Choosing the Correct Illumination

By Jeremy Govier

Often, a customer struggles with contrast and resolution problems in an imaging system, while underestimating the power of proper illumination. In fact, desired image quality can typically be met by improving a system's illumination rather than investing in higher resolution detectors, imaging lenses and software. System integrators should remember that proper light intensity in the final image is directly dependent upon component selection.

PHOTOMETRIC UNITS

1 footcandle	=	1 lumen/ft^2
1 footcandle	=	10.764 meter candles
1 footcandle	=	10.764 lux
1 candle	=	1 lumen/steradian
1 candle	=	3.142 x 10^{-4} Lambert
1 Lambert	=	2.054 candle/in^2
1 lux	=	meter candle
1 lux	=	0.0929 footcandle
1 meter candle	=	1 lumen/m^2

Correct illumination is critical to an image system and improper illumination can cause a variety of image problems. Blooming or hot spots, for example, can hide important image information, as can shadowing. In addition, shadowing can also cause false edge calculations when measuring, resulting in inaccurate measurements. Poor illumination can also result in a low signal-to-noise ratio. Non-uniform lighting, in particular, can harm signal-to-noise ratios and make tasks such as thresholding more difficult. These are only a few of the reasons why correct illumination for your application is so important.

The pitfalls of improper illumination are clear, but how are they avoided? To ensure optimal illumination when integrating a system, it is important to recognize the role that choosing the right components plays. Refer below for advantages and disadvantages of different illumination methods and for the effects of using filters and polarizers.

Every component affects the amount of light incident on the sensor and, therefore, the system's image quality. The imaging lens' aperture (f/#) impacts the amount of light incident on the camera. Illumination should be increased as the lens aperture is closed (i.e. higher f/#). High power lenses usually require more illumination, as smaller areas viewed reflect less light back into the lens. The camera's minimum sensitivity is also important in determining the minimum amount of light required in the system. In addition, CCD camera settings such as gain, shutter speed, etc., affect the sensor's sensitivity. Fiber optic illumination usually involves an illuminator and light guide, each of which should be integrated to optimize lighting at the object.

The light intensity for our illumination products is typically specified in terms of footcandles (English unit). Lux, the SI unit equivalent, can be related to footcandles as follows:

1 Lux = 0.0929 Footcandle

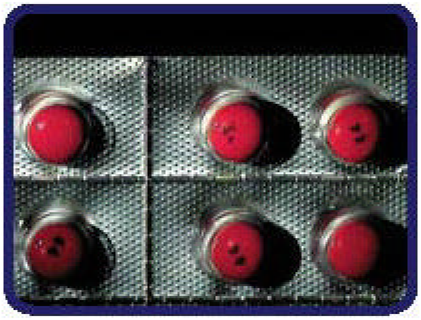
See above for more photometric conversions.

Application Requirements	Type of Object Under inspection	Illumination Type Suggested
Reduction of Specularity	Shiny Object	Diffuse Front, Diffuse Axial, Polarizing
Even Illumination of Object	Any Type of Object	Diffuse Front, Diffuse Axial,

		Ring Guide
Highlight Surface Defects or Topology	Nearly Flat (2-D) Object	Single Directional, Structured Light
Highlight Texture of Object with Shadows	Any Type of Object	Directional, Structured Light
Reduce Shadows	Object with Protrusions, 3-D Object	Diffuse Front, Diffuse Axial, Ring Guide
Highlight Defects within Object	Transparent object	Dark Field
Silhouetting Object	Any Type of Object	Backlighting
3-D Shape Profiling of Object	Object with Protrusions, 3-D Object	Structured Light

