Techniques for Suppressing Adverse Lighting to Improve Vision System Success

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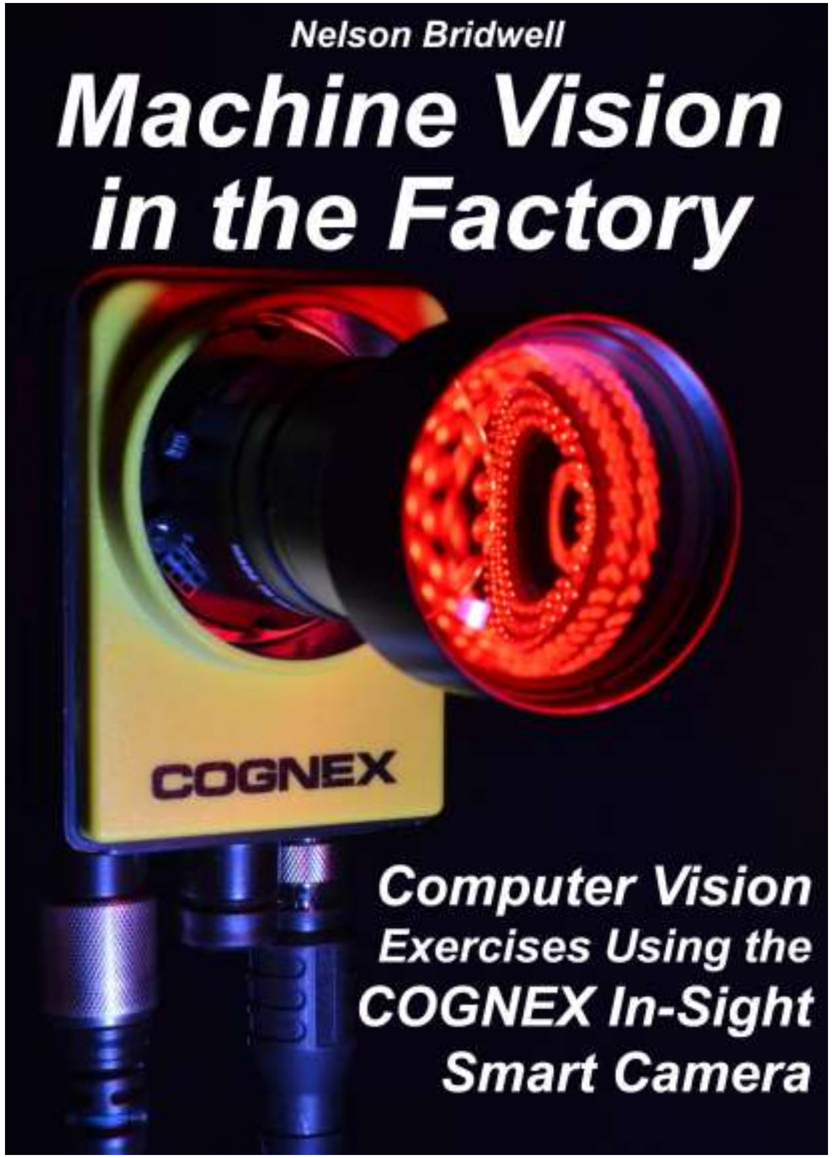
Nelson Bridwell

- President of Machine Vision Engineering LLC.
- AIA Certified Vision Professional (advanced).
- Very familiar with lighting, filters, optics, lenses, cameras, interfaces, and software.
- Have found effective solutions to challenging machine vision problems that were considered impossible by others.
- Published in Vision System Design Magazine and Quality Magazine.
- Conference presentation on vision system optimization at 2016 The Vision Show.
- Presented webinars for AIA, Vision System Design, and Photonics.
- Previously:
  - Senior Vision Engineer at ATS Systems Oregon
  - Senior software engineer at Intel Portland Technology Development.
- MS in Computer Science and BS in Engineering from Northwestern University.

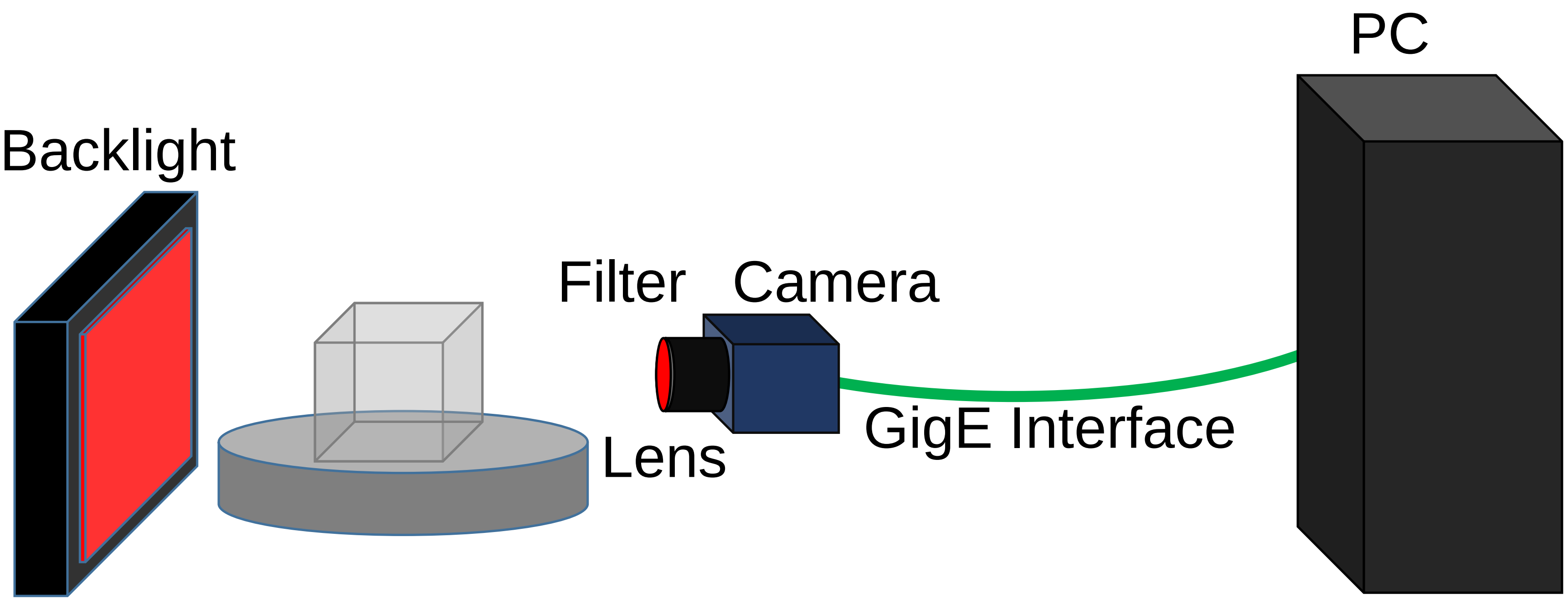
Machine Vision Engineering LLC

- Deliver machine vision solutions.
- Provide contract machine vison engineering services for automation companies and manufacturers.
  - Free evaluation studies, including second opinions
  - Design
  - Installation and configuration
  - Unit testing and integration testing
  - Accuracy, repeatability, gauge R&R studies
  - Documentation and on-site training
  - Optimization, troubleshooting, maintenance, and upgrades

Writing a Book



Vision System Components



Three Most Important Design Considerations

- Lighting
- Lighting
- Lighting

Standard Machine Vision Lighting Techniques

- Backlighting
- Diffuse
- Darkfield
- Brightfield




Adverse Lighting

- Most machine vision systems are not located in total darkness.
- In addition to the desired vision lighting, there may also be other sources of light.
- Sometimes these other light sources can present problems.
- Finding ways to eliminate unwanted lighting can be just as vital and challenging as identifying the right lighting technique.

