Back Lighting and Wavelength-Specific Penetration

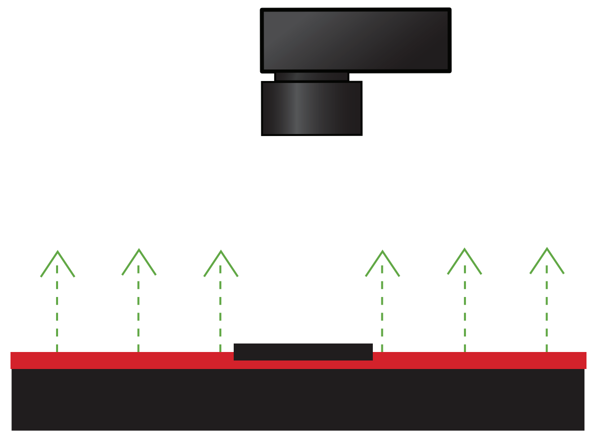

Fig. 1a
Back Light Function Diagram

In machine vision, back lighting is one of the more useful, and also the most common, lighting techniques (Fig. 1a); it is typically used for parts presence/absence, gauging, and also orientation/location, particularly when coupled with pick and place or vision-guided robotics applications. However, there are limitations when using back lighting, primarily in that it requires access to the part top and bottom, or front and back for the camera and back light, respectively. This geometry can be difficult to implement if parts are moving on a conveyor line, especially if a back light cannot be inserted into the conveyor, where product is effectively "pushed" over the flush lighting surface. Most of the above-mentioned applications require only a silhouette, effectively generating instant contrast, white background - black part, where it is expected that light does not penetrate the sample (See Fig. 1b). However, there are variations on the black – white silhouette theme, namely those applications requiring the light to differentially penetrate portions of the sample, such as locating a solid object, or liquid level within another object. We will concentrate on differential back light penetration, and illustrate examples where and why different wavelengths may be useful, depending on sample transmissivity and color.

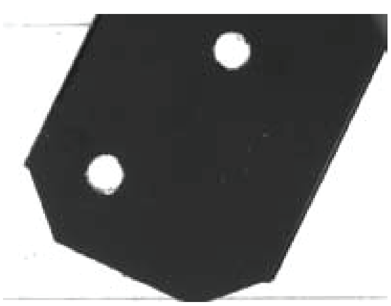

Fig. 1b
Typical Silhouetted BL Image

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A common back lighting application in the pharmaceuticals industry is to verify the presence of bandages, pads or gauze materials after wrapping in their sterile packages. Because both the inserted objects and their packaging are soft and often semi-transparent, we can readily inspect for presence/absence with a standard back light (Fig. 2a).

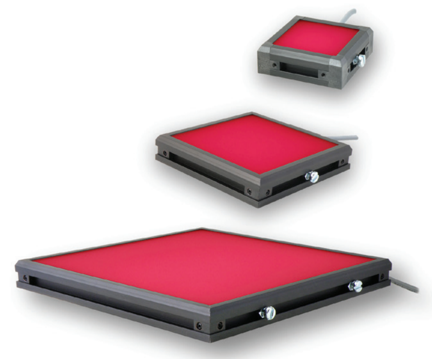

Fig. 2a
BL Series (red)

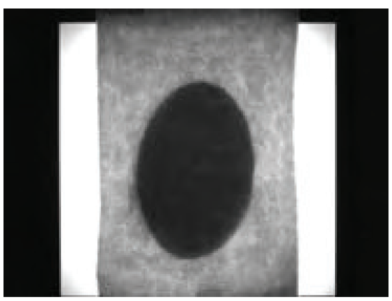

Fig. 2b
Sterile Pad in Wrapper

Figure 2b illustrates a small, cotton eye pad in its sterile paper wrap; in this example, the vision system can quickly verify presence/absence, and also gauge approximate size and shape parameters to verify the correct pad is wrapped. Compare this image with that in Fig. 2c where no pad was inserted. Finally, in Fig. 2d, we can see the result of more than one pad in the wrap.

Fig. 2c
No Sterile Pad Present

Note that, in this application, back light uniformity is less important than having sufficient light intensity to penetrate the sample and its packaging. Is having sufficient intensity necessarily the only solution we have when looking to penetrate materials in back lighting applications? If we consider the visible and near-visible light spectrum (Fig. 3), we see that white, or human-visible light, ranges from 400 nm to about 700 nm in wavelength. UV light ranges from 400 nm down to about 200 nm, and IR light ranges from 700 nm up.

