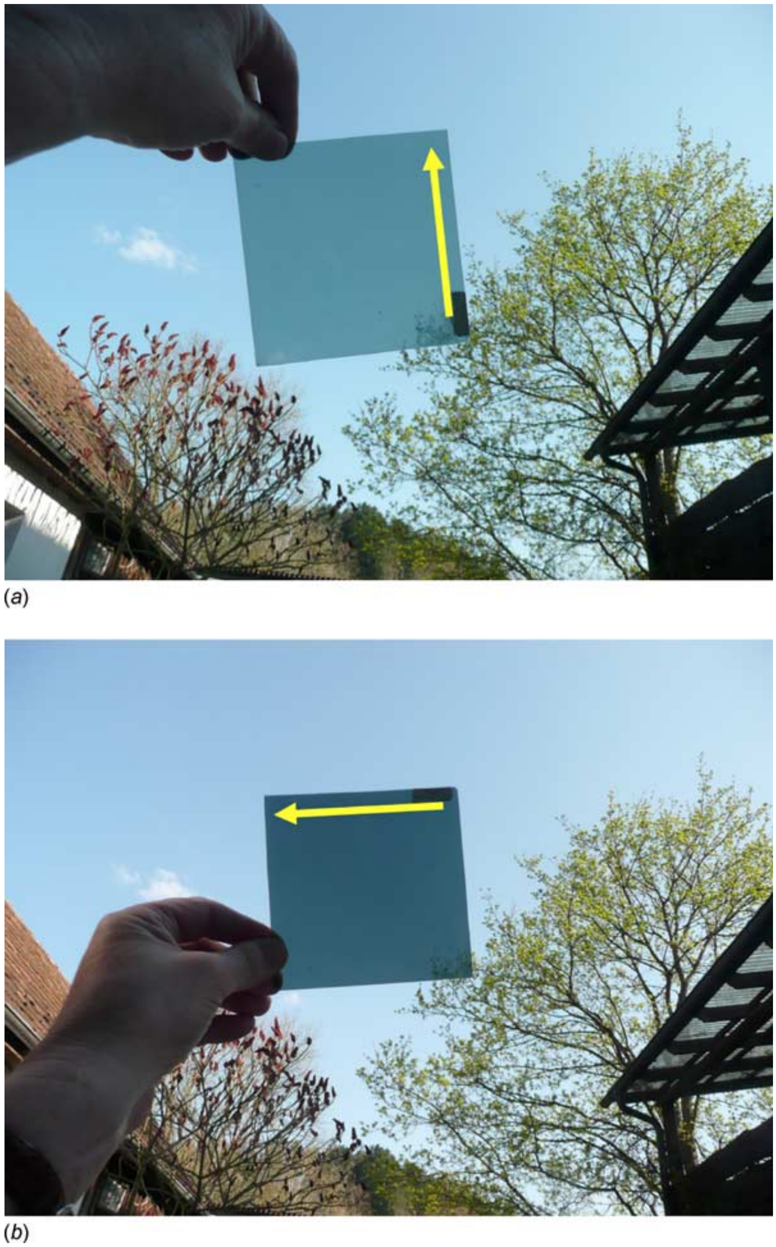


FIG. 1—*(a) Direction of polarizer: Vertical, as indicated. The sun is on the right side. (b) Direction of polarizer: Horizontal. The blue light is partially vertical polarized and is blocked by the filter. Therefore, the filter appears darker than in (a).*

surface. The reflected ray is also found in that plane (Fig. 2). The electric field vector is decomposed in a component in the incidental plane (parallel component) and in a component perpendicular to that plane (perpendicular component). It should be noted that these directions depend on the orientation of the surface. Mostly, they are different from the usual meaning of horizontal or vertical. If a surface is flat on the ground, then the perpendicular component concerning the incident plane is also flat. We then would call it in our own coordinate system where horizontal is flat and vertical is the opposite direction of gravity the "horizontal component."