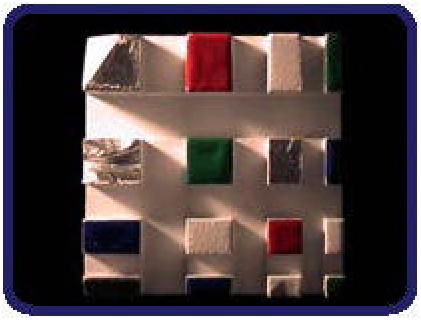
TYPES OF ILLUMINATION

Directional Illumination



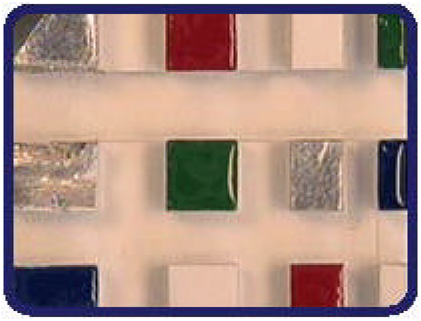
Point source illumination from single or multiple sources. Lenses can be used to focus or spread out illumination.
Pros: Bright, flexible, and can be used in various applications. Easily fit into different packaging.
Cons: Shadowing and glare.
Products Used: Fiber optic light guides, focusing assemblies, LED spot lights, and incandescent light.
Applications: Inspection and measurement of matte and flat objects.

Glancing Illumination



Point source illumination similar to directional illumination, except at a sharp angle of incidence.
Pros: Shows surface structure and enhances object topography
Cons: Hot spots and extreme shadowing
Products Used: Fiber optic light guides, focusing assemblies, LED spot lights, and incandescent light and line light guides.
Applications: Identifying defects in an object with depth and examining finish of opaque objects.

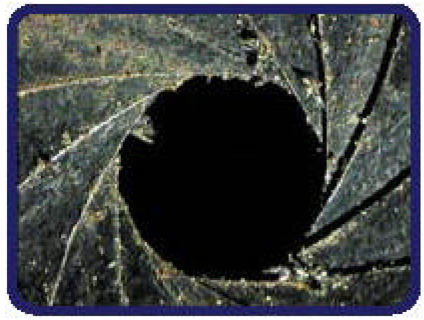
Diffuse Illumination



Diffuse, even light from an extended source.
Pros: Reduces glare and provides even illumination.
Cons: Large and difficult to fit in confined spaces.
Products Used: Fluorescent linear lights (shown at right).
Applications: Best for imaging large, shiny objects with large working distances.

Ring Light

Coaxial illumination that mounts directly on a lens.
Pros: Mounts directly to lens and reduces shadowing.



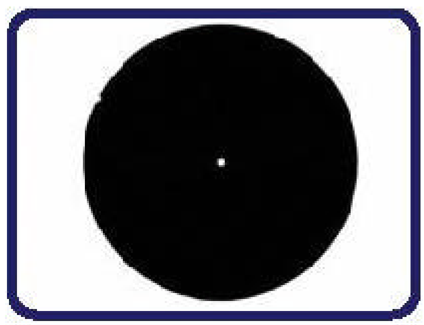
Uniform illumination when used at proper distances.
Cons: Circular glare pattern from reflective surfaces. Works only in relatively short working distances.
Products Used: Fiber optic ring light guides and fluorescent ring lights; LED ring lights.
Applications: Wide variety of inspection and measurement systems with matte objects.

Diffuse Axial Illumination

Diffuse light in-line with the optics. Lens looks through a beamsplitter that is reflecting light onto the object. Illumination is coaxial to imaging access.

Pros: Very even and diffuse; greatly reduces shadowing; very little glare.
Cons: Large and difficult to mount; limited working distance; low throughput such that multiple fiber optic sources may be needed to provide sufficient illumination.
Products Used: Fiber optic diffuse axial attachment. Single or multiple fiber optic illuminators. Single, dual, or quad fiber bundles depending on size of attachment and number of illuminators used. LED diffuse axial illuminator.
Applications: Measurements and inspection of shiny objects.

Brightfield / Backlight



Object is lit from behind. Used to silhouette opaque objects or for imaging through transparent objects.
Pros: High contrast for edge detection.
Cons: Eliminates surface detail.
Products Used: Fiber optic backlights and LED backlights.
Applications: Targets and test patterns, edge detection, measurement of opaque objects and sorting of translucent colored objects.