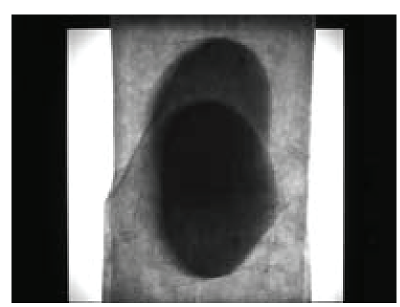

Fig. 2d
Multiple Sterile Pads in Wrapper

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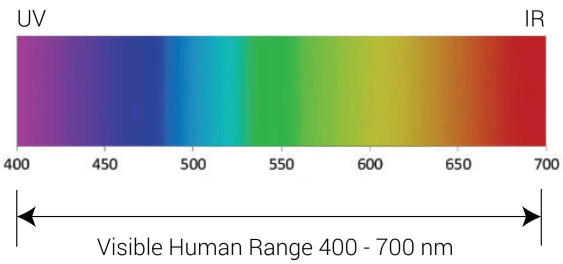

Fig. 3
Visible and Near-Visible Light Spectrum

With this information in mind, it is useful to remember there is a direct correlation between light wavelength and penetration ability; hence for the same material, the longer wavelength light, such as red or IR, may penetrate more deeply than blue in back lighting applications. We see this effect in the following application: We used BL040401-660 (Red) and BL040401-880 (Near IR) surface mount back lights on a semitransparent, populated PCB (Figs. 4a and 4b, respectively) to test how well each wavelength actually penetrated the material. We see that the 880 nm IR light better defines the traces in the board than does the red 660 nm light. However, how do we know that the IR light wasn't just more intense with respect to the camera, or that perhaps the camera was more sensitive to IR light? Examining the board images more closely, we notice a hole in the upper portion of the board. Notice how the red (shorter wavelength) light was so bright it bloomed the hole edges, compared to that in the 880 nm IR image. Despite the camera being more sensitive to the red light, the IR light clearly penetrated the board better. A similar penetration trend can be observed in inspecting an incandescent light bulb filament. A series of images taken with 470 nm blue, 660 nm red, and 880 nm IR back lights (Figs. 5a, b, c respectively) illustrate this point. Blue light does not penetrate the light bulb glass and diffuser coatings; the red light shows some filament detail, whereas the IR light clearly produces the most useful inspection detail.

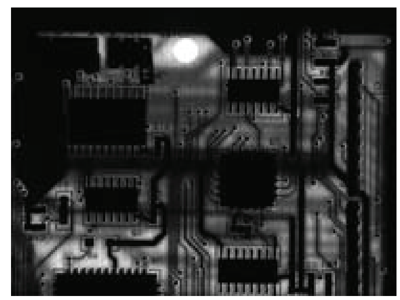

Fig. 4a
PCB w/ Red (660nm) BL

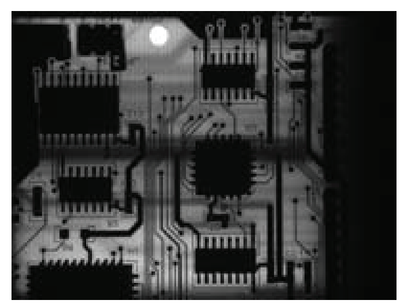

Fig. 4b
PCB w/ IR (880nm) BL

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Fig. 5a
Blue (470nm) BL

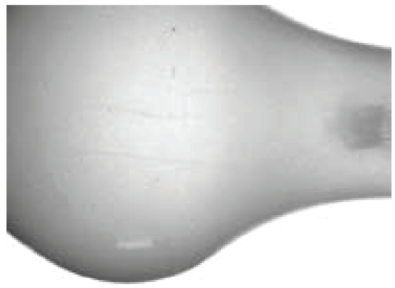

Fig. 5b
Red (660nm) BL

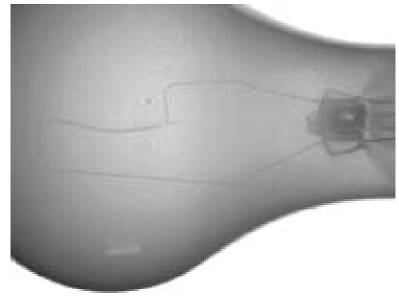

Fig. 5c
IR (880nm) BL

Another common back lighting application is verifying fluid fill level in bottles. In this instance, a colored glass bottle contains clear cologne. If we back light with the most common color - red, we see that the light does not penetrate the bottle (Fig. 6a). Based on the notion of a longer wavelength light penetrating better, we switch to IR 880 nm light, and notice it still does not penetrate the bottle and contents (Fig. 6b). For the sake of completeness, we try the shortest wavelength light - blue, and interestingly, it penetrates the bottle and contents well enough to verify the liquid fill height (Fig. 6c). inspection detail. If we recognize that sample colors may also influence light transmission with respect to wavelength, we can rightly conclude, in this case, that the bottle is composed of blue glass. We may further deduce that not only do solid color objects reflect light of the same color more effectively, but that translucent color objects may also transmit light of the same color similarly.

Fig. 6a
Cologne Bottle w/ Red
(660nm)

Fig. 6b
Cologne Bottle w/ IR
(880nm)

Fig. 6c
Cologne Bottle w/ Blue
(470nm)