The two components do not follow the same equations. Besides the special case, incident angle ε equal to zero, the power of the perpendicular component is always stronger than the parallel component. As a result, reflected light is always partially polarized perpendicular to the plane of incidence. But there is one special angle of incidence where the parallel component vanishes totally. In that case, only the perpendicular component is present, and the light is 100 % polarized (Fig. 3).

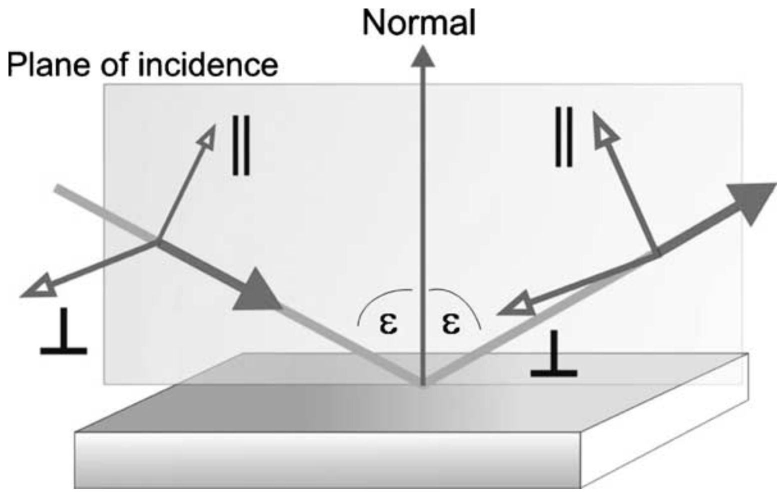


FIG. 2—*Incidental plane. Light is decomposed into a vector in the plane and in a vector perpendicular to the plane. The components are called parallel and perpendicular components of the incident light. Fresnel's formulas describe how these components change depending on the incident angle and the refraction index of the material.*

The Philosophy behind Polarized Sunglasses

In most practical cases, e.g., the reflected light from the surface of water or from the back window of a car in front is horizontally polarized. The normal on the surface of water is vertical, and therefore the direction of polarization is horizontal. When looking at the back window of a car in front, at least, the incident plane is vertical. The component in that plane nearly vanishes, and the remaining light is the horizontal component.

In both cases, sunglasses with vertical polarizer will erase most of the reflected light.

Looking at a natural scene, the direction of polarization usually is horizontal. To get rid of that disturbing light, the direction of polarization has to be vertical. All polarized sunglasses have vertical polarization.

Polarizing sunglasses/filters are therefore particularly helpful in environments where reflected glare from water or road surfaces is troublesome. They have particular advantages, e.g., as anglers, as the specular reflections are eliminated, enabling objects located below the surface of the water to be seen or identified more easily. They are also useful in a variety of water sports (e.g., sailing) [8]. On the other