Darkfield

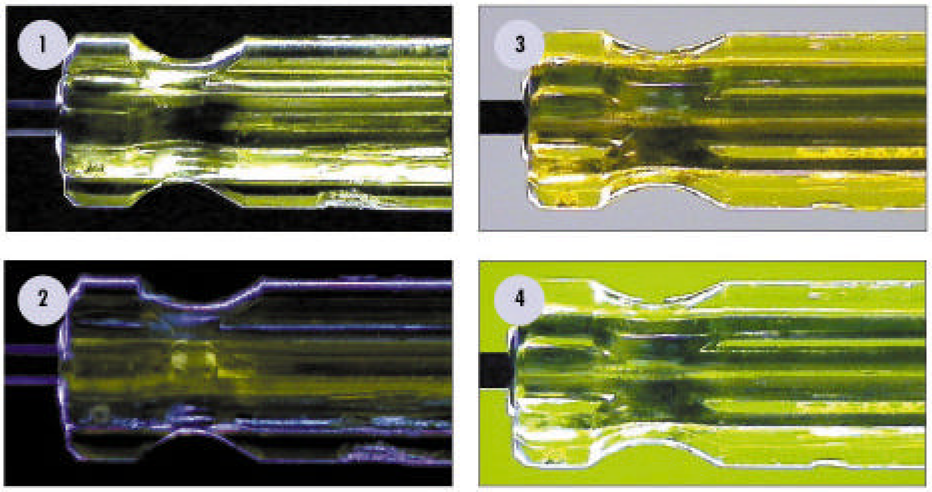
Light enters a transparent or translucent object through the edges perpendicular to the lens.
Pros: High contrast of internal and surface details. Enhances scratches, cracks, and bubbles in clear objects.
Cons: Poor edge contrast. Not useful for opaque objects.
Products Used: Fiber optic darkfield attachment, line light guides, and laser line generators.
Applications: Glass and plastic inspection.

Structured Light (Line Generators)

Patterns that are projected onto the object. Typically laser projected lines, spots, grids, or circles.
Pros: Enhances surface features by providing intense illumination over a small area. Can be used to get depth information from object.
Cons: May cause blooming and is absorbed by some colors.
Products Used: Lasers with line generating or diffractive pattern generating optics.
Applications: Inspection of three-dimensional objects for

missing features. Topography measurements.

FILTERING PROVIDES VARIOUS LEVELS OF CONTRAST



Examples illustrate darkfield and backlight illumination with assorted color filters

1) Darkfield only: defects appear white.

2) Darkfield only with a blue filter: defects show up as blue.

