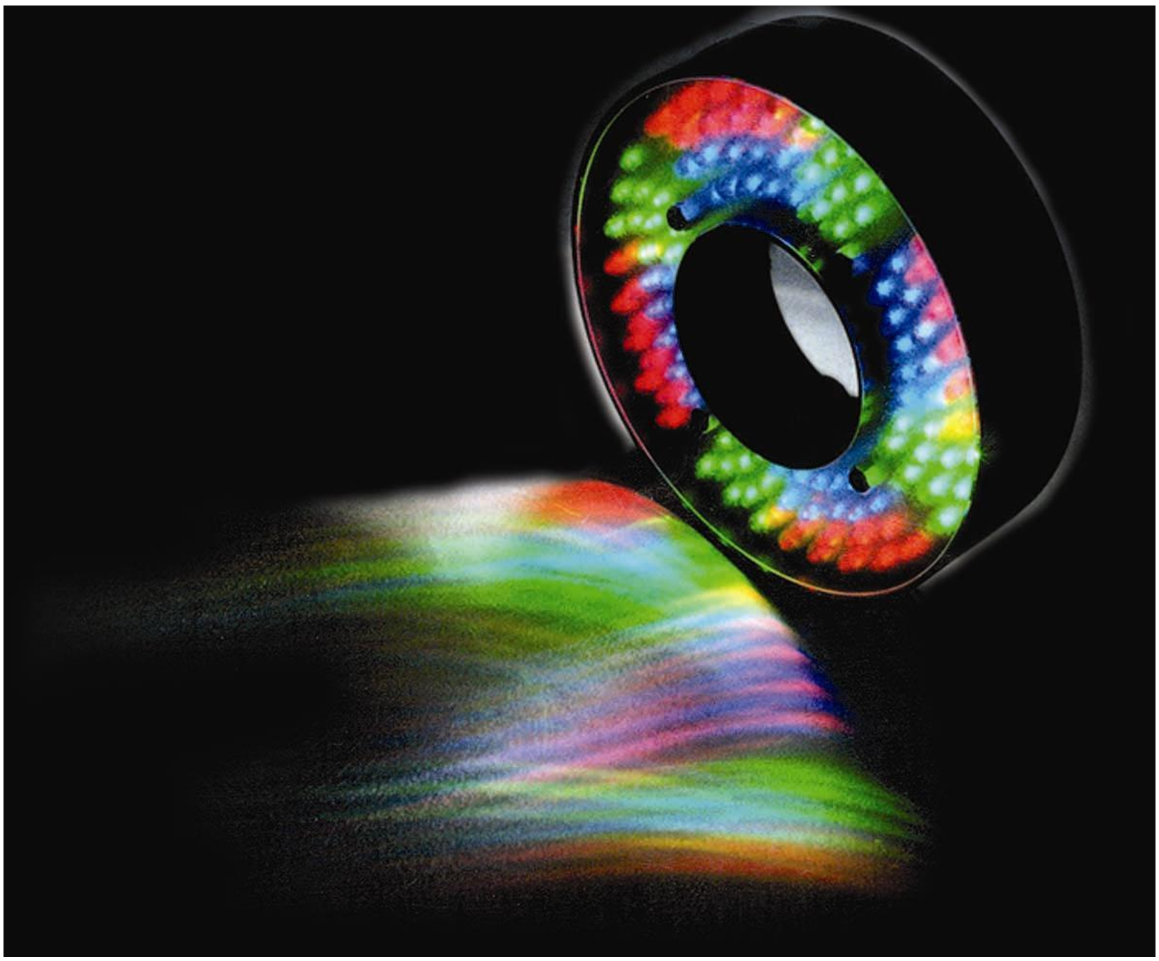
A Practical Guide to Machine Vision Lighting



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February, 2013

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Abstract: It is well-understood that the quality and appropriateness of lighting are critical aspects for creating a quality, robust, and timely vision inspection. In addition to an understanding of illumination types and techniques, geometry, filtering, sensor characteristics, and color, a thorough analysis of the inspection environment, including sample presentation and sample-light interactions, provide a foundation upon which to design an effective vision lighting solution. It is suggested that designing and following a rigorous lighting analysis sequence will provide a consistent, and robust environment, thereby maximizing time, effort, and resources – items better used in other critical aspects of vision system design, testing, and implementation.

Introduction

Perhaps no other aspect of vision system design and implementation consistently has caused more delay, cost-overruns, and general consternation than lighting. Historically, lighting often was the last aspect specified, developed, and or funded, if at all. And this approach was not entirely unwarranted, as until recently there was no real vision-specific lighting on the market, meaning lighting solutions typically consisted of standard incandescent or fluorescent consumer products, with various amounts of ambient contribution.

The objective of this paper, rather than to dwell on theoretical treatments, is to present a "Standard Method for Developing Sample Appropriate Lighting". We will accomplish this goal by detailing relevant aspects, in a practical framework, with examples, where applicable, from the following 3 areas:

1) Knowledge of:
    - Lighting types, and application advantages and disadvantages
    - Vision camera and sensor quantum efficiency and spectral range
    - Illumination Techniques and their application fields relative to surface flatness and surface reflectivity

2) Familiarity with the 4 cornerstones of vision illumination:
    - Geometry
    - Pattern, or Structure
    - Wavelength
    - Filters

3) Detailed analysis of:
    - Immediate Inspection Environment – Physical constraints and requirements
    - Sample – Light Interactions with respect to your unique samples

When the information from these 3 areas is accumulated and analyzed, with respect to the specific sample and inspection requirements, we can achieve the primary goal of machine vision lighting analysis - to provide sample appropriate lighting that meets 3 Acceptance Criteria consistently:

1) maximize the contrast on those features of interest
2) minimize the contrast elsewhere
3) provide for a measure of robustness

As we are all aware, each inspection is different, thus it is possible, for example, for lighting solutions that meet Acceptance Criteria 1 and 2 only to be effective, provided there are no inconsistencies in part size, shape, orientation, placement, or environmental variables, such as ambient light contribution (See Fig. 1).

Fig. 1 - Cellophane wrapper on a pack of note cards. Left: meets all 3 Acceptance Criteria. Right: meets only criteria 1 & 2. In this circumstance, the “wrinkle” is not precluding a good barcode reading, but what if the “wrinkles” were in a different place in the next pack on the line?

Vision Illumination Sources and Spectral Content

The following lighting sources are now commonly used in machine vision:

- Fluorescent
- Quartz Halogen – Fiber Optics
- LED - Light Emitting Diode
- Metal Halide (Mercury)
- Xenon - Strobing

Fluorescent, quartz-halogen, and LED are by far the most widely used lighting types in machine vision, particularly for small to medium scale inspection stations, whereas metal halide and xenon are more typically used in large scale applications, or in areas requiring a very bright source. Metal halide, also known as mercury, is often used in microscopy because it has many discrete wavelength peaks, which complements the use of filters for fluorescence studies. A xenon source is useful for applications requiring a very bright, strobed light. Fig. 2 shows the advantages and disadvantages of xenon, fluorescent, quartz halogen, and LED lighting types, and relevant selection criteria, as applied to machine vision. For example, whereas LED lighting has a longer life expectancy, quartz halogen lighting may be the choice for a particular inspection because it offers greater intensity.

