Advanced Machine Vision Lighting

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Basics and Introduction

Why are you here?

- **Your background and experience?**
  - **Attended Basic Vision Lighting course?**
  - **Formal study of optics?**
  - **Amateur photographer?**
  - **Have you ever put a your digital camera into manual mode?**

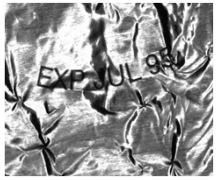
- **My background?**

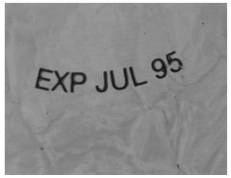
Session Objectives

- Discuss the “scientific method” for selecting the correct lighting geometry.

  Means thinking “What would a photon do”?

- Consider selection and placement of lighting using the scientific method.





  Means applying analytical and practical knowledge to make signal

- Discuss examples of practical light selection for different geometries and surfaces.

  Means thinking about real world lights and surfaces

- Review current developments in Machine Vision lighting.

  Check on what’s new

- Discuss how light intensity, color, polarization and part motion factor into design of a robust lighting solution.

  Means how to deal with color, glare and moving parts

- Cover what is in the Exam

  Means I will cover everything in the test!

Common Knowledge About Light

WHAT WE TO KNOW

- Fuzzy balls of vibrating energy moving at “c = 300,000,000 Meters/Sec” (Fast!)
- Always travel in very straight lines except when reflected of refracted
- Red light $\lambda \sim 640$ nm = 0.64 microns – about a 1000 atoms for one wavelength

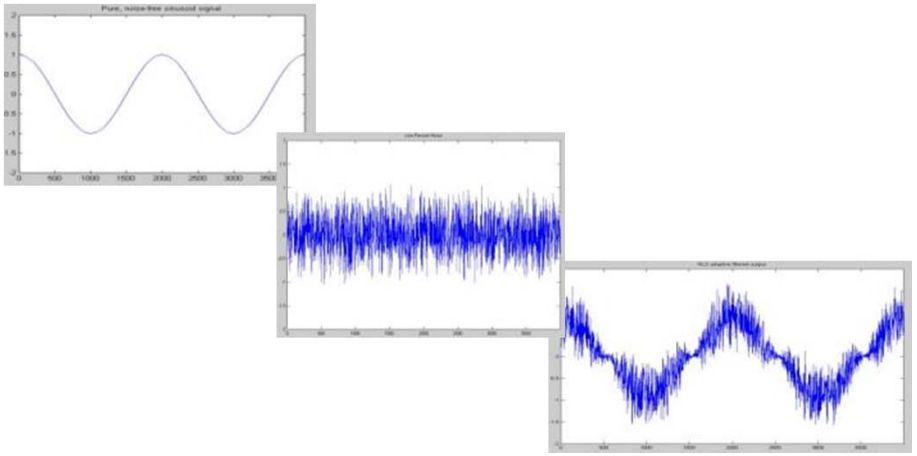
WHAT WE CARE ABOUT

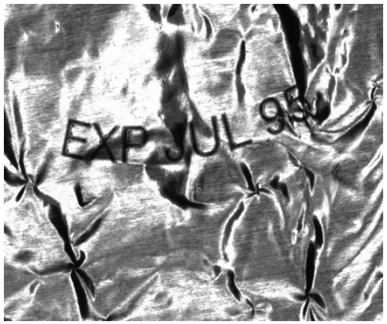
- How light interacts with solids (and liquids)
- How it is distributed when it gets to a sensor
- How to distribute light sources to get a useful image on our sensor
- This usually means creating contrast

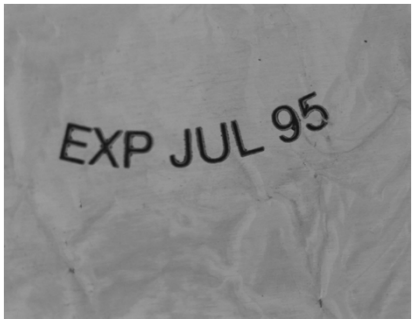
Pop Quiz – (Easy) – Difference between Reflection and Refraction?

Goals in Machine Vision Lighting Design

- 1,2, and 3 Create Useful Signal!
- Signal carry information
  - Useful information = S
  - Irrelevant information = Noise, N
- Create an image with high S/N Ratio







- Machine Vision – extracting useful information from digital images
- Useful information is the Feature Data contained in the Signal part of the Image

The Scientific Method

- The “Scientific Method” of Machine Vision Lighting Design
  - 3-step procedure to selecting the correct lighting geometry

1 – Consider how light will interact with surfaces in your scene

Think about Surface Properties and Geometry

2 – Think about how light will get to the sensor to be turned into an image

Think about Part and Camera Geometry, Lens, Sensor

3 – Choose a lighting geometry that will maximize Signal to Noise Ratio

Think about Type of Light, Position of Light

What is it made of and what will it do to light?

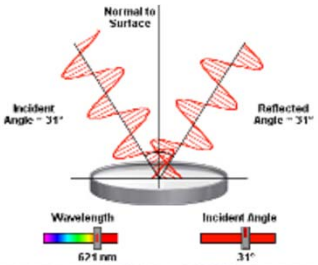
How do I need the image to look?

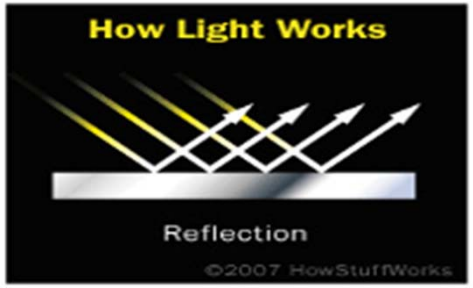
Where to put the lights?

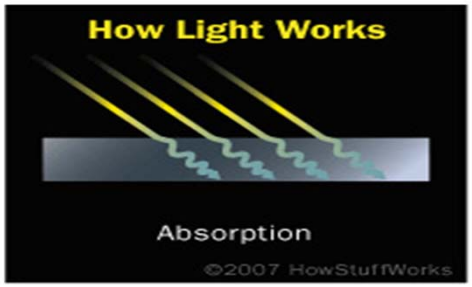
Step 1 - Light and Surfaces

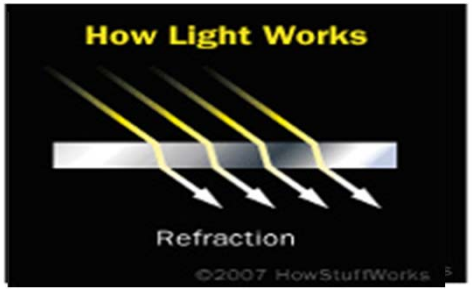
Light a wave or a particle – do we care?

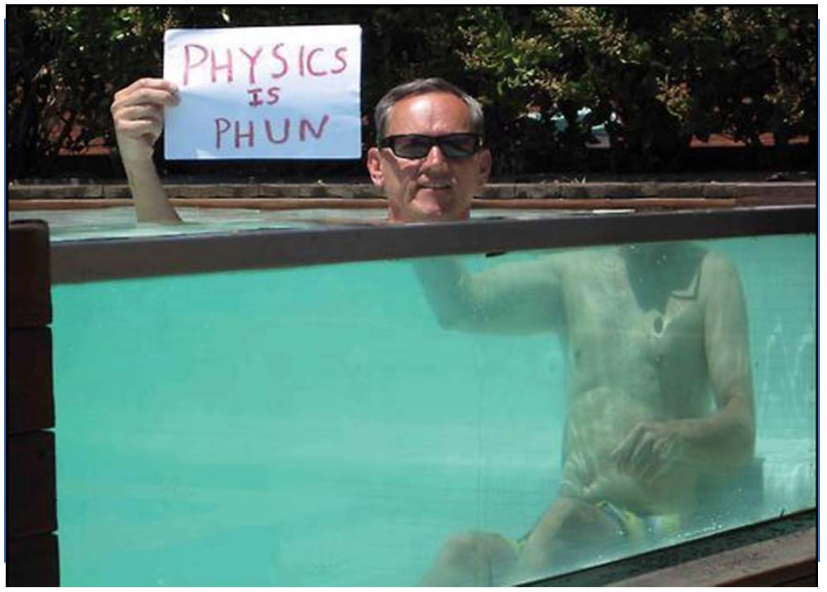
Step 1 – Interaction with surfaces





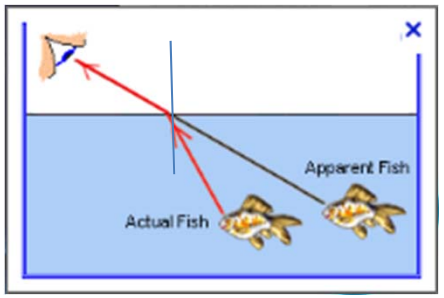






FB: Science is Awesome

- Pop Quiz –
  - In reflection – How does angle of incidence relate to angle of reflection?
  - In refraction – On entering a denser medium which way does the ray bend?
  - In fishing – Is the fish actually closer of further away?

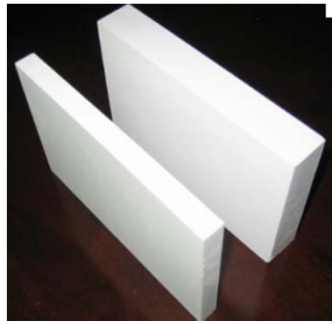


Light and Surfaces

- Real Surfaces – the easy ones

Reflection I = R

- **Specular Flat**
  - First Surface Mirrors
  - Highly Polished Metal or Ceramics
  - Mercury
  - Liquids at low angles



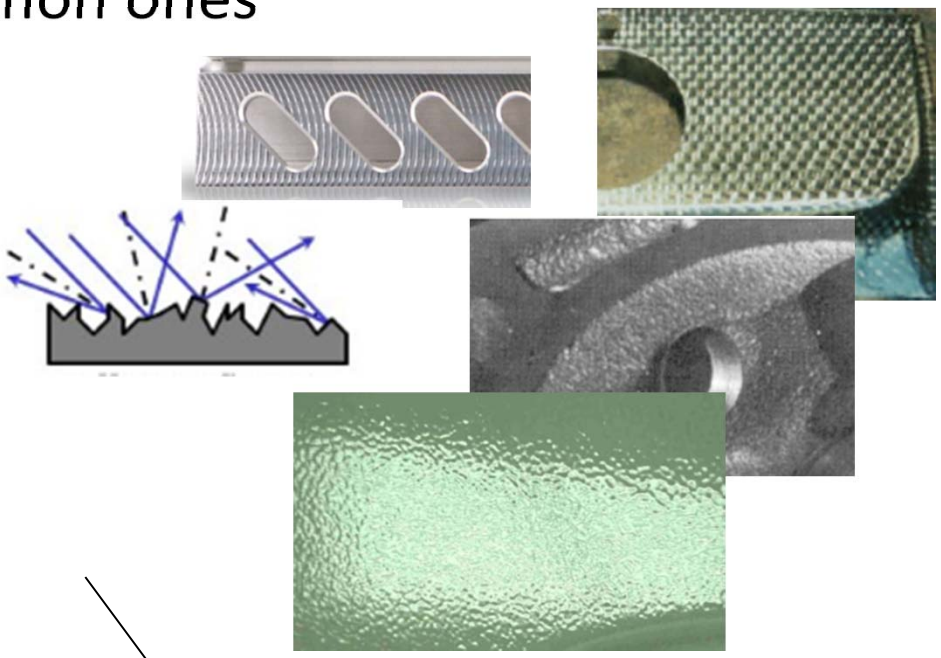
- **Amorphous**
  - White Paper
  - White Ceramic
  - Fine White Powders
  - Inside of a CDI

Diffuse Reflection

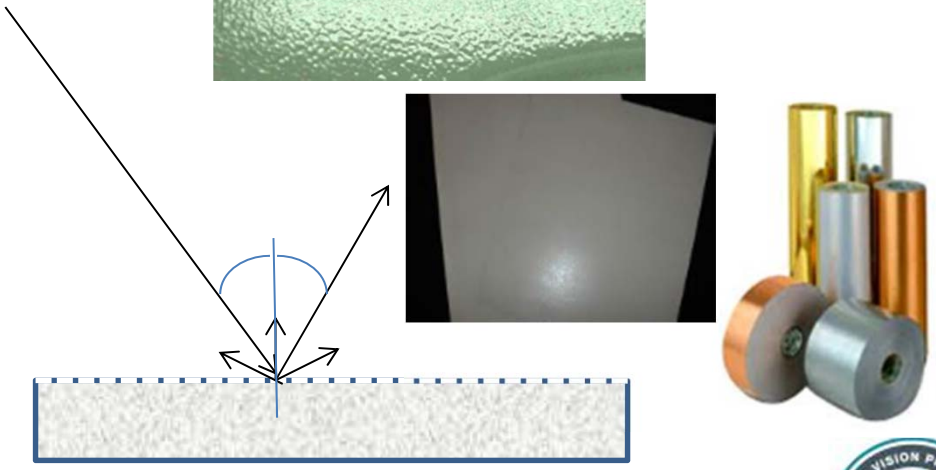
Light and Surfaces

- Real Surfaces – the common ones

- **Specular Multi-faceted**
  - Machined Metal
  - New as-cast/rolled meta
  - Fresh solder

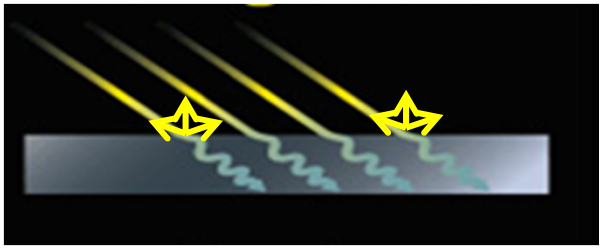


- **Amorphous/Reflective**
  - Plastics
  - Coated Paper
  - Partially Oxidized Metal
  - ……



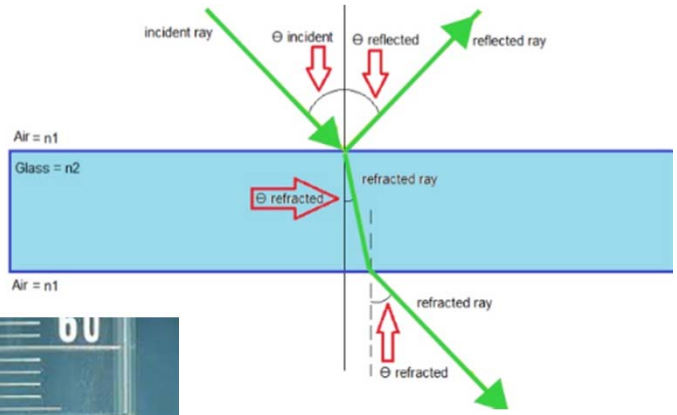
Light and Surfaces

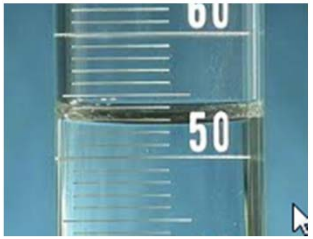
- Real Surfaces – more common ones



- **Partially absorptive**
  - Any printing
  - Dark or colored materials
  - Fine powders (not white)
  - Translucent solids and liquids

- **Refractive/Reflective**
  - Glass/Air or Glass/Liquid
  - Transparent Liquid Surfaces

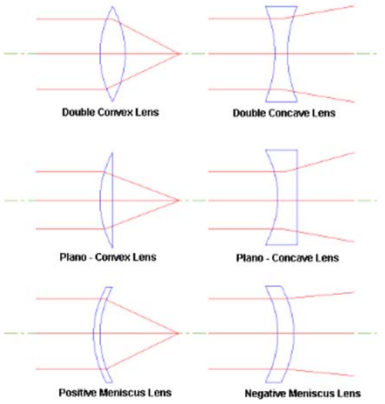




Step 2 – Turning Light into an Image

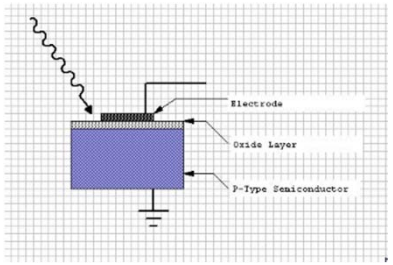
Optics get the light into the camera

- Different Seminar!



Sensor turns light into a digital image

- Lighting topic because S/N influenced by
  - Sensor sensitivity (cell size)
  - Frequency/wavelength response



Anatomy of the Active Pixel Sensor Photodiode

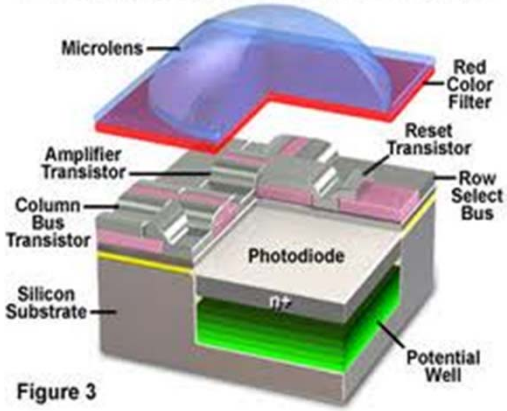
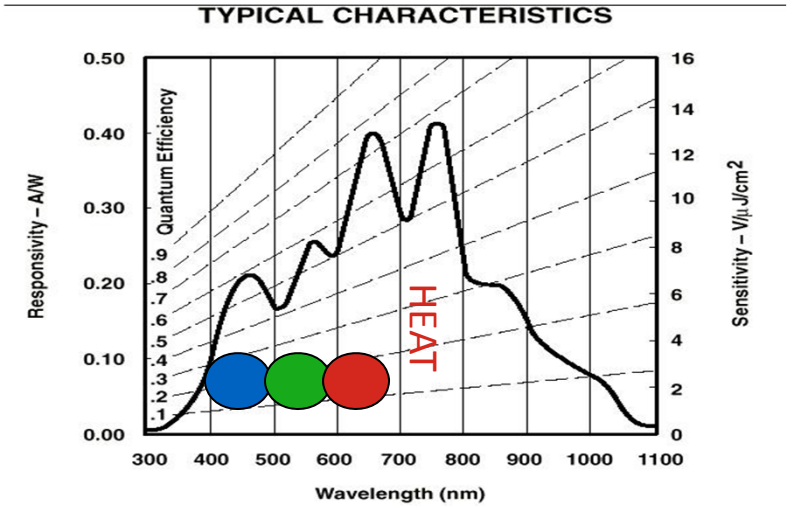


Figure 3

Turning Light into an Image

Sensors are photovoltaics!

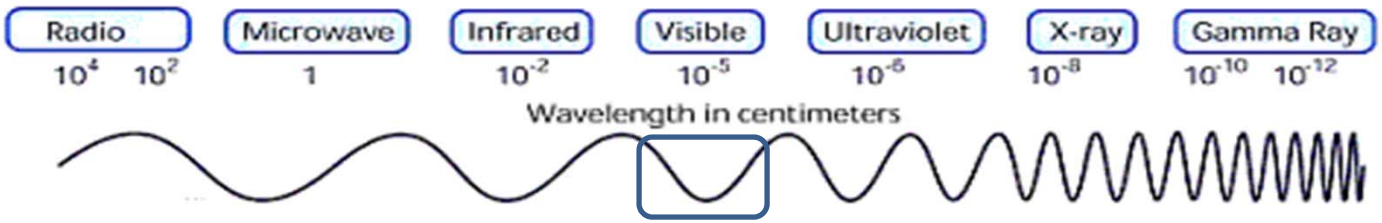
- The sensor receives wavelengths which make it through the lens system
- CMOS/CCD converts visible and NIR photons to an electrical charge
- Charge is converted to grey level
- Machine Vision is computerized light measurement



CCD Camera Response

There is another definition

Why do flames often look wrong on the TV? (or cheap/modern movies)



Why are our eyes good at 400 to 700 nm?