Problems Resulting From Adverse Lighting

- Incorrect measurement of surface brightness or color.
- False defects.
- Parts that are not recognized.
- Incorrect dimensional measurements.

Problematic Materials

- Highly reflective surfaces such as polished metals and plastics.
- Curved transparent plastic or glass.

With these types of materials unwanted reflected or refracted light from a variety of directions may appear in images.

Problematic Environments

- Environments with bright light sources such as lasers.
- Environments with fluctuating lighting.

- May be important to understand the exact lighting conditions at the factory location where the vision system will be installed.
- A vision system that works flawlessly in pre-delivery testing may fail at the customer site because of ambient lighting issues.

An Actual Situation

- A glass tube inspection system was designed for installation in a cleanroom.
- The customer changed their plans and instead installed it on their loading dock.
- Whenever overhead doors were open it was exposed to daylight variations as well as the elements!

Solution: Lights Off

- If practical, turn off any lights that are causing problems.
- In some cases where the vision lighting for one camera is causing problems for another camera it might be possible to synchronize inspections so that machine vision lighting for only one camera is turned on at a time.

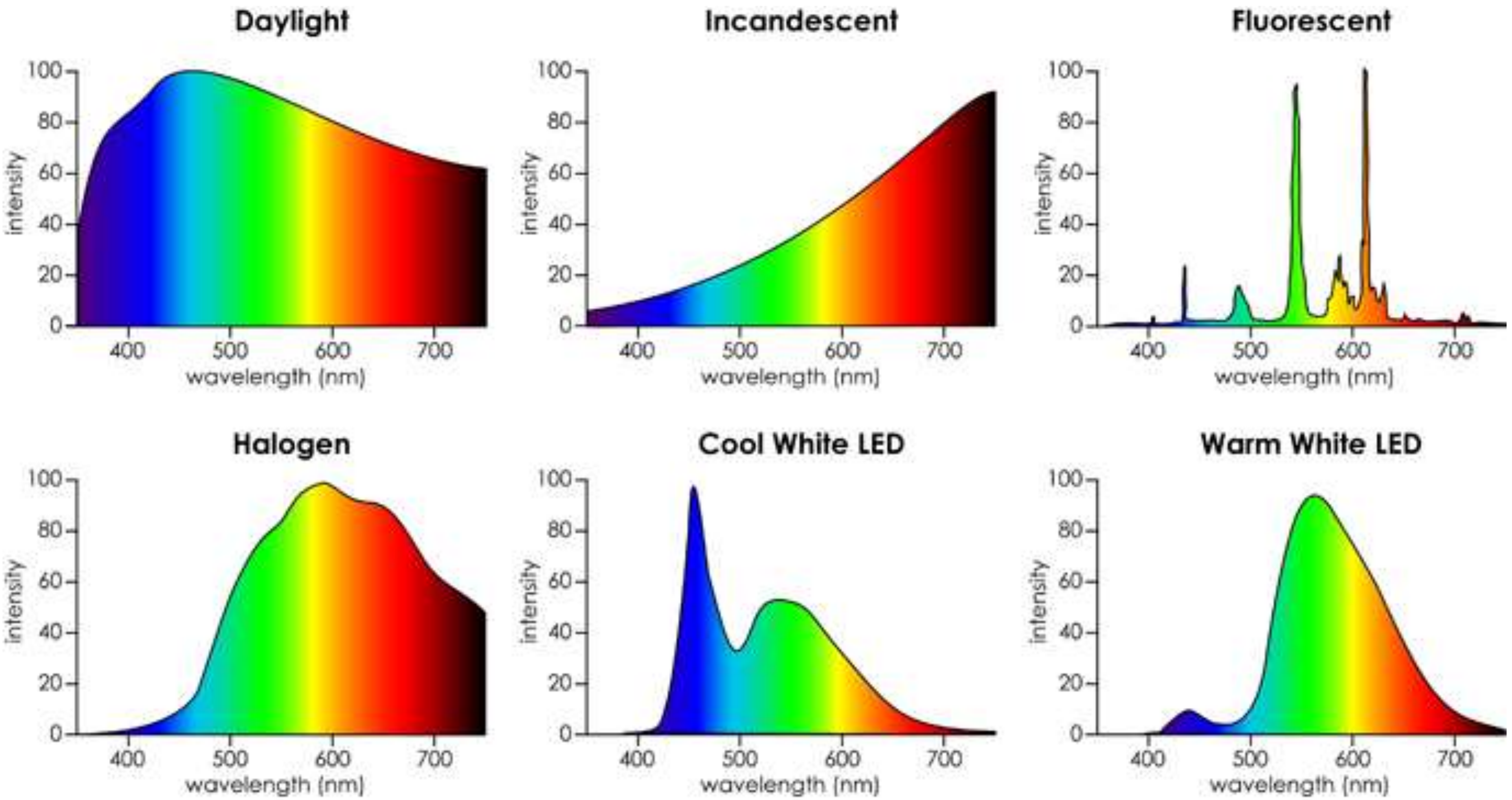
Solution: Shielding and Enclosures

It may be possible to eliminate adverse lighting by:

- Completely enclosing the vision system.
- Positioning dark panels between unwanted light sources and the vison system.
- Using matte black surfaces to minimize unwanted reflections.
- It may be possible to employ “light traps” to minimize reflections from lasers or other bright light sources.

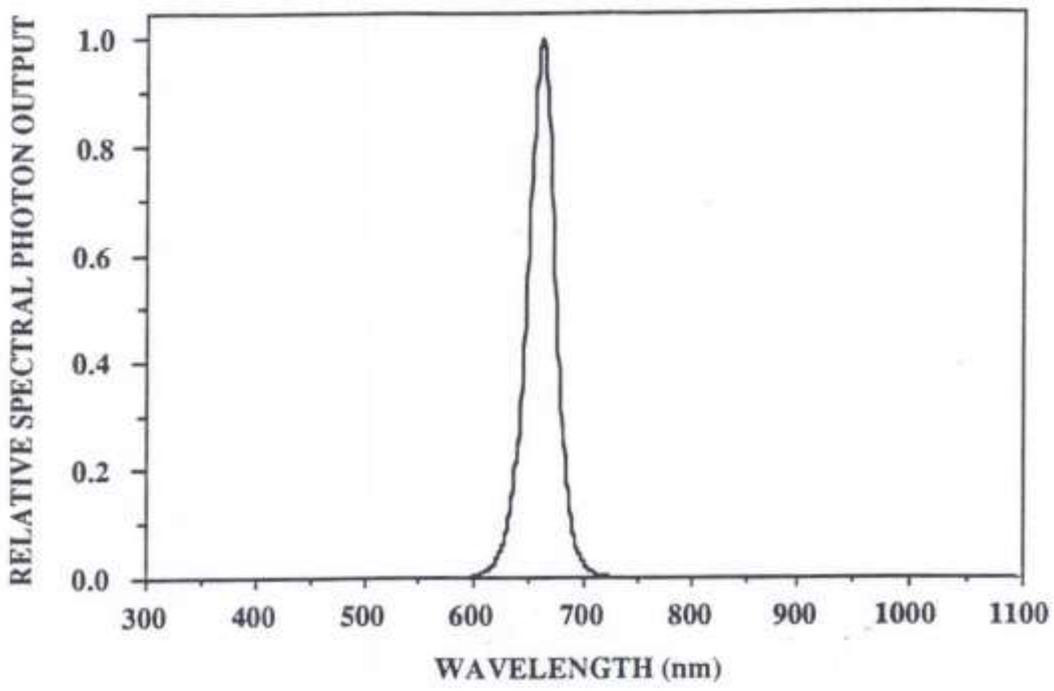
Spectral Distribution of Light Sources

Most ambient light is widely distributed across the spectrum.