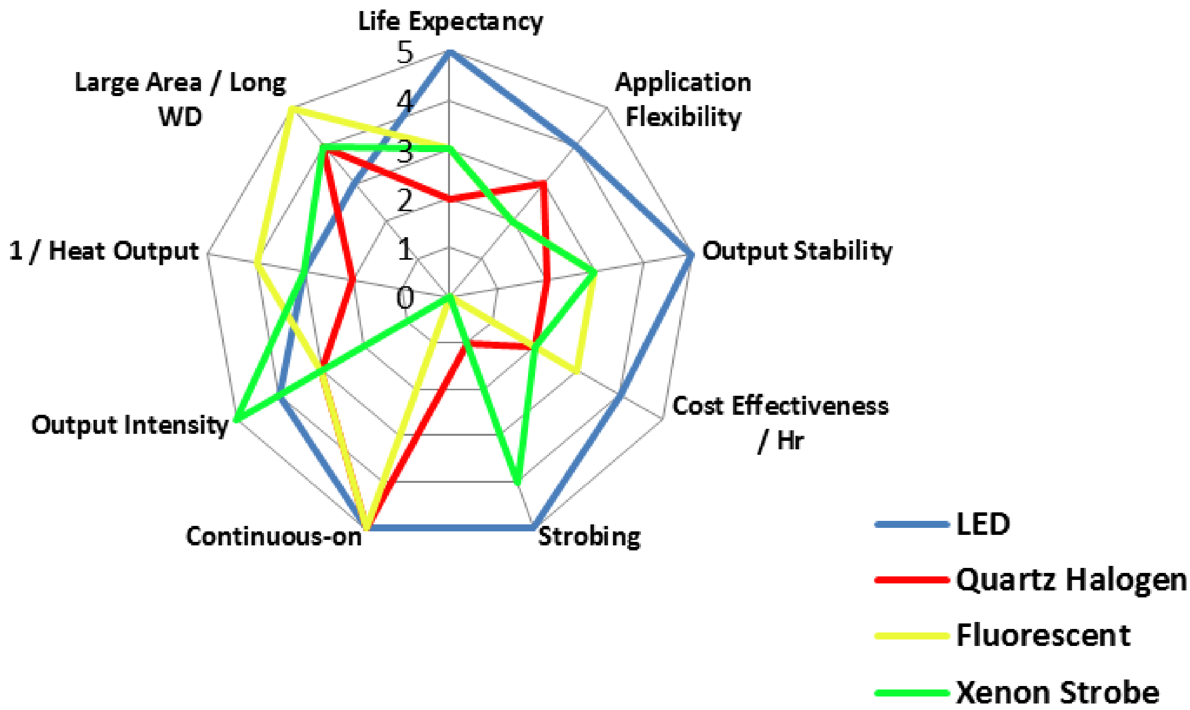


Fig. 2 – Comparison and contrast of common vision lighting sources.

Historically, fluorescent and quartz halogen lighting sources have been used most commonly. In recent years, LED technology has improved in stability, intensity, and cost-effectiveness; however, it is still not as cost-effective for large area lighting deployment, particularly compared with fluorescent sources. However, on the other hand, if application flexibility, output stability, and longevity are important parameters, then LED lighting might be more appropriate. Depending on the exact lighting requirements, oftentimes more than one source type may be used for a specific implementation, and most vision experts agree that one source type cannot adequately solve all lighting issues.

It is important to consider not only a source's brightness, but also its spectral content (Fig. 3). Microscopy applications, for example often use a full spectrum quartz halogen, xenon, or mercury source, particularly when imaging in color; however a monochrome LED source is also useful for B&W CCD camera, and also now for color applications, with the advent of "all color – RGB" and white LED light heads.

In those applications requiring high light intensity, such as high-speed inspections, it may be useful to match the source's spectral output with the spectral sensitivity of your particular vision camera (Fig. 4). For example, CMOS sensor based cameras are more IR sensitive than their CCD counterparts, imparting a significant sensitivity advantage in light-starved inspection settings when using IR LED or IR-rich Tungsten sources.

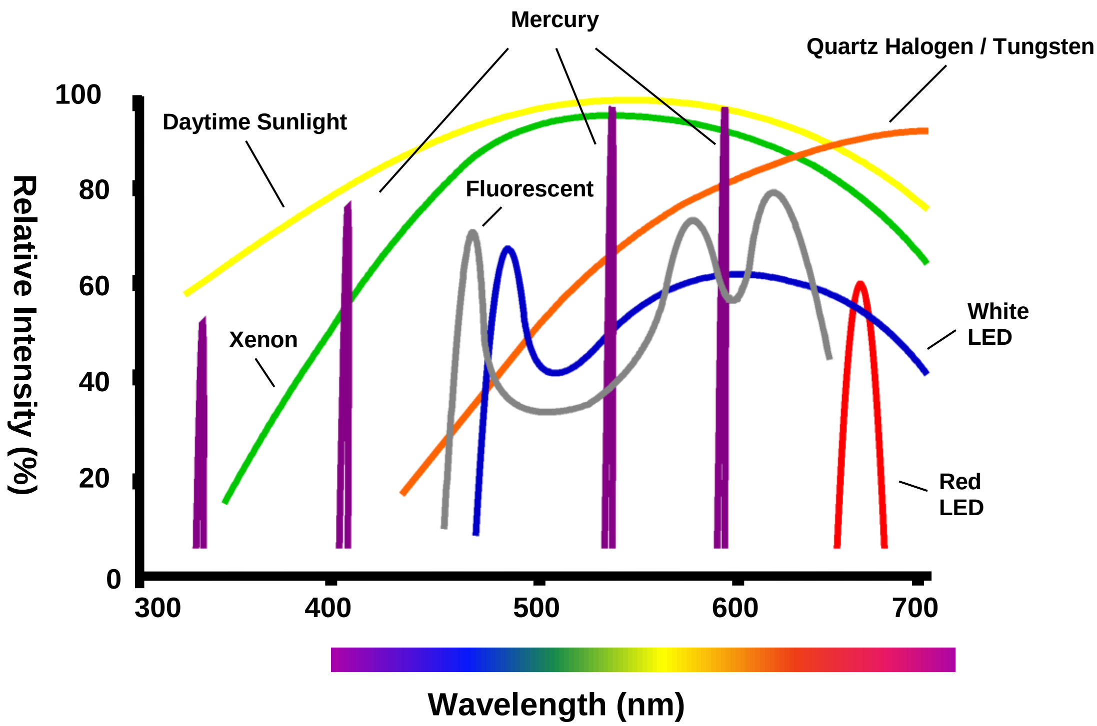


Fig. 3 – Light Source Relative Intensity vs. Spectral Content. Bar at bottom denotes approximate human visible wavelength range.

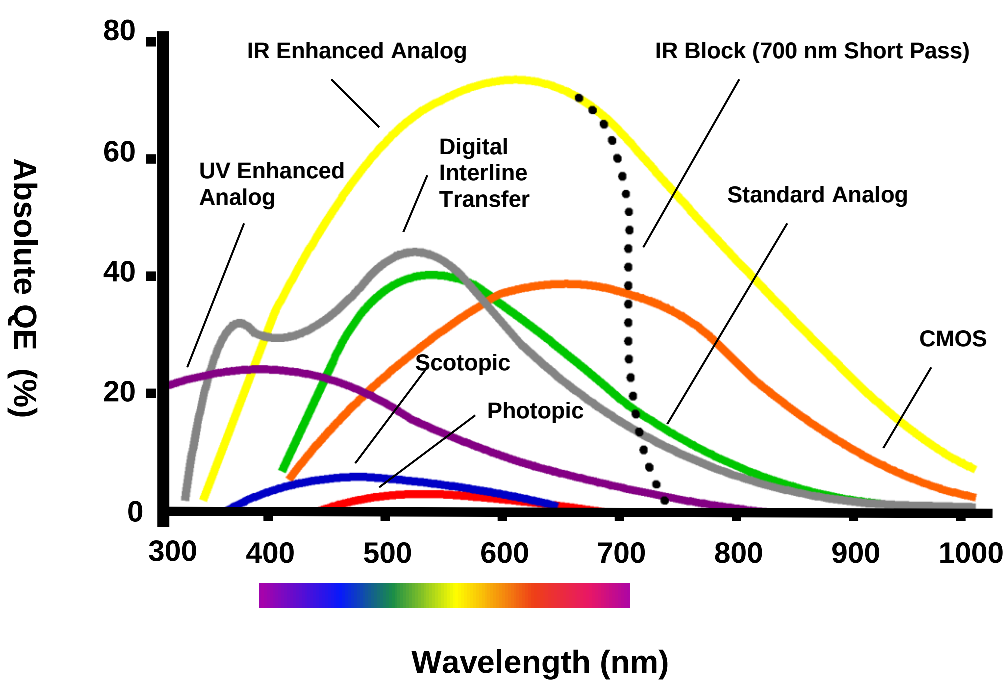


Fig. 4 – Camera Sensor Absolute Quantum Efficiency vs. Wavelength. Bar at bottom denotes approximate human visible wavelength range.