- No resolution
- Low resolution
- Everything looks the same
- Damages tissue
- Goes straight through

Review of Goals for Lighting Design

- High Signal/Low Noise
- High Contrast (but not washed out)

- Evenly Lit
- Unaffected by Product Variation
- Unaffected by Environmental Variation

We have thought about:

Properties of light
What happens at surfaces and sensors
What happens at the sensor

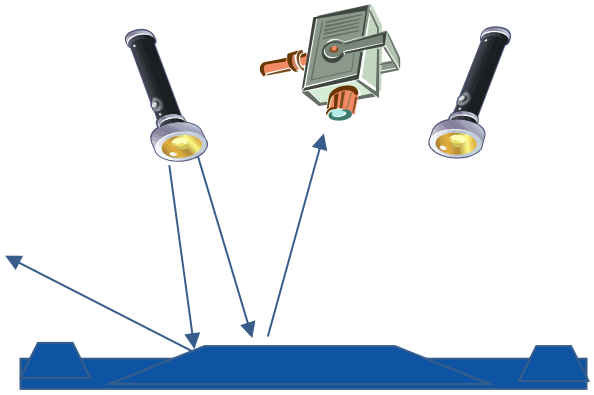
Now consider effect of lighting geometry as Part 3 of the "Scientific Method"

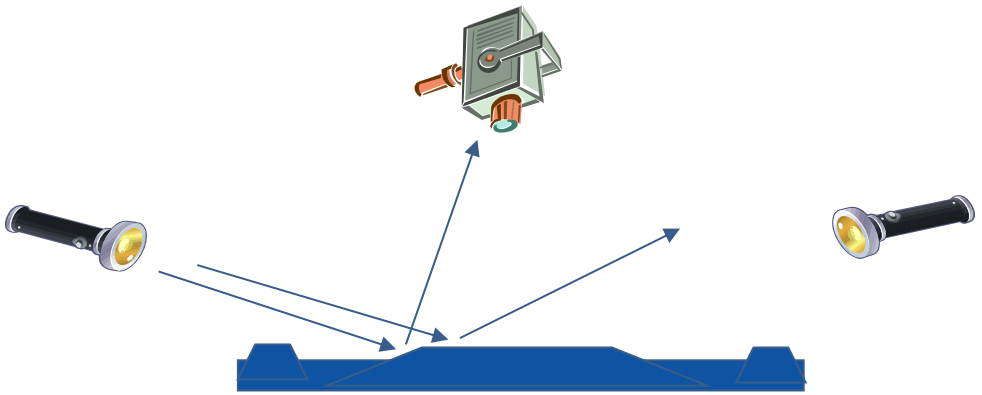
But first– review <u>Bright Field</u>, <u>Dark Field</u> and <u>The "W"</u>

Bright Field and Dark Field

- Dark Field or Bright Field – you have a sample in your pocket

- GW lit by a light in the Bright Field – and a light in the Dark Field



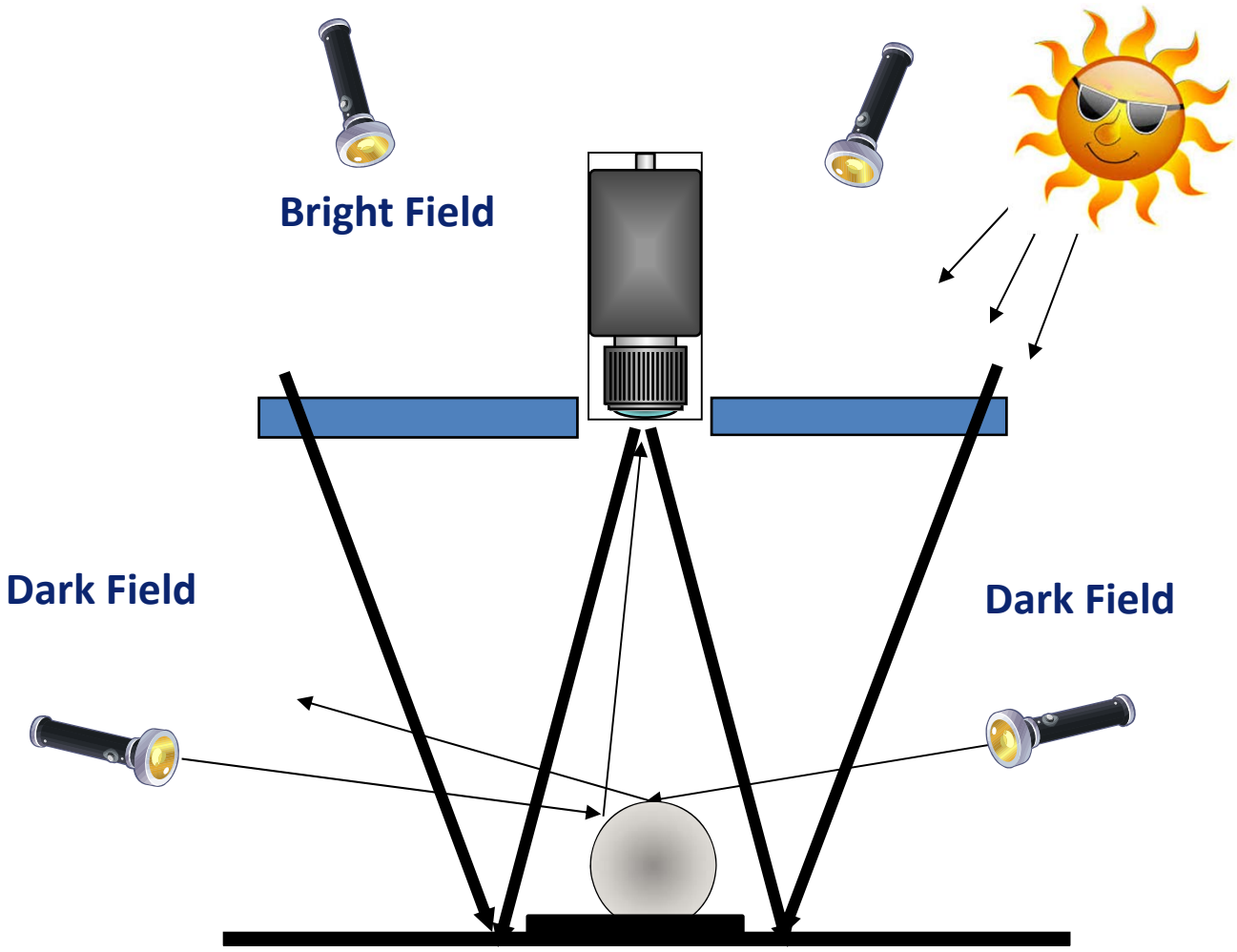


- On Axis - Flat bits bright

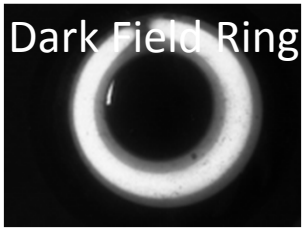
Off Axis - Inclined surfaces bright

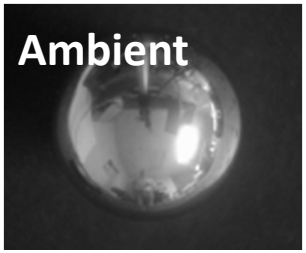
Only applies to surfaces that are at least a bit specular!

“W” Defines Bright Field and Dark Field Zones



PQ – what is wrong with this guy?

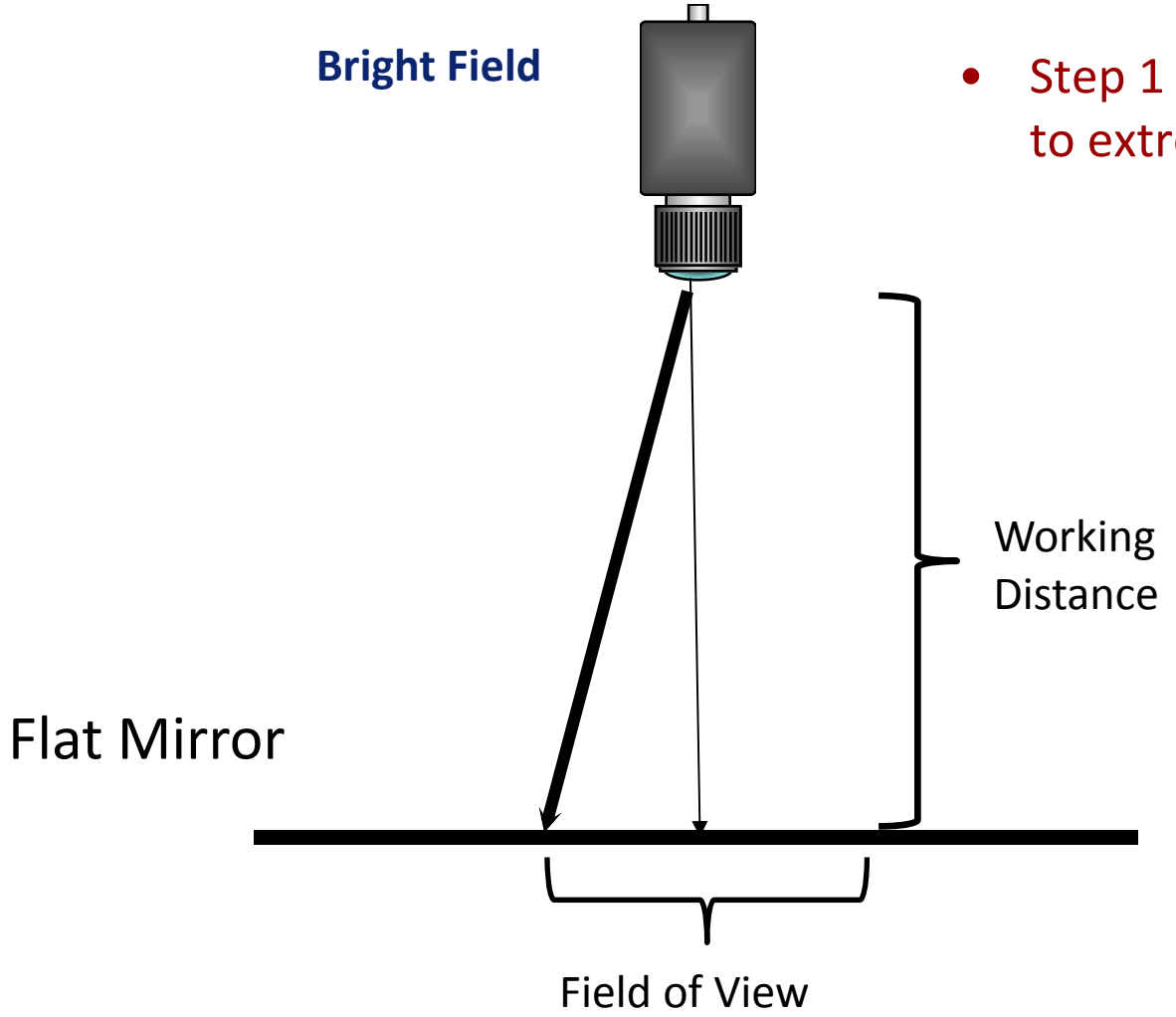




The “W” defines Bright Field/Dark Field boundary for flat objects

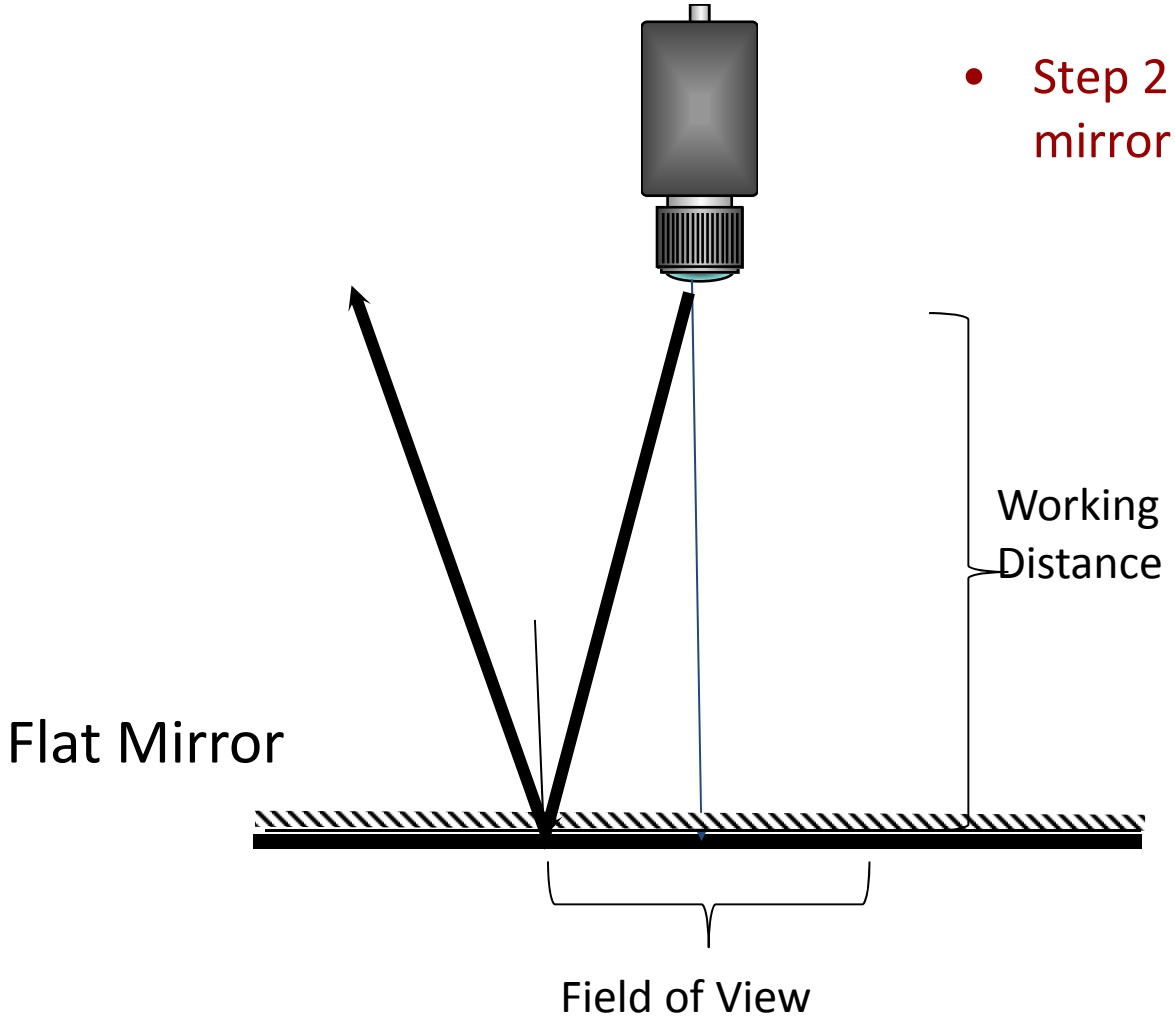
Test Technique: Test your lighting / ambient issues with a mirror & ball bearing

Reflection Geometry: Defining the "W"



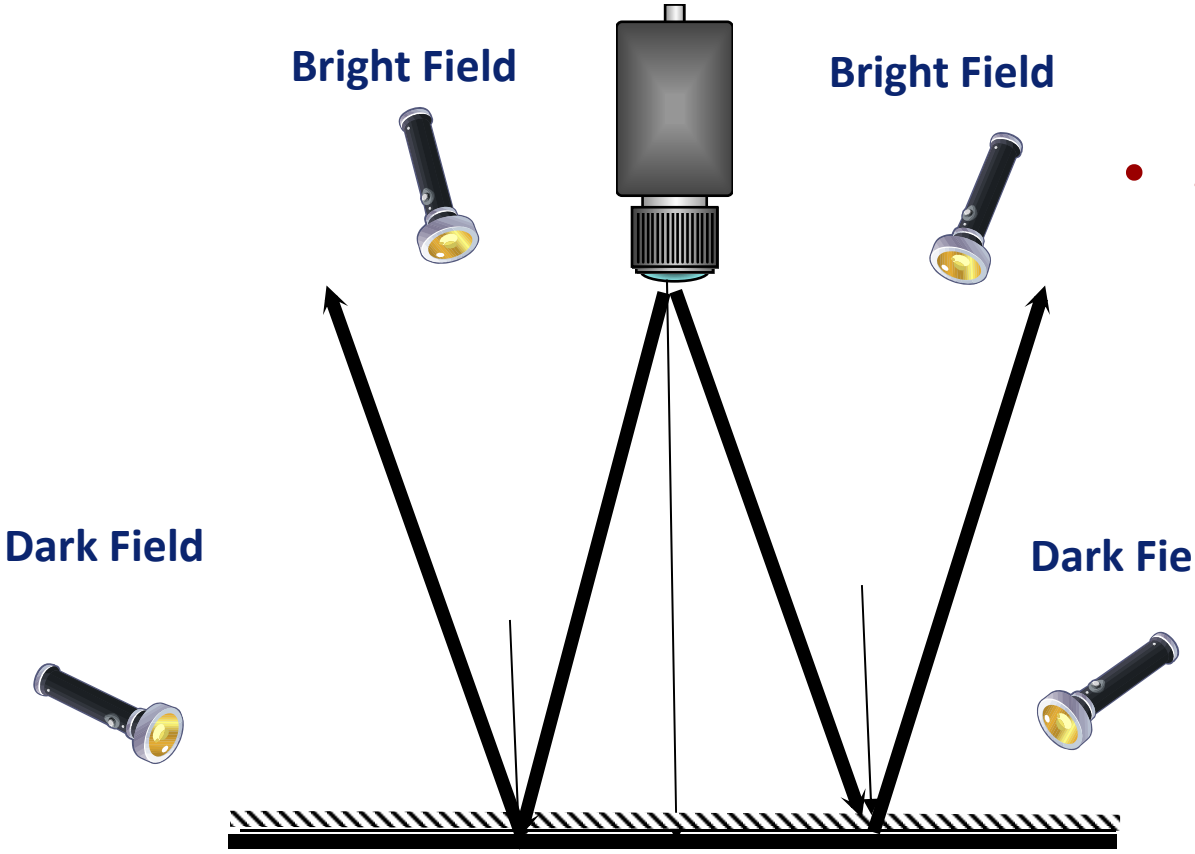
- Step 1 – Draw line from lens to extreme edge of FOV

Reflection Geometry: the “W”



- Step 2 – Reflect this line off a mirror at the object plane

Reflection Geometry: the “W”

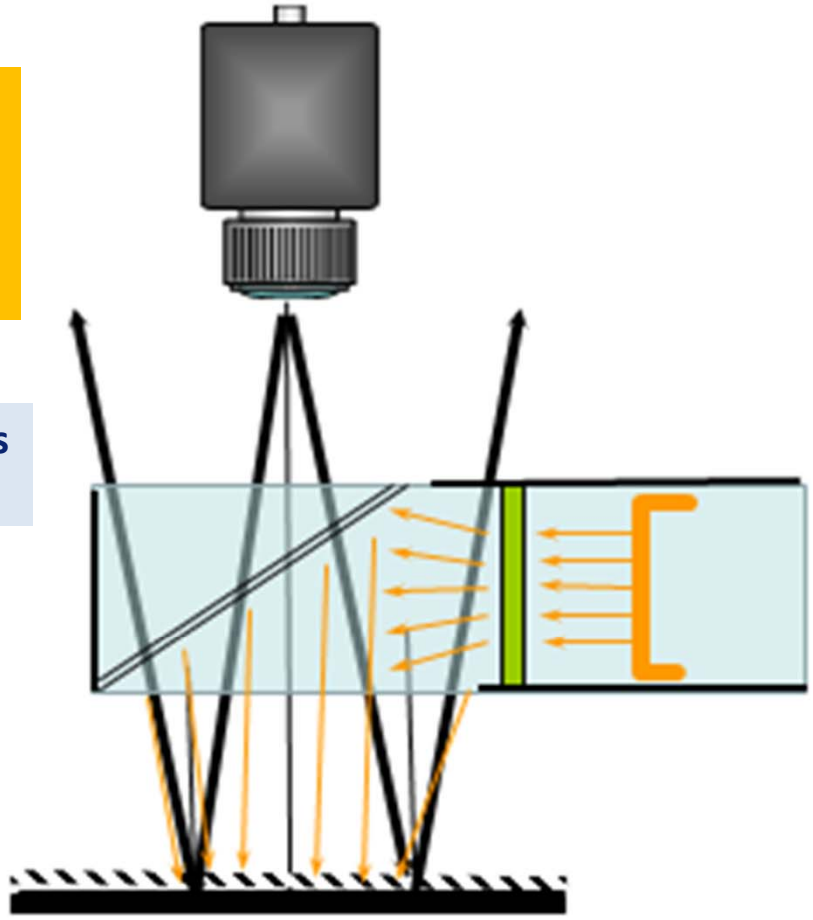


- Step 3 – Do the same on the other side and admire the “W”

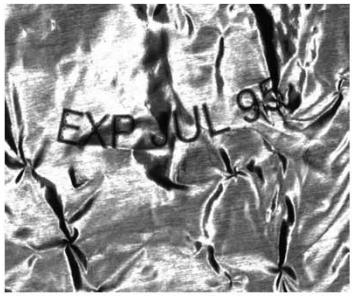
Reflection Geometry: the “W”

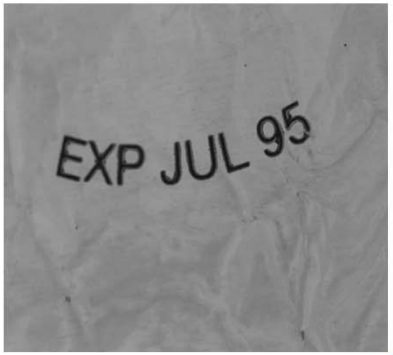
Fill the W (and then a little bit more) to evenly illuminate flat specular surfaces