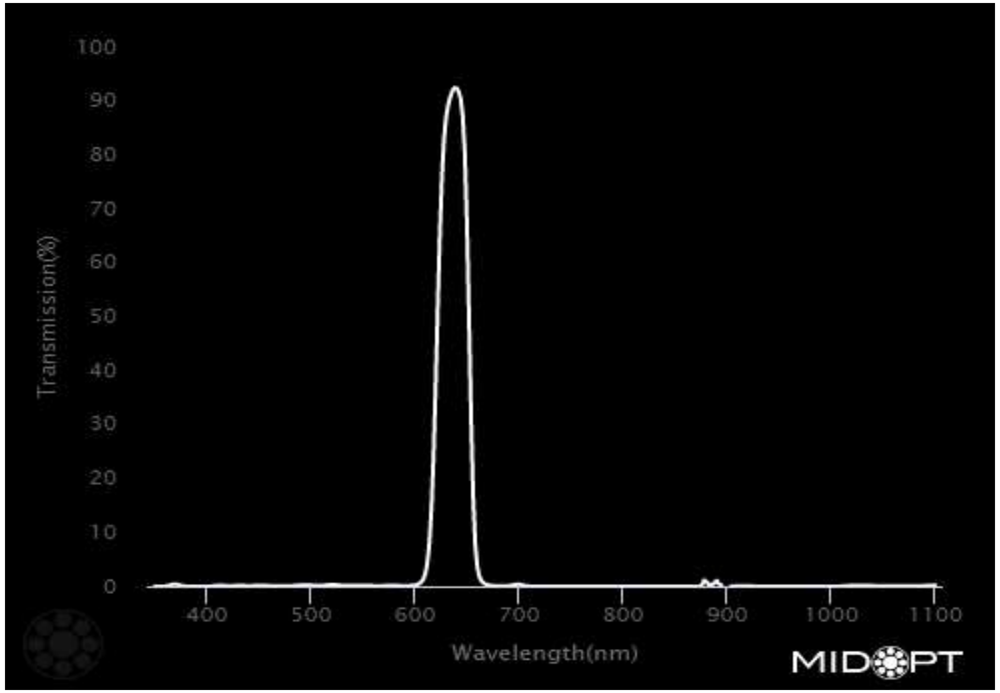
Machine Vision Light Spectrum

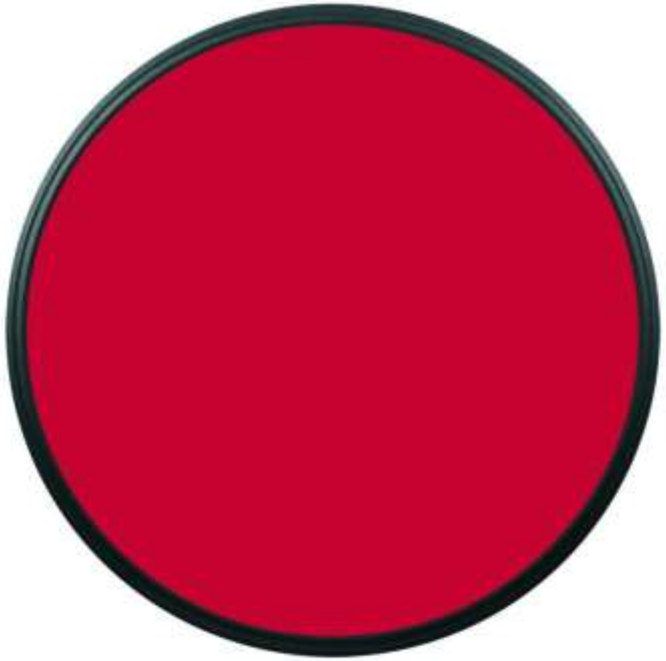
Most machine vision lights use LEDs or laser diodes with a very narrow wavelength distribution.



Machine Vision Bandpass Filters

Machine vision bandpass filters are color filters that only admit light from a very narrow band of wavelengths that closely match the emission spectrum of machine vision lights.