Additionally, the information in Figs 3-4 illustrates several other relevant points to consider when selecting a camera and light source.

- Attempt to match your sensor's peak sensitivity with your lighting source's peak wavelength to take the fullest advantage of its output.
- Narrow wavelength sources, such as monochrome LEDs, or mercury are beneficial for passing strategic wavelengths when matched with narrow pass filters. For example, a red 660 nm band pass filter, when matched to red LED light, is very effective at blocking ambient light on the plant floor from overhead fluorescent or mercury sources.
- Sunlight has the raw intensity and broadband spectral content to call into question any vision inspection results – use an opaque housing.
- Even though our minds are very good at interpreting what our eyes see, the human visual system is woefully inadequate in terms of ultimate sensitivity and spectral dynamic range – let your eyes view the image as acquired with the vision camera.

The Cornerstones of Vision Illumination

The 4 cornerstones of vision illumination are:

1) Geometry - The 3-D spatial relationship among sample, light and camera.
2) Structure, or Pattern - The shape of the light projected onto the sample.
3) Wavelength, or Color - How the light is differentially reflected or absorbed by the sample and its immediate background.
4) Filters - Differentially blocking and passing wavelengths and/or light directions.

Understanding how manipulating and enhancing sample contrast using the 4 cornerstones is crucial in meeting the 3 aforementioned Acceptance Criteria for assessing the quality and robustness of lighting. Effecting contrast changes via Geometry involves moving the sample, light, and/or camera positions until a suitable configuration is found. For example, a co-axial ring light (one typically mounted around the lens, or at least around the camera/lens optical path) may generate hot spot glare on a semi-reflective bar code surface, but by simply moving the light off-axis, the hot spot glare is also moved out of the camera's view. Contrast changes via Structure, or the shape of the light projected on the sample is generally light head, or lighting technique specific (See later section on Lighting Techniques). Contrast changes via Color lighting are related to differential color absorbance vs. reflectance (See Sample – Light Interaction).

A common question raised about the 4 cornerstones is priority of investigation. For example, is wavelength more important than geometry, and when to apply filtering? There is no easy answer to this question, and of course the priority of investigation is usually highly sample and application-specific. Typically, geometry is more important when dealing with specular application samples, whereas wavelength and filtering are more crucial for color and transparency applications. Figure 5 illustrates how crucial geometry is for a consistent and robust inspection application on a specular cylinder.

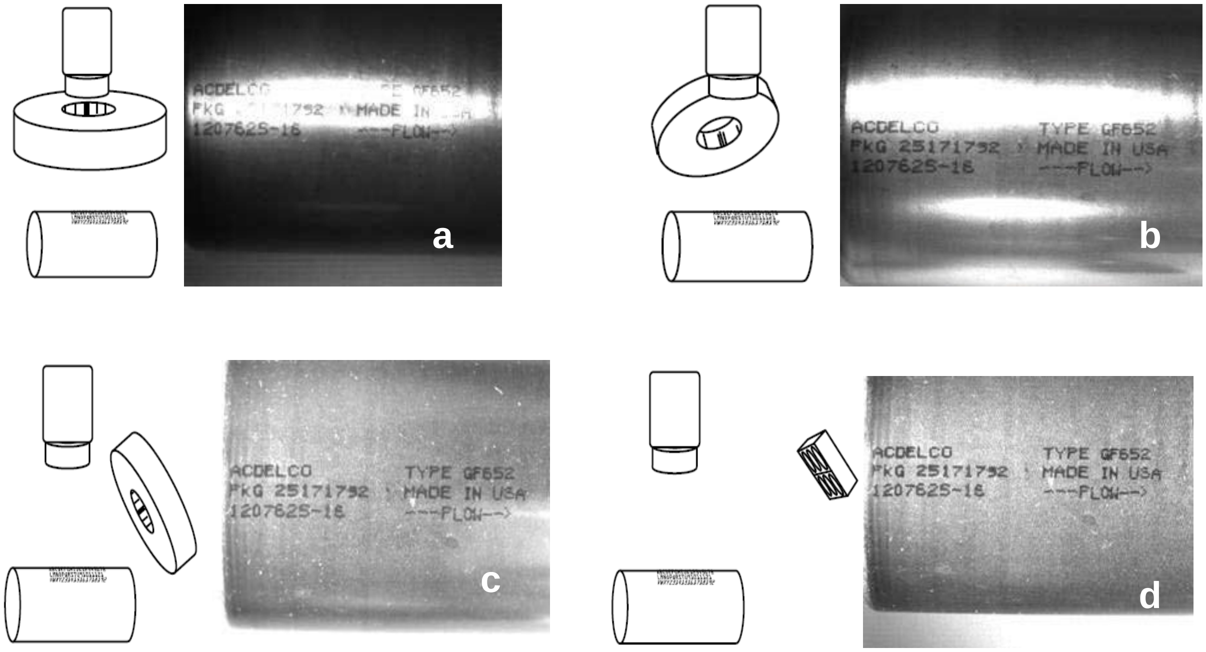


Fig. 5 – Lighting Geometry: Reading ink print on an inline fuel filter. a: std coaxial geometry, note the hot spot reflection directly over the print, b: Off axis – Acceptance Criteria 1&2 met, but what happens when the print is rotated slightly up or down? c: Off axis down the long axis of the cylinder – all 3 Criteria met, d: Same as in image “c”, but from a longer working distance.

Issues to Consider

With respect to the lighting environment, there are 2 aspects to evaluate when determining the optimal lighting solution:

1) Immediate Inspection Environment
2) Sample – Light Interaction

All the information from these evaluations should be considered together w/ the available optics, Lighting Types, Techniques, and the 4 Cornerstones to develop a sample-appropriate lighting solution that meets the 3 Acceptance Criteria listed earlier.

Immediate Inspection Environment

Fully understanding the immediate inspection area’s physical requirements and limitations, in 3-D space, is critical. In particular, depending on the specific inspection requirements, the use of robotic pick and place machines, or pre-existing, but necessary support structures may severely limit the choice of effective lighting solutions, by forcing a compromise in not only the type of lighting, but its geometry, working distance, intensity, and pattern as well. For example, it may be determined that a diffuse light source is required, but cannot be applied because of limited close-up, top-down access. Inspection on high-speed lines may require intense continuous or strobed light to freeze motion, and of course large objects present an altogether different challenge for lighting.

Additionally, consistent part placement and presentation are also important, particularly depending on which features are being inspected; however, even lighting for inconsistencies in part placement and presentation can be developed, as a last resort, if fully understood.

Ambient Light Contribution

As mentioned earlier, the presence of ambient light input can have a tremendous impact on the quality and consistency of inspections, particularly when using a multi-spectral source, such as white light. The most common ambient contributors are overhead factory lights and sunlight, but occasionally errant vision-specific task lighting from other inspection stations, or even other stations in the same work cell, can have an impact.

There are 3 active methods for dealing with ambient light – high power strobing with short duration pulses, physical enclosures, and pass filters (see Fig 6 for pass filter varieties). Which method is applied is a function of many factors, most of which will be discussed in some detail in later sections.