How much more depends on surface geometry



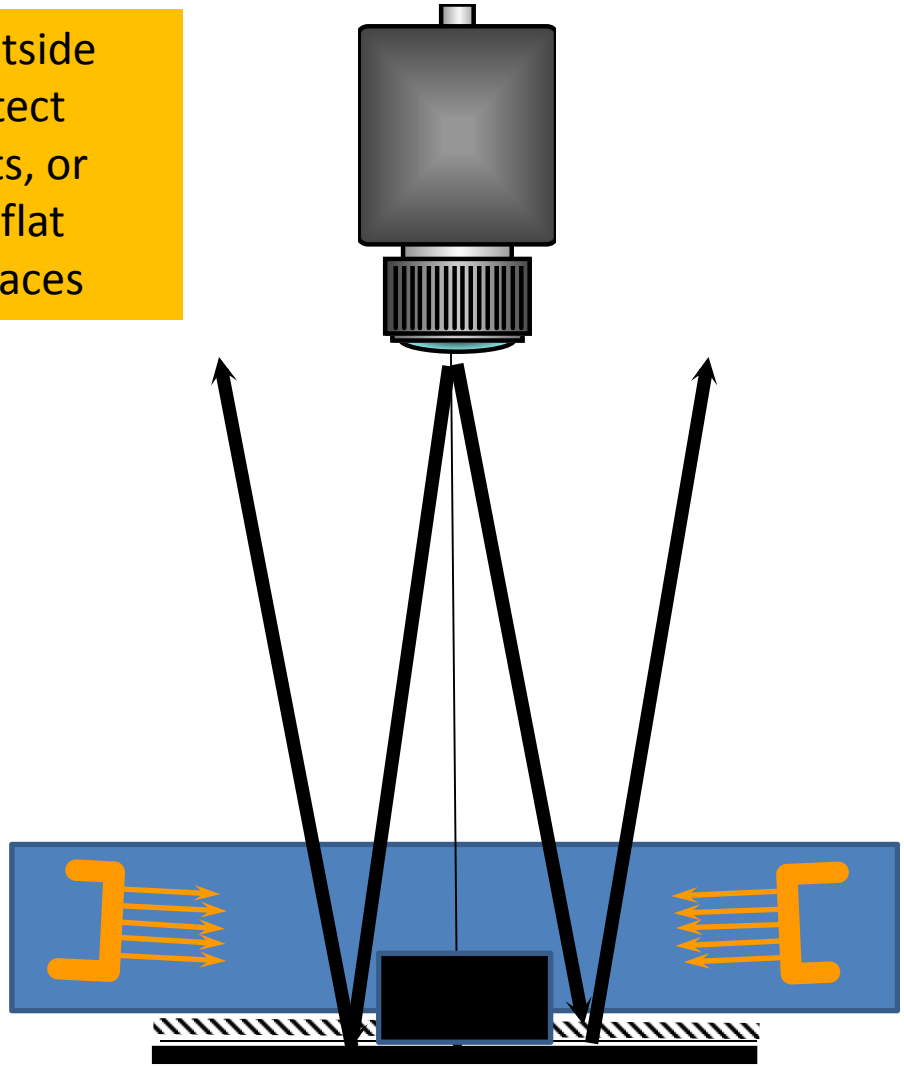
Field of View





Reflection Geometry: the “W”

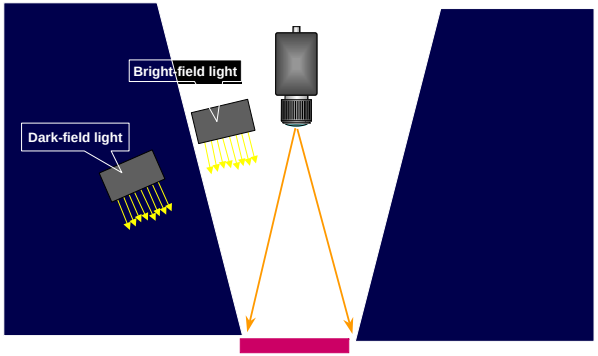
Stay (low) outside the W to detect scratches, pits, or elevation on flat specular surfaces



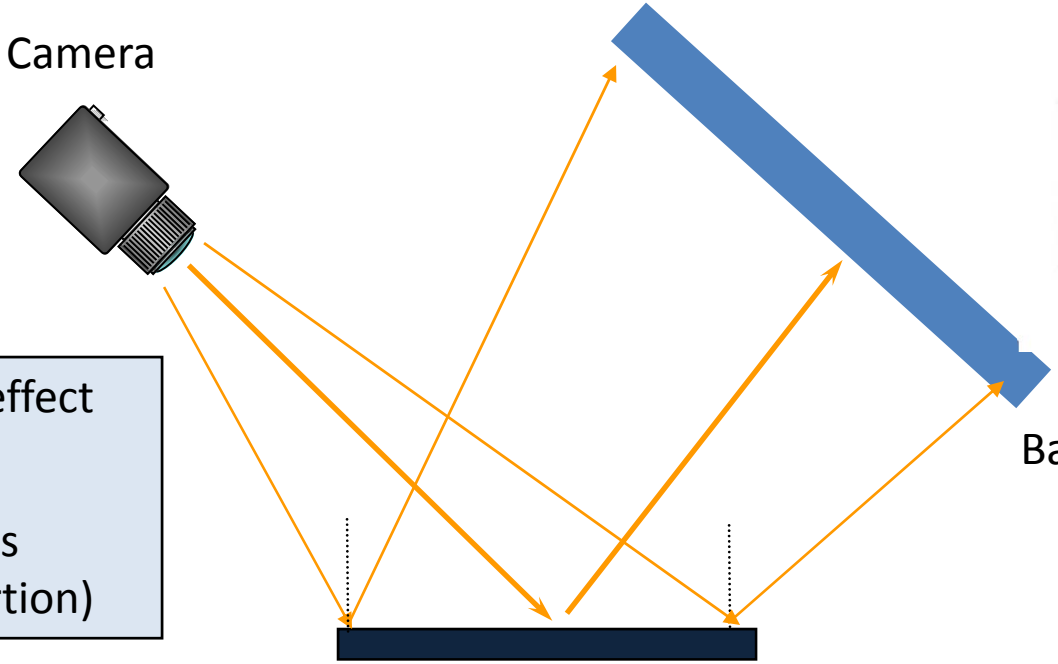
Bright Field Lighting with a “Warped W”

Is this bright field or dark field?

Where does the W go when you tilt the camera?



Uniform lighting is presented within the bright field, providing diffused on-axis illumination.



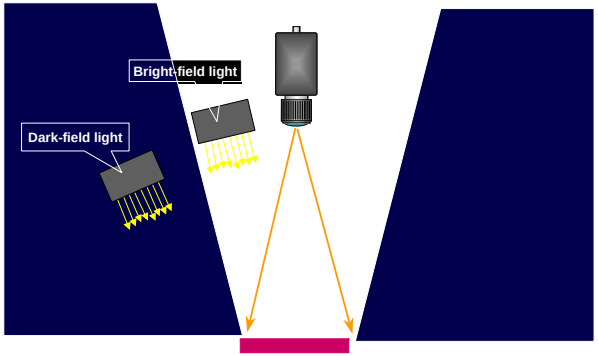
Nearly the same effect as a DOAL

(But the image has perspective distortion)

Dark Field Lighting with a “Warped W”

Is this bright field or dark field?

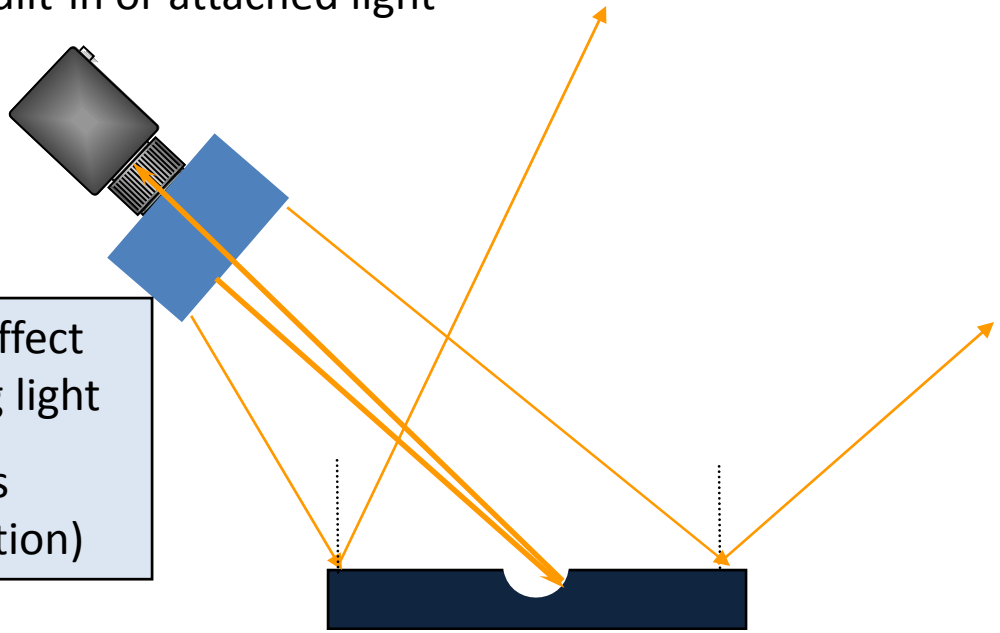
Where does the W go when you tilt the camera?



One sided dark field lighting is produced if the camera is tilted > 20 degrees

Built-in light

Camera with built-in or attached light



Nearly the same effect as a low angle ring light

(But the image has perspective distortion)

Ensuring Uniformity

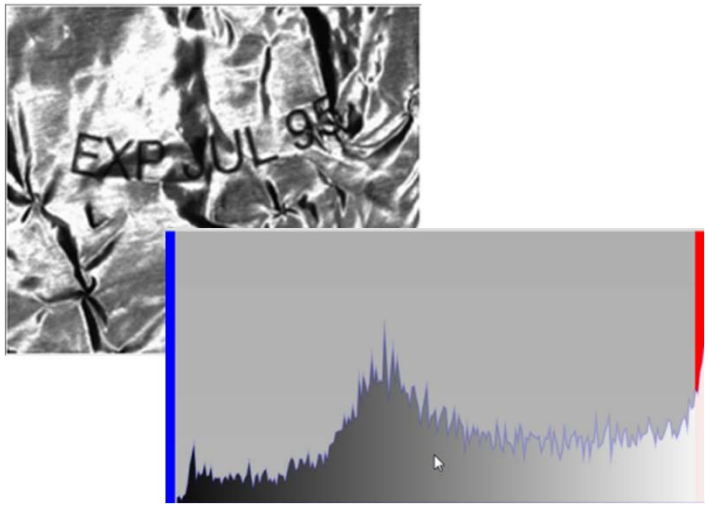
Can fix some of this in software but better to have a nice image.

Want the part histogram and the background histogram to be as skinny and as far apart as possible.

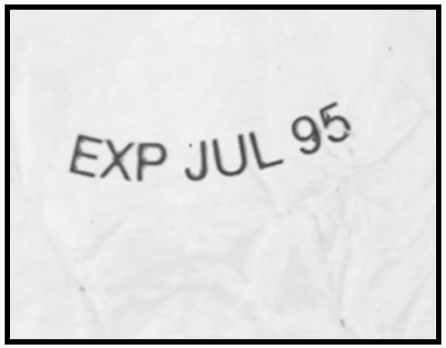
Uniformity is relative to:

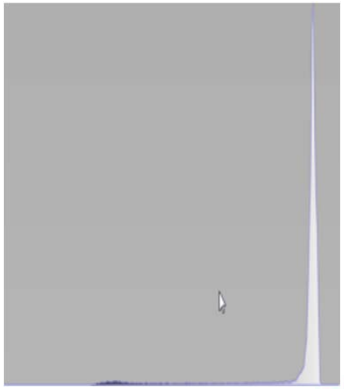
- Field of view
  - In the camera field of views, is the light intensity equalized?
- Surface angularity and shape
  - Does the light reflect from all the surfaces of the part evenly?
- Equal light delivery/emission
  - Is the light transmitted evenly from the source?

Uniform light provides uniform reflection



Does it all have the same chance of getting to the sensor?





The Story So Far

- Consider how light interacts with surfaces
- Classify the surfaces you are looking at (specular/crystalline absorptive/ amorphous)
- Considered how light effects the sensor
- Are aware of the boundary between dark field and bright field
- Can draw or imagine the W

Nearly Ready to move on to "Lighting Geometry at the Movies"

But First - Ray Tracing or "Think Like a Photon"

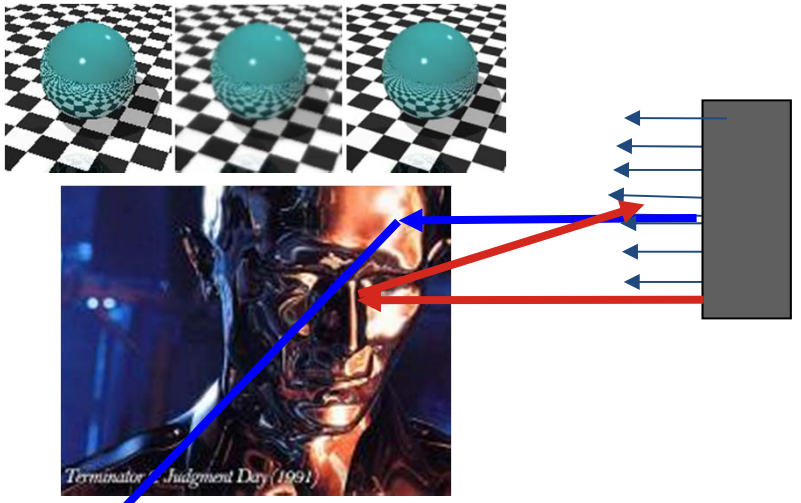
Ray Tracing or "Think Like a Photon"

Q - What is ray tracing? A - Follow the rays . All of them!

Why is it important? CGI (Computer Generated Imagery)

Did you enjoy….. TRON(s), Toy Story, Bug's Life, Finding Nemo, 300! (all CGI) (but not Wallace and Grommet)

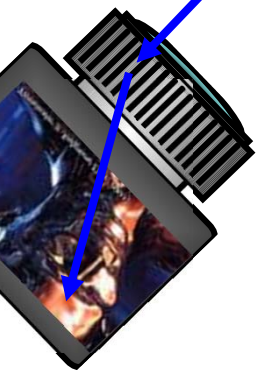
Uses MASSIVE computing power!



- The Scientific Method: - use tracing to determine lighting/scene camera geometry to achieve the desired result.

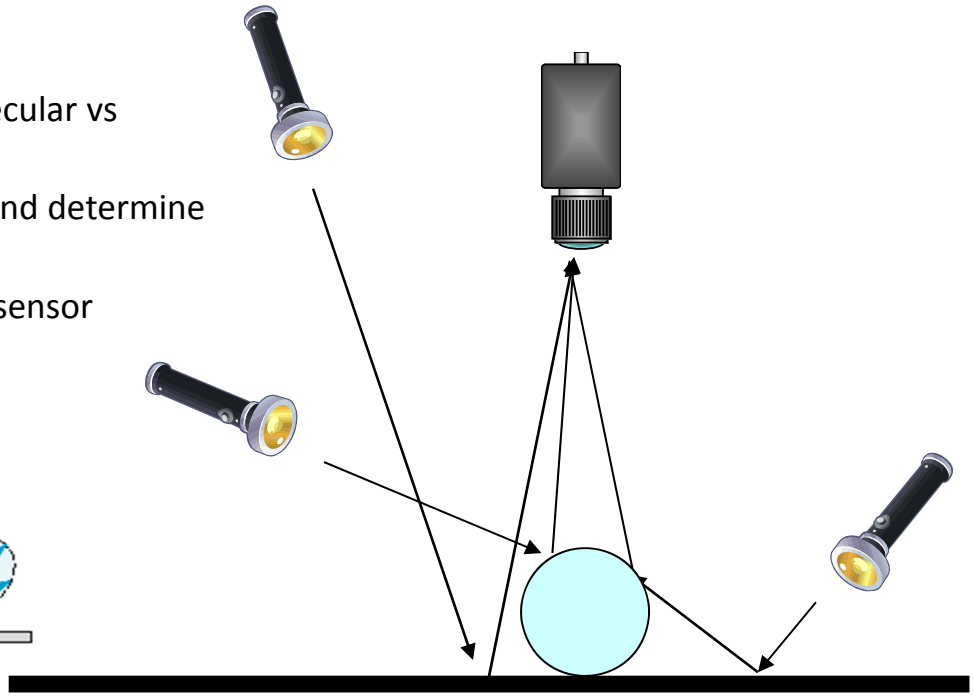
- Each place on the object that is in the FOV has a corresponding cell on the sensor
- So – Trace <u>all</u> light paths from the SOURCE to the OBJECT to the SENSOR and determine which of the paths land on a particular PIXEL on the SENSOR.
- If there are <u>many paths</u> then this location on the SENSOR and the corresponding location in the IMAGE will be <u>bright</u>.
- <u>No or few paths</u> then the location will be <u>dark</u>

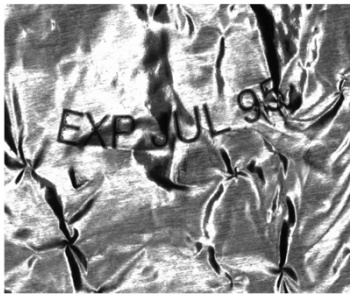
- Takes account of light, object and sensor geometry, shape, and surface properties.

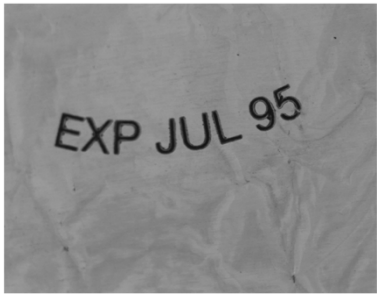


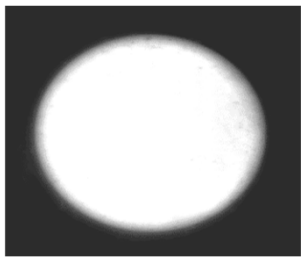
Amateur Ray Tracing

- Draw the rays from the light
- Light reflects at the angle of incidence
  (angle of incidence = angle of reflection)
- Light spread depends upon surface conditions (specular vs matte)
- Draw a simple diagram to understand your setup and determine light placement. Follow your arrows
  - Does the arrow terminate at a pixel in the sensor
  - What does uniformity look like?









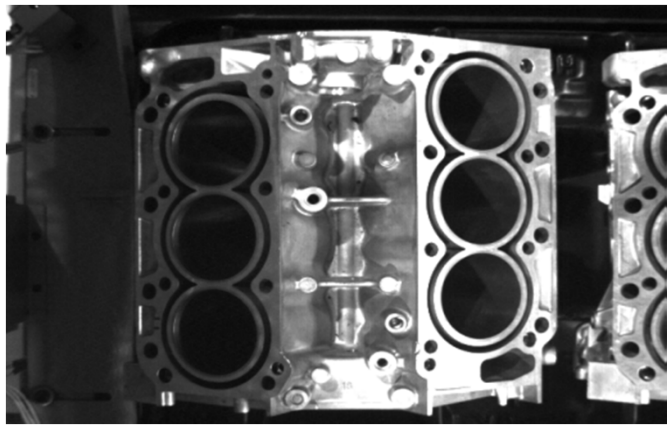
Application: Engine Block Pick-up

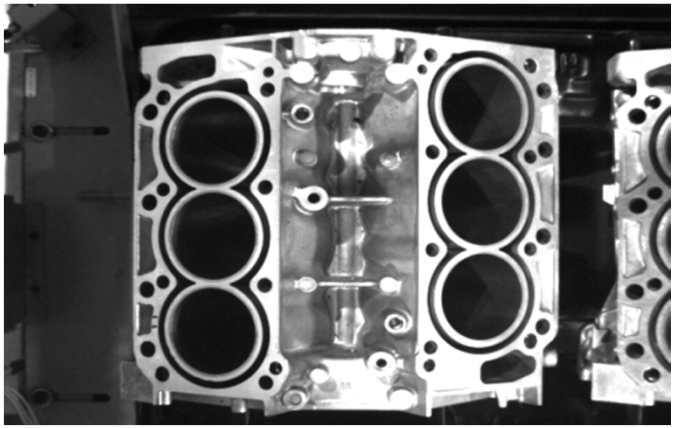
- **Application:** Robotic work cell placing engine blocks on conveyor line. Need good contrast on holes for orientation.

- **Issues:** Large robotic cell provided major space constraint on lighting placement. Specular metallic surfaces, ambient light.

