Bright Field vs. Dark Field in Vision

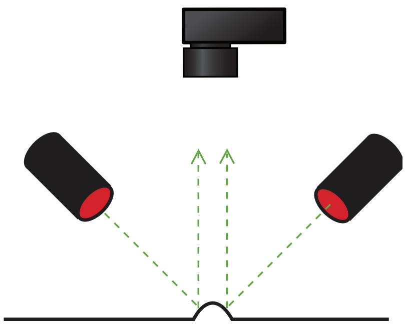

Fig. 1a
Partial Bright
Field Function

One of the more difficult concepts in machine vision lighting is recognizing when it is advantageous to use dark field lighting over its more commonly applied bright field counterpart. Both techniques have advantages and disadvantages; whereas bright field lighting has a wider application envelope for most samples, dark field lighting has a more limited set of conditions necessary for its successful application. We will concentrate on a comparison – contrast between bright field (BF) and dark field (DF) lighting using common vision applications.

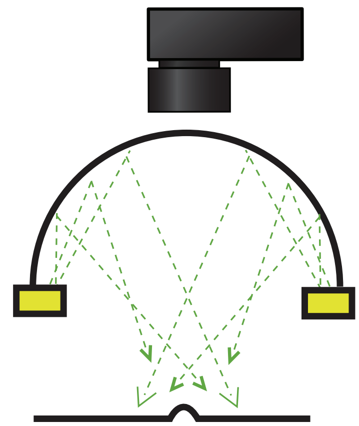

Fig. 1b
Diffuse Dome
Light Function

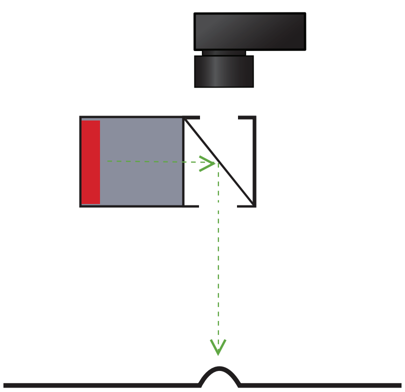

Fig. 1c
Axial Diffuse Light
Function

As used in vision inspection, bright field lighting is defined as lighting that is primarily incident on the field of view from a source oriented at greater than 45 degrees relative to the sample surface. Bright field can be further divided into 2 sub-techniques, and solid angle - a measure of the amount of relative area from which the light is sourced - is an effective differentiator. Bar, spot and ring lights, or any light at a significant working distance (WD), have a relatively low solid angle, and are therefore termed partial or directional BF point sources (Fig. 1a). Conversely, high solid angle hemispherical or planar lights, such as diffuse domes and cylinders (Fig. 1b), or axial diffuse (Fig. 1c) and "flat" arrays (Fig. 1d), respectively, are termed full bright field sources.

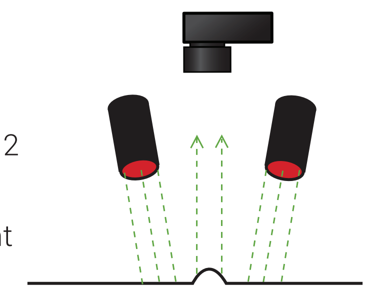

Fig. 2a
Dark Field

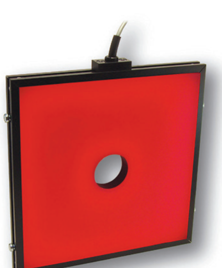

Fig. 1d
Flat Diffuse
Illuminator

Consider also, for a full bright field light to be effective, hence subtending a large solid angle, it must be placed relatively close to the sample.