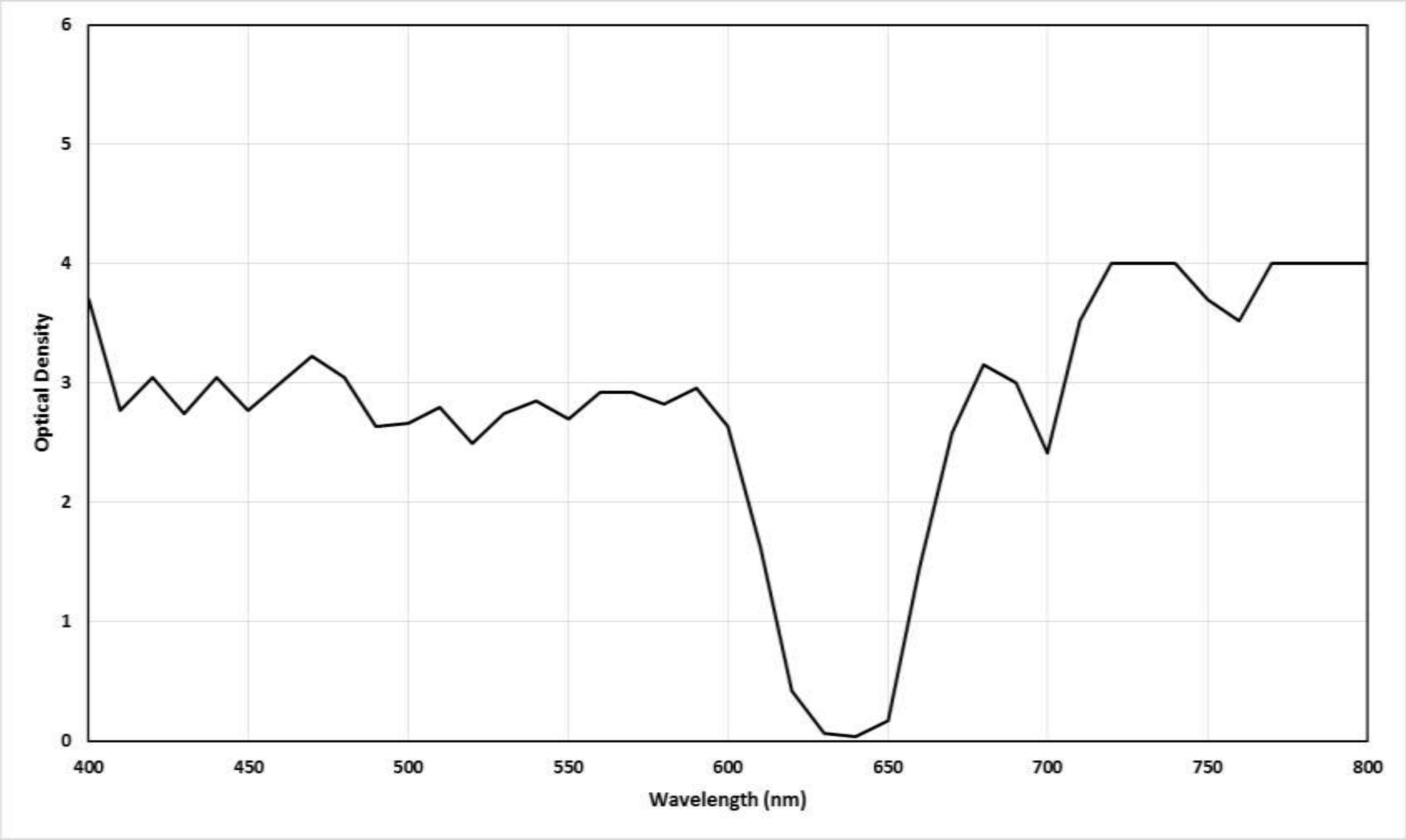
Solution: Bandpass Filters

- By using a narrow bandpass color filter matched to the spectrum of the machine vision light source, it’s possible to block out the 90% of ambient light that falls outside of that narrow range of wavelengths while admitting all of the desired vision lighting.
- If the unwanted illumination is coming from a narrow wavelength light source then 100% of this unwanted light can be eliminated by using a different wavelength bandpass filter.
- However, this technique doesn’t work for color images.

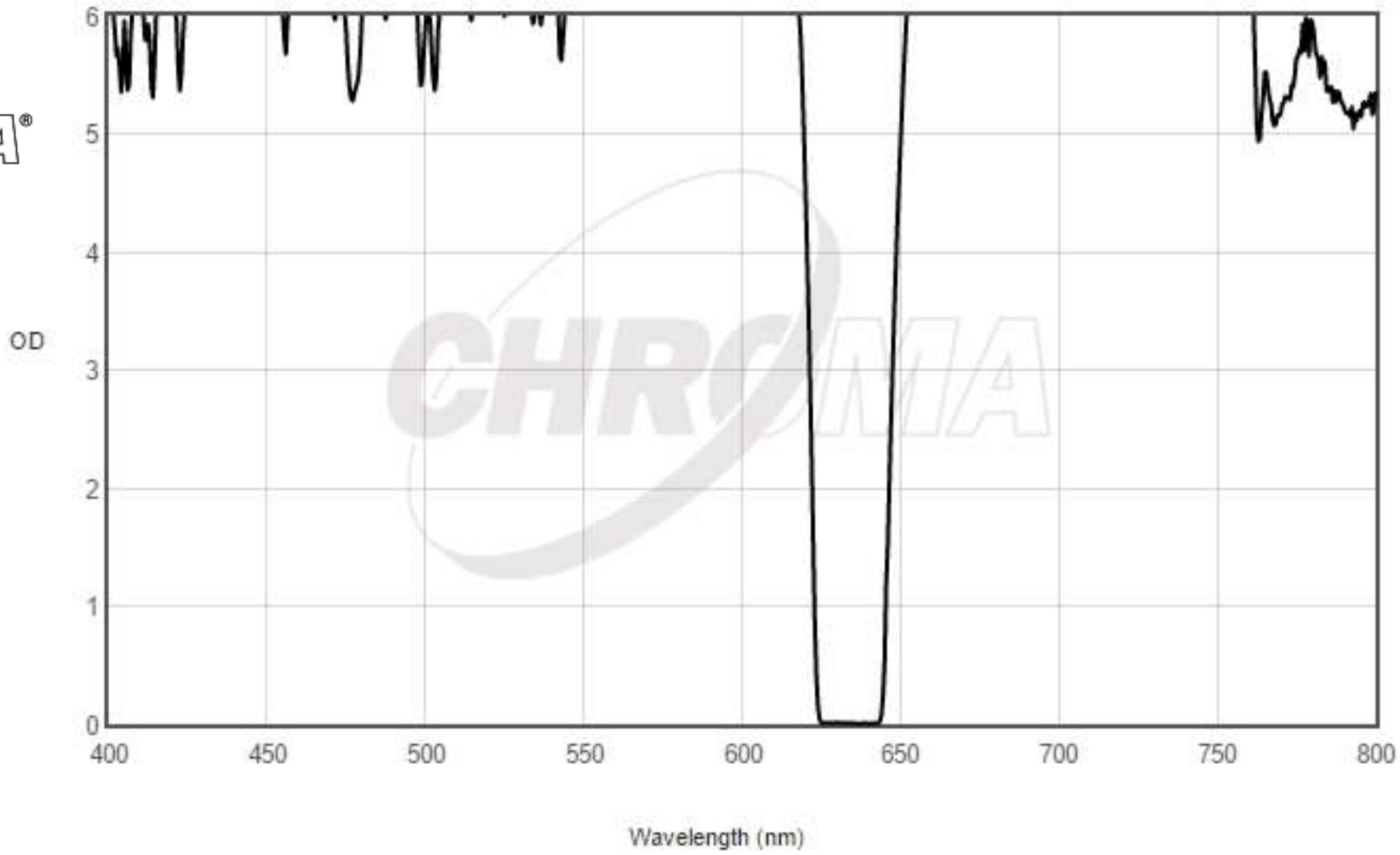
High Optical Density Bandpass Filters

- Sometimes it's necessary to filter out especially bright light sources:
  - Lasers
  - Linescan Bar Lights
- Because these lights are so bright, even a conventional machine vision bandpass filter that reduces the intensity of unwanted wavelengths by 1000X may not be enough.
- A high optical density (OD) bandpass filter may be needed.