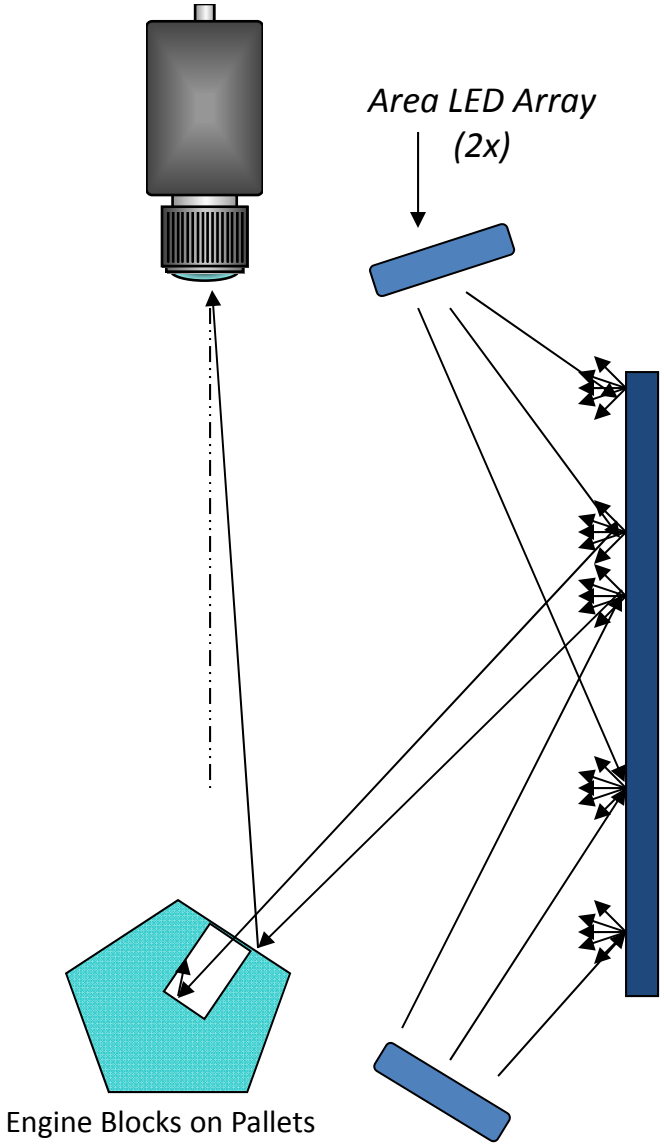
- **Solution:** Based on simple ray tracing, large matte white panels were employed on the cell cage and illuminated. Shiny surface allowed good reflectance and allowed f-stop to be turned down, eliminating ambient light.

Putting tracing to work!

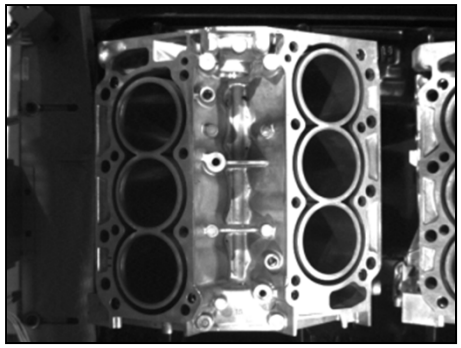




Example - Applying Ray Tracing



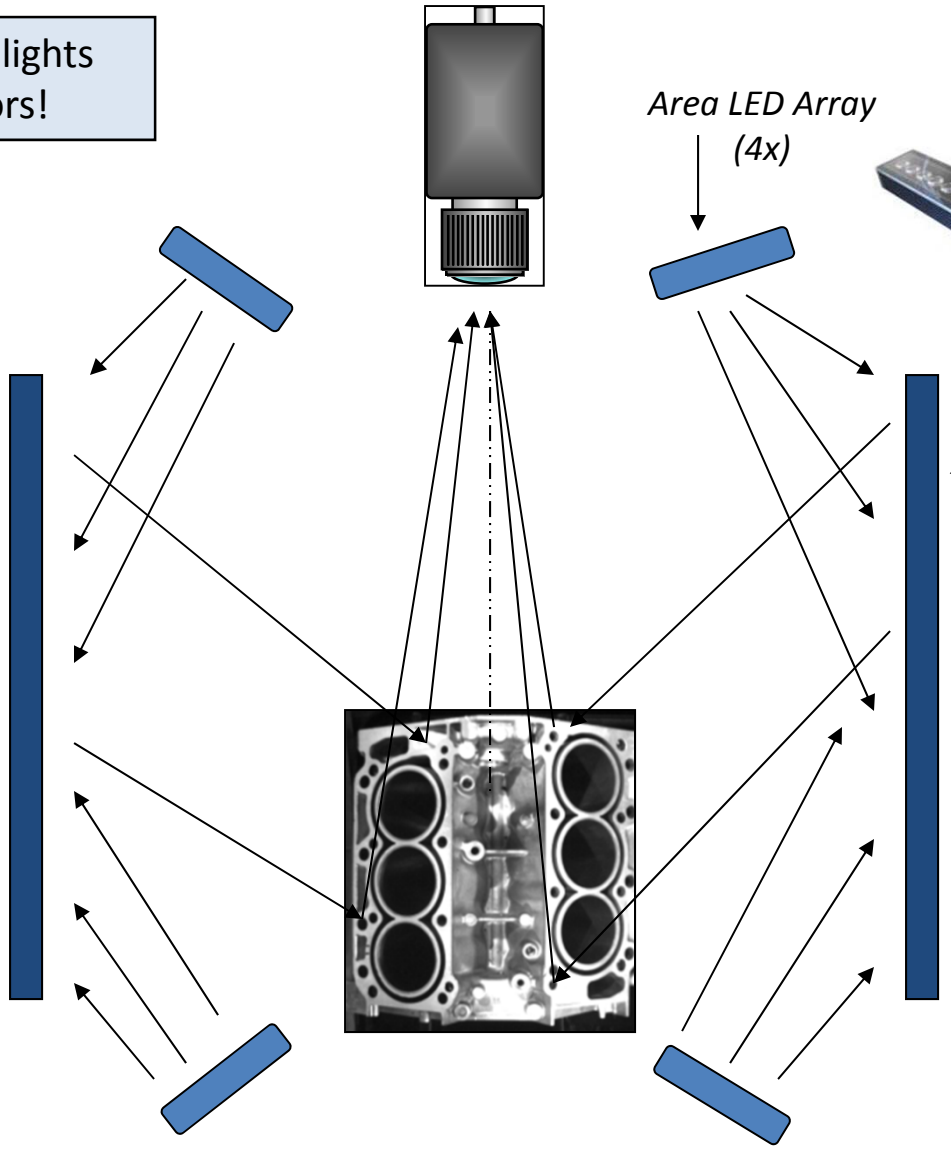
- Follow your arrows!
- Is there a ray path to the camera from all the places you want to be bright?
- Do rays get lost from all the places you want dark?
- This will identify the placement required for your lighting (e.g., lighting top of engine block).



Q) How do we light both sides?

More Ray Tracing

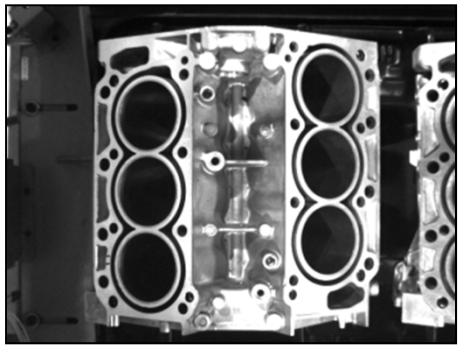
Two sets of lights and reflectors!

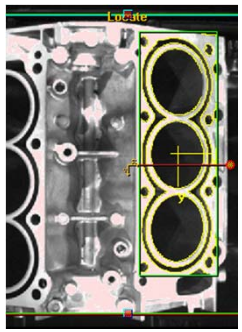


Area LED Array (4x)

Ray tracing shows that to light both sides, lighting must be placed accordingly.

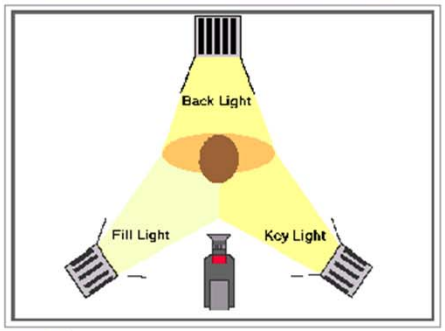
Uniform Light Reflector (Passive – 2x)





The World of Portrait and Movie Photography

- Finally - Fun at the movies… or… Where are the lights?
- “Three Point Lighting” is standard for Portraits, Movies & TV



- **Back Light**
  - Outline
- **Fill Light**
  - Fills Shadows
- **Key Light**
  - Brightest

Play Where Is The Light?

Strongly recommend the “where is the light coming from” game!

- Natural lighting?

GM CEO asked to quit

Rick Wagoner, Chairman and CEO of GM, will step down immediately at the request of the White House. » **Details**

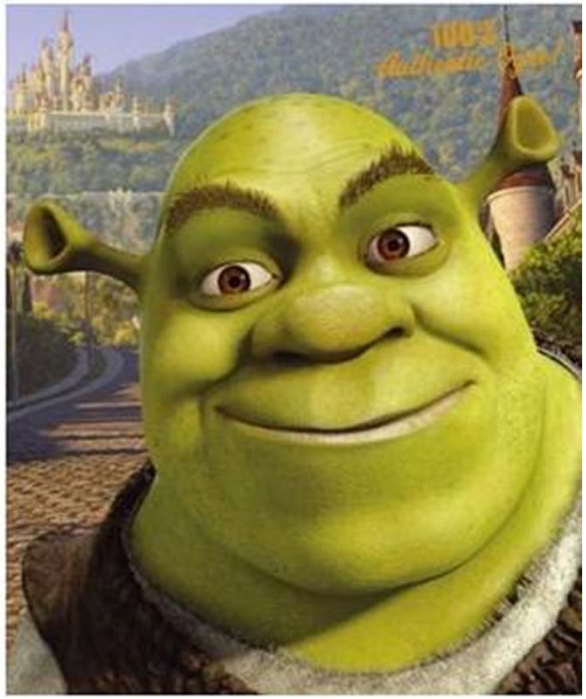
Search Rick Wagoner's salary

• Obama seeks sacrifices from autos

This “candid” shot was probably posed- Key, Fill, Back are all there.

Shrek is “Three Point Lit” with the Key on the right

….but the castle and trees are lit from the left!



May cause Angry Spouse Syndrome

Sometimes They Get it Right - Eventually

First Coors Light Commercial – Coach Jim Mora

Beer Guy is lit from his right
Coach is also lit from his right

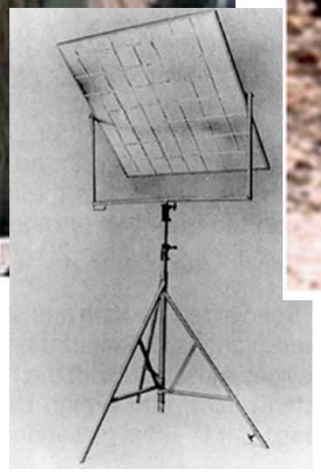
No!

Second Coors Light Commercial

Same Beer Guy is lit from his left
Coach is lit from his right

OK! Got it right!

Natural Lighting?



- And on another world with two suns

- Tattooine?

Summary

You know a few things about light

- Straight lines and fast!
- Reflect / Refract / Absorb / Scatter
- Plan to maximize SNR
- Think Bright Field / Dark Field
- Will fill the “W” for Bright Field
- Know how to follow the rays (ray tracing)
- Play the “where is the light?” game
- You can think like a photon…..

Now to specify real lights to achieve the desired SNR, etc.

Specifying Real Lights

Examine Commonly Used Lights

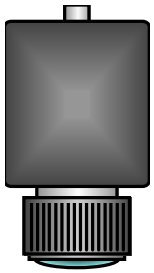
- DOALS On-Axis Lighting
- Dome Lights
- Back Light
- Line Lights
- Multi-Axis - Combination Source
- Structured Lighting

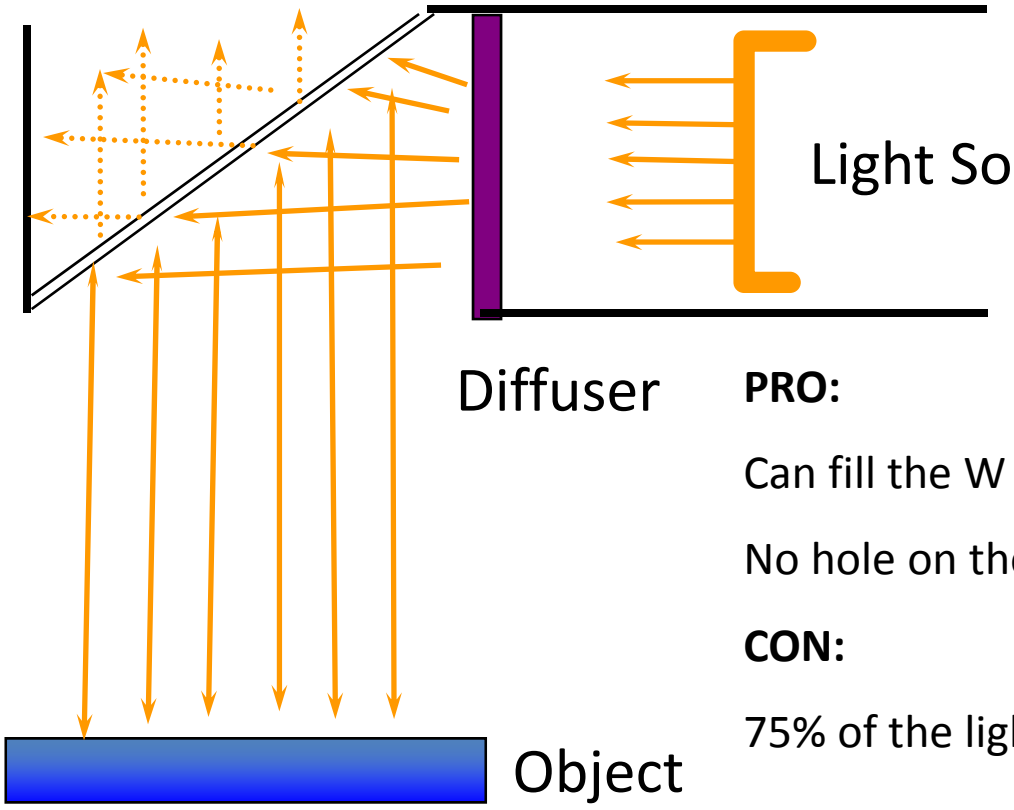
Consider actual practical lights and how they perform

Diffuse On-Axis Light (DOAL®)

Diffused On-Axis Light

Diffused on-axis light, also know as co-axial light





PRO:

Can fill the W

No hole on the sky

CON:

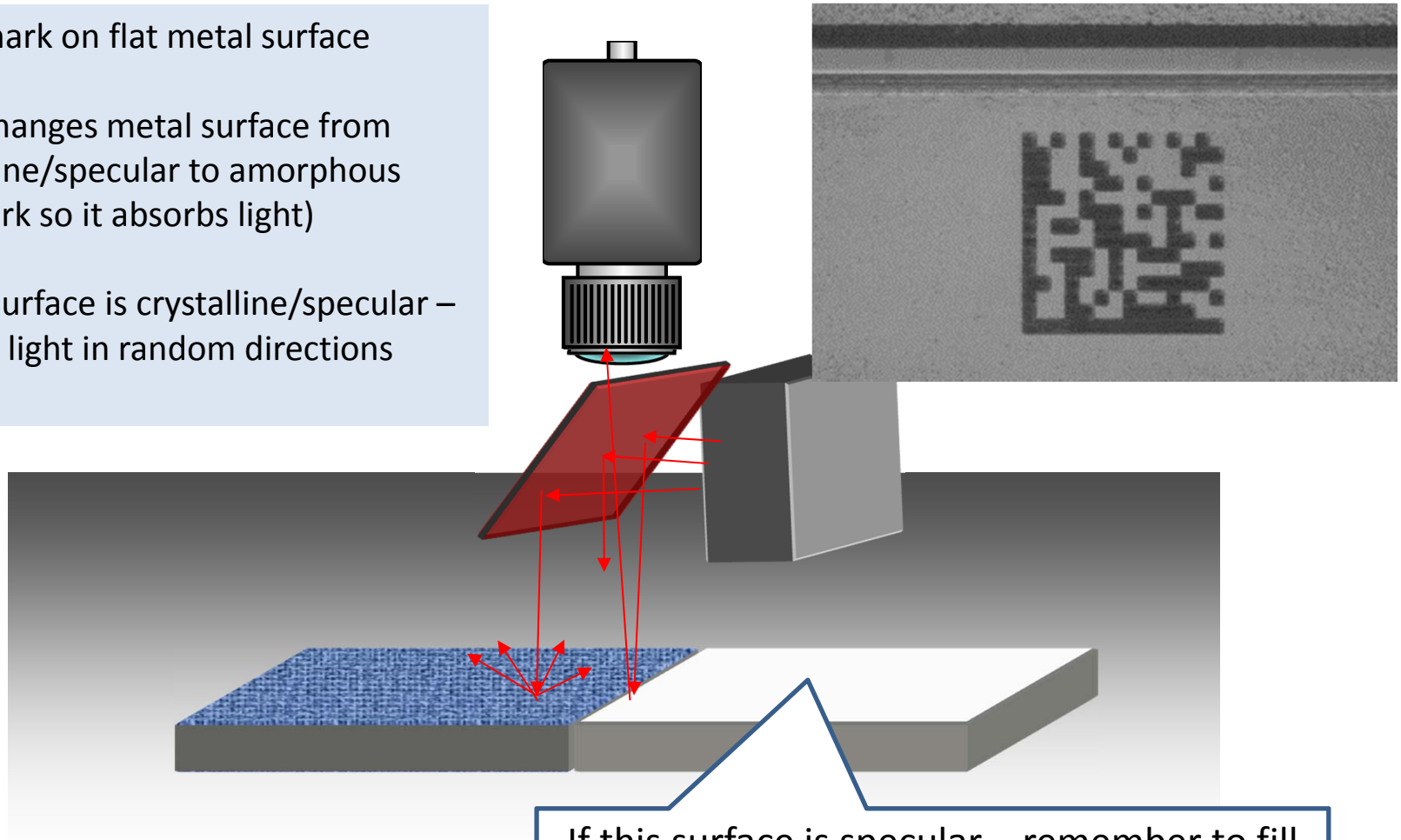
75% of the light gets lost

Use of DOAL 1 – Surface Properties

Laser mark on flat metal surface

Laser changes metal surface from crystalline/specular to amorphous (and dark so it absorbs light)