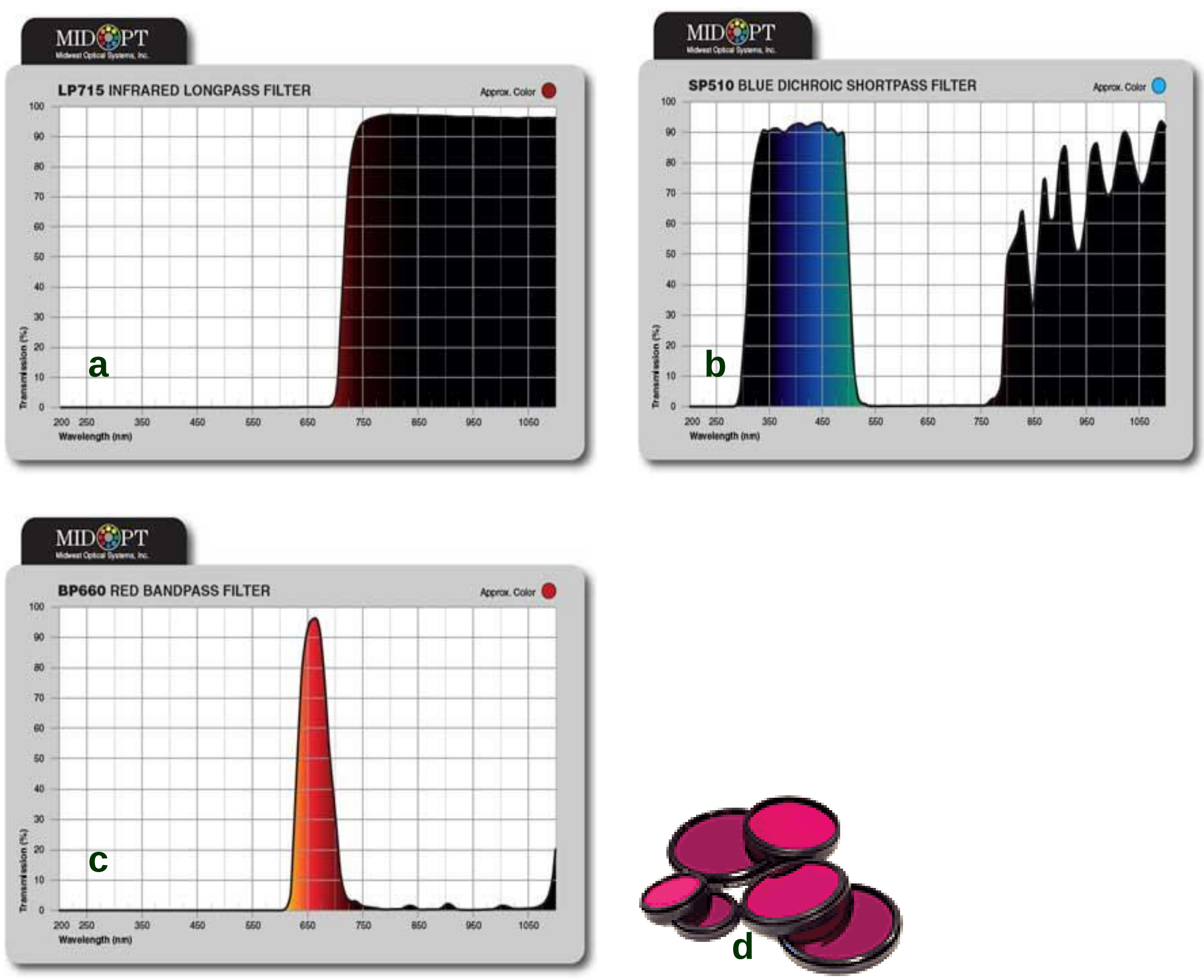


Fig. 6 – Typical spectral transmission curves for pass filters - a: Long pass, b: short pass, c: band pass, d: Typical red 660 nm threaded band pass filter. Graphics Courtesy of Midwest Optical, Palatine, IL.

High-power strobing simply overwhelms and washes out the ambient contribution, but has disadvantages in ergonomics, cost, implementation effort, and not all sources can be strobed, e.g. - fluorescent. If strobing cannot be employed, and if the application calls for using a color camera, multi-spectral white light is necessary for accurate color reproduction and balance. Thus, in this circumstance a narrow wavelength pass filter is ineffective, as it will block a major portion of the white light contribution, and thus an enclosure is the best choice.

There are exceptions to this rule-of-thumb, however. For example, a 700 nm short pass filter, otherwise known as an IR blocker is standard in color cameras because IR content can alter the color accuracy and balance, particularly of the green channel. Figure 7 illustrates how the use of a pass filter can block ambient light very effectively, particularly when the light of interest is low yield fluorescence.

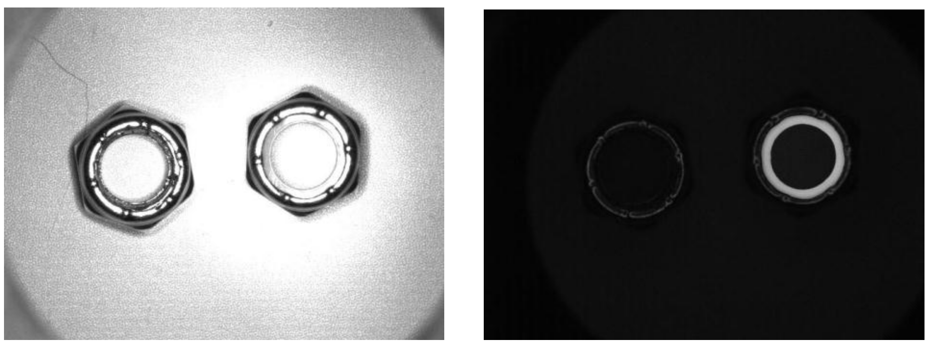


Fig. 7 – Nyloc Nuts. Left: imaged with a UV ring light, but flooded with red 660 nm "ambient" light. The goal is to determine nylon presence / absence. Given the large ambient contribution, it is difficult to get sufficient contrast from the relatively low-yield blue fluoresced light from the sample. Right: Same lighting, except a 510 nm short pass, effectively blocking the red "ambient" light and allowing the blue 450 nm light to pass.

Sample – Light Interactions

How a sample's surface interacts with task-specific and ambient light is related to many factors, including the gross surface shape, geometry, and reflectivity, as well as its composition, topography and color. Some combination of these factors will determine how much light, and in what manner, it is reflected to the camera, and subsequently available for acquisition, processing, and measurement/analysis (see Fig. 8). An important principle to remember is that when dealing with specular surfaces light reflects from these surfaces at the angle of incidence – this is a useful property to apply for use with dark field lighting applications (see Fig. 10, right image for example).

Additionally, a curved, specular surface, such as the bottom of a soda can (Fig. 9), will reflect a directional light source differently from a flat, diffuse surface, such as copy paper. Similarly, a topographic surface, such as a populated PCB, will reflect differently from a flat, but finely textured or dimpled (Fig. 10) surface depending on the light type and geometry.

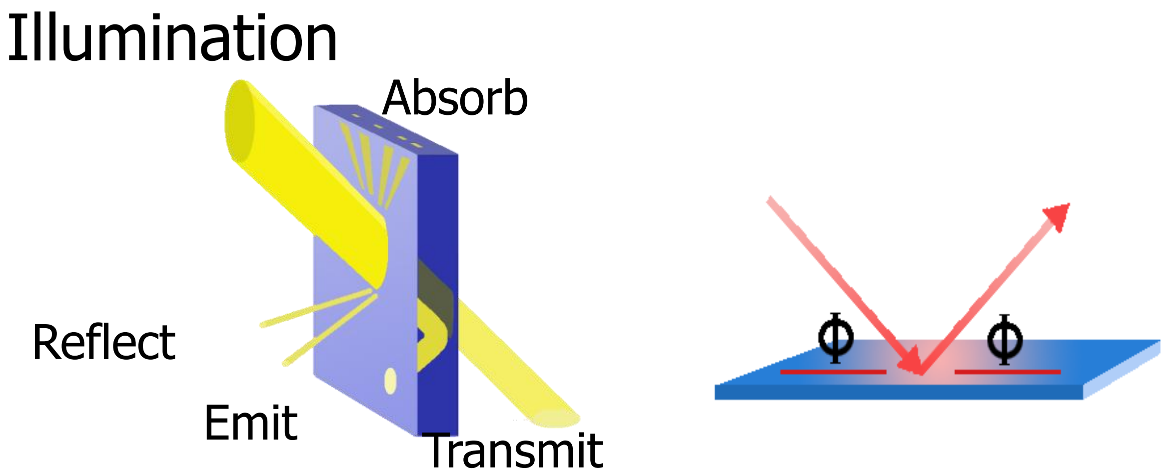


Fig. 8 – Left: Light interaction on sample surfaces. Right: Specular surface, angle of reflection = angle of incidence (*Phi* 1 = *Phi* 2).

