Optimizing Illumination in Line Scan Vision Systems

Whitepaper

ProPhotonix
An Exaktera Company

Optimizing Illumination in Line Scan Vision Systems

High quality illumination is the key to a successful vision system. Optimizing your illumination is critical to maximize inspection quality, speed and reliability. This is particularly challenging in high speed, high resolution line scan applications. This paper examines lighting technologies and techniques for line scan illumination. It also illustrates, through application examples, how to achieve the optimum performance from a line scan vision system.

What is a line scan application?

A line scan application is defined as a machine vision application that utilizes a one-dimensional (1D) line scan camera. Fundamentally, a line scan camera differs from an area scan camera in that it has a linear array of sensors as opposed to a two-dimensional (2D) matrix. A 2D image is obtained by the system's 1D camera which is built up line by line as the target is in motion. In some applications, e.g. rail inspection, it is the motion of the camera that creates the 2D image but this type of system is much less prevalent in the manufacturing industry. The most common type of line scan application is in web manufacturing of materials like paper, foil, film and high resolution of larger discrete parts. These webs operate at very high speeds and often operate 24/7. Reliable, low maintenance illumination plays a vital part in maintaining the quality of output and avoiding downtime. For a given cost, line scan cameras have the potential to provide much higher resolution images than area scan counterparts. For this reason, line scan is often the vision system of choice when high resolution defects need to be identified in products that are moving. This high resolution is achieved by the density of pixels across the 1D sensor (cross-web resolution) and the line rate at which the camera runs (down-web resolution). As line rates tend to be high frequency this results in short exposure times which means line scan systems require more light than typical area scan systems. An example of this type of application is in the solar industry, when silicon wafers are inspected for micro cracks and occlusions. Line scan technology can also be used in the imaging of cylindrical objects. Here, the target is rotating as the camera acquires the image lines. The resulting 2D image is inspected by the vision system. This type of system is commonly used in the food & beverage and pharmaceutical industries for critical applications such as final label inspection. Line scan vision systems are also used in restricted spaces. In certain applications, particularly where vision systems are being retro-fitted onto existing web production lines, space constraints make the form factor of the illuminators critical.

Overview of Lighting Technologies

There has been a dramatic shift in the technologies used for line scan lighting in the past ten years. According to the Automated Imaging Association (AIA), in 2008, LEDs represented over 65% of lighting technologies used in vision systems with 30% using lasers and less than 5% of systems using other lighting technologies such as fluorescent and fiber-delivered halogen.

Fluorescent Technology

Fluorescent technology is a low cost technology; however, the drawbacks generally outweigh the economic advantages. Fluorescents are not appropriate for high speed applications due to relatively low output intensity. Fluorescent lights color temperature changes over their lifetime resulting in inconsistent illumination. This results in the machine vision system requiring regular calibration and maintenance/ replacement.

Fiber-Delivered Halogen (FDH) Fiber-delivered halogen once was the machine vision system light of choice. The main disadvantages of FDH systems are that they are cumbersome and very hot. The FDH systems require large light sources to be kept separately from the fiber glass head. FDH systems have shortened lifetimes (< 3,000 hours) if driven hard. In addition, FDH intensity variations can prove difficult for vision systems.

Light Emitting Diodes (LEDs)

LED illumination is now the technology of choice for the vast majority of line scan applications. Properly designed LED line lights provide high intensity, long lifetimes, and consistent stable light output. Throughout a LEDs lifetime, the intensity remains constant and spectral output is very stable. This means that the vision system performs more consistently over its operating life. When considering an LED Line light for your vision system, be aware that there can be significant differences in the output, expected lifetime and performance. The illuminator performance depends on how well the illuminators are designed and manufactured. ProPhotonix products are designed using Chip-on-Board technology; the mounting of a bare LED chip in direct contact with the substrate to produce LED arrays. This means that the LED chip is placed in direct contact with a thermally efficient substrate providing the maximum heat dissipation and therefore maximizing the lifetime of the product. In addition, due to the small size of the bare LED chip, Chip-on-Board technology allows for a much higher packing density than surface mount technology. This results in higher intensity & greater uniformity. ProPhotonix employs Chip-on-Board technology in its entire range of COBRA Slim solutions.