Metal Surface is crystalline/specular – reflects light in random directions



If this surface is specular – remember to fill the W

Emphasize finish / texture (reflection) differences

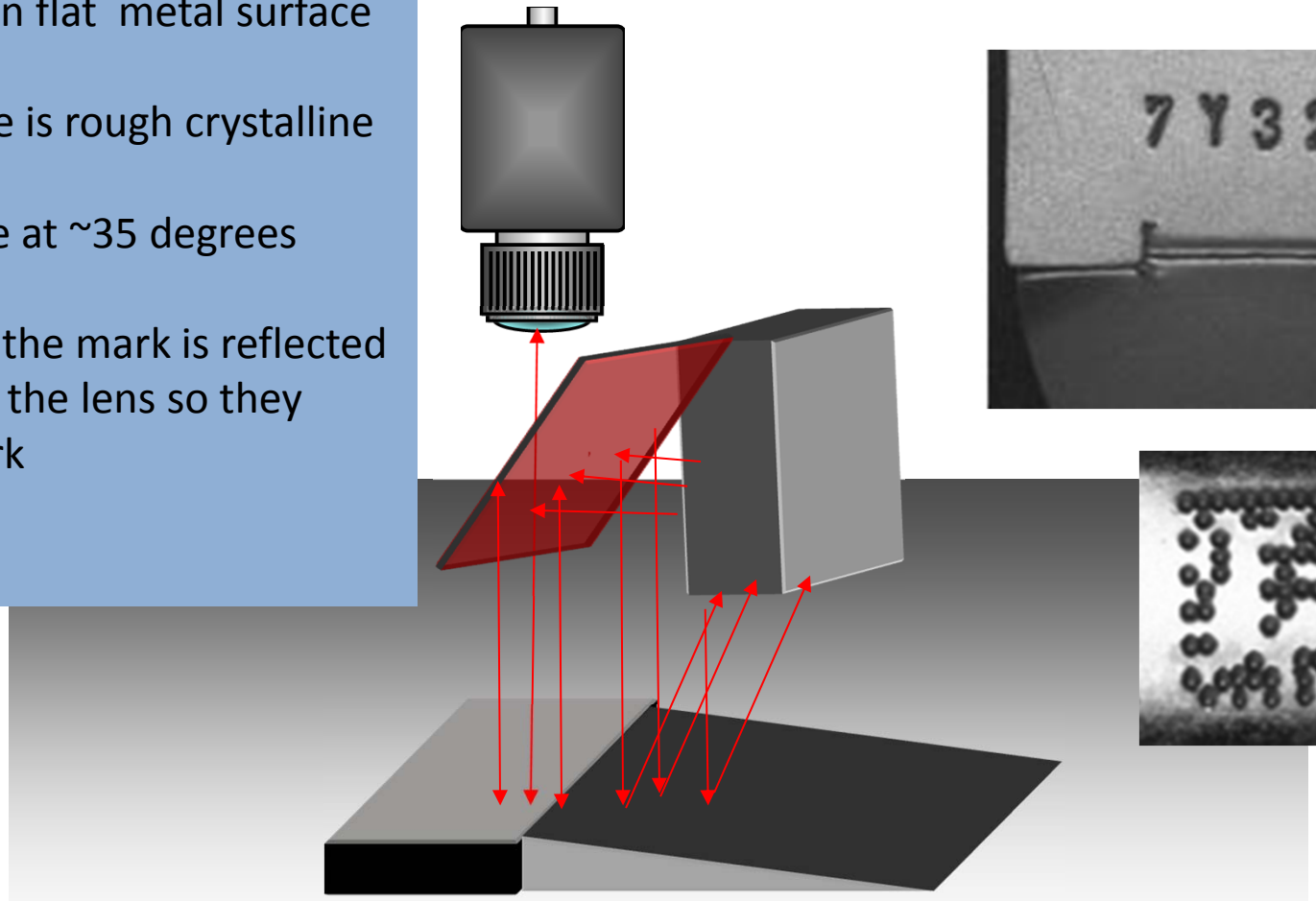
Use of DOAL 2 - Elevation

Stamped on flat metal surface

Flat surface is rough crystalline

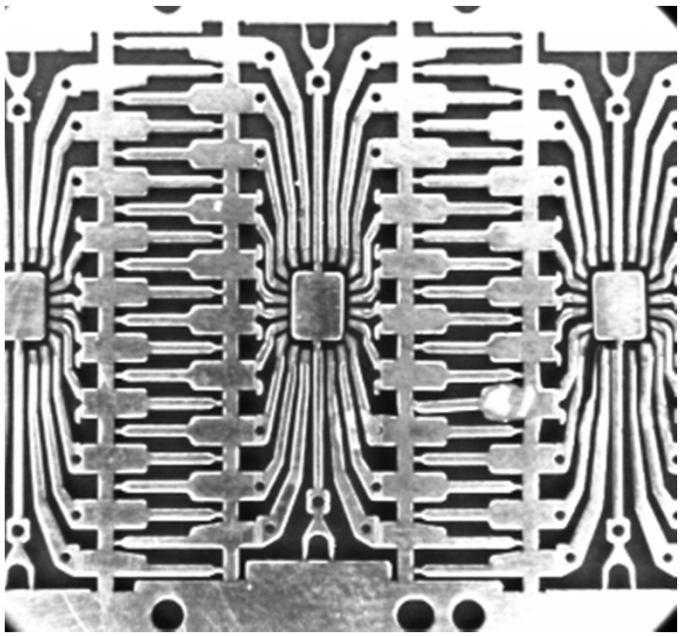
Indents are at ~35 degrees

Light from the mark is reflected away from the lens so they appear dark

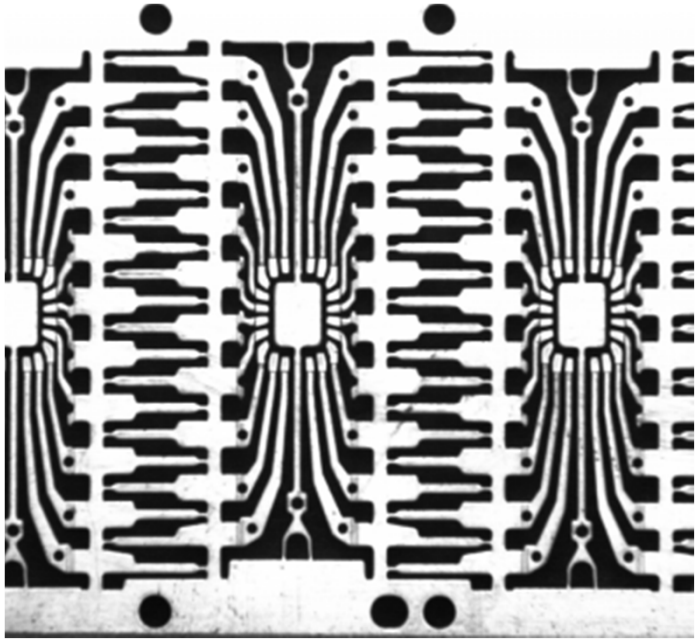


Emphasize elevation differences

DOAL® Lighting Example



Lead frame with ring light

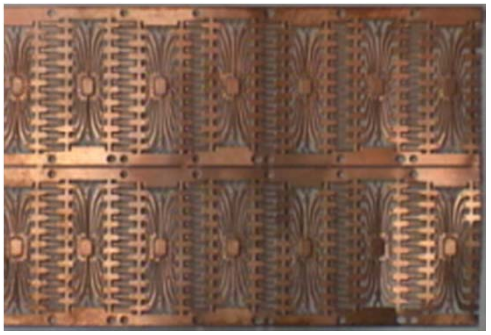


Lead frame with DOAL

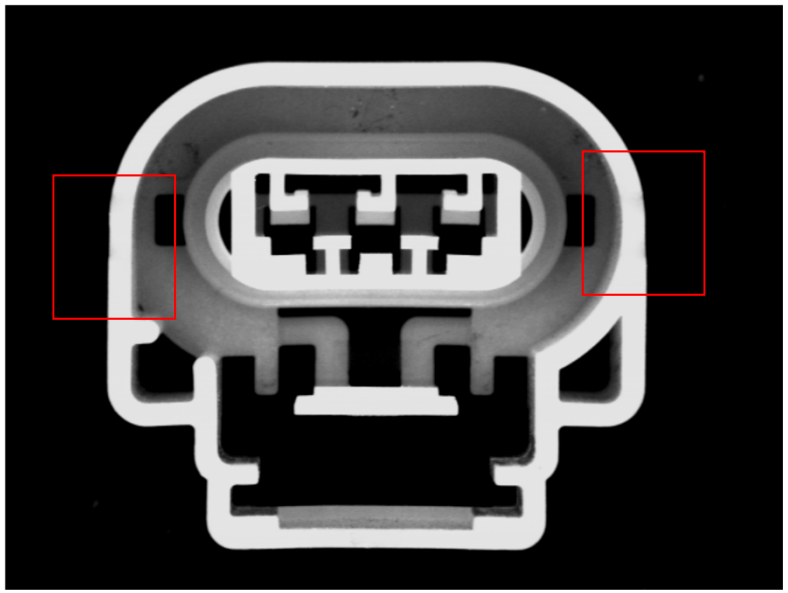
For 10 years we always reached for a ring light

Then came DOALs

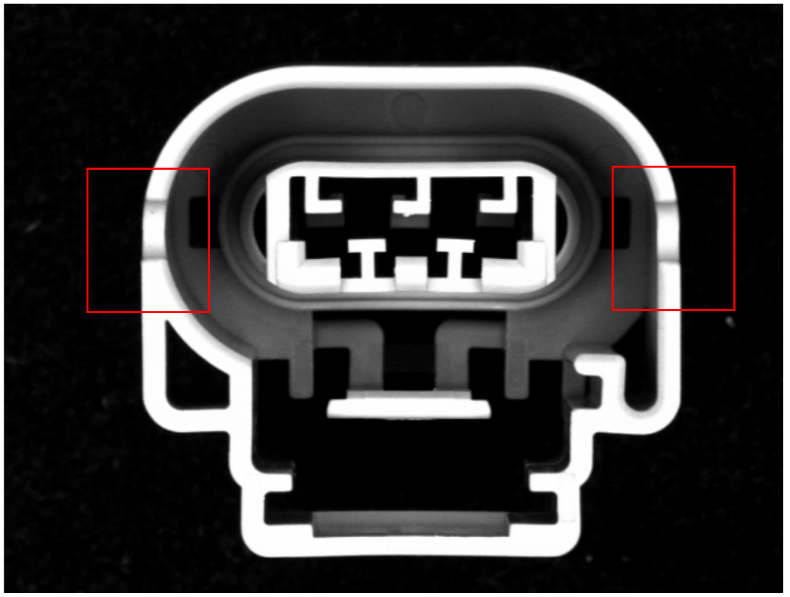
They fill the “hole in the sky”



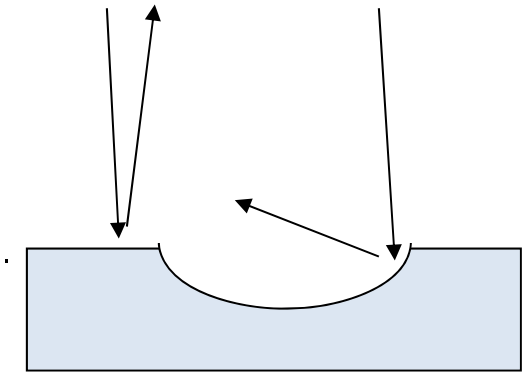
Another DOAL® Lighting Example



Housing



Notched Housing



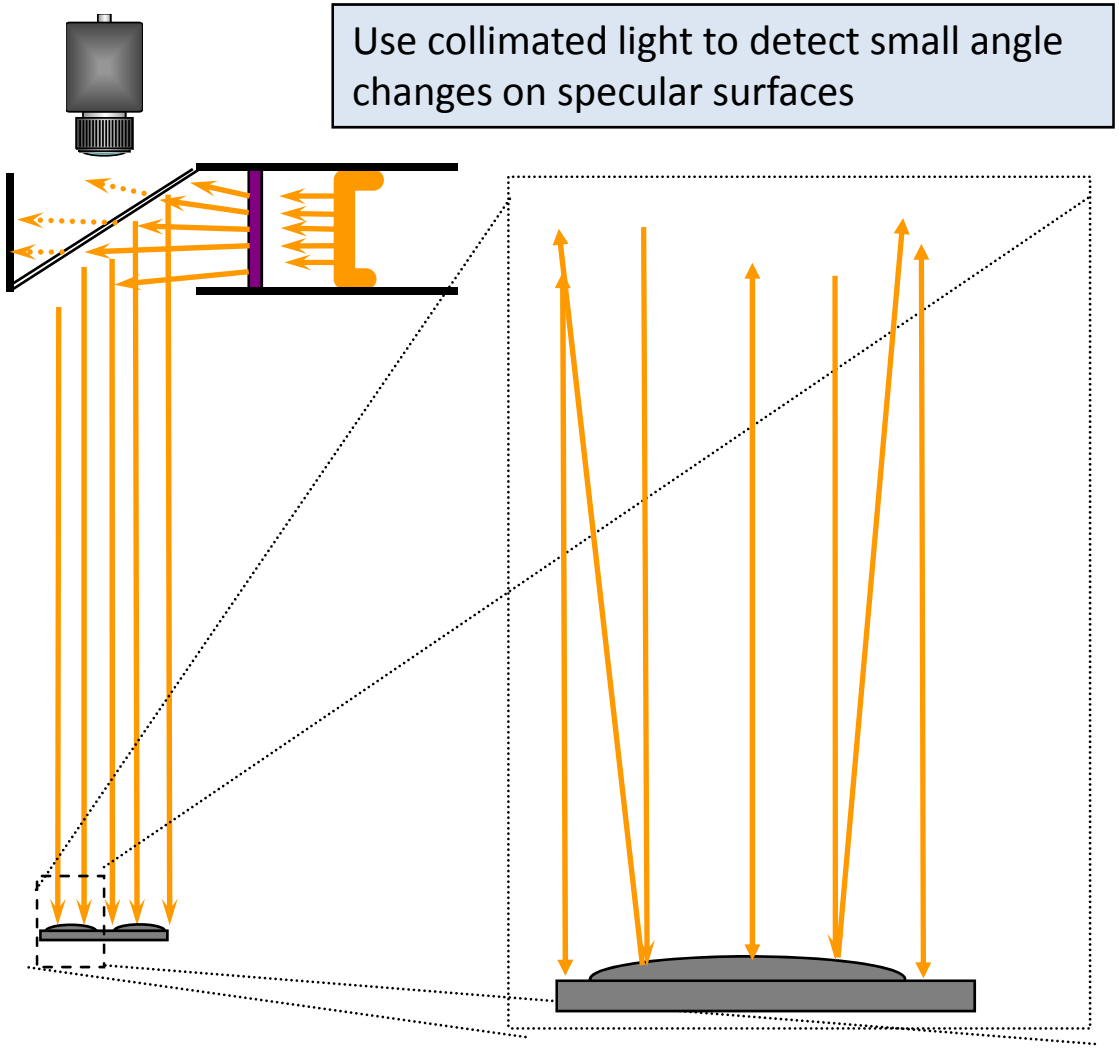
Spot Quiz

Why does this application work?

Distant DOAL Effect: Collimation

Approximating Parallel Rays

Use collimated light to detect small angle changes on specular surfaces

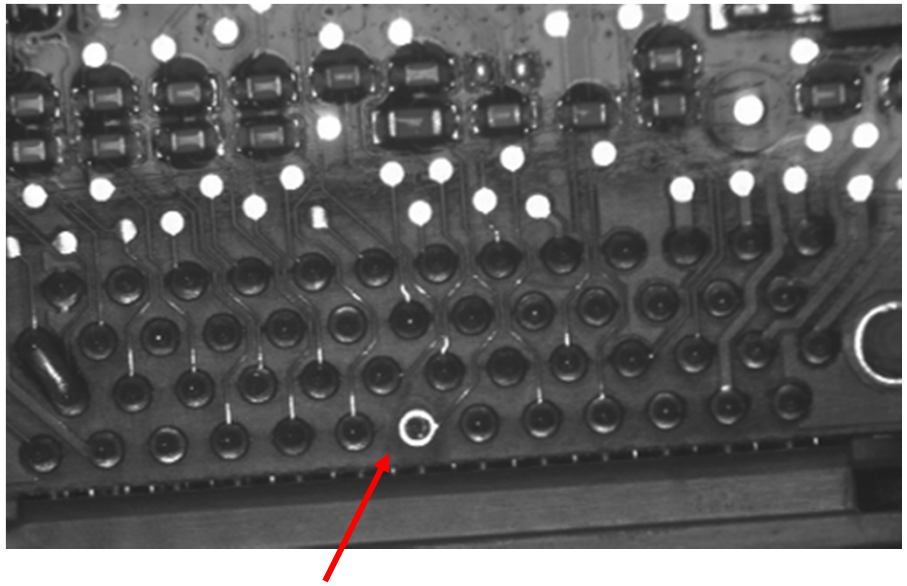


At long distance a DOAL produced light rays that are almost parallel

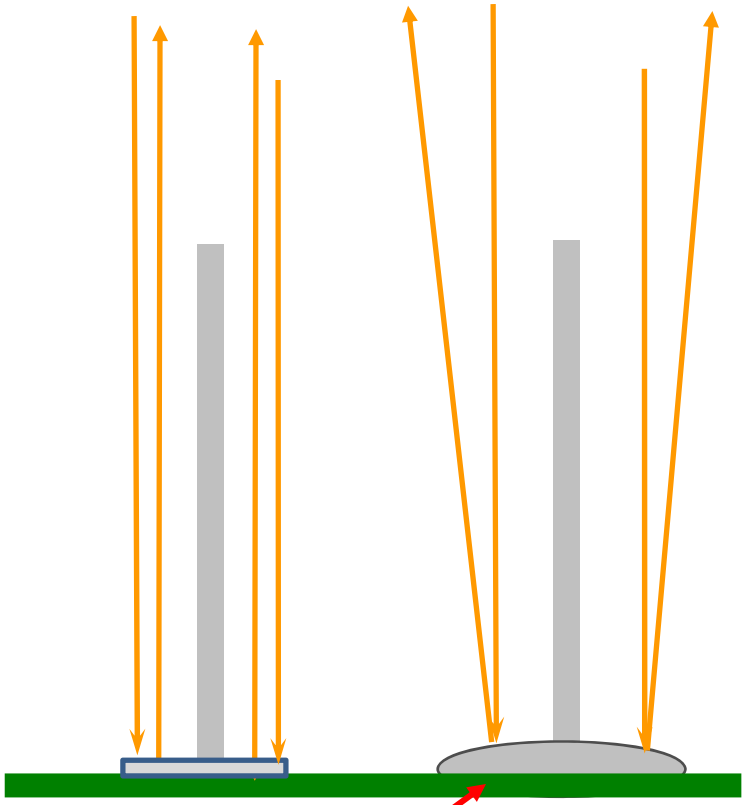
Only the surfaces that are perpendicular to the light source will reflect to the camera. Even the slightest indentation creates contrast.

Differences in surface angle are emphasized.

Distant DOAL Effect

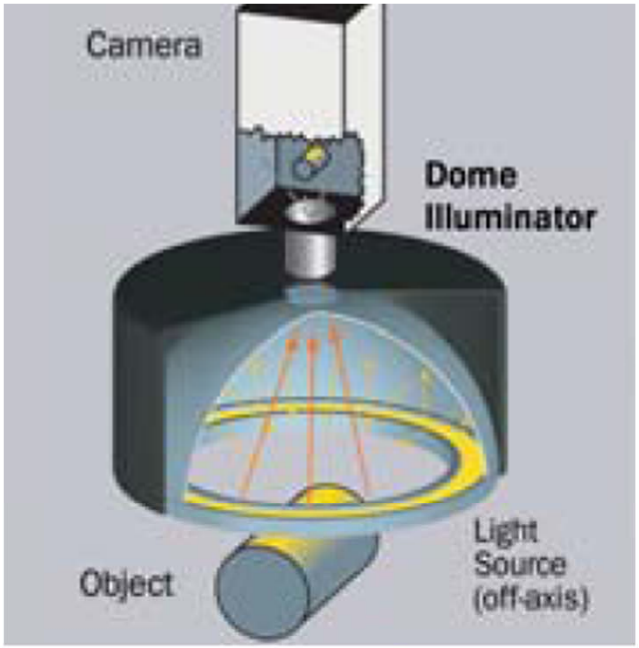


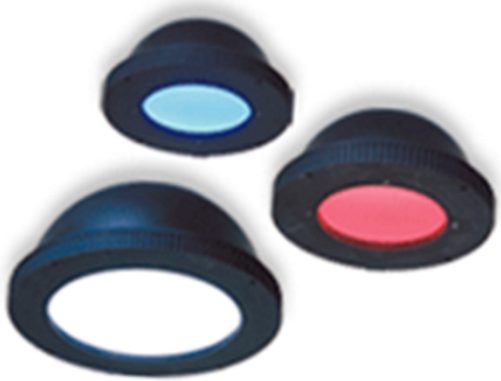
Through hole connector - missing solder at base of a pin



Light reflects at an angle in the presence of solder – so base is dark

Dome Lights – for when the W is very BIG

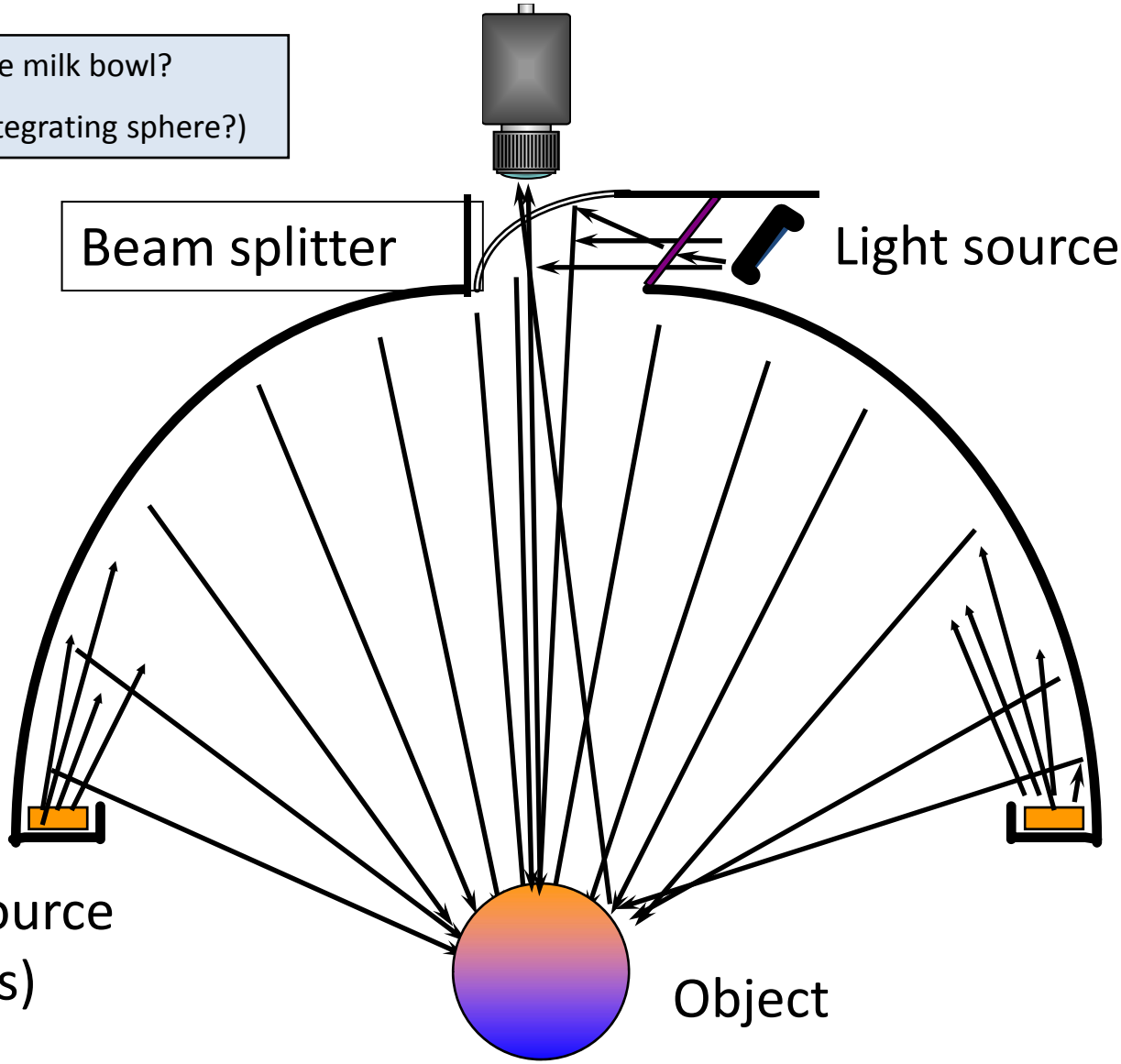




The Super Dome! - Continuous Diffuse Illumination (CDI)

Inside the milk bowl?

