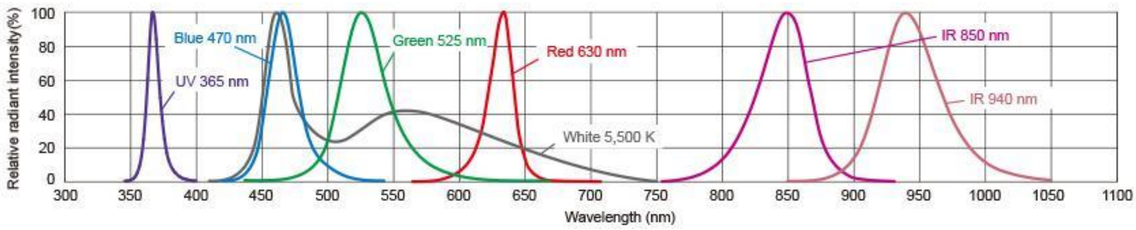
ILLUMINATION METHODS IN MACHINE VISION

Wavelength is a key factor when selecting a light as it determines the type of image produced. This guide provides an overview of wavelength considerations for machine vision illumination.

Standard Wavelengths for Machine Vision Lights

Although many lighting companies can customize lights to emit the exact wavelength you need, these are the standard wavelengths you tend to find in machine vision:



Imaging with White Light and Colored Light

The white LED lights used in machine vision have a color temperature between 4,500 K – 10,000 K. Generally, white light is used when paired with a color camera or when a workpiece has various colors. Though white light contains the 3 primary colors (red, blue, and green), a multi-colored object appears gray with similar brightness when imaged with a monochrome camera.

The 3 standard colors used in machine vision are red, blue, and green. Colored light is used when there is specific target information that needs to be captured with the highest contrast possible. Similar colors will *lighten* the object, while opposite colors will *darken* the object. Consider the card on the left and how different light colors affect its image:

White Light (LDR2-70SW2)

Red Light (LDR2-70RD2)

Blue Light (LDR2-70BL2)

Green Light (LDR2-70GR2)

Imaging Metal Workpieces with Different Wavelengths

When imaging metal workpieces, there are cases where wavelength does not affect the image, and cases where it does.

Example 1: Emitted color does not affect the image

Workpiece: Bearing

White Light (FPR-100SW2)

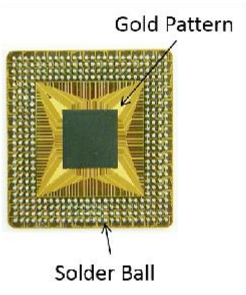
Red Light (FPR-100RD2)

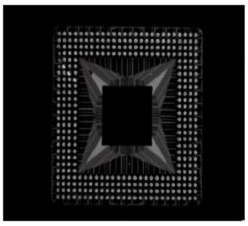
Blue Light (FPR-100BL2)

Green Light (FPR-100GR2)

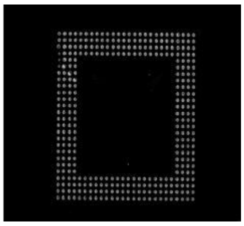
In Example 2, the spectral reflectance of gold causes the difference in the output image. The graph (below right) shows the spectral reflectance curve for several commonly used metals.

Example 2: Emitted color does affect the image

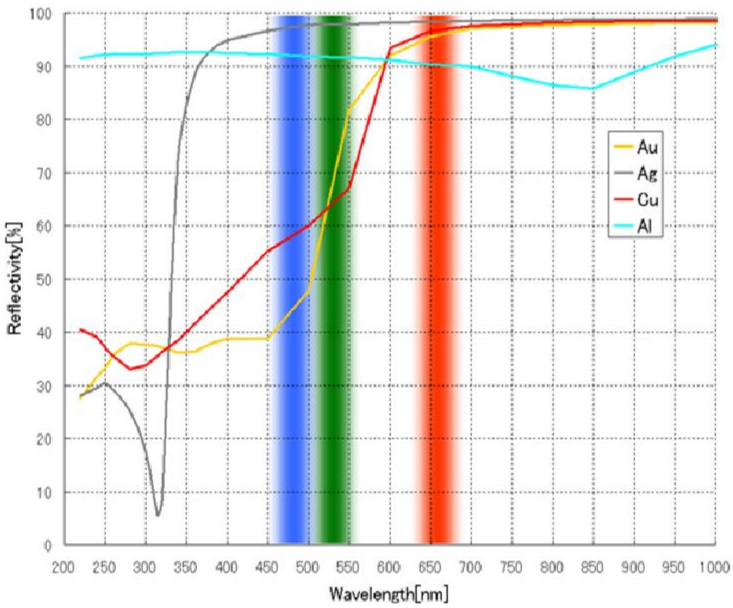




Red Light
(HPR2-100RD)