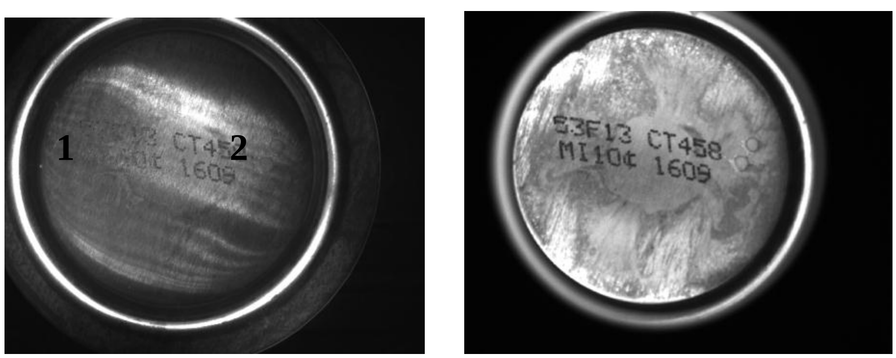


Fig. 9 – Bottom of a soda can. Left: illuminated with a bright field ring light, but shows poor contrast, uneven lighting, and specular reflections. Right: imaged with diffuse light, creating an even background allowing the code to be read.

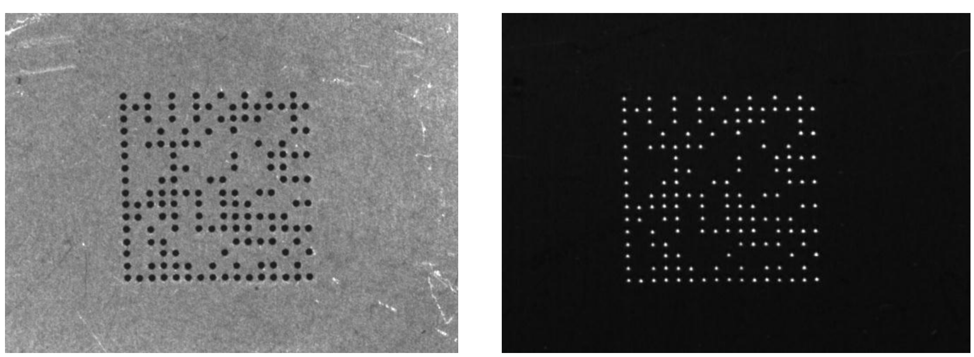


Fig. 10 – 2-D dot peen matrix code. Left: illuminated by bright field ring light. Right: imaged with a low angle linear dark field light. A simple change in light pattern created a more effective and robust inspection.

Warm **Cool**

Color Analysis

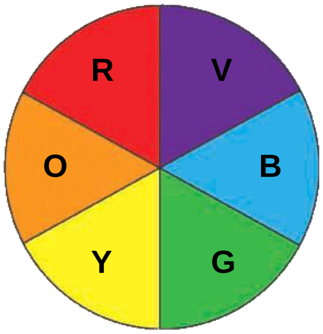


Fig. 11 – Color Wheel

Materials reflect and/or absorb various wavelengths of light differentially, an effect that is valid for both B&W and color imaging space. As we all remember from grammar school, like colors reflect, and surfaces are brightened; conversely, opposing colors absorb, and surfaces are darkened. Using a simple color wheel of Warm vs. Cool colors (Fig. 11), we can generate differential contrast between a part and its background (Fig. 12), and even differentiate color parts, given a limited, known palette of colors, with a B&W camera (Fig. 13).

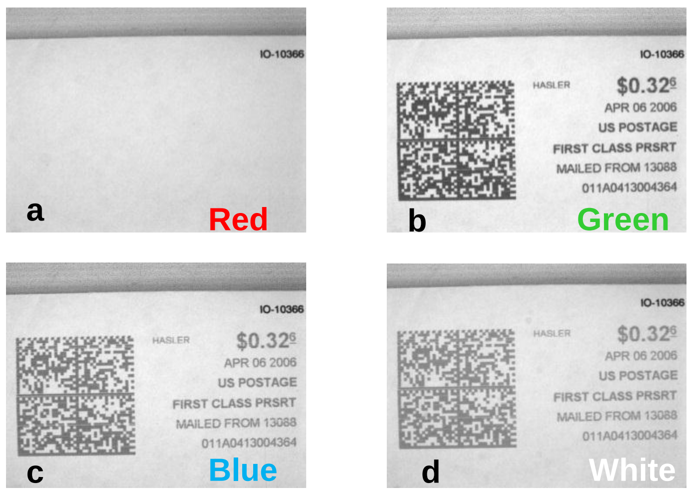


Fig. 12a – Mail stamp imaged under Red light, b - Green light, c - Blue light, generating less contrast than green, d – White light, generating less contrast than either Blue or Green light. White light will contrast all colors, but it may be a contrast compromise.

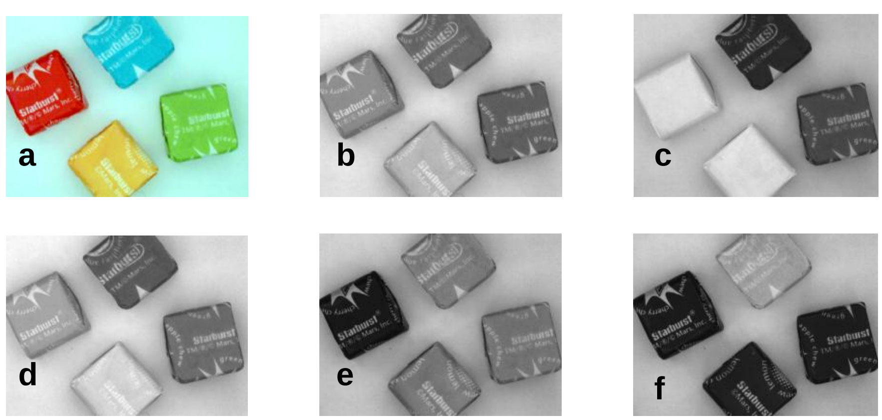


Fig. 13a - Candy pieces imaged under white light and a color CCD camera, b - White light and a B&W camera, c - Red light, lightening both the red & yellow and darkening the blue, d – Red & Green light, yielding yellow, lightening the yellow more than the red, e – Green light, lightening the green & blue and darkening the red, f – Blue light, lightening the blue and darkening the others.

Sample Composition and Transmittance

Sample composition can greatly affect what happens to task lighting impinging on a part. Some plastics may transmit light only of certain wavelength ranges, and are otherwise opaque; some may not transmit, but rather internally diffuse the light; and still some may absorb the light only to re-emit it at the same wavelength, or at a different wavelength (fluorescence). Fluorescence labels and dyes are commonly used in inks for the printing industry as well (Fig. 14).

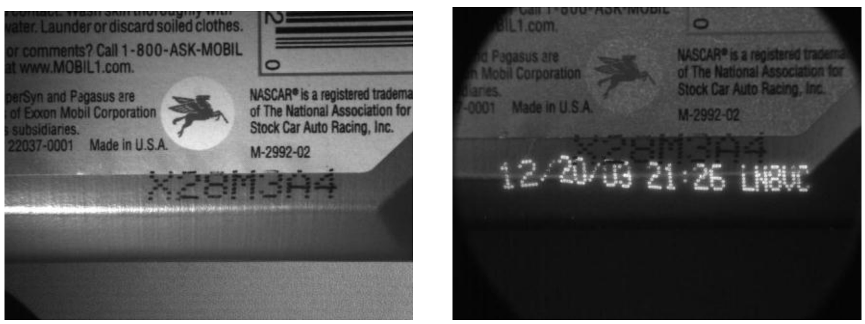


Fig. 14 – Motor oil bottle. Left: illuminated with a red 660 nm ring light. Right: illuminated with a 360 nm UV fluorescent light.

The properties of IR light can be useful in vision inspection for a variety of reasons. First, IR light is effective at neutralizing contrast differences based on color, primarily because reflection of IR light is based more on sample composition, rather than color differences. This property can be used when less contrast, normally based on color reflectance from white light is the desired effect (See Fig. 15).