(or an integrating sphere?)



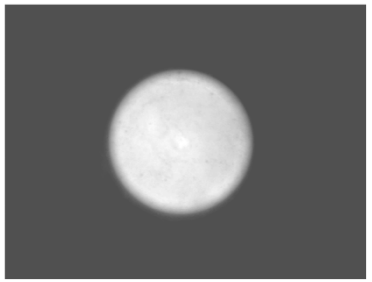
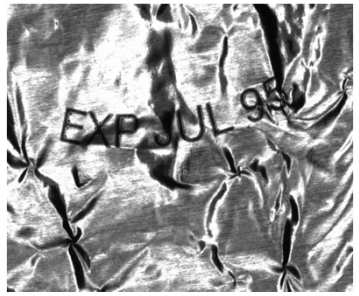
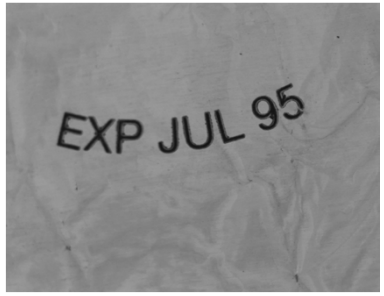


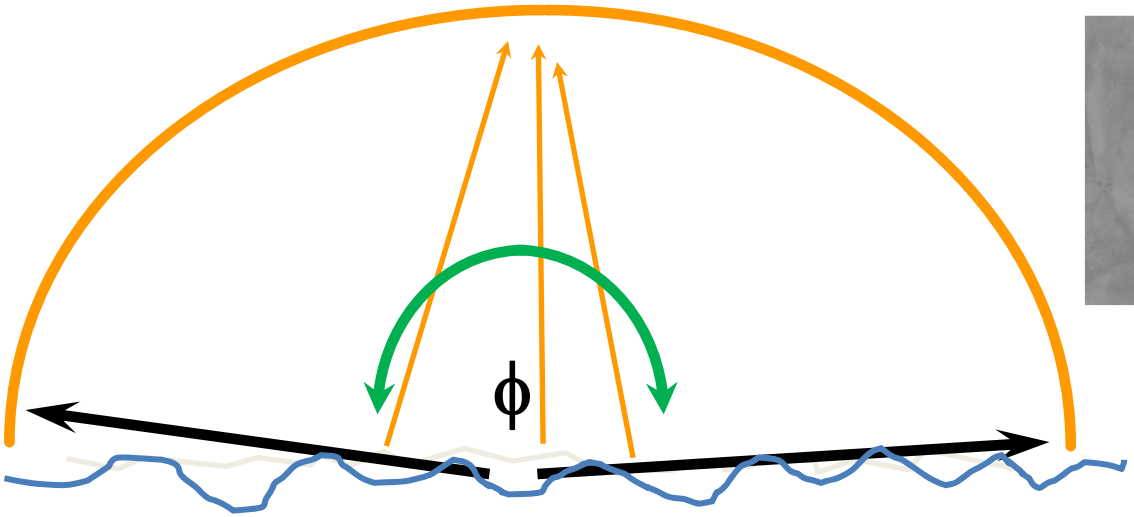
Image of Specular Sphere

Continuous Diffuse Illumination (CDI)

- De-emphasize surface texture
- Enhance absorption versus non-absorption
- De-emphasize elevation







Creates large solid angle of illumination

Example of Using CDI Lighting

The Problem:
Detect Print and Defects on Beverage can base

The Solution:
CDI illuminator delivers a large solid angle of illumination - uniform white light from every angle.

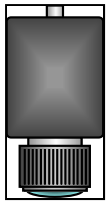
Beverage can with ring light

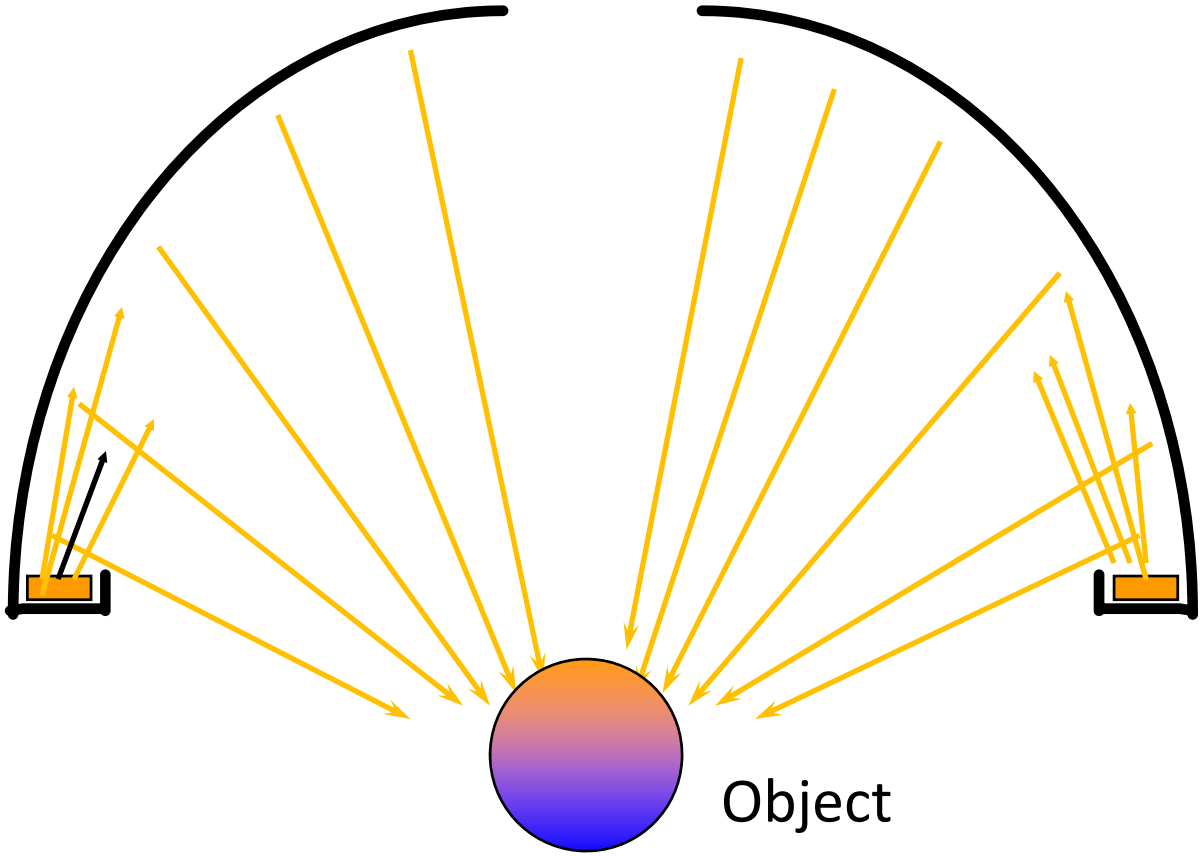
Beverage can with CDI

Dome Illumination

Simpler than a CDI

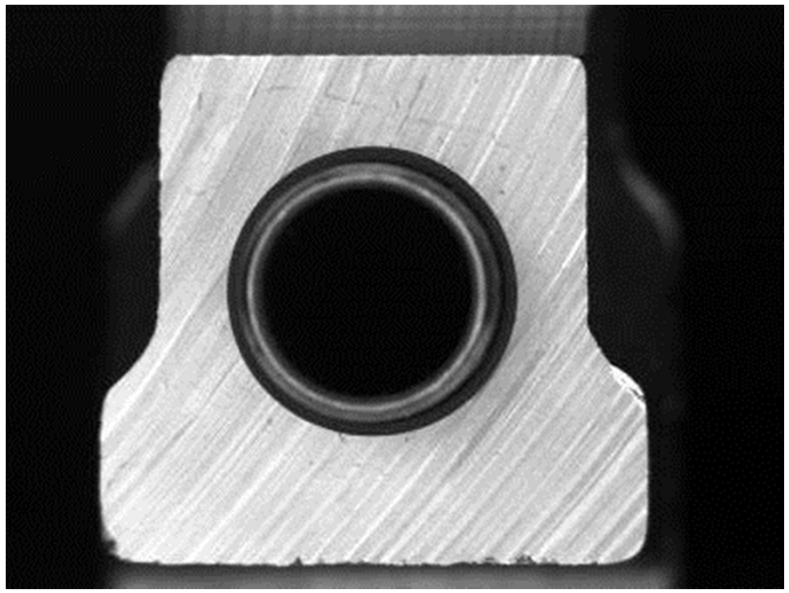
Gives a small hole in the sky



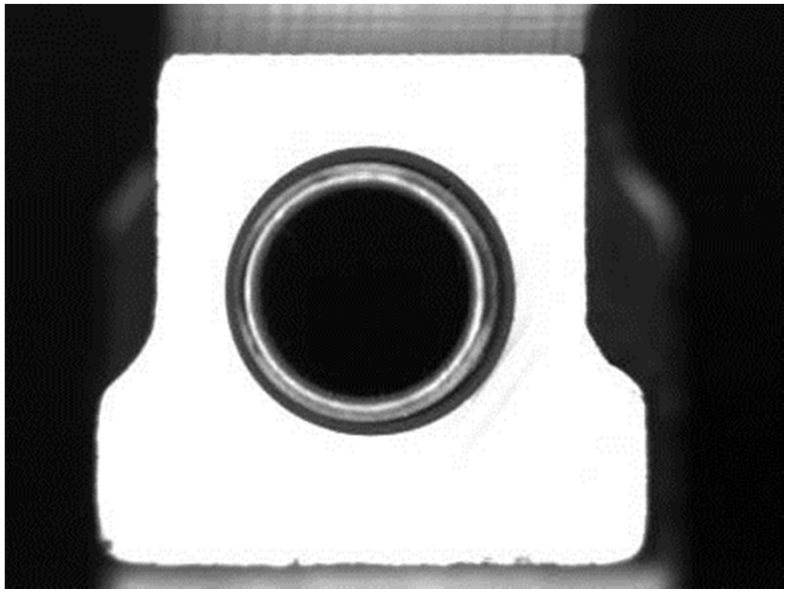


Dome Lighting Example

Sometimes it is OK

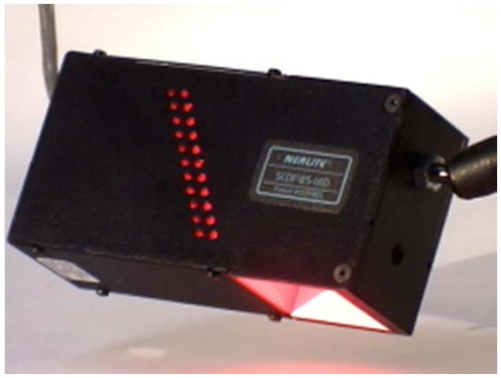


Machined surface with area light

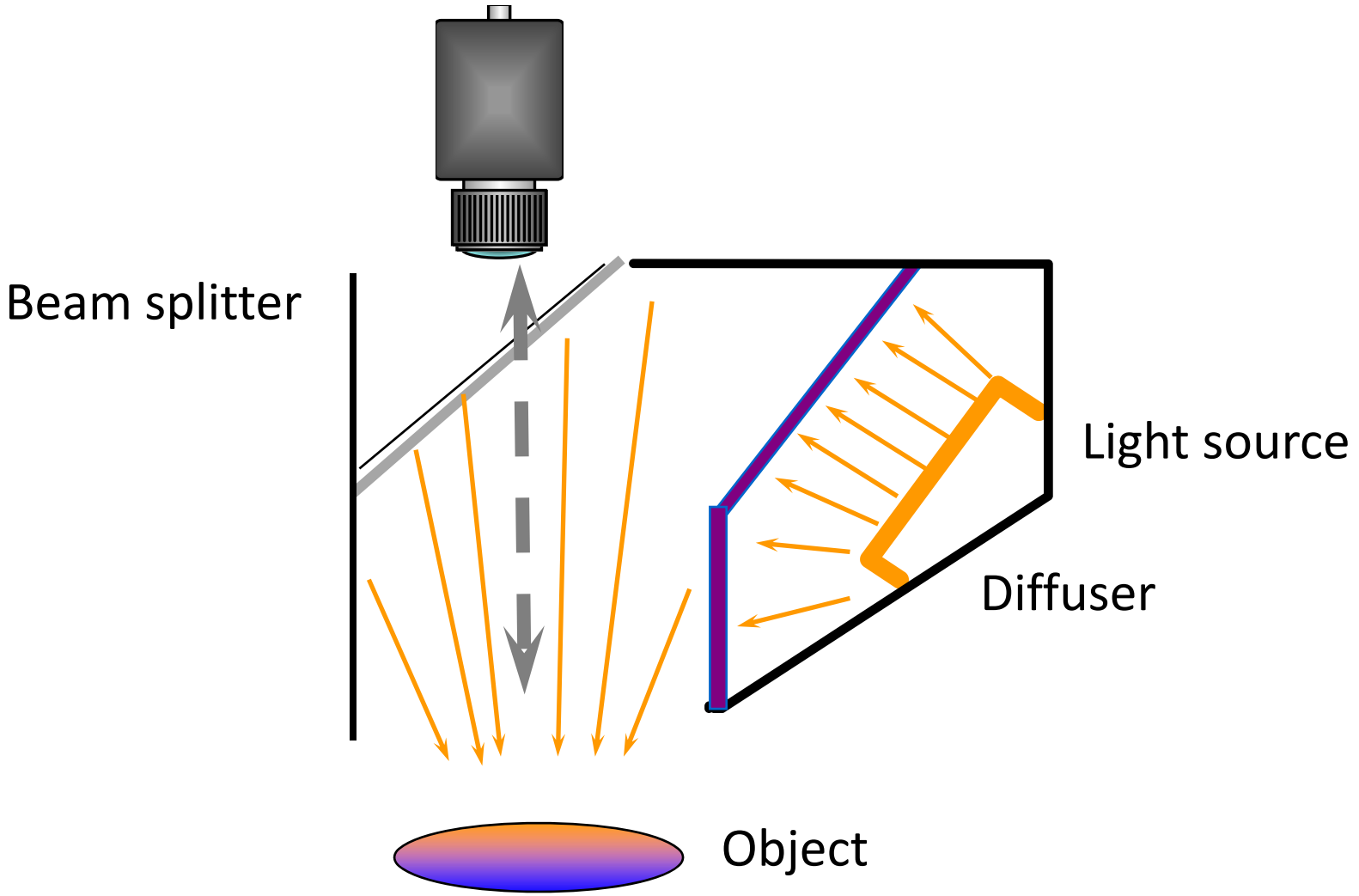


Machined surface with dome light

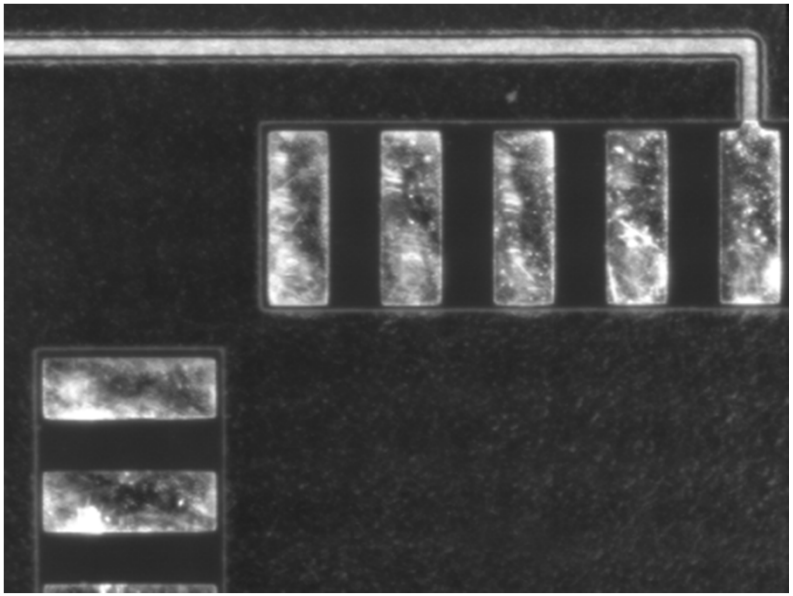
Square Continuous Diffuse Illumination (SCDI®)



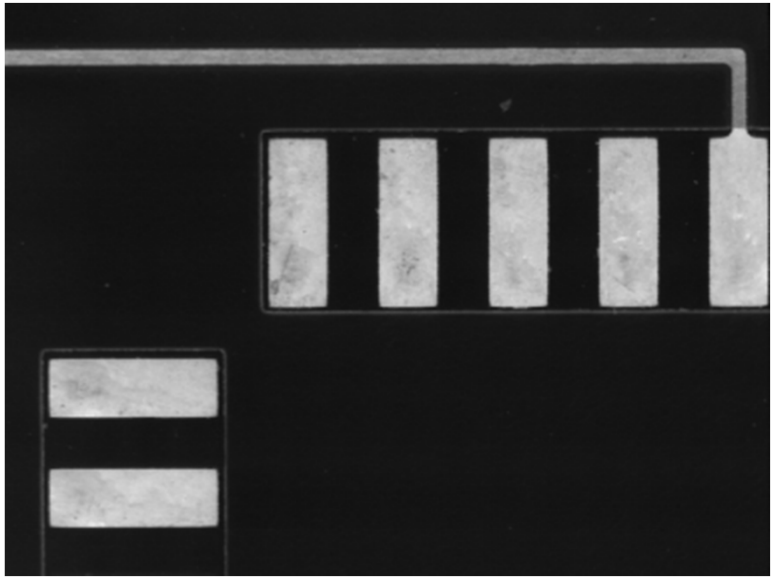
Almost a Dome Light - Square Continuous Diffuse Illumination (SCDI)



SCDI® Lighting Example

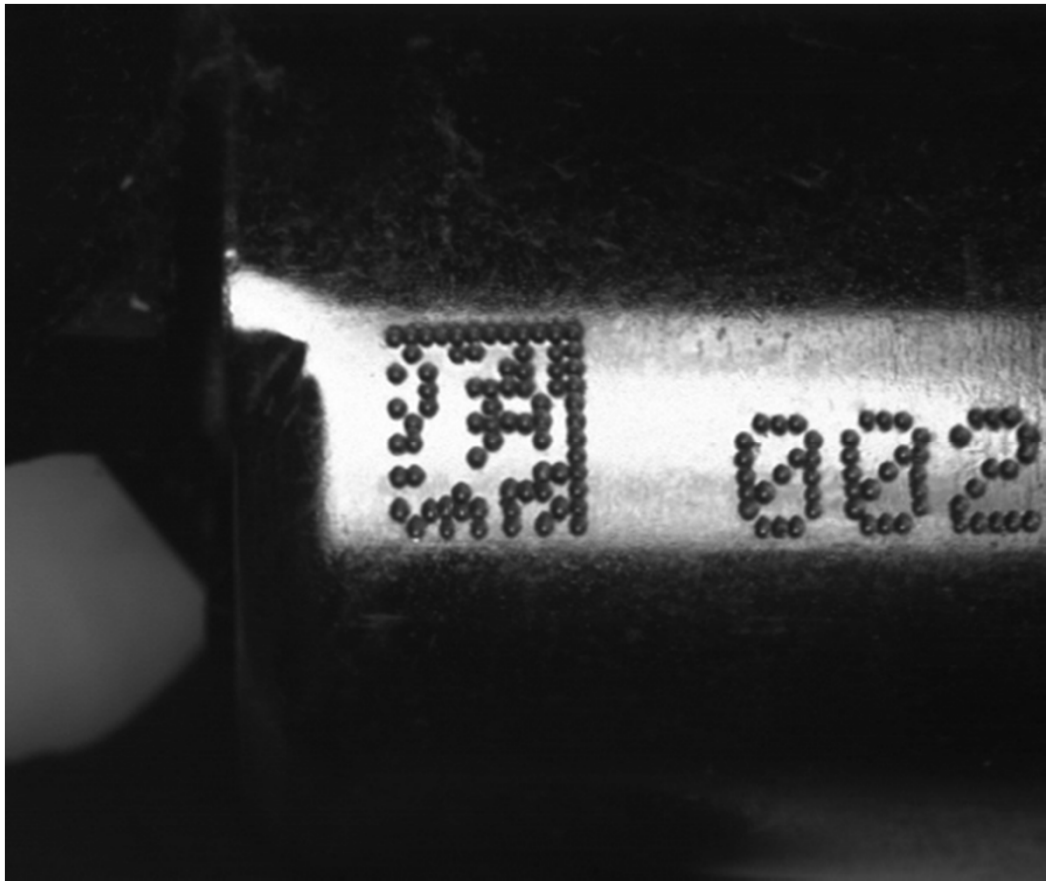


HASL board with ring light



HASL board with SCDI

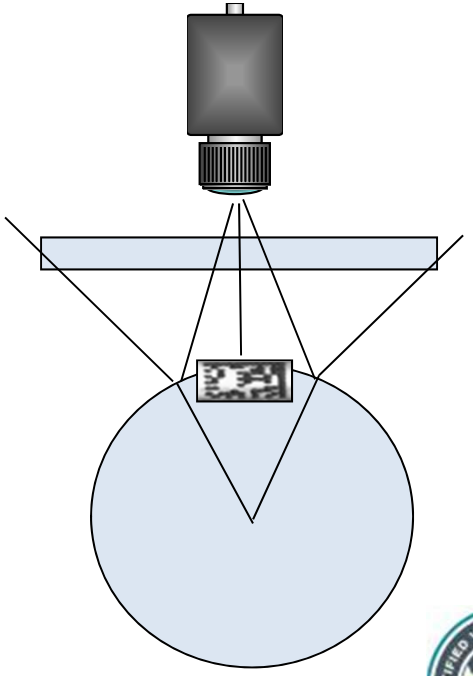
SCDI® Lighting Example



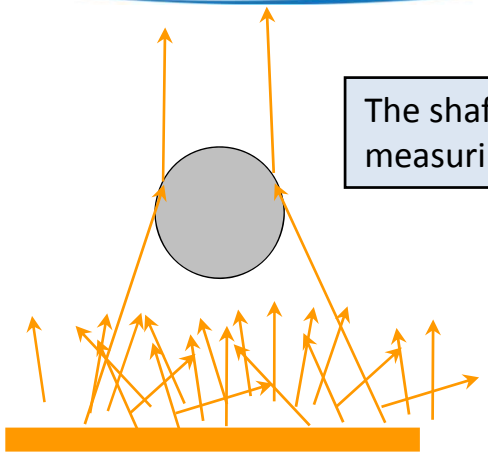
Stamp on shiny cylindrical surface

Data Matrix can cover 1/6 diameter of the circumference of a cylinder.