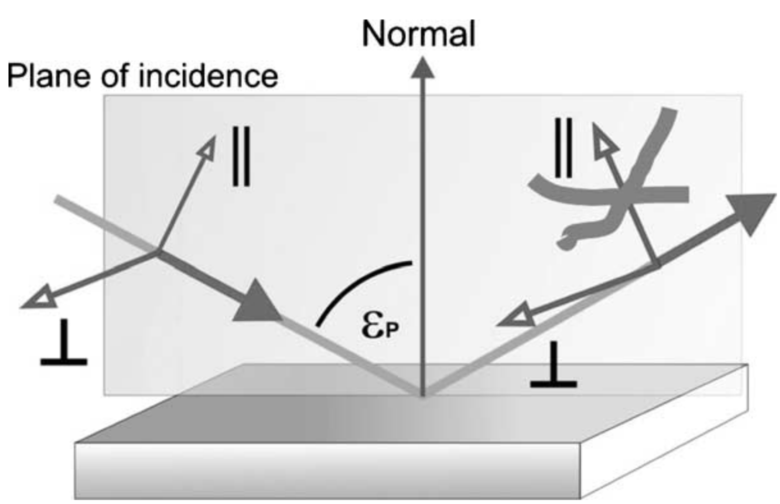
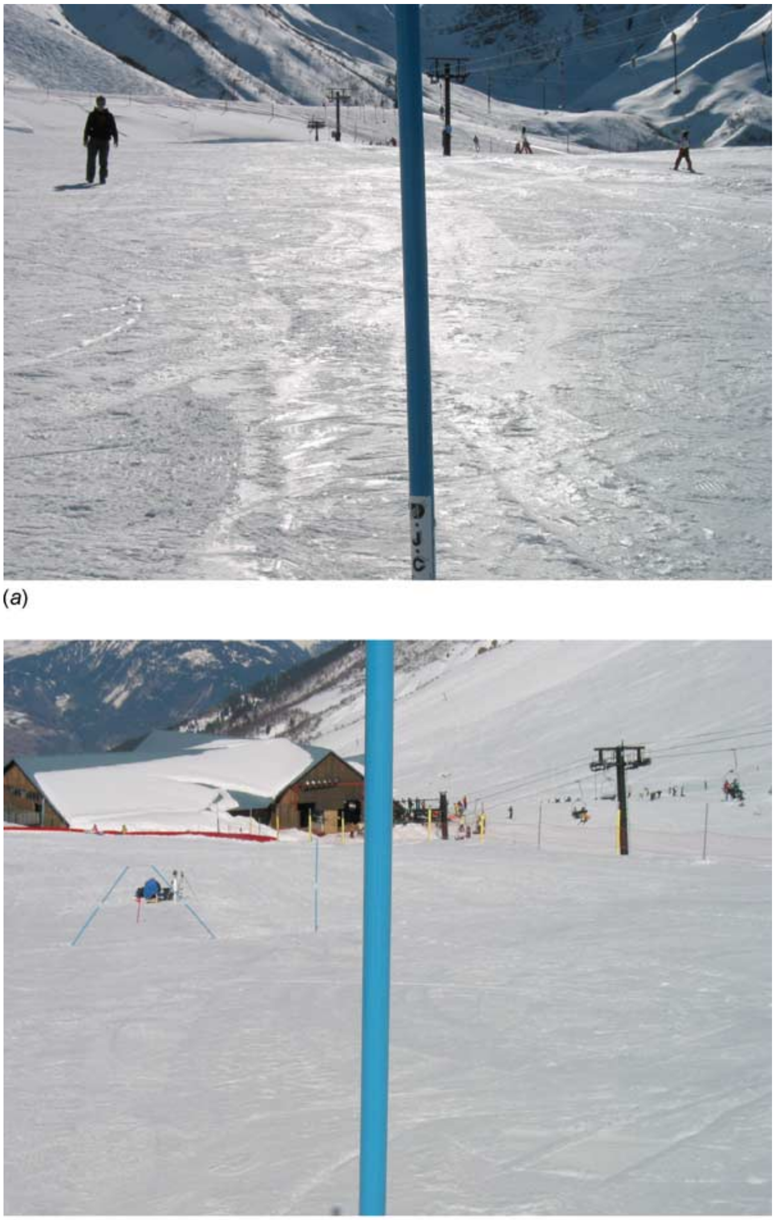


FIG. 3—*If the incident angle* ε *fulfills the equation* $n = \tan(\varepsilon)$*, then the parallel component vanishes totally.* ε *is then called the polarizing angle* ε_P*. The remaining light is polarized perpendicular to the plane of incidence. For water or ice,* ε_P *is about 53°.*



(a)

(b)

FIG. 4—*(a) "Uphill"-view against the sun. The polarized light of the ice patches is visible. (b) "Downhill"-view at the same time (as in (a)) with the sun (opposite direction). No polarized light, very poor contrasts.*

hand, Reichow et al. demonstrated that polarized filters do not offer any statistically significant advantage or disadvantage, e.g., on putting performance when golfing (over non-polarized filters) [9].