Midwest Optics Bi632 Light Red Filter



Chroma Technology MV635/20 Narrow Red Filter



Solution: Brighter Machine Vision Lights

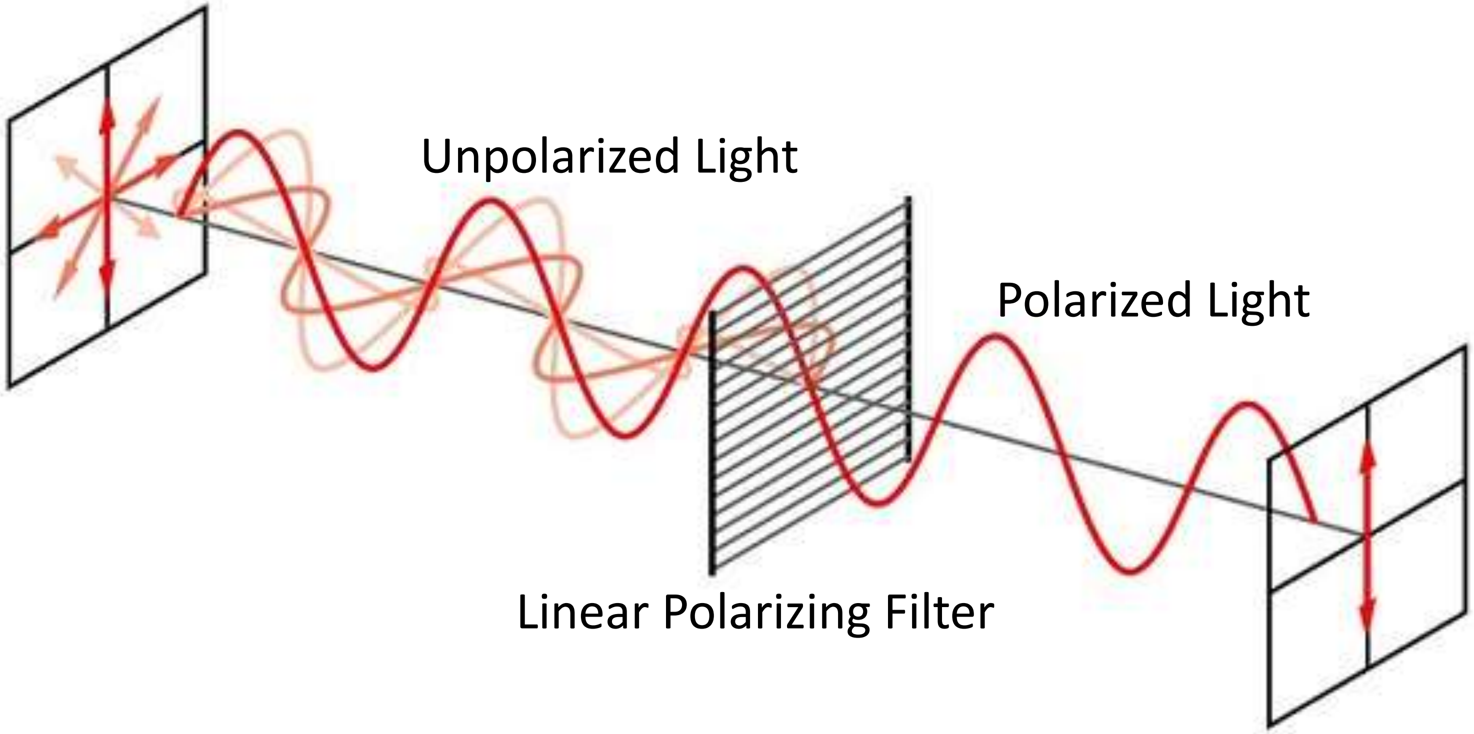
- Use vision lighting that is much brighter than ambient lighting.
- If possible, use backlighting, which should appear brighter than illuminated part surfaces.
- High intensity LED machine vision lights are available.
- When selecting machine vision lights, strobed LEDs can be 10X brighter than continuous LED lights.
- Sometimes bright lights, especially strobes, can create problems for other nearby vision stations. Strobed or excessively bright lights can also be visually annoying.

Polarized Light

Light consists of oscillating electromagnetic waves.

If these electromagnetic waves are always oriented in one directions then the light is **polarized**.

If there are electromagnetic waves that are oriented in all direction then the light is **unpolarized**.

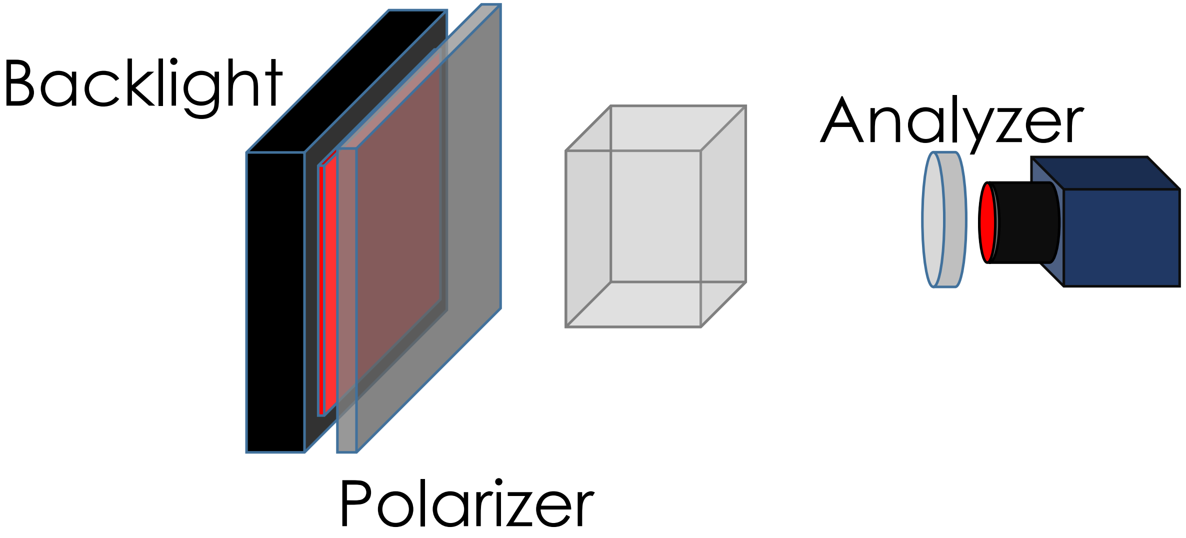


Solution: Polarizing Filter

- Light that reflects off of nonmetallic surfaces such as plastics and glass can become polarized.
- By the use of a linear polarizing filter this reflected light can be eliminated, permitting a better internal view of the contents of plastic packaging.

Solution: Birefringence

- Some clear plastic materials rotate the polarization of light.
- A pair of linear polarizing filters, one over the machine vision light and another over the camera lens (analyzer), can be used to create useful high contrast images of clear plastics.



Solution: Birefringence

- By adjusting the rotation angle of the analyzer, it may be possible to select light from either the backlight or from the plastic part.

Solution: Birefringence

- Birefringence can also be used to detect the presence of cracks and mechanical stress in clear plastic parts.

Solution: Image Subtraction

If the unwanted lighting is stable and the part that is being inspected is stationary then it may be possible to capture two images:

- A first image with just the ambient lighting.
- A second image with the ambient lighting plus the machine vision lighting.

By subtracting the first image from the second image it should be possible to obtain an image with only the desired machine vision lighting.

Consistent Lighting

A related problem can be how to maintain consistent lighting as much as possible.