Must fill the “W” for at least 10% more than that of the mark.

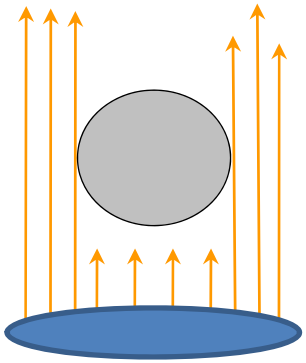


Collimated vs. Diffused Backlight



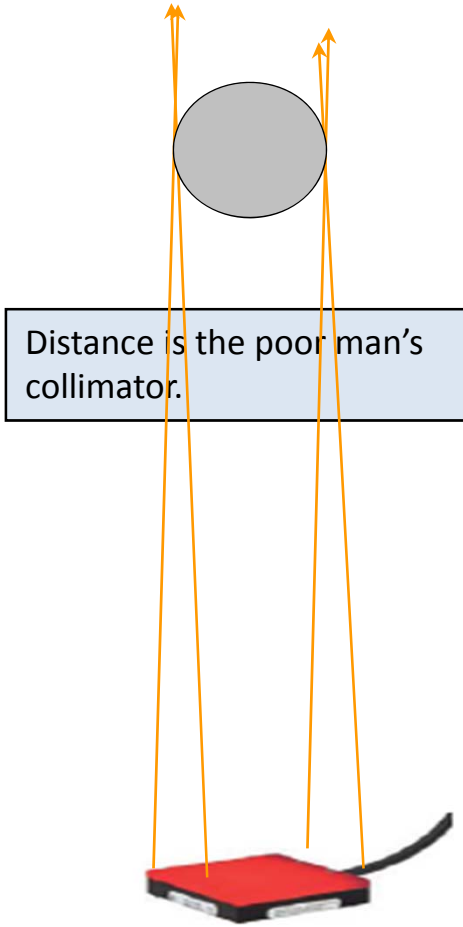
The shaft diameter measuring problem.

Diffused



Collimated

To achieve collimated light use a collimated lens or elongate the optical path.



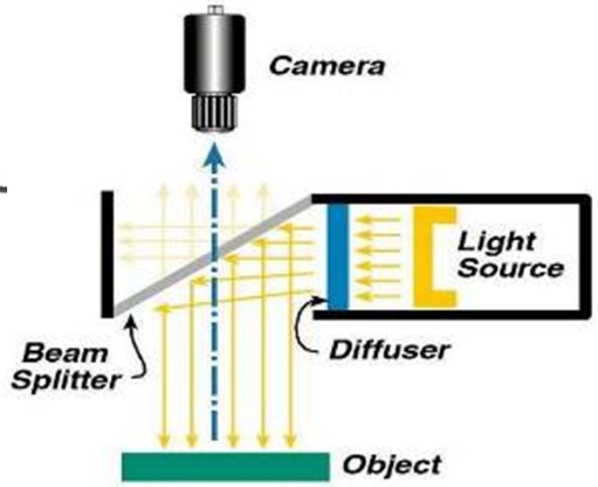
Distance is the poor man's collimator.

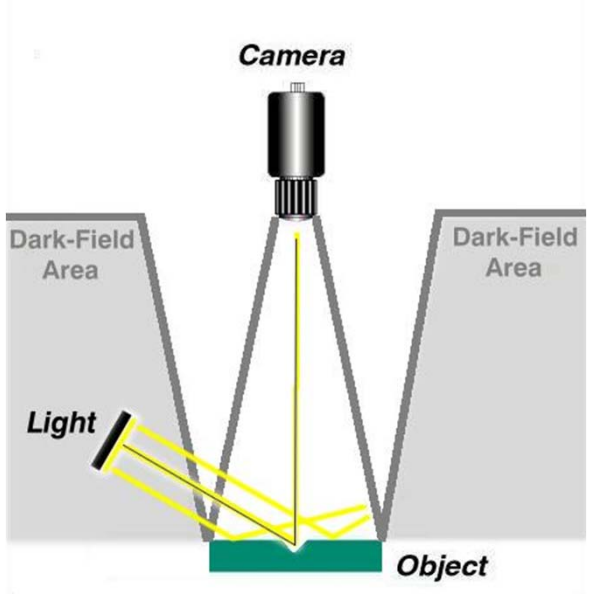
Nearly Collimated

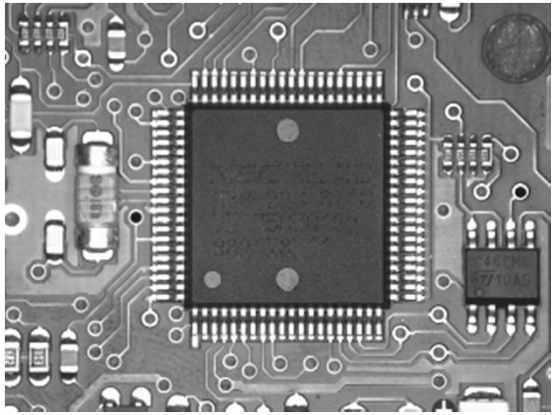
Use a collimated backlight to avoid glancing stray light off curved surfaces and reflecting to the camera.

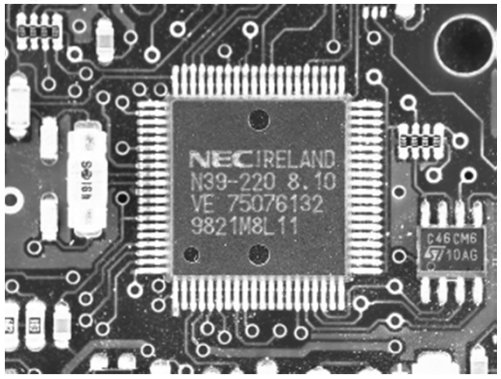
Multi-Axis Lighting Example

Problem: Inspecting assembled PWBs
The Solution: DOAL Lighting in combination with a Dark Field ring light enabled accurate "AOI"





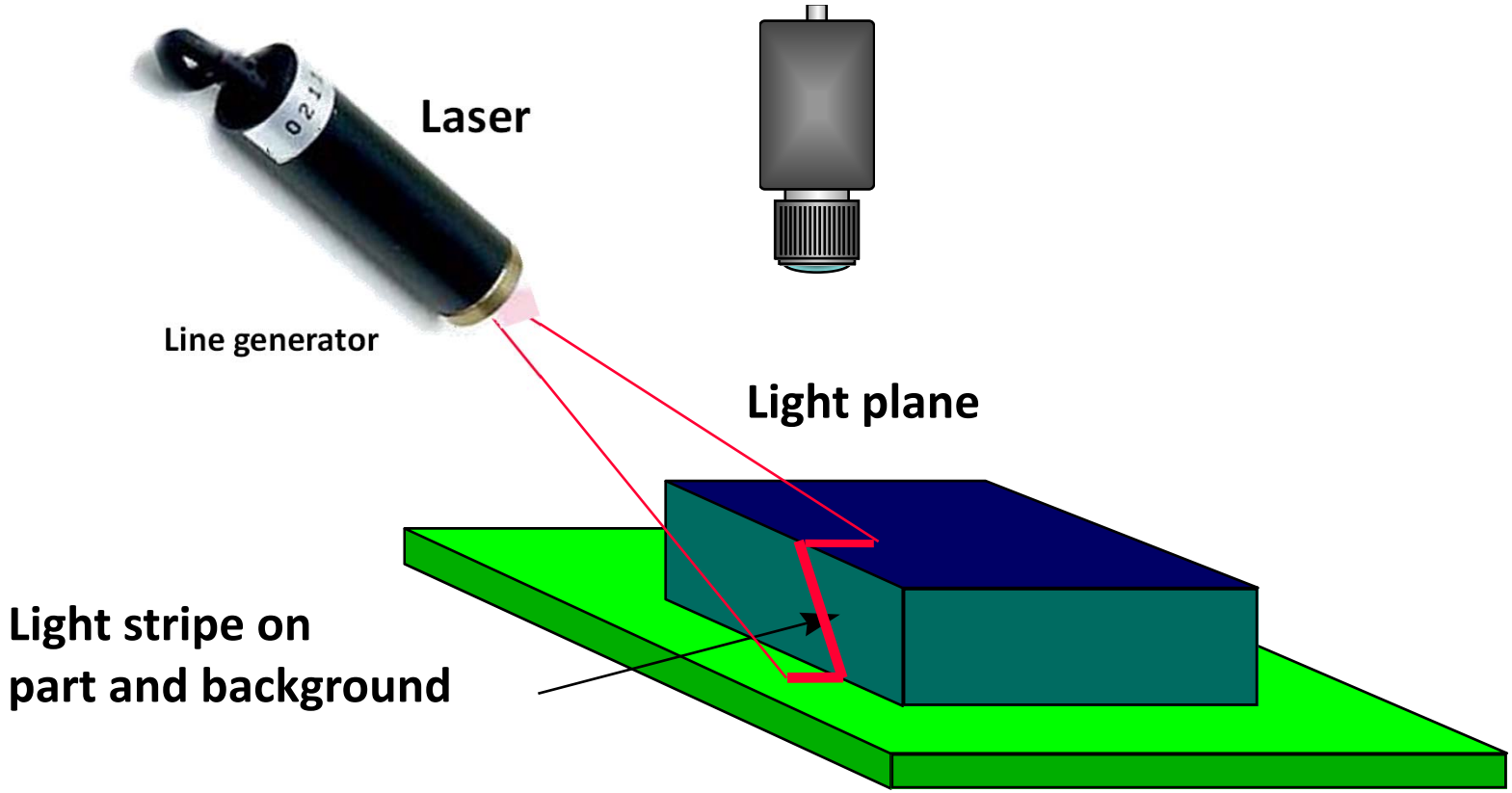




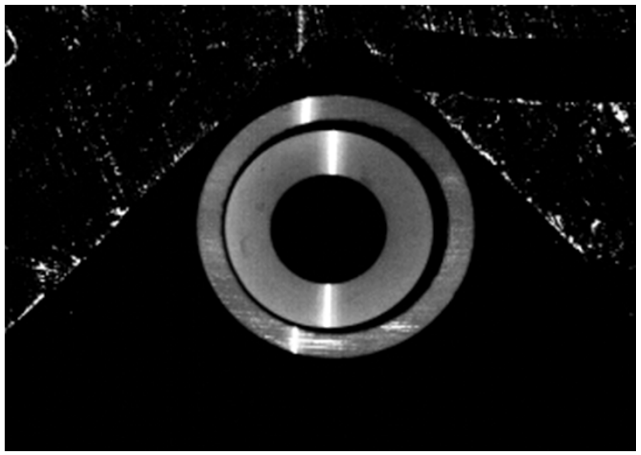
Dark field ring light is the laser marked plastic package's best friend

Consider **Image Arithmetic**

Structured Light

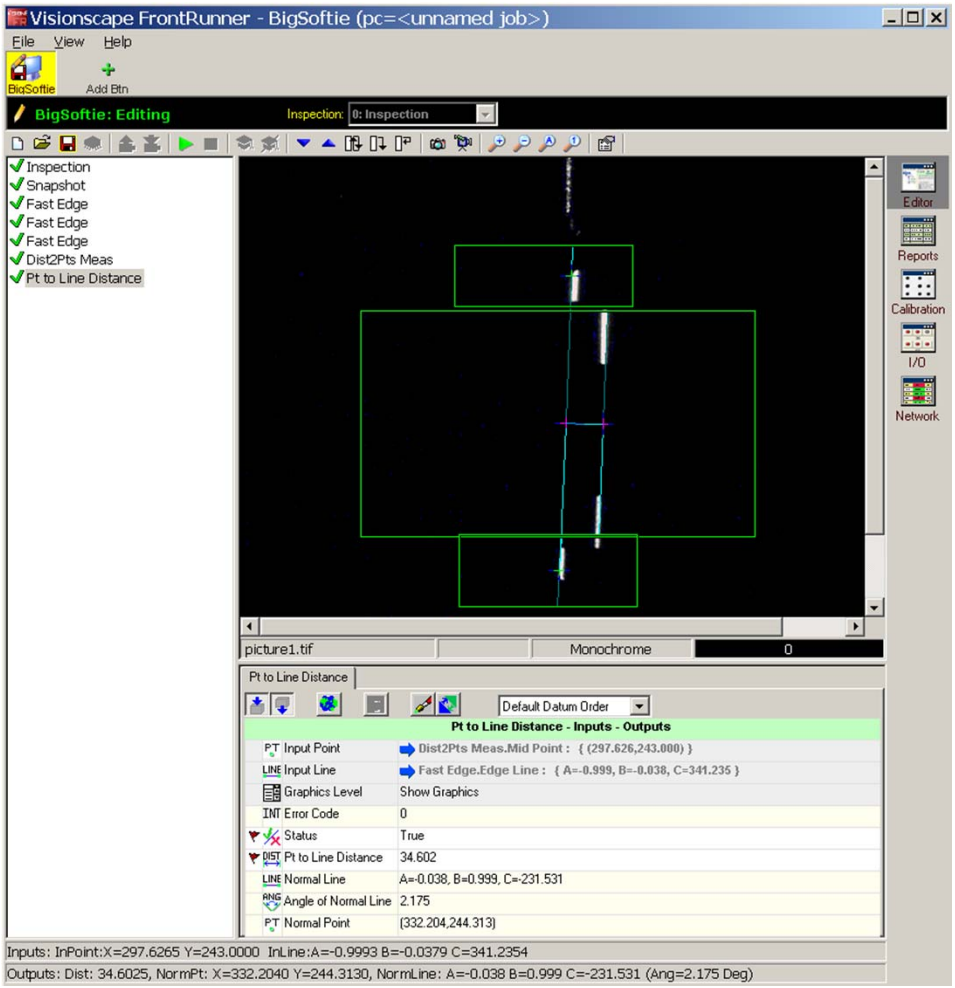


Structured Lighting Images



Tube with line light

Tube with line light “F-stopped” down



Application to measure tube step height

Summary: Advanced Techniques

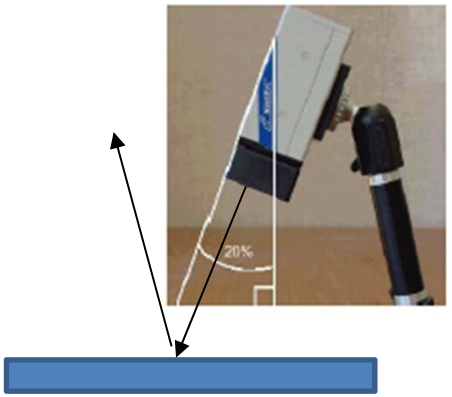
- Co-Axial (DOAL)
  - Makes flat shiny things bright, discriminates elevation & texture
- Collimated Co-Axial (Move the DOAL away)
  - High intensity, parallel rays, detect small angle or elevation changes
- Domes and Continuous Diffused Illumination
  - Minimize texture, elevation changes, creates a “flat field”, measure absorption
- Multi-Axis
  - Combination lighting for interesting projects
- Structured Lighting
  - Looking at patterns of light and deviations and infer Z height

Smart Cameras with Built-in Lights

- Smart Cameras and Symbology Readers may have built-in lights

Q - What is a practitioner of the scientific method to do?

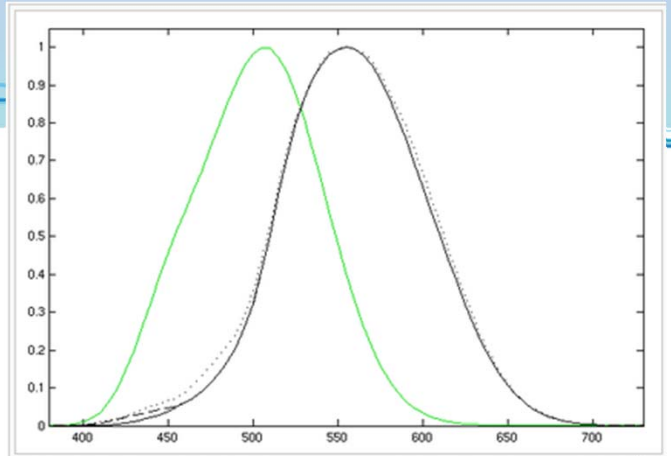
A - If the surface is crystalline/specular – angle to camera 15 – 20 degrees to create dark field lighting – without too much distortion.



Other Topics

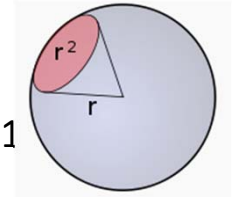
- Lighting Intensity
- Polarization
- Color Imaging and Colored Lights
- Lighting Trends and the World of LEDs
- Strobe Lighting and Control
- The Eight Things to Remember

Lighting Intensity



Photopic (daytime-adapted, black curve) and scotopic [1] (darkness-adapted, green curve) luminosity functions. The photopic includes the CIE 1931 standard

- **What is the relative overall output of this light?**
- **How much gets to where I need it?**
- **How much do I need?**
- **Definition of Radiometry and <u>Photometry</u>**
- **SI Units**
  - Lumens– Total amount of <u>visible</u> light emitted by a source. The effective power of a light
    - 100 Watt incandescent bulb is 1600 lumens
  - Candela – Power in a particular direction. One candela is one lumen heading out in 1 steradian solid angle
  - Lux – Luminous Flux per square meter. One Lux is one Lumen arriving at or leaving one square meter.



