Introduction to Lighting Selection:

Background and purpose of this document

JAI cameras are used in variety of applications. In each application, the image capturing method and the image processing method are generally a bit different. In order to capture the most useful image for a particular type of inspection or application, selecting the appropriate light source is one of several key factors.

This document provides an introduction to the process of selecting a light source which is suitable for your application and for the type of camera you are using. Ultimately, you will want to work with a lighting vendor or system integrator to make a final selection from many available choices, but this document will get you started in the right direction.

1. Wavelength

One of the first things that needs to be considered is the proper wavelength of light needed to capture images for your application. Figure 1 shows the wavelengths that you will need to consider during this initial step.

Figure 1 - Light wavelengths chart

1.1. Human visible light

If the types of defects you are trying to detect or the information you need to capture can be seen and recognized by human eyes, then in most cases the light source(s) you can use can operate with visible wavelengths from 400 nm to 700 nm. Most JAI cameras are designed to provide excellent images in the visible portion of the spectrum. This includes cameras in the Go-X Series, Go Series, Spark Series, Apex Series, and Sweep Series.

For applications involving monochrome cameras/images, standard white LEDs can normally be used without concern for specific color parameters. If the work involves some color parts/patterns, it is possible to achieve higher contrast and more effective inspections by using a complementary color LED against the color of the parts/patterns under inspection. The complementary LEDs cause a sharp difference between the amount of light that is reflected by the part/pattern and the amount which is reflected by the background, causing the part/pattern to darken and "stand out" for easier analysis.

A hue circle is shown in Figure 2. Colors located at the opposite side of the circle from each other are complementary colors.

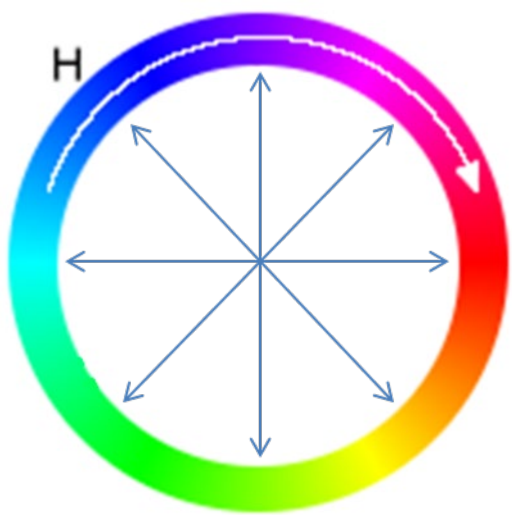

Figure 2 - Hue circle and complementary colors

1.2. Near Infrared (NIR)

By capturing images under NIR light (700 nm – 900 nm), some colors disappear and some materials become transparent due to the penetration capability of the longer NIR wavelengths. This depends on the nature of the materials and types of inks or dyes used including natural substances like skins and crops, and man-made items like packages.

These aspects of NIR lighting can be used to more effectively perform a variety of inspections, such as analyzing the freshness/rot of fruits and vegetables, locating foreign objects (stones, twigs, debris) during food inspection, checking for improperly filled or sealed packages, and many other applications.

Many light source manufacturers can provide dedicated NIR light sources to support such applications. On the other hand, even a broad-spectrum halogen light source can provide effective NIR lighting, either in combination with its visible light properties, or by using a visible-light-cut-filter to provide NIR-only lighting.

When using any of these illumination methods, Go Series, Spark Series, and Sweep Series monochrome cameras provide enough sensitivity to capture NIR images for applications that need them. In addition, Apex Series 3-sensor prism color cameras, which normally block NIR lighting to avoid contaminating the accuracy of the RGB color values, are also available in special “NF” (no filter) configurations with the IR-cut filter removed. These configurations intentionally extend the response of the red channel to also include NIR information, which can be utilized for color applications where enhanced red/NIR response is desired.

One final option for NIR imaging is JAI’s Fusion Series of cameras. Fusion Series cameras are designed to combine multiple spectral bands into a single image. Several models are available with specific NIR channels without the need for any visible-light-cut-filter. Users can capture images just from the NIR channel, or can combine this information with other channels, such as a visible channel.

1.3. Short wave near infrared (SWIR)

By capturing images under SWIR light (1000 nm – 3000 nm), some materials absorb SWIR light and are captured as black, and some other materials become transparent due to the deep penetration of the SWIR waves. This depends on the combination of materials and the wavelength of the light.