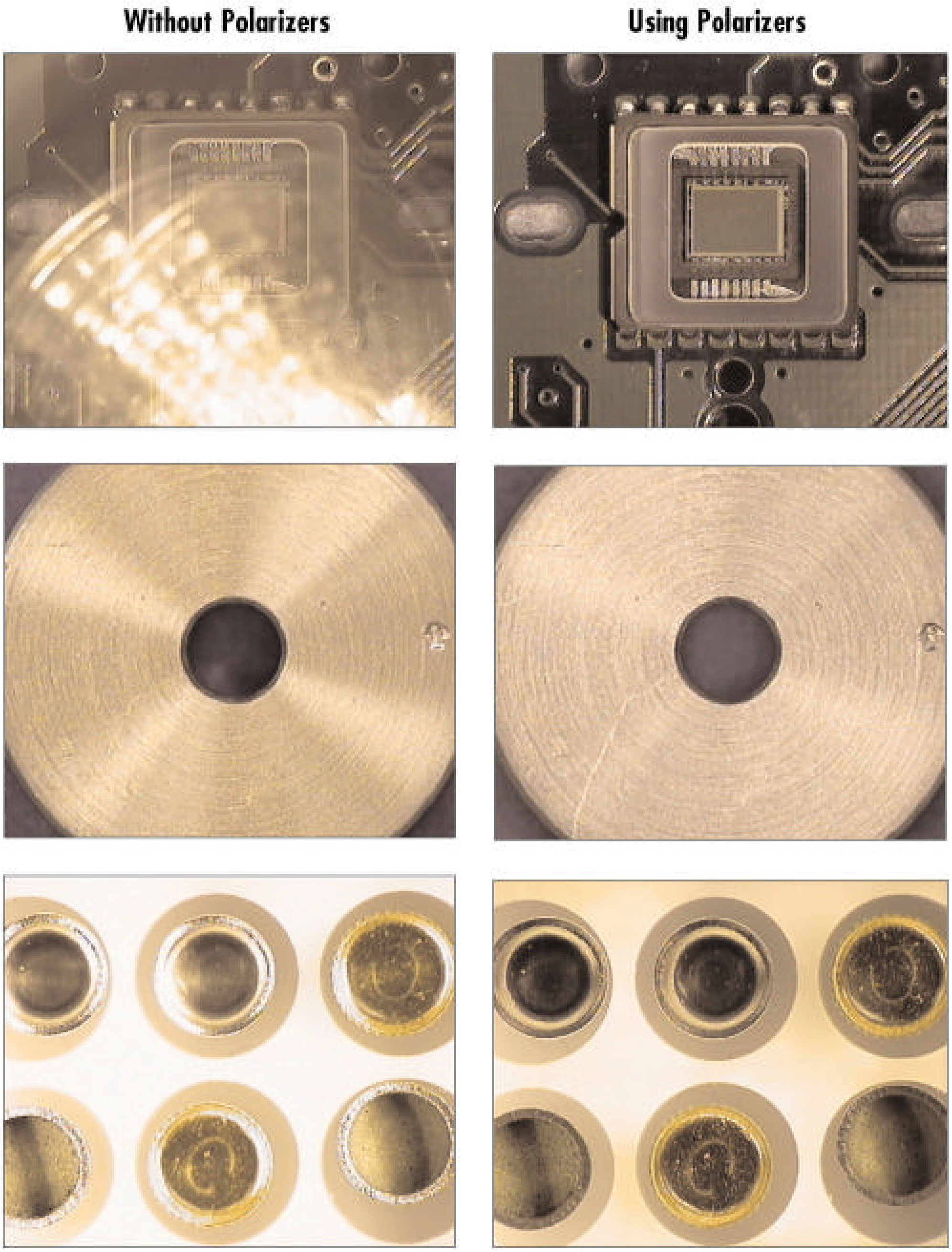
3) Darkfield and Backlight: no filter is used, but edge contrast improves.

4) Darkfield (no filter) with backlighting (yellow filter): enhances overall contrast, defects show up as white in contrast to rest of field.

Images taken with a Close Focus Zoom Lens, 18 - 180mm FL (#54-363) Field of View = 30mm, Working Distance = 200mm

IMAGE ENHANCEMENT USING POLARIZERS

A polarizer is useful for eliminating specular reflections (glare) and bringing out surface defects in an image. A polarizer can be mounted either on the light source, on the video lens, or on both depending upon the object under inspection. When two polarizers are used, one on the illumination source and one on the video lens, their polarization axes must be oriented perpendicular to each other. The following are polarization solutions to glare problems for several material types and circumstances.

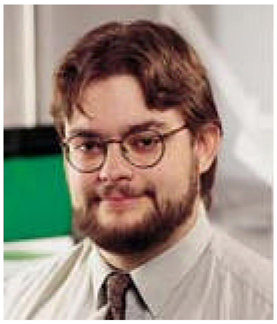


1. When the object is non-metallic and illumination strikes it at a sharp angle: A polarizer on the lens is usually sufficient for blocking glare. (Rotate the polarizer until glare is at a minimum.) Add a polarizer in front of the light source if glare is still present.

2. When the object has a metallic or

shiny surface: Mounting a polarizer on the light source as well as on the lens is recommended for enhancing contrast and bringing out surface details. The polarized light incident on the shiny surface will remain polarized when it's reflected. Surface defects in the metal will alter the polarization of the reflected light. Turning the polarizer on the lens so its polarization axis is perpendicular to that of the illumination source will reduce the glare and make scratches and digs in the surface visible.

3. When the object has both highly reflective and diffuse areas: Using two polarizers with perpendicular orientation will eliminate hot spots in the image caused by the metallic parts. The rest of the field will be evenly illuminated due to the diffuse areas reflecting randomly polarized light to the lens.



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