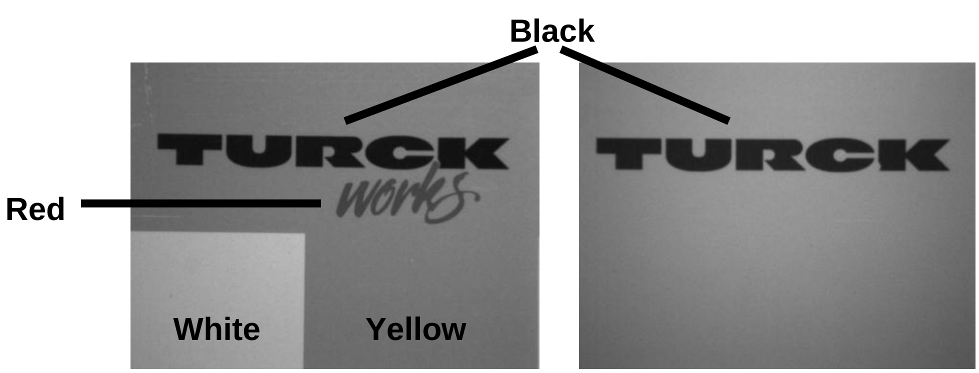


Fig. 15 – Glossy paper sample. Left: under diffuse white light. Right: under diffuse IR light.

IR light is considerably more effective at penetrating polymer materials than the short wavelengths, such as UV or blue, and even red in some cases (See Fig. 16). Conversely, it is this lack of penetration depth, however, that makes blue light more useful for imaging shallow surface features of black rubber compounds or laser etchings, for instance.

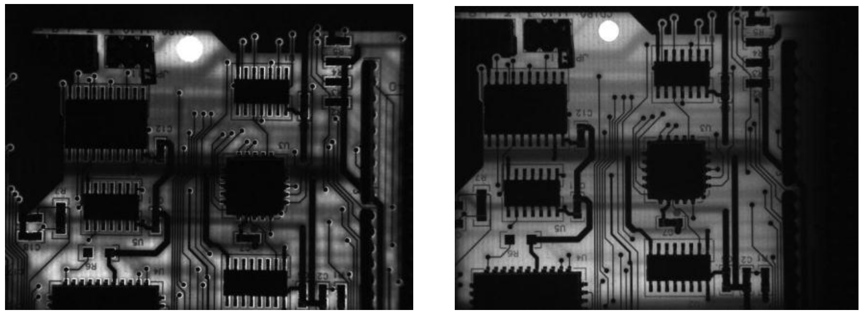


Fig 16 – Populated PCB. Penetration of red 660 nm (left image) and IR 880 nm light. Notice the better penetration of IR despite the red blooming out from the hole in the top center of the board.

Polarizing filters, when applied in pairs, one between the light and sample, the other between the sample and camera, typically affixed to the lens via screw threads, are useful for detecting structural lattice damage in otherwise transparent samples (Fig. 17).

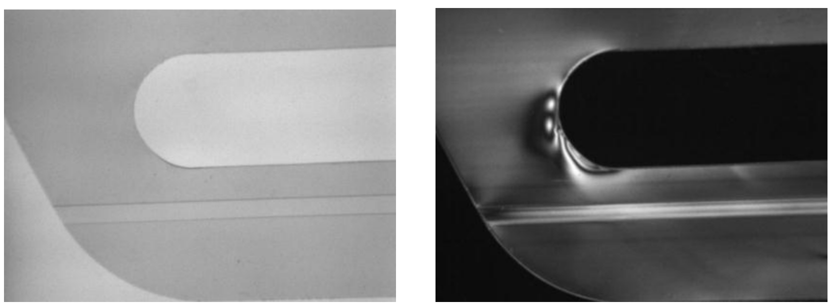


Fig. 17 – Transparent plastic 6-pack can holder. Left: with a red back light. Right: Same, except for the addition of a polarizer pair, showing stress fields in the polymer.

Particularly when used to block specular reflections on samples, any use of polarization filters comes with inherent compromises, however. The images depicted in Fig. 18 demonstrate: 1) moderately effective, and 2) highly effective use of polarization filters specifically for blocking glare.

In samples depicted in Figs. 18a-c, we see that glare reflected from a curved surface, such as this personal care product bottle, can be controlled, but not entirely eliminated (Fig. 18b – center area). This is true because there are multiple reflection directions produced on the curved surface from a directional light source, and polarization filters cannot block all vibration directions simultaneously, thus always leaving some areas vignetted. In this case, a more effective approach to glare control, given the flexibility to do so, is to reconsider the lighting geometry. By simple moving the light from a coaxial position around the lens to a relatively high angle, but off-axis position, we can completely eliminate all specular reflection. Conversely, for the relatively flat and planar jar top surface depicted in Figs. 18d-e, the specular glare can be largely removed, producing a clear image for inspection. However, a caveat for using dual polarizers is that they can reduce the allowable light considerably – up to 2 ½ f-stops in the case of the jar top example, which could be detrimental for high-speed, light-starved inspections.

Fig. 18 - A change in "lighting – sample – camera" geometry or type may be more effective than applying polarizers to stop glare. a – Coaxial Ring Light w/o Polarizers. b – Coaxial Ring Light w/ Polarizers (note some residual glare). c – Off-axis (light axis parallel to the sample long axis) Ring Light w/o Polarizers. d – Coaxial Ring Light w/o Polarizers. e – Coaxial Ring Light w/ Polarizers (note: 2 ½ f-stop opening).

Illumination Techniques

Illumination techniques comprise the following:

- Back Lighting
- Diffuse Lighting (also known as full bright field)
- Bright Field (actually partial bright field or directional)
- Dark Field

The application of some techniques requires a specific light and geometry, or relative placement of the camera, sample, and light; others do not. For example, a standard bright field bar light may also be used in dark-field mode; whereas a diffuse light is used exclusively as such.

Most manufacturers of vision lighting products also offer lights with various combinations of techniques available in the same light, and at least in the case of LED-based varieties, each of the techniques may individually addressable. This circumstance allows for greater flexibility and also reduces potential costs when many different inspections can be accomplished in a single station, rather than two. If the application conditions and limitations of each of these lighting techniques, as well as the intricacies of the inspection environment and sample – light interactions are well-understood, it is possible to develop an effective lighting solution that meets the 3 Acceptance Criteria listed earlier.

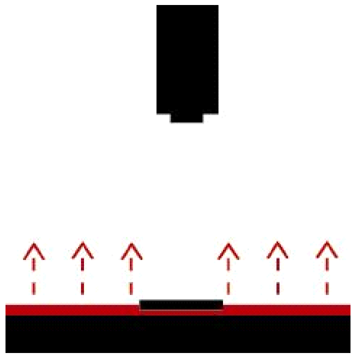


Fig. 19 – Back Lighting

Back Lighting

Back lighting generates instant contrast as it creates dark silhouettes against a bright background (Fig. 19). The most common uses are detecting presence / absence of holes and gaps, part placement or orientation, or for measuring objects. Often it is useful to use a monochrome light, such as red, green, or blue, with light control polarization if very precise (subpixel) edge detection becomes necessary.

Diffuse (Full Bright Field) Lighting

Diffuse, or full bright field lighting is most commonly used on shiny specular, or mixed reflectivity samples where even, but multi-directional light is needed. There are several implementations of diffuse lighting generally available, but 3 primary types, hemispherical dome / cylinder or on-axis (Figs. 20a-c) being the most common.