Lighting Techniques for Line scan Applications

There are several techniques used in line scan lighting, the more common of which are discussed below:

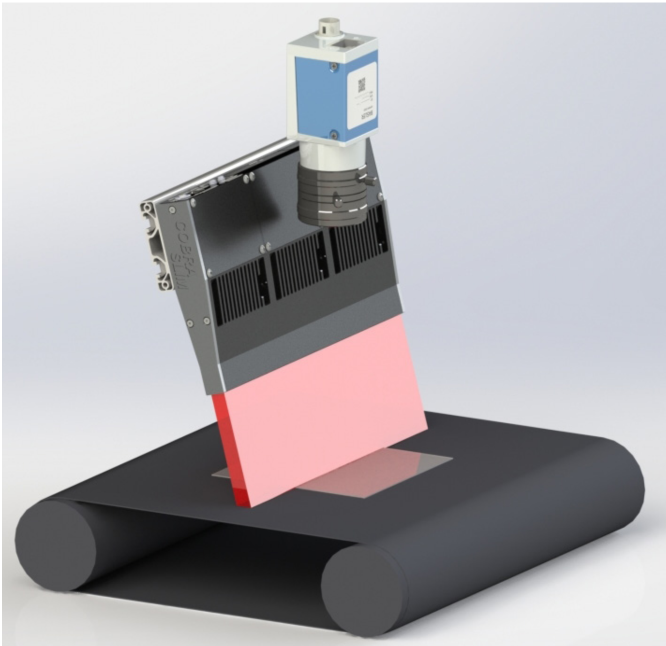

Figure 1: Front lighting system in inspection application

1. Front lighting

The term "front lighting" describes an application where the camera and the light source are on the same side of the target. The most important illumination requirement is optical intensity. The intensity of the illumination can determine the speed of the vision system and must be adequate so that optimal resolution is achieved at a given line speed. A light with sub-optimum intensity will cause the system operating speed to slow in order to achieve the required resolution, resulting in a decrease in capacity utilization.

a. Bright-Field illumination

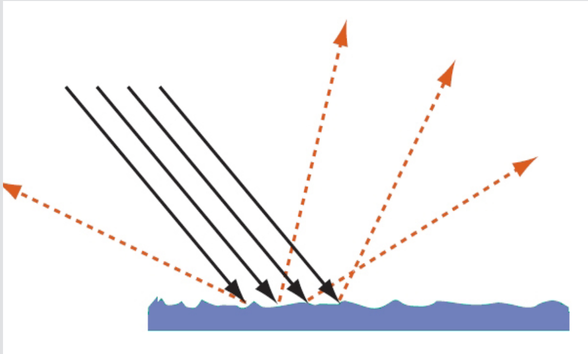

Figure 2(a): Diffuse Reflection

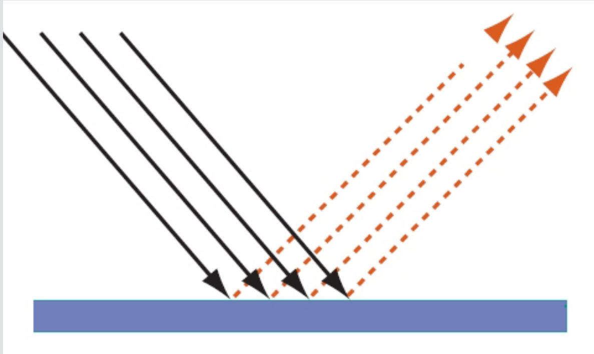

Figure 2: (b) Specular Reflection

Within front lighting applications, bright-field illumination describes applications where the light from the target is uniformly reflected into the camera. Faults will typically present as darker parts of the image. Bright-field illumination is most often used where the target reflects the light in a diffuse way i.e. the target is a non-shiny surface. A typical example of a bright field application is fabric inspection. These systems are used to examine the fabric between threads of slightly varying colors, the thread make up or to inspect the stitching. In these applications it is critical to maximize the contrast on the image. Color and uniformity play a significant role in providing good quality images.

b. Dark-Field illumination

Dark-field illumination describes applications where the majority of light is reflected away from the camera. This is more commonly used for highly reflective materials such as glass or films. Dark-field systems are often used to inspect the surface quality of a target for very fine defects or features. These systems are very demanding of illumination with respect to alignment precision and angular uniformity. This is especially true as the defect size and camera pixel sizes become smaller. In dark field lighting the form factor of the light is particularly important as a slim profile allows the light to be positioned at a low angle relative to the web. An application for this type of illumination is in glass inspection when looking for surface defects. In this example the light will scatter when there is a scratch on the surface.