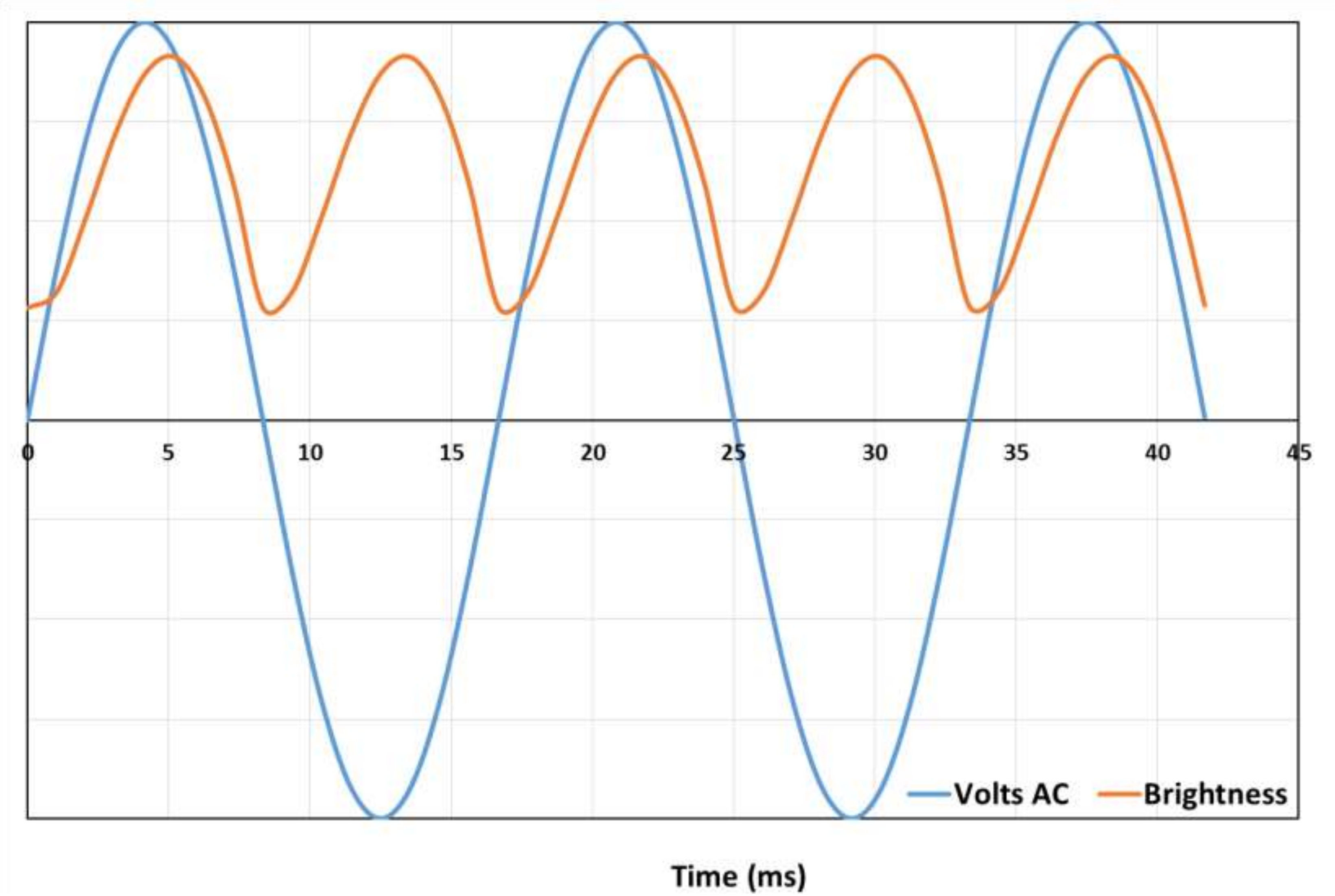
Solution: Stable Power

Avoid running machine vision lighting on the same DC or AC power circuit as heavy electrical machinery. Circuits that power heavy machinery can sometimes experience transients and other disturbances that can impact vision lighting.

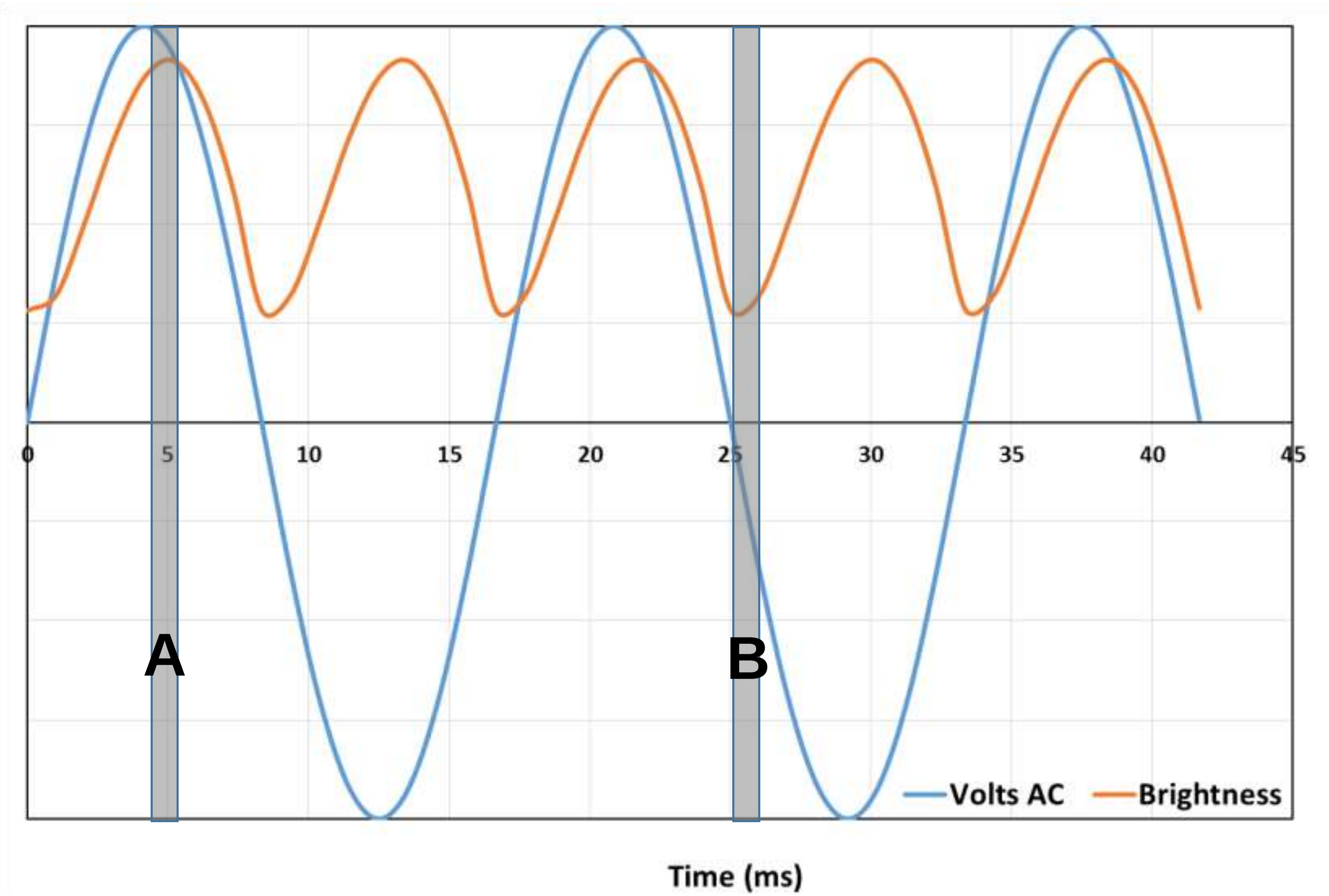
Solution: LED Controllers

If there are concerns about the slow fading of LED brightness over the course of years, it might be worthwhile to consider the use of sophisticated LED lighting controllers that can correct for these slow changes.