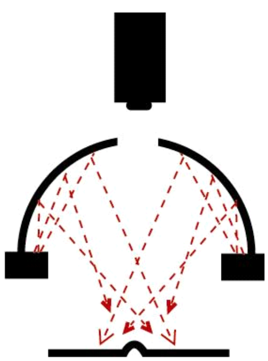


Fig. 20a – Dome Diffuse

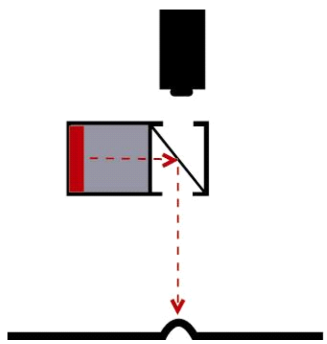


Fig. 20b – On-axis Diffuse

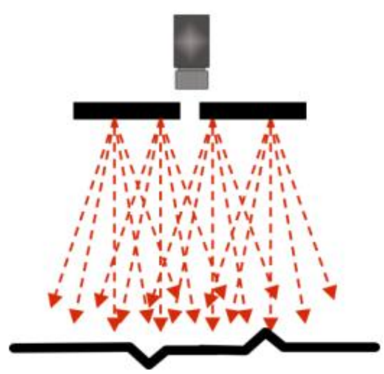


Fig. 20c – Flat diffuse

Diffuse dome lights are very effective at lighting curved, specular surfaces, commonly found in the automotive industry, for example. On-axis lights work in similar fashion for flat samples, and are particularly effective at enhancing differentially angled, textured, or topographic features on relatively flat objects.

A useful property of axial diffuse lighting is that in this case, rather than rejecting or avoiding specular glare, we may actually take advantage of the glare – if it can be isolated specifically to uniquely define the feature(s) of interest required for a consistent and robust inspection (see Fig. 21).

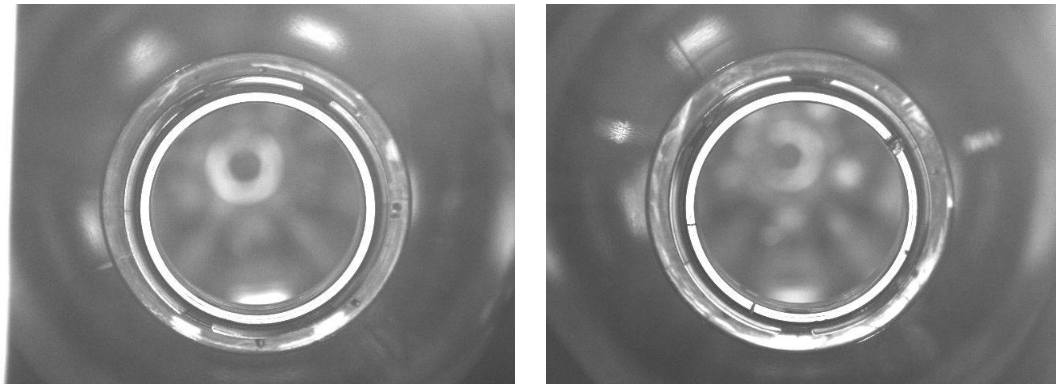
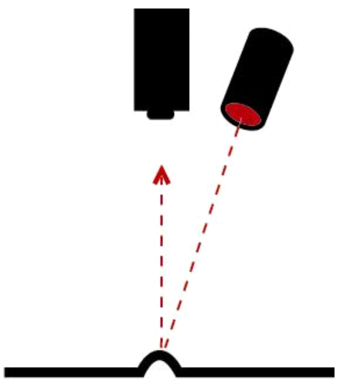


Fig. 21 – Blown pop bottle sealing surface under axial diffuse lighting. Left: Clean and unblemished surface (white ring). Right: Damaged surface – note the discontinuities in the reflectivity profile.

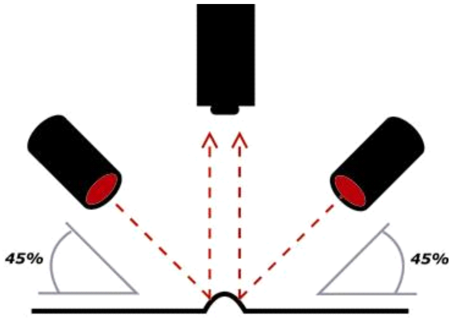


Partial Bright Field or Directional Lighting

Partial bright field lighting is the most commonly used vision lighting technique, and is the most familiar lighting we use everyday, including sunlight. This type of lighting is distinguished from full bright field in that it is directional, typically from a point source, and because of its directional nature, it is a good choice for generating contrast and enhancing topographic detail. It is much less effective, however when used on-axis with specular surfaces, generating the familiar "hotspot" reflection.

Fig. 22 – Directional Bright Field

To be effective, diffuse lights, particularly dome varieties, require close proximity to the sample. The flat diffuse light is an exception; it can be placed at any distance while still keeping the inverse square rule for intensity fall-off in mind.



Dark Field Lighting

Dark field lighting is perhaps the least well understood of all the techniques, although we do use these techniques in everyday life. For example, the use of automobile headlights relies on light incident at low angles on the road surface, reflecting back from the small surface imperfections, and also nearby objects.

Fig. 23 – Medium Angle Dark Field

Dark field lighting can be subdivided into circular and linear, or directional types, the former requiring a specific light head geometry design. This type of lighting is characterized by low or medium angle of light incidence, typically requiring close proximity, particularly for the circular light head varieties (Fig. 24b).

Bright Field vs. Dark Field

The following figures illustrate the differences in implementation and result of circular directional (partial bright field) and circular dark field lights, on a mirrored surface:

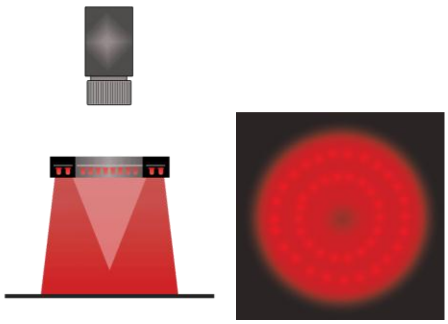


Fig. 24a – Bright field image of a mirror.

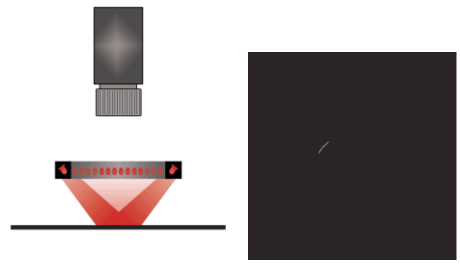


Fig. 24b – Dark field image of a mirror; note scratch.

Effective application of dark field lighting relies on the fact that much of the light incident on a mirrored surface that would otherwise flood the scene as a hot spot glare, is reflected away from, rather than toward the camera. The relatively small amount of light that is reflected back into the camera is what happened to catch an edge of a small feature on the surface, satisfying the “angle of reflection equals the angle of incidence” equation (See Fig 25 for another example).

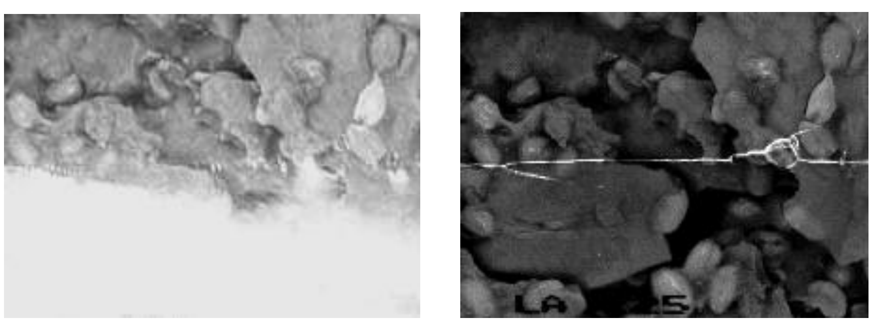


Fig. 25 – Peanut Brittle Bag. Left: under a bright field ring light. Right: under a dark field ring light – note the seam is very visible.

Another important aspect of dark field lighting is its flexibility. Many standard bright field lights can be used in a dark field geometry, typically the directional types only. This technique is also very good for detecting edges in topographic samples, and the directional variety can be used effectively if there is a known, standard orientation in a sample (See Fig. 10, right image).

Application Fields

Fig. 26 illustrates potential application fields for the different lighting techniques, based on the 2 most prevalent gross surface characteristics:

1) Surface Flatness and Texture
2) Surface Reflectivity

This diagram plots surface reflectivity, divided into 3 categories, matte, mirror, and mixed versus surface flatness and texture, or topography. As one moves right and downward on the diagram, more specialized lighting Geometries and Structured Lighting types are necessary.