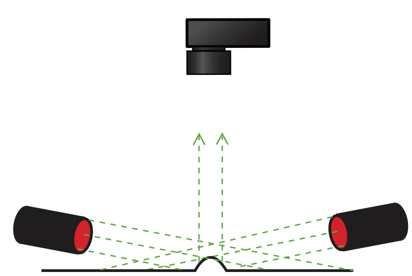

Fig. 2b
Low Angle Dark
Field

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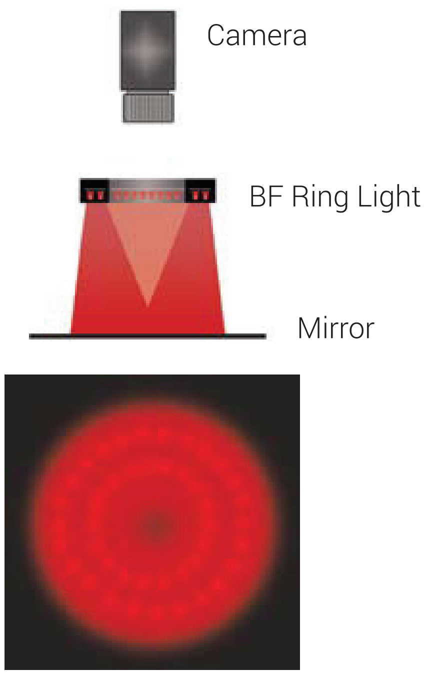

Fig. 3a
Bright Field Set Up and Image

Thus it follows that as a light's WD increases, its solid angle decreases, rendering the effect of a full BF light more typical of a partial BF light. Why is this dichotomy important? Simply because each combination of light presentation, geometry, WD and solid angle has its own advantages depending on the sample characteristics, inspection features of interest, and sample access considerations, to name just a few.

If a bright field is characterized as the result of high angle incident light producing a "bright" field of view, then we can correctly conclude that dark field lighting can be said to generate a primarily "dark" field of view, at low angles of incidence (Fig. 2a). How can this be? How can light produce a "dark" field? Dark field lighting was first used in microscopy and was defined by circular light incident on a sample surface at 45 degrees. As commonly used in machine vision today, we also see very low angle DF with incident light as low as 10-15 degrees from the sample surface (Fig. 2b), as well as from a single direction, not just from circular sources. Figures 3a & 3b illustrate the results of how BF and DF light responds differently on a mirrored surface.

To fully understand how dark field light is produced and used, it is important to remember a simple physical property of incident light: Fig. 3b Dark Field Set Up and Image scratch the angle of reflection is equal to the angle of incidence. Further, as a corollary, it is the actual detail of the surface features that determines how and where light reflects. If we examine the angle of incidence and similarly project what the angle of reflection of the light function diagrams in Figs. 3a & 3b, would be, we can start to understand how dark field is produced.

For example, with the BF ring light, if we project the amount of light reflected from the mirror that actually returns back into the lens, we see that it is quite large; in fact, most of the light is reflected into the camera. This effect produces the image we see in Fig. 3a, typically referred to as a specular hot spot. Comparing the projected amount of light from the low angle DF ring light

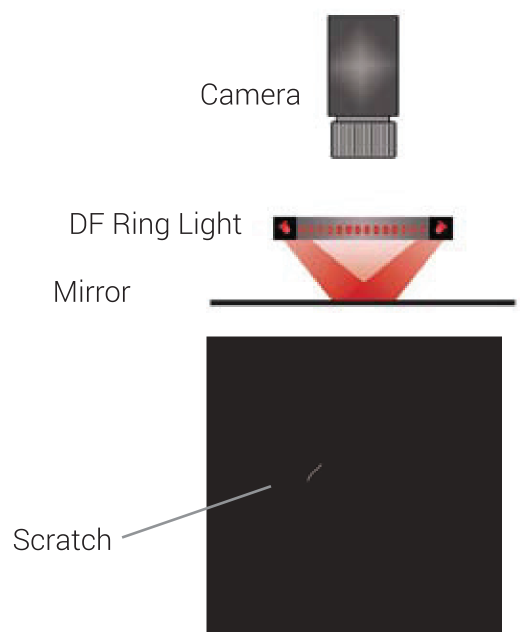

Fig. 3b
Dark Field Set Up and Image

Bright Field vs. Dark Field in Vision

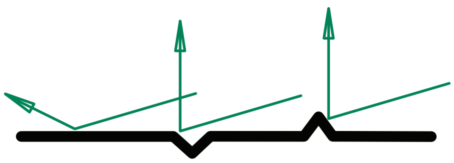

Fig. 4
Ray Function
Diagram Dark Field

in Fig. 3b, we see clearly that most of the light reflects away from the camera, and thus is not collected, hence we see a “dark field”. Naturally this begs the question – how is this fact useful?