Incandescent Light 60 Hz AC Ripple



1 Millisecond Exposure Time



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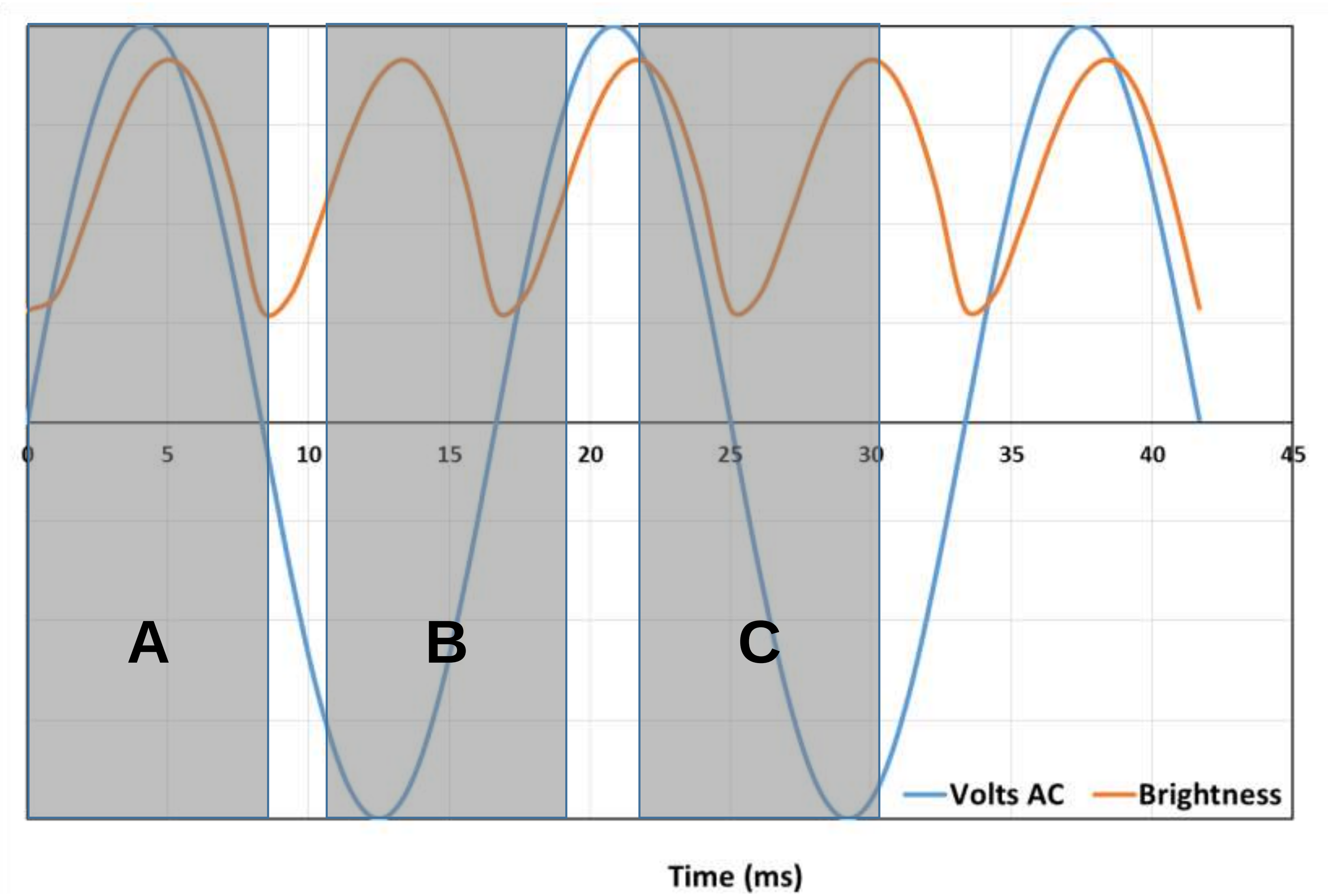
8.333 Millisecond Exposure Time



Solution: Exposure Time

- For 60 Hz AC power, use an exposure time that is a multiple of **16.667 milliseconds** to eliminate lighting ripple. For incandescent lighting you may be able to use a multiple of 8.333 milliseconds.
- For 50 Hz AC power, use an exposure time that is a multiple of **20 milliseconds** to eliminate lighting ripple. For incandescent lighting you may be able to use a multiple of 10 milliseconds.

Solution: Reference Surfaces

By placing a uniform white surface in the image, it may be possible to detect and correct for variations in lighting:

- Many cameras have an auto exposure time feature that can be configured to use the reference surface to automatically adjust the exposure time. Color cameras may also auto color balance.
- It should be possible to configure most machine vision systems to automatically compensate for lighting changes indicated by the brightness of the reference surface.

Problem: Trade Show Vision Demo

Your machine vision demo needs to function successfully in the exhibit hall of the 2017 AUTOMATE trade show.

There will be bright overhead lights and moving shadows because of attendees passing through your booth.

Solutions?

Solution: Trade Show Vision Demo

- If possible, use a narrow bandpass filter matching the color of the machine vision lighting to minimize any ambient lighting.
- If practical, use backlighting, which should be brighter than lighting reflected off of demo parts.

Problem: Auto Unibody Paint Inspection

- An automated inspection station on an auto assembly line inspects the paint color at one location on a painted unibody.
- Each unibody is indexed into this inspection station and remains stationary for 2 seconds.
- This section of the assembly line is surrounded by a considerable amount of AC-powered lighting.

Solutions?

Solution: Auto Unibody Paint Inspection

- A light-tight enclosure containing the camera and lighting is momentarily placed over the part of the unibody that will be inspected.
- A white LED machine vision light source is used.
- The vision lighting is electrically isolated from any heavy electrical machinery.
- A sophisticated LED lighting controller is used to ensure the stability of the lighting output.
- In addition, a white reference surface is located in the camera field of view to monitor the brightness and color of the lighting.

Problem: Manual Assembly Station

An inexpensive “vision sensor” inspects a manually assembled product for missing components, using simple brightness and contrast functions in various regions of the image. The product has polished metal surfaces.

At this assembly station, right next to the assembly, there is a pass/fail light tower that gives off a different colored lighting pattern, depending upon the results of the previous inspection. This lighting difference can result in different brightness and contrast values for the part-present inspections.

Solutions?

Solution: Manual Assembly Station

- Turn off the pass/fail status lights at the very beginning of each inspection.
- Where possible, use contrast rather than brightness tests to check for the presence of a part.

Problem: Metal Foil Inspection

A vison system continuously monitors the width of a roll of metal foil and detects any holes or tears.

The shiny metal foil moves over a backlight.

Unfortunately, bright overhead lights are reflected by the metal foil. To the vision system these bright reflections can look like holes or tears, resulting in false alarms.

Solutions?

Solution: Metal Foil Inspection

- Position dark panels above the vison system to eliminate any overhead reflections.
- Use a narrow bandpass filter matching the color of the backlight.

Problem: Plastic Wrapper Position

Several rolls of paper are packaged in a plastic wrapper.

There is important product artwork on this wrapper, including the brand, logo, quantity, and UPC barcode.

The vision system needs to verify the correct positioning of this wrapper.

Unfortunately, some of the artwork cannot be seen due to bright surface reflections from the plastic wrapper.

Solutions?

Solution: Plastic Wrapper Position

- Use a polarizing filter over the light source and over the lens, with the rotation adjusted to the optimal angle, in order to eliminate bright surface reflections.