As might be expected, the "Geometry Independent" section implies that relatively flat and diffuse surfaces do not require specific lighting, but rather any light technique may be effective, provided it meets all the other criteria necessary, such as working distance, access, brightness, and projected pattern, for example.

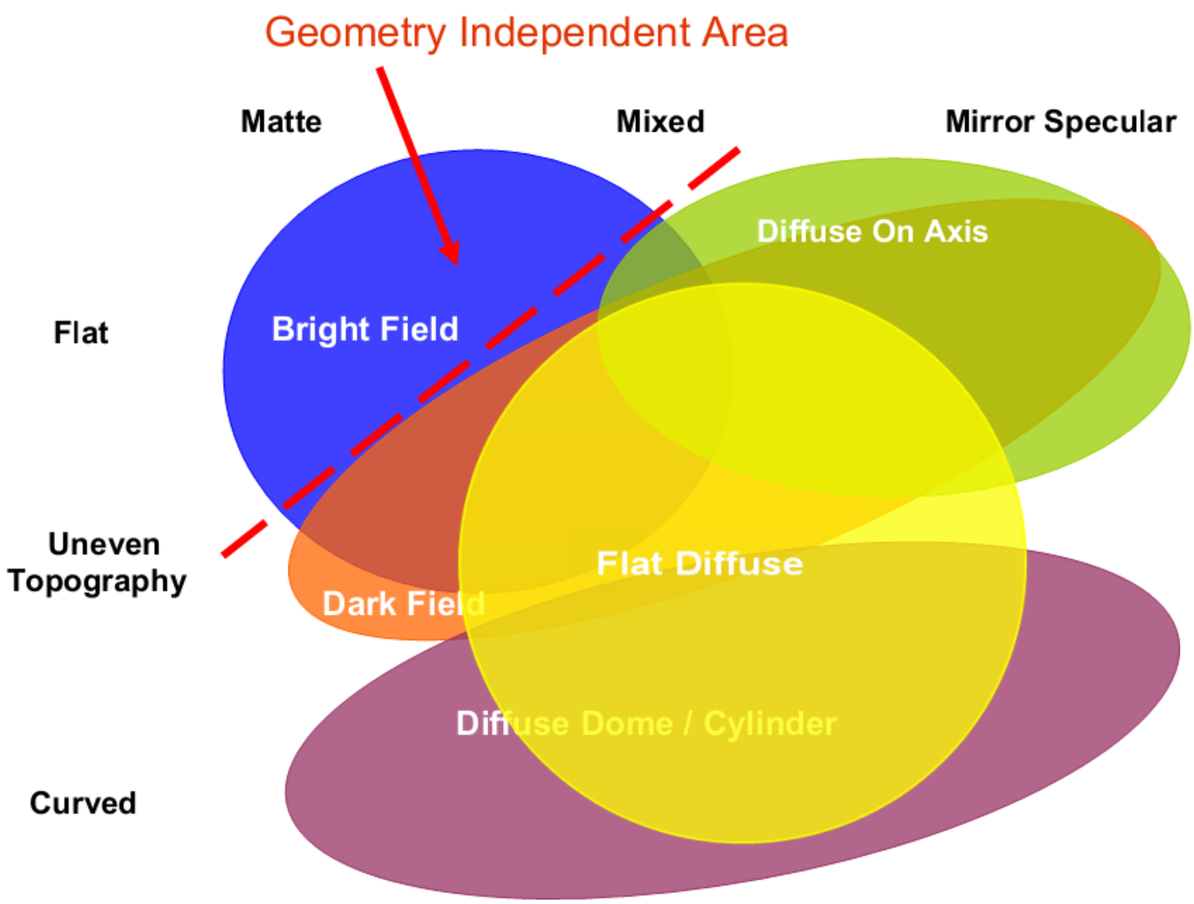


Fig. 26 – Lighting Technique Application Fields – surface shape vs. surface reflectivity detail. Note that although not shown, any light technique is generally effective in the "Geometry Independent" portion of the diagram.

Sequence of Lighting Analysis

The following "Sequence of Lighting Analysis" assumes a working knowledge of Lighting Types, Camera Sensitivities, optics, and familiarity with Illumination Techniques and the 4 Cornerstones of Vision Illumination. It can be used as a checklist to follow and it is by no means comprehensive, but it does provide a good working foundation for a standardized method that can be modified and/or expanded for the inspection's requirements.

1) Immediate Inspection Physical Environment
    a) Physical Constraints
        - Access for camera, lens, and lighting in 3-D space (working volume)
        - The size and shape of the working volume
        - Min and max camera, lighting working distance and field-of-view
    b) Part Characteristics
        - Sample stationary, moving, or indexed?
        - If moving or indexed, speeds, feeds, and expected cycle time?
        - Strobing? Expected pulse rate, on-time, and duty cycle?
        - Are there any continuous or shock vibrations?
        - Is the part presented consistently in orientation and position?
        - Any potential for ambient light contamination?
    c) Ergonomics and safety
        - Man-in-the-loop for operator interaction?
        - Safety related to strobing or intense lighting applications?

2) Sample – Light Interactions
    a) Sample Surface
        - Reflectivity - Diffuse, specular, or mixed?
        - Overall Geometry - Flat, curved, or mixed?
        - Texture - Smooth, polished, rough, irregular, multiple?
        - Topography – Flat, multiple elevations, angles?
        - Light Intensity needed?
    b) Composition and Color
        - Metallic, non-metallic, mixed, polymer?
        - Part color vs. background color
        - Transparent, semi-transparent, or opaque – IR transmission?
        - UV dye, or fluorescent polymer?
    c) Light Contamination
        - Ambient contribution from overhead or operator station lighting?
        - Light contamination from another inspection station?
        - Light contamination from the same inspection station?

3) What are the features of interest?

4) Applying the 4 Cornerstones of Lighting
    a) Light – Camera – Sample Geometry issues

    b) Light pattern issues
    c) Color differences between sample and background
    d) Filters for short, long, or band pass applications, incl. polarization

5) Applying the Lighting Techniques and Types Knowledge, including Intensity
    a) Fluorescent vs. Quartz-Halogen vs. LED vs. others
    b) Bright field, dark field, diffuse, back lighting
    c) Vision camera and sensor quantum efficiency and spectral range

Summary and Further Reading

It is important to understand that this level of in-depth analysis can and often does result in seemingly contradictory directions, and a compromise is necessary. For example, detailed sample – light interaction analysis might point to the use of the dark field lighting technique, but the inspection environment analysis indicates that the light must be remote from the part. In this instance, then a more intense linear bar light(s), oriented in dark field configuration may create the desired contrast, but perhaps require more image post processing, or other system changes to accommodate.

Finally, no matter the level of analysis, and understanding, there is quite often no substitute for actually testing the 2 or 3 light types and techniques first on the bench, then in actual floor implementation whenever possible. And it is advantageous when designing the vision inspection and parts handling / presentation from scratch, to get the lighting solution in place first, then build the remainder of the inspection around the lighting requirements.

The ultimate objective of this form of detailed analysis and application of what might be termed a “tool box” of lighting types, techniques, tips, and often acquired “tricks” is simply to arrive at an optimal lighting solution – one that takes into account and balances issues of ergonomics, cost, efficiency, and consistent application. This frees the integrator and developer to better direct their time, effort, and resources – items better used in other critical aspects of vision system design, testing, and implementation.

Further Reading

“Machine Vision and Lighting”, Nello Zuech, President, Vision Systems International, Consultancy;
http://www.machinevisiononline.org/public/articles/archivedetails.cfm?id=1430

“The Fundamentals: Getting Started with Machine Vision”, Valerie Bolhouse, Automation Systems Specialist, Ford Motor Company;
http://www.machinevisiononline.org/public/articles/articlesdetails.cfm?id=131

Download the MVA Lighting and Optics Poster - Machine Vision Association of SME,
http://www.sme.org/downloads/mva/mvaposter

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