c. Co-Axial illumination

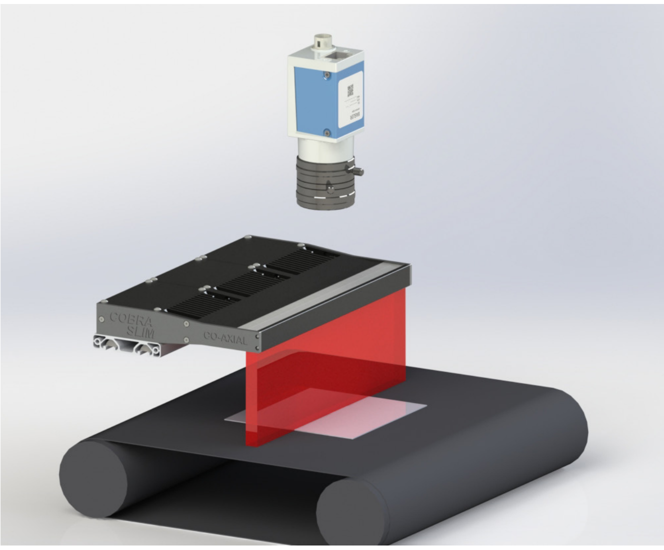

Figure 3: Co-axial Illumination

Co-axial illumination is not commonly used in line scan applications since a beam splitter is required to illuminate the entire width of the web. It is used, however, in some applications e.g. In PCB inspection. A populated PCB has a surface of varying heights. If the illumination is off axis with the camera high components will cast shadows on lower components. Co-axial illumination allows all the surfaces being viewed by the camera to be illuminated with uniform light and avoids excessive bright spots and shadows in the image. A narrow form factor is advantageous here because the illuminator can be placed very close to the camera.

2. Backlighting

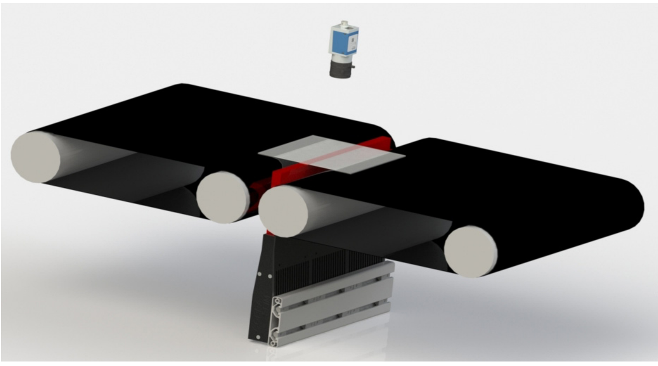

Figure 4: Backlighting System

In backlighting systems, the camera and illuminator are on opposite sides of the target. The camera views the light directly through the target material. Here, applications range from detecting small perforations in a substrate to qualitative measurements of opacity.

The demands on the lighting for a backlight application vary depending on the characteristics of the observed material. The two key illumination properties are intensity and uniformity.

For very transparent materials, intensity is not as critical since much of the light will pass through the material into the camera. However, since the camera is effectively viewing the structure of the light, the uniformity is very important. For a very dense material, such as cotton based composites, the relative importance of the properties invert. In this case, the camera does not view any light directly so intensity is most important, since very little light reached the camera, and uniformity of the light source is not as critical.

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The majority of applications are somewhere between the two extremes so the ability to control and optimize the illuminator to find the correct balance is critical. For this reason, ProPhotonix designed the COBRA Slim Series with field adjustable optics in the lens position and diffuser option types. This allows us to offer our customers maximum configurability, not typically found in standard products, without the costs associated with a custom designed module. Should our customers' machine vision set-up requirements change over time, the COBRA Slim is easily reconfigured in the field. It is also worth noting that the optical lens is supported within the mechanical design along the entire lens length. This is extremely important for longer lights, where if the lens is not positively located and supported, the lens