By using this feature, different substances can be recognized based on how they react to specific narrow band wavelengths of SWIR light. For example, water can be easily recognized at a specific wavelength.

JAI’s WA-1000D-CL (Wave Series) camera has two prism-mounted sensors and each sensor can capture a different wavelength. As a result, the camera can capture two images at the same time representing the response to two different wavelengths. By processing these two images, more complicated inspections and analyses of materials can be achieved.

2. Color temperature and white balance

White balance adjustment is generally used to adjust captured images to make the colors in the scene seem “correct” to the human eye. The human brain has the ability to change our perception so that a red ball, for example, looks the same to us in many different lighting conditions.

On the other hand, the color data captured by a camera can be very different depending on the light source used. In general, white color light sources can have a variety of “color temperatures” as shown in Figure 3. The color temperature scale is meant to replicate the way the color of metal changes as it is heated. At lower temperatures, heated metal glows with a more yellowish tint, while at higher temperatures the glow has a slight blue tint. White balancing is designed to adjust the color data so any tint from the lighting is not included. Thus, if the light source is changed, re-adjustment of the white balance is recommended.

Light	Colro Temperature	LED	Halogen	Fluorescent
Daylight, overcast	6500K	✔	--	✔
Horizon daylight	5000K	✔	--	✔
Cool White	4500K	✔	--	✔
Studio Lamp	3200K	✔	--	✔
Soft White	2700K	✔	✔	✔

Figure 3 - Light sources and color temperatures

3. Polarized light

In normal light (non-polarized light), the light waves have no specific orientation. Instead, the waves oscillate in all directions. On the other hand, polarized light has a specific orientation for the light waves (vertical, horizontal, diagonal, etc.). For example, when non-polarized light reflects off a smooth (specular) surface, a significant portion of the reflected light tends to oscillate in a plane that is parallel to the surface (i.e., light waves reflecting off the surface of a lake tend to be polarized in a horizontal direction).

For vision applications, the properties of polarized light can be used to improve the recognition of objects.

For example, the following figure shows four images captured by a JAI polarization camera. Glare from the reflective label consists mostly of polarized light. The four images show the results of four different polarizing filters set at 90, 45, 0, and 135 degrees (clockwise from upper left). In this case, the 90 degree (upper left) filter is most effective at blocking out the horizontally-polarized reflective glare to make the label fully readable.

In other applications, polarized light can be used to differentiate between two items based on their different reflective/polarizing properties.

Figure 4 - Polarized light and glare

4. LED, halogen, and fluorescent

For machine vision applications you will have multiple choices for lighting type. The most common are LED, halogen, and fluorescent.

Halogen is a broad-spectrum light source that typically covers a wide range of wavelengths with high brightness. As noted earlier, a wavelength cut filter can be used with halogen lighting if you need to reduce the spectrum to a narrower waveband. Because of its brightness and wide spectrum, halogen is useful for many types of applications. However, its weak points are shorter life and slow response.

LED lighting is available in a variety of wavelengths. White LEDs cover the human visible range and can be tuned to a variety of color temperatures. LEDs are also available in specific colors, including both broad and narrow wavelengths, and are also available in non-visible configurations, such as NIR, SWIR, or UV. LED's strengths include long life, fast response, and wide range of size options.

Fluorescent lighting has longer life and lower cost than halogen. On the other hand, its size depends on its power and small size fabrication is difficult. Spectral response is on the same level with halogen's, though the bandwidth is typically narrower and the color balance is typically quite different.

The following table provides an overview of the key characteristics of each lighting type.

Items	LED	Halogen	Fluorescent
Bandwidth of Wave Length	Narrow Bandwith is selectable	Wide Bandwith	Narrower Bandwith
Figure/Size	Each Light-emitting element is small. Figure variation of Light source equipment can be availabe by placing the elements into the equipment.	Variation of figure is limited, but it can be small.	Size is up to power.
Life	◎	△	○
Brightness	○	◎	○
Response	◎	×	×
Cost	○	△	◎

◎ = Excellent ○ = Good △ = Fair × = Poor

Figure 5 - Comparison of lighting types

End.

Revision History

Revision	Date	Changes
1	2019/03/11	New release
2	2019/04/05	Edited to add the word “rot” on Pg. 2 to clarify freshness analysis
3	2023/03/01	Updated “Figure 1 - Light wavelengths chart” on the first page