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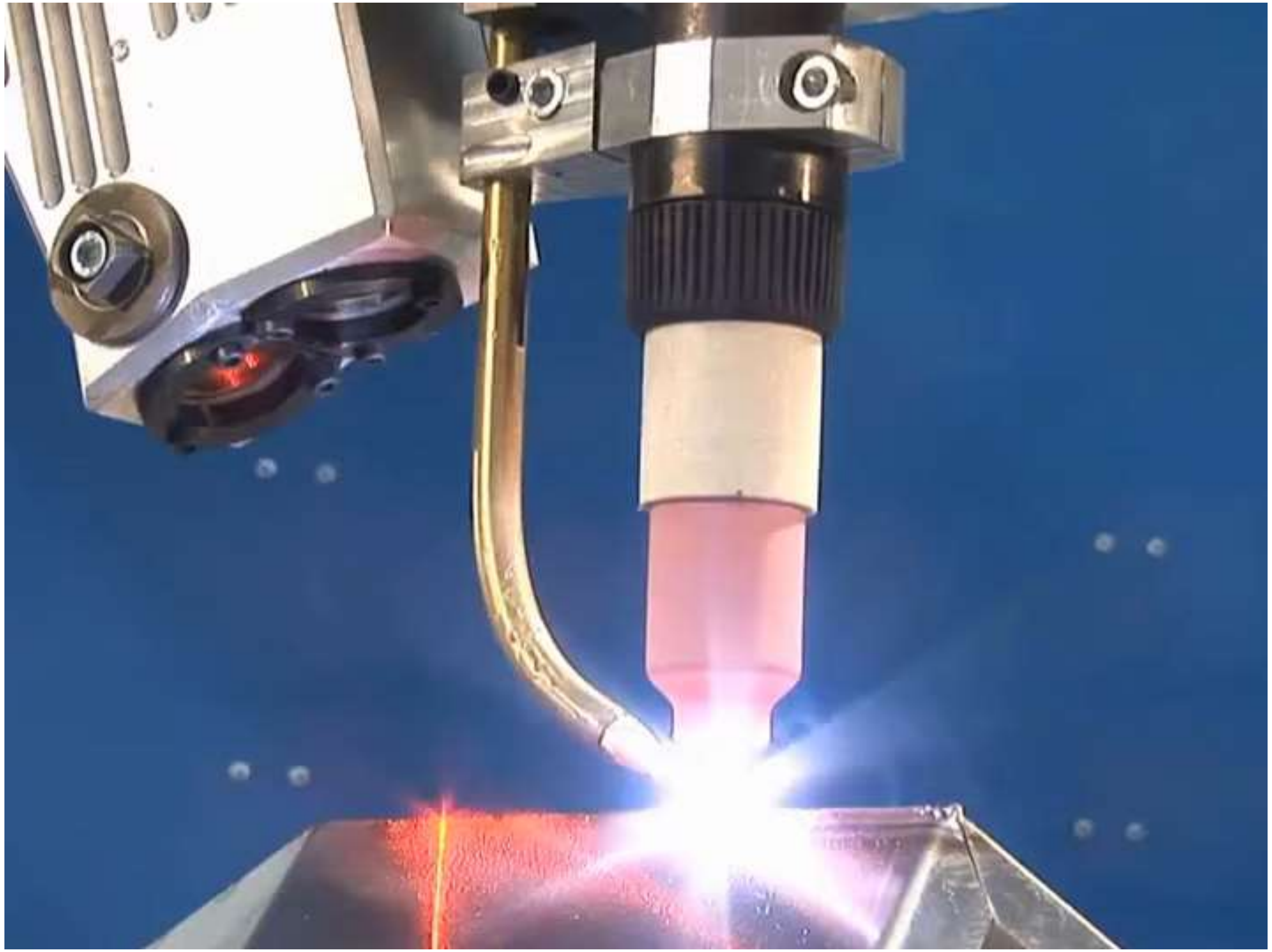
Problem: 3D Vision Guided Welding

A structured light stripe and camera are used to precisely locate in 3D a weld seam in order to guide a robotic welding system.

Unfortunately, the light emitted by the welder can interfere with the visibility of the light stripe.

Solutions?

Problem: Vision Guided Welding



Solution: Vision Guided Welding

- Make a first pass with the welder turned off in order to locate the seam, and then a “blind” second pass through the corrected trajectory, performing the actual weld operation.
- If stitch welding, perform vision in between weld segments.
- Use a bright laser stripe projector and a bandpass lens filter matching the wavelength of the light stripe.

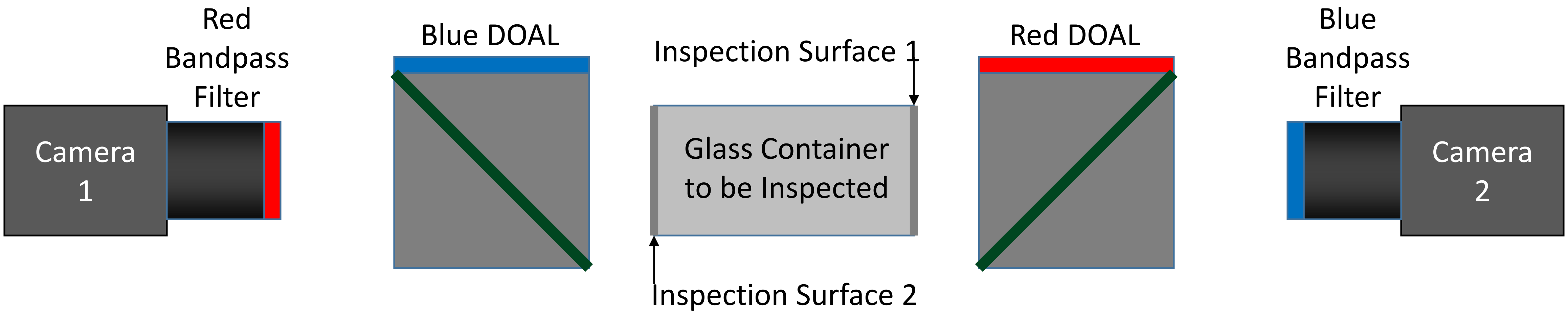
Problem: Glass Inspection

Opposite sides of a clear glass container need to be simultaneously inspected for scratches, cracks, and other defects. The lighting for each camera needs to not cause problems for the other camera.

Solutions?

Solution: Glass Inspection

- Use a different colored light source and filter for each camera.
- Each camera has a colored bandpass filter that matches the DOAL (backlight) on the opposite side of the container and that blocks out reflected DOAL lighting from this side.



Problem: Auto Body Panel 3D Location

- An auto body panel is indexed via conveyor to a load station where a laser light stripe pattern is projected onto the panel in order to determine its 3D position and orientation so that it can be picked up by a robot.
- For reasons of eye safety, a very low power laser must be used.
- This section of the assembly line is surrounded by large numbers of AC-powered fluorescent lights.

Solutions?

Solution: Auto Body Panel 3D Location

- Select a color for the laser and camera bandpass filter that does not match any of the peak wavelengths of the fluorescent lighting.
- Use an exposure time that is a multiple of 16.667 milliseconds in order to eliminate fluorescent lighting AC ripple.
- Capture three successive images, first without the light stripes, second with the light stripes, and last without the light stripes.
- Subtract the first and last images to make sure that there are not any ambient lighting transients.
- Subtract the average of the first and third images from the second in order to construct an image of just the light stripe pattern.

Problem: Aircraft Window Inspection

- Each new polycarbonate aircraft window panel needs to be inspected for cracks, scratches, and mechanical stress.

Solutions?

Solution: Aircraft Window Inspection

- This vision system is located inside a dark enclosure.
- The aircraft window panel is placed over a polarized backlight.
- The rotation of the camera polarizing filter is configured so that the window is bright and the background is dark. Any cracks or mechanical stress will appear as darker features that can be detected via a blob tool.

Contact

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