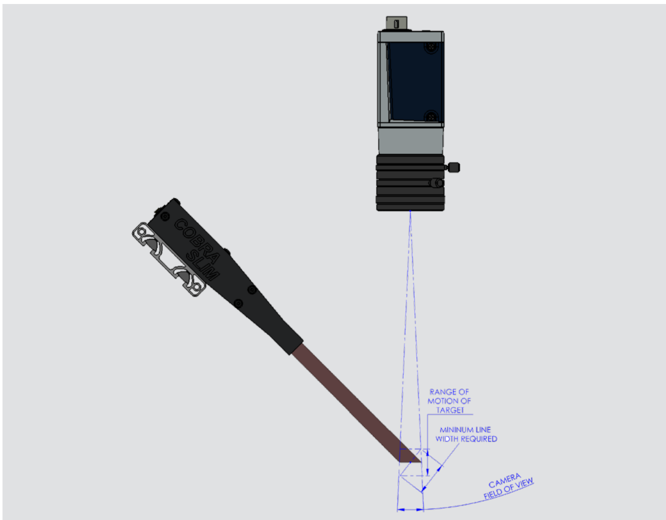

Figure 5: Geometrical Structure

can bow over time. This is particularly important in applications with high ambient temperatures. The width of a web can vary significantly depending on what is being produced. ProPhotonix produces line lights up to 5meters in length and all of its line light products are modular; typically available in increments of 100mm.

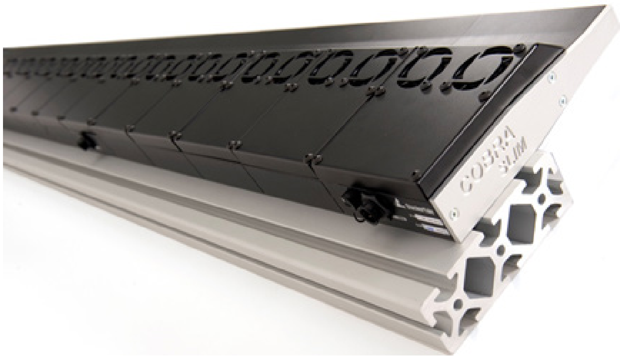

Figure 6: COBRA Slim LED Line Light

4. Wavelength

Line scan imaging applications traditionally use a monochromatic camera. When using a monochromatic camera the user is trying to achieve maximum contrast with the feature of interest. If the color of the material under inspection is constant and has a broad spectral response then the challenge is to balance the trade-offs between output power and camera sensitivity while optimizing contrast in the image and LED efficiency in the light. A monochromatic light source is advantageous since chromatic aberrations are reduced. In cases where the color of the material under inspection varies, a monochromatic source will produce varying levels of intensity or contrast depending on the target material's reflectance characteristics (in the worst case some features may be invisible). The use of a broadband white source helps alleviate this problem. Where a color line scan camera is used, a white line light may be used. The challenge here is to have a good quality spectrum providing good color representation in the image. Spectral consistency and stability are also important to ensure consistency in the inspection process.

Some materials do not reflect or transmit visible light. In these cases, wavelengths outside of the visible spectrum are used in combination with an infrared sensitive camera (usually InGaAs) e.g. inspecting for internal defects in a silicon wafer. Other applications rely on a fluorescence based measurement. There are two considerations here. First, to stimulate the material under inspection an optimum wavelength must be selected close to the absorption peak of the fluorescent activator. Secondly, the wavelength needs to be sufficiently narrow so as not to overlap with the fluorescent excitation spectrum. In these applications, UV light is often used as the excitation source.

5. Special Electronic techniques

A line scan image is made up of multiple lines that are acquired by a camera within a certain timeframe. In principle the illumination can be varied for each and every line acquisition. This technique requires fast and precise control of the light synchronized with the camera. The effective intensity of the light can be controlled by varying the illumination timing or a number of different lights can be used to capture different line images from different angles. ProPhotonix' COBRA Slim Series has a strobe function to synchronize the light flash to the camera frame. This provides control of the intensity of the image, frame by frame, without adjusting camera exposure or gain.

Key considerations when selecting a LED Line Light

Optimizing illumination in your line scan vision system can significantly improve the speed, accuracy, and reliability of your system. While LEDs are now the technology of choice for line scan illumination, there are considerable differences in the performance of LED products due to the quality of their design and manufacturing.

The key considerations in line scan imaging are dependent on the chosen lighting technique. Form factor, intensity, uniformity, wavelength and electronic capabilities can all be key considerations.

The COBRA Slim series from ProPhotonix is the result of more than 10 years of experience in line scan illumination across a wide range of applications. Its slim, modular form factor combines with chip-on-board technology to deliver market leading intensity and excellent uniformity, available in any wavelength.

Need more information on Machine Vision Lighting?

Download our Machine Vision Lighting Brochure here.