Blue Light
(HPR2-100BL)

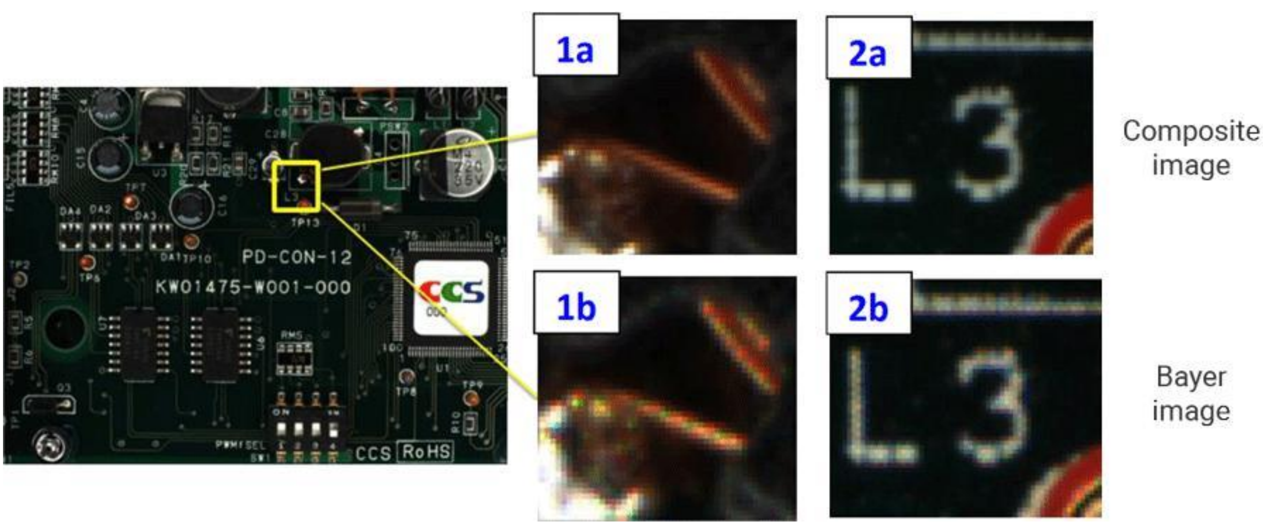


Full-Color RGB

Full-color RGB lights are built with red, blue and green LEDs, which allows users to choose which color the light emits. The light can be switched between each primary color, or by mixing the primaries, you can create multiple colors to meet the exact needs of your application.

This simplifies inspections where the workpiece has several colors, or if the colors of objects on an inspection line are not the same. Using an RGB light, machine vision systems only require 1 light instead of multiple lights each emitting a different color.

A new application of full-color lights is a technique called ultra-resolution color (URC) for computational imaging. Three monochrome full resolution images are captured sequentially, each strobed with a single color: red, green, or blue. A composite color image with the full resolution of the monochrome camera can be created from the data of the 3 input images without interpolation artifacts and other noise, as shown below.



Imaging the Invisible: Ultraviolet and Infrared

Non-visible wavelengths in the ultraviolet (UV) and infrared (IR) spectra have valuable applications in machine vision.

Ultraviolet in Machine Vision

UV is electromagnetic radiation with a wavelength from 10 – 400 nm. The most commonly used UV wavelengths in machine vision are 395 nm or 365 nm. There are two major uses for UV lighting in machine vision: fluorescence applications and reflectance applications.

Fluorescence

In UV-fluorescence imaging, the fluorescent property of certain materials used in a workpiece will absorb the UV light and re-radiate a longer diffuse wavelength. These materials include plastics, printing inks and dyes that have optical brighteners added to them. Example applications:

- Reading invisible print or code
- Magnetic particle inspection
- Imaging thread coated in fluorescent dye

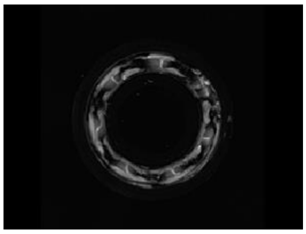
Reflectance

In UV-reflectance imaging, the application relies on the differences of spectral reflectivity and absorption in a workpiece to make transluscent information visible.