Polarized Skiing Goggles

A snow area is a low-contrast area. In the direction of the sun, there are at least some reflections of icy patches visible (Fig. 4(*a*)). In the opposite direction, with the sun in the back, there are no reflections of icy patches visible even if they are there (Fig. 4(*b*)). Only against the sun there is enough glare indicating the ice plates (as potential danger spots on the slope). This light is strongly horizontally polarized. Therefore, the polarized light contains information about the presence of dangerous ice sheets. Even that might be reduced because the vertical component of the skylight usually is stronger than the horizontal component. The reflection of the horizontal component would be stronger if the skylight would not be polarized.

Going downhill by ski, the requirements for polarized light are very scarcely fulfilled. Most of the ice

(*a*)

(*b*)

FIG. 5—*(a) Direction of polarizer = 0°. (b) Direction of polarizer = 90°.*

patches remain nearly invisible. If they are there, the light would be horizontally polarized. A goggle with a vertical polarized filter will take out this actual useful information.

Figure 5(*a*) and 5(*b*) was taken with a horizontal polarizer (*a*) and a vertical polarizer (*b*) in front of the camera. In (*b*), all horizontal polarization is taken out. Fortunately, there are still some icy stripes visible. 100 % polarization needs incident light impinging on the polarization angle. That cannot be true for any location in that scenery. But even on a first glance in (*b*), information is reduced. Some icy patches are smaller in size; others nearly vanish.

In Fig. 6, the left lower part of Fig. 5 is enlarged. In Fig. 6(*a*), all details of the traces (skiing lane) are visible. The reflected light is horizontally polarized to a high degree and passes the horizontal (=0°) polarizer in front of the camera. If the polarizer is turned to 90° (vertical), then all the horizontally polarized light cannot pass the filter. Most information about the traces is erased. Therefore, a polarized skiing goggle is "ideal" to hide icy patches and other details of the skiing area. Most details become invisible.

To avoid total invisibility of icy patches, some polarized skiing goggles do not polarize in the whole visible spectrum (~380–780 nm). The polarization is only present from 380 to roughly 600 nm, that is from blue over green to yellow. In the red range, no polarization occurs. The result is that icy patches