Consider the above-mentioned corollary: It is the individual surface details that reflect differently from the overall mirrored surface, and some of the light reflected off these surface imperfections reaches the camera (See Fig 4). In this fashion, we can effectively inspect the surface of a mirror for scratches.

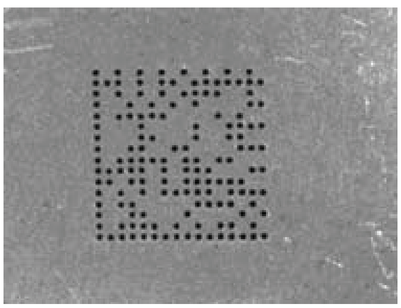

Fig. 5a
Dot Peen in
Bright Field

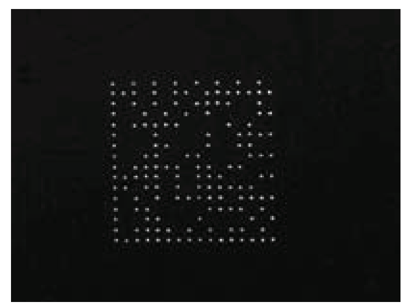

Fig. 5b
Dot Peen in
Dark Field

Figures 5a and 5b illustrate another example of the robustness of dark field vs. bright field lighting for some common inspections. The image depicted in Fig. 5a was captured with a standard coaxial BF ring light, whereas the image in Fig. 5b was generated by a linear bar (Fig. 5c – AL4424-660 BALA) oriented from the side in classic dark field geometry. We can see that either image is likely suitable as-is, but consider if the next sample had considerable dark staining: The DF image likely would not change, whereas the stain might be plainly visible in the bright field image, and thus more likely to affect the inspection results.

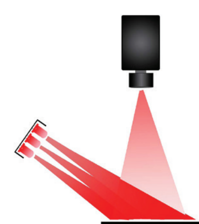

Fig. 5c
BALA Function
Diagram

Does it necessarily follow that all dark field lights are applied at very low angles of incidence, to produce a completely dark field, except for surface abnormalities? No. In the following example, we see that by using a light off axis near 45 degrees, we can take advantage of the dark field effect, thus erasing a specular glare problem In the following example, we see that by using a light off axis near 45 degrees, we can take advantage of the dark field effect, thus erasing a specular glare problem.

The series of images in Fig. 6 illustrates the effect of applying both ring and bar lights at an angle that allows the majority of the light to reflect away from the camera, thus eliminating specular glare, yet still allowing enough captured field lighting to view the surface label and details. The image in Fig. 6a shows specular reflection of a co-axial bright field light. Compare this image with that in Fig. 6b where the same light was

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Fig. 6a
Coaxial BF Ring Light

Fig. 6b BF Ring Light at Low Angle

Fig. 6c Linear Array Light

moved off-axis to produce an acceptable result for inspection. Similarly, a high intensity array light (Figs. 6c & d) may be used mounted transversely to the bottle length from a greater WD to produce the same acceptable inspection result if part access is limited.

We have compared the application and results of bright and dark field lighting techniques, but there are some usage criteria to consider for each. Directional or partial BF lights are the most versatile, from a positioning stand point, so long as they don't produce specular glare; i.e. – try imaging the surface of a ball-bearing with a ring light. Full BF lights, particularly the diffuse dome and cylinder varieties generally need to be in close proximity to the sample, and also may need to be selected with specific lenses in mind to avoid vignetting issues, and there is always the possibility that these lights may block part access, particularly in a vision guided robotics implementation. Dark field lights, particularly the circular varieties also must be placed very close to the part, and suffer similar problems as full BF lights. Assuming circular DF is not necessary, bar lights, of sufficient power, can be placed in a dark field orientation from a longer WD, alleviating some part access issues. Almost any light, except for diffuse area lights and back lights can be used in a dark field orientation, namely 45 degrees or less to the sample surface.

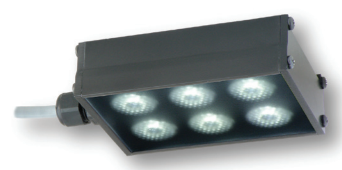

Fig. 6d
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