Example applications:

- Detecting air pockets on labels
- Inspecting clear protective film on a clear plates, screens
- Imaging glue and other clear adhesives

Workpiece: Greased Bearing



UV Light (LDR2-100UV2-365-W)

Workpiece: Contact Lenses

UV Light (LNSP-300UV365-FNNR)

Infrared in Machine Vision

IR is electromagnetic radiation with wavelengths ranging from 700 nm – 1 mm. The most commonly used wavelengths in machine vision are 850 nm and 940 nm.

Compared to visible red light, infrared light has a low scattering rate and higher transmission, which makes it useful for imaging that penetrates or cancels out printed patterns or liquids. Example applications:

- Presence/absence of foreign materials in dark, opaque liquids or food products
- Inspecting the surface of printed packaging

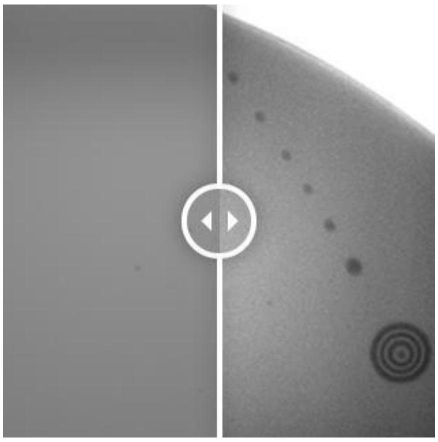
Workpiece: Disinfectant

Visible Light

IR Light (LFL-100IR2-940)

Emerging Technologies: SWIR, Multispectral and Hyperspectral Imaging

Within the machine vision industry, several advancements in illumination are expanding imaging possibilities for previously impossible inspections. A few rapidly growing technologies are Short-wave infrared (SWIR), and multispectral and hyperspectral imaging.



Wafer bonding inspection without SWIR (left) and with SWIR lighting (right).

Short-Wave Infrared

SWIR light refers to a specific spectral band in the infrared range from 1,000 – 2,500 nm.

Its behavior is similar to visible light, and when used with a SWIR camera, the images produced achieve high resolution and strong contrast in a way that is impossible for the visible spectrum.

Imaging with SWIR's longer wavelengths has made it possible to reveal phenomena and elements invisible to standard CMOS/CCD cameras.

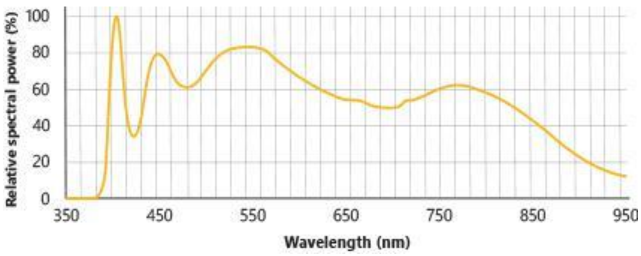
- See through opaque materials (plastics, silicon, glass, etc.)
- Differentiate chemical elements (water, lipids, collagen, etc.)
- Offer visibility in harsh conditions (through smoke, dust, etc.)

Multispectral and Hyperspectral Imaging

Two emerging lighting technologies in machine vision are multispectral and hyperspectral imaging systems, which differentiate materials based on their unique chemical and elemental makeup for inspections.

Multispectral imaging (MSI) uses a small number of targeted, relatively narrow wavelength bands from select locations on the spectrum. Images are captured using each of these bands, which can be chosen from across ultraviolet to infrared.

Hyperspectral imaging (HSI) is a technique that combines spectroscopy and imaging to provide spectral signatures of objects along with spatial information. It uses narrow spectral bands (typically < 10 nm) over a wide continuous spectral range. The resulting image contains the spectral information at each pixel location. Depending on the spectral range and size of sensor, there can be many gigabytes of data in a hyperspectral image (hypercube).



Spectral distribution graph of proprietary CCS LED technology used in the Hyper Spectral Range. These LEDs have continuous and tunable wide-band spectrums and can be adapted to any form factor, for better performance and cost benefits compared to traditional MSI/HSI solutions like halogen.