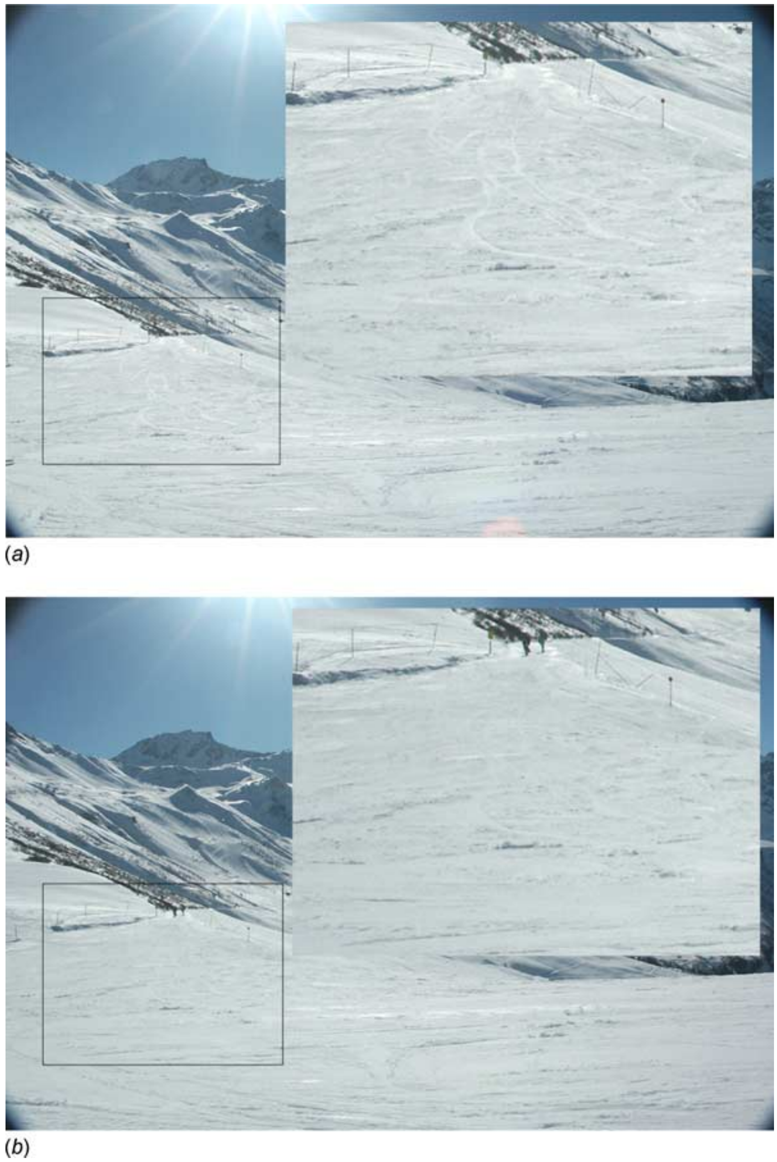


FIG. 6—*(a) Direction of polarizer = 0°. The lower left part is enlarged. All (gleaming) traces are visible. (b) Direction of polarizer = 90°. Most of the information is taken out! The traces nearly vanish with a skiing goggle with vertical polarization.*

might appear red if the polarization requirements are fulfilled. The polarized reflected light of the icy patches is eliminated by the polarizing skiing goggle—but only up to about 600 nm. The remaining red part of the reflected light can pass the filter and the ice comes out red. Also, typically for that kind of filter is the funny appearance of the blue sky if the polarizing ski goggle is turned vertical. If the light of the sky is partially vertical polarized, then the sky appears red because the blue and green part of the spectrum is filtered out.

Anyway, the intensity of the light coming from the icy patches is reduced, and they might not be detected even if in some cases the reflecting patches might appear red.

Discussion

Swimming goggles or diving masks having polarized lenses provide a glare-eliminating feature, which is particularly useful for water sports where glare significantly inhibits participant vision [10,8]. The physics is the same as it is for the polarizing skiing goggles. But the goal is completely different. The aim is to cut out the polarized reflections. With skiing goggles, it is necessary to emphasize the polarized patches because they contain the information for safe(r) skiing. But they are taken out—at least partially.

In general, a skiing area is a field of low visual contrast. The eye is searching for any irregularities because it helps for orientation on the ski slope. These might be traces or ice plates or anything else (e.g., moguls or hollows). In most cases, a polarization filter does not change the appearance of the area because in general there is no polarization. But in a few conditions, the polarization filter can reduce the light. The direction of polarization of the polarized skiing goggle is vertical, thus taking out all the horizontal components. If there is polarized light, e.g., the reflected light of a sheet of ice or compressed snow as in traces of a ski-run, the reflected light has a strong horizontal component that is taken out. Even if the local glare might be reduced, it is more important that other information (which is crucial for movement control) is lost. Without a polarization filter, traces in the snow might be brighter. A polarization filter can make the traces invisible. Even ice patches may vanish. A vertical polarization filter will reduce everything into a low-contrast scene as it is, e.g., in bad weather conditions.

Conclusion

A polarization filter is good for driving, walking, having fun on a blue sky, or all water sports. Polarizing goggles can lead to fantastic visual experiences because contrasts are enhanced when glare is taken out. In alpine skiing, it might be the other way round. In general, the contrasts in a skiing area are very low. The little bit of glare coming from an icy patch or traces might be the only hint that there are dangerous sections on the slope like ice sheets. A polarization filter might take out or at least reduce this important information. These filters reduce the wearer's ability to detect certain details like traces on the slope etc.

Polarizing goggles are fine for most applications, but they are not good for alpine skiing.

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