These emerging technologies are opening up an enormous range of new applications for image processing in the visible-NIR region of the spectrum:

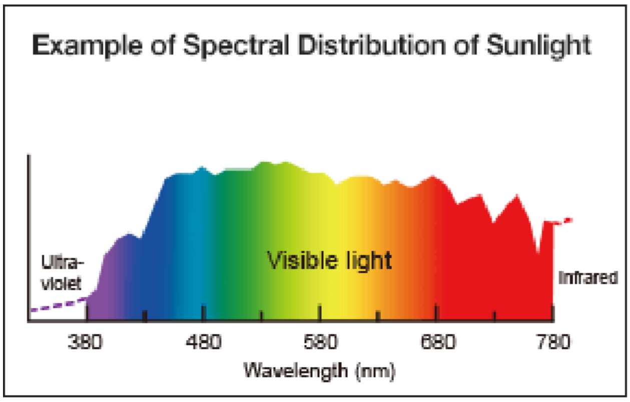
- Identifying chemical compositions in the food industry
- Detecting foreign contaminants or materials
- Optical sorting of waste, plastics
- Pharmaceutical inspection Metrology
- and calibration of sensors

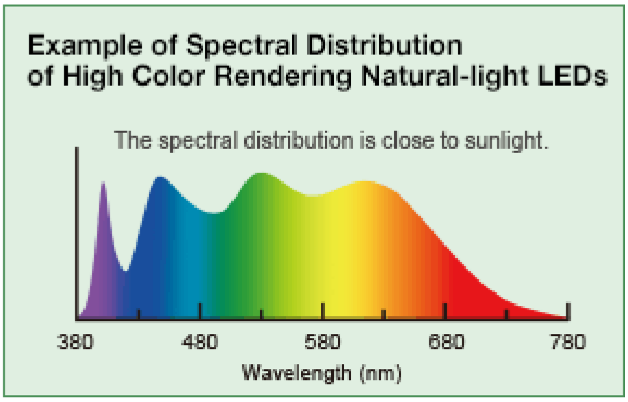
Natural-Light LEDs

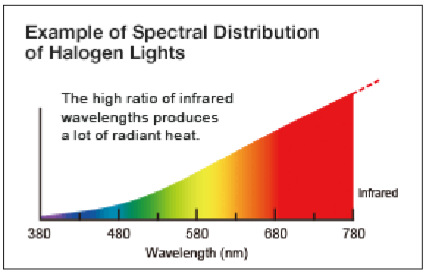
CCS developed a high color rendering (natural-light) LED to reproduce natural-light colors close to those of sunlight. These LEDs are the optimal solution for inspections that demand accurate color information.

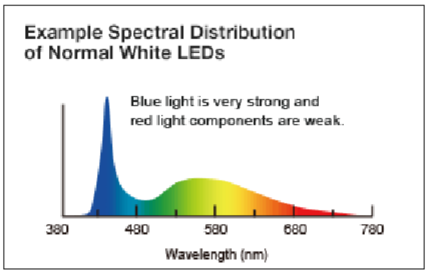
Color rendering is the affect of a light source on the appearance of the colors of an object. A light source with good light rendering properties can illuminate an object without changing the colors of the object. At Ra98, CCS's natural-light LEDs have achieved one of the world's highest general color rendering index (CRI), which indicates how close a light is to sunlight.

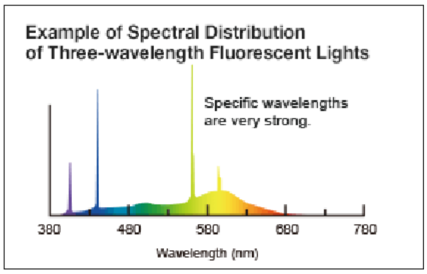
These natural-light LEDs produce a smooth continuous light spectral distribution across all wavelengths, just like the spectral distribution of sunlight. While normal white LEDs and fluorescent lights have some wavelength regions that are very strong or even missing, CCS's high color rendering LEDs cover almost the entire range of visible light, as shown by the graphs below.











Conclusion

When selecting a light, one of the first questions to consider is which wavelength will produce the best contrast for a particular application. While it may require trial and error, the wide range of wavelengths available within machine vision means users can get the optimal light source that produces the image they need.

Distributed by:
1stVision Inc.
2 Dundee Park
Andover, MA 01810
info@1stvision.com
www.1stvision.com
978-474-0044