Lighting Vendors specify in Lumens, Candelas – or not at all

Modern High Bright HB-300	5000 lumens
On-Axis Light	90 candelas (directional)
Backlight	20 candelas (directional)

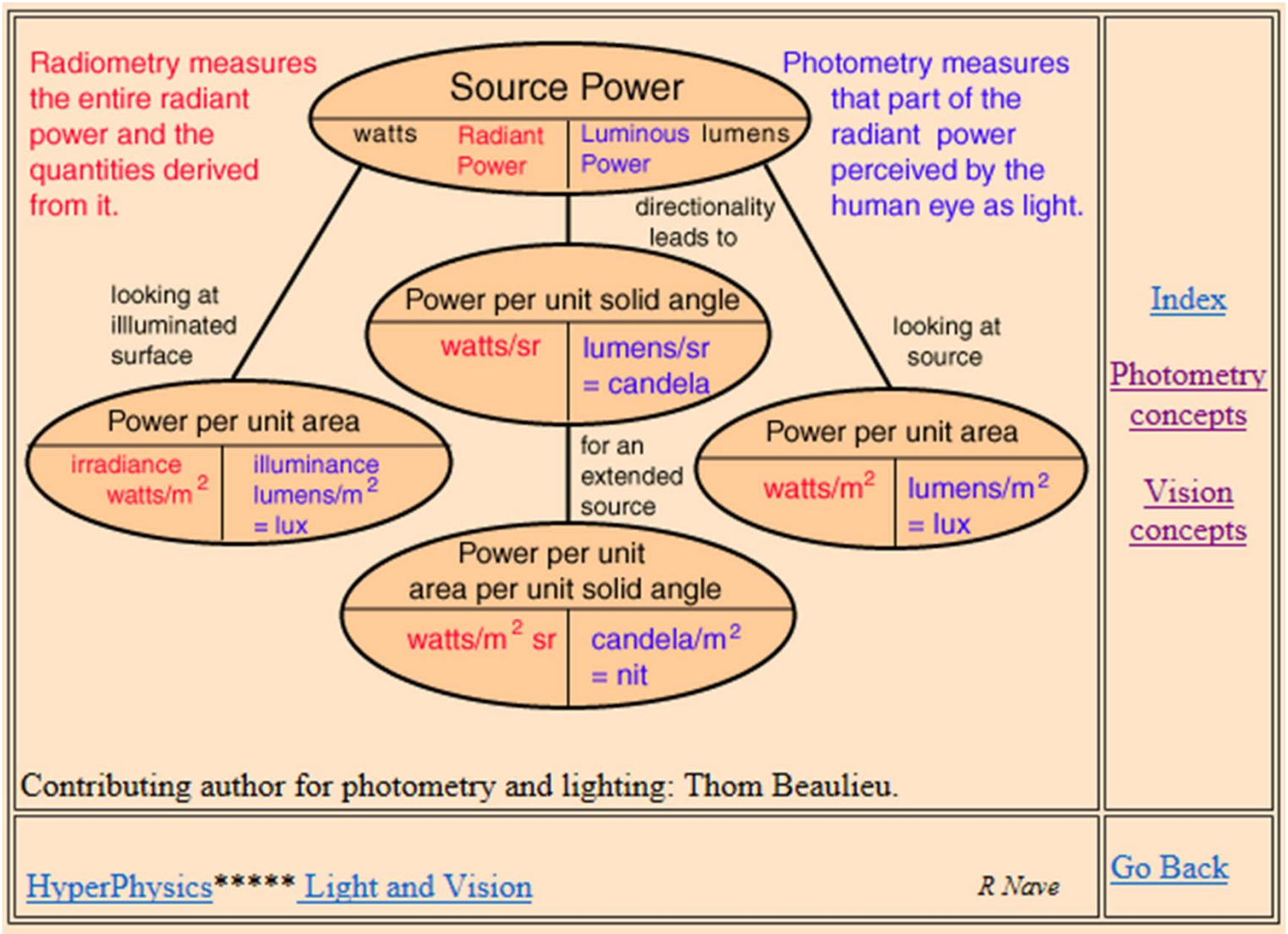
10 Lux	Twilight
100 Lux	Dark overcast day
1000 Lux	TV Studio
10,000 Lux	Full daylight
100,000 Lux	Bright Sunlight
2,000,000 Lux	Water Cooled

Line Light for Line Scan Machine Vision

How much light required at the object depends on

Object, Sensor, Aperture, Distance, Exposure Time (continuous, strobe, line scan), Ambient Lighting

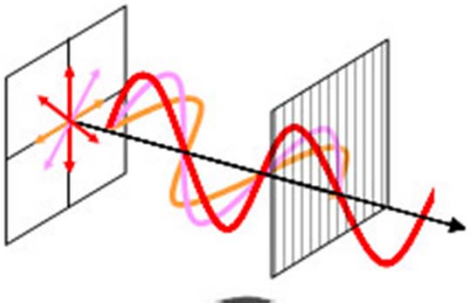
Further Reading

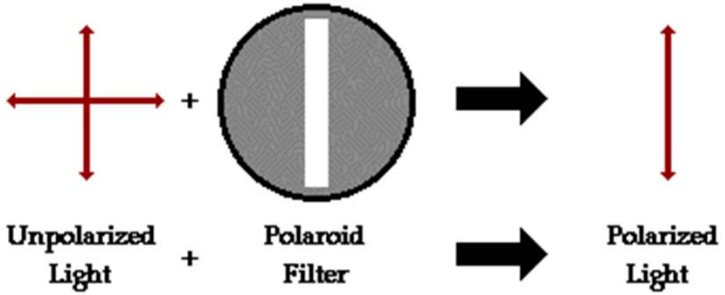


http://hyperphysics.phy-astr.gsu.edu/hbase/vision/radphocon.html#c1

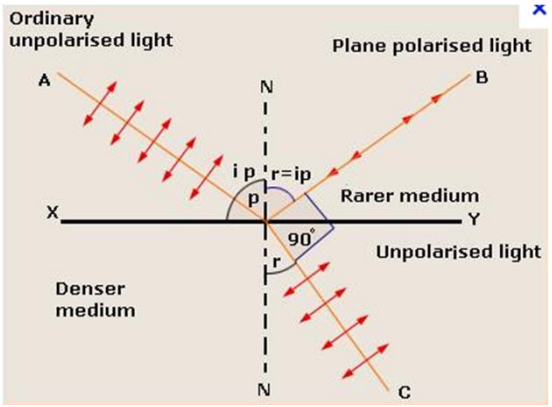
Using Polarized Light

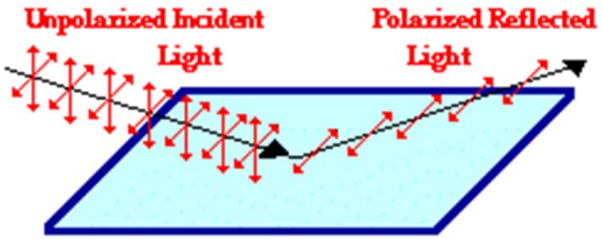
- Polarization?
  - Light vibrates in two orthogonal planes
  - Polarizing filter can cut out one of these.





In nature light is polarized by reflection from a flat specular surface





Reflection of light off of non-metallic surfaces results in some degree of polarization parallel to the surface.

The Polarized Sunglasses Effect

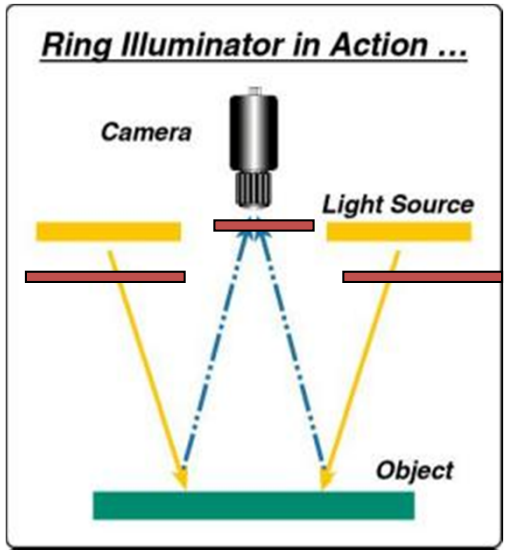
- View a scene through a polarized filter that cuts the reflected polarized light and you will cut the reflection (glare).
- Practical applications

Fishing

Machine Vision

Non-Polarized, F 16

Polarized, **F 5.6**



Polarizer filter at source or camera or both

Color - Why Objects Have Color

col·or

That aspect of things that is caused by differing qualities of the light reflected or emitted by them, definable in terms of the observer.. or your Machine Vision Sensor!

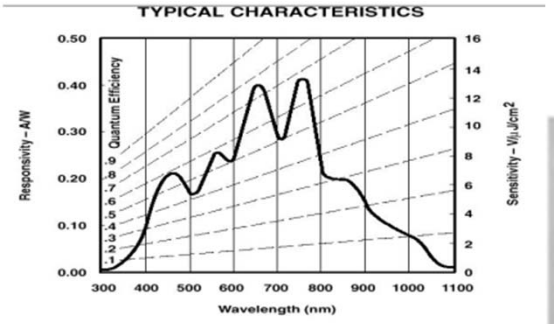
For reflected light - The color perceived by the viewer is the reflected wavelengths, all others are absorbed. (Think about why grass is green!...)

Transmission **Radiation** **Absorption**

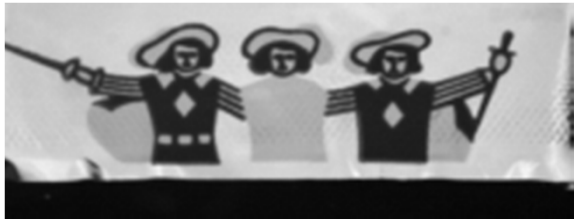
Color Discrimination with Monochrome Cameras

- Case 1: Illumination with White Light
  - Blue darker than green darker than red
  - So colors will have different grey levels with white light
  - POOR MAN'S COLOR

Camera Spectral Response



White Light, B&W Camera



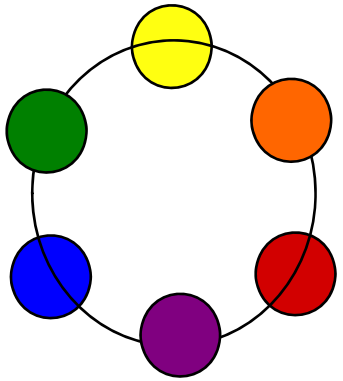
- Case 2: Illumination with Red Light
  - Features that are white or red will be bright
  - Other colors will be dark
  - ANOTHER WAY TO MAKE CONTRAST

Monochromatic Light Effects

More than poor man's color – eliminate background

What color light will provide the highest contrast for the red text and wash out the blue graphics?

BLUE LIGHT: Blue light is reflected from the graphics and absorbed into the red text to create high contrast.

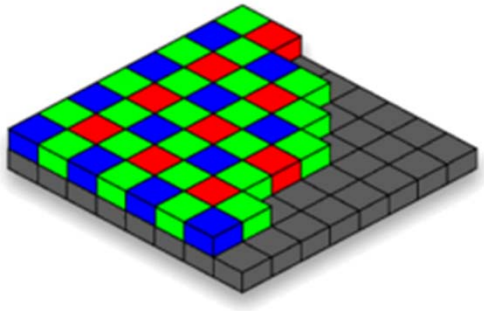


Bayer Filter

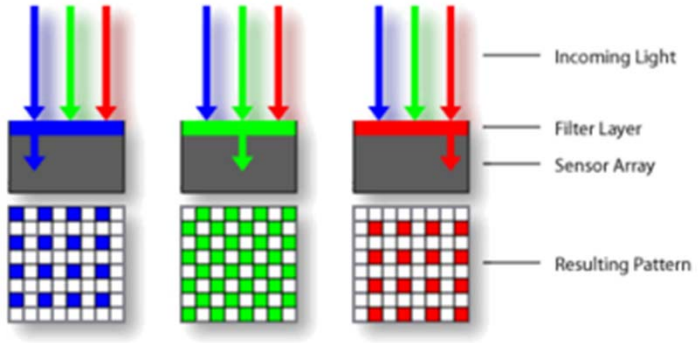
- A quick word about color machine vision cameras
  - Usually have a Bayer Filter
  - Green at ½ resolution
    - Because we humans see more detail in green
  - Blue and Red at ¼ resolution
  - Software interpolates back to full resolution

Remember that you are using a Low resolution image!

For gauging use a 3 sensor camera



Bryce Bayer
RIP 2012



Not All White Lights Are Equal

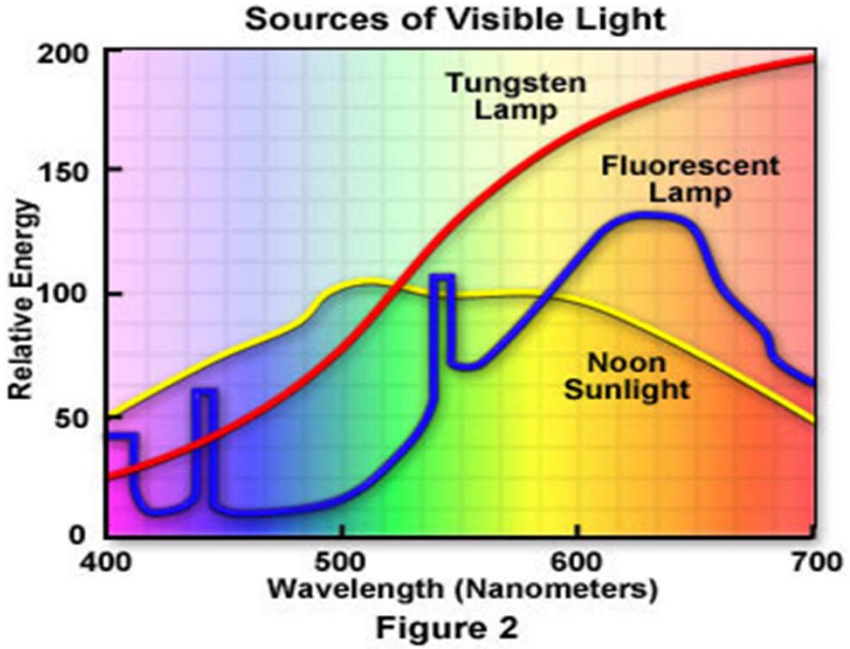


Figure 2

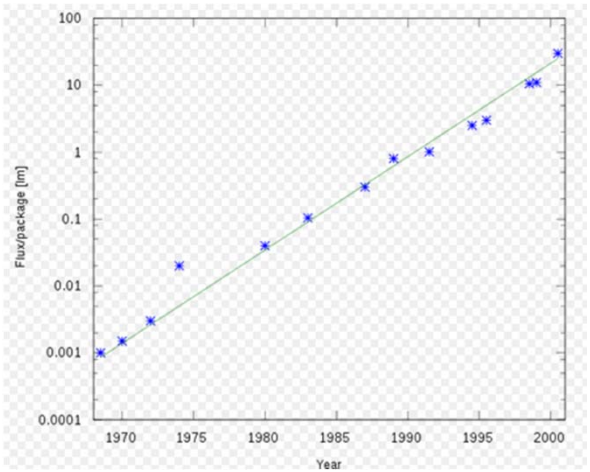
White light sources are measured in Corrected Color Temperature (Kelvin) and have a Color Rendering Index (CRI) number.

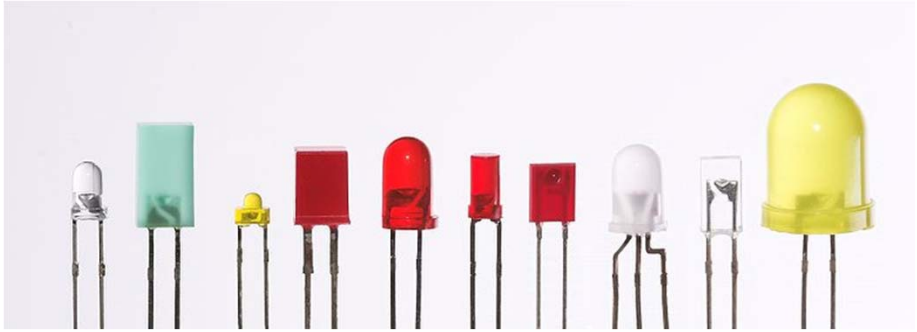
For color camera applications, choose a source with good CRI number. An ideal source will have an ample amount of energy.

LEDs

Have you noticed that LEDs are getting brighter?

Haitz's Law
Every 10 years – Cost /10, Light per package x 20





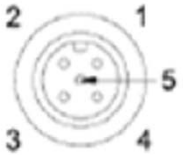
5 Watt LEDs

Say thank you to all those transportation applications

Machine Vision LED Lighting Trends

- **Brighter**
  - Why is this good?
  - Has anyone <u>ever</u> had too much light?
- **Cooler – No Fans**
  - Allows IP (67 or 65)
  - Longer life
  - Lower maintenance
- **Built-in Control**
  - Current Control
  - Built in Strobe
  - Network Devices

M12 5-pin plug:

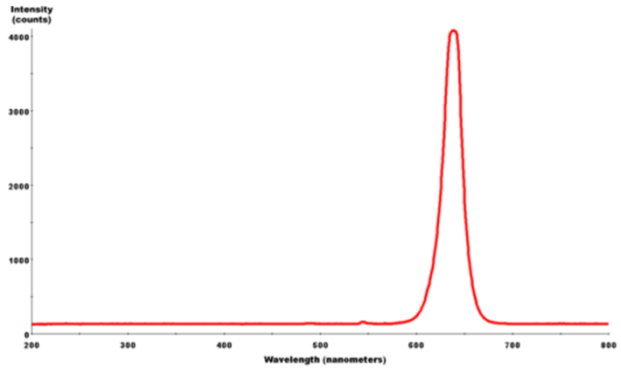


Pin Assignment

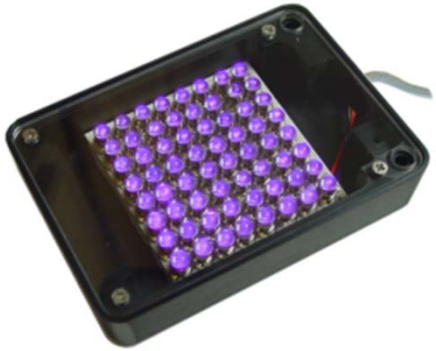
1 +24 VDC
2 Trigger (-)
3 DC Ground
4 Trigger (+)
5 Dimmer

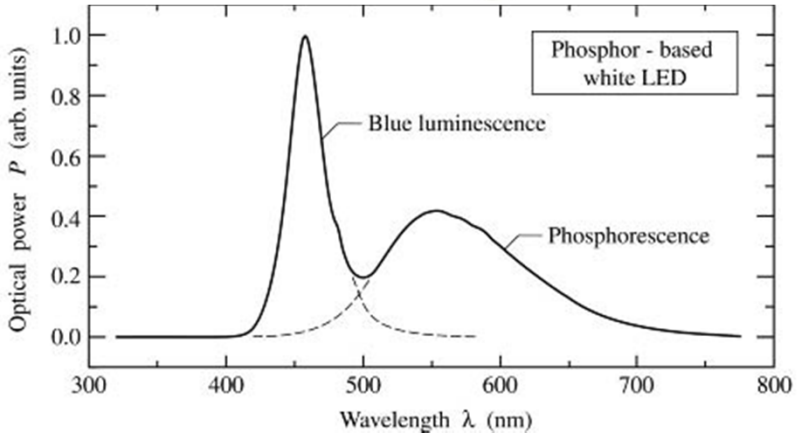
LEDs as Light Sources

- Monochrome LEDs are typically very narrow wavelength band sources
- White LEDs are of monochrome LEDs plus a phosphor – have a spectral peak



Red LED – single peak



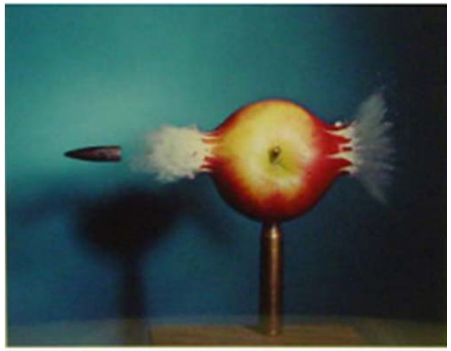


White LED – peaks in blue

Lighting Control: Effect of Motion

- Issue: Moving parts

If you strobe, you must keep out ambient light.



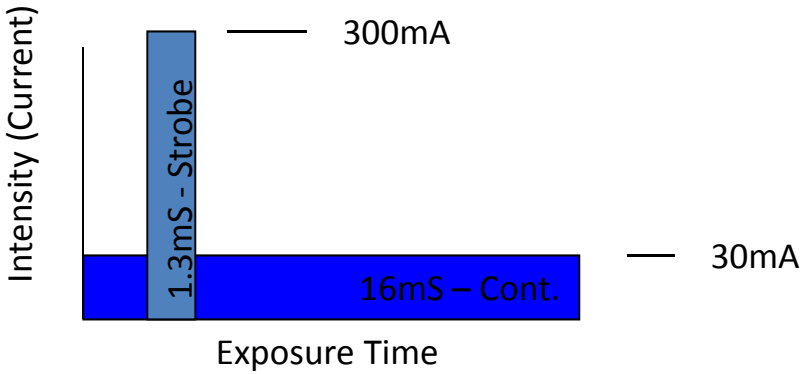
- Solution:
  - Shutter the camera /short image acquisition time
    - Continuous light can be used if intensity is adequate
    - BUT short exposure needs very bright light

  - So strobe the light source
    - Pulse width of light to stop pixel blur
    - Synchronize with image capture via strobe trigger signal from vision system
    - Trigger acquire when part is in place
    - Strobed LED lights can be ~10 times brighter than continuously lit LEDs

Strobe vs. Continuous

To strobe or not to strobe. That is the question!

- Camera Shutter Solution/Continuous Light:
- 50 microsecond exposure is 16000/50 = 320 times less light than a normal 16 millisecond exposure. Needs 320 times brighter light.
- Typical LED strobe is about 10 times brighter that a continuous LED light (while it is on).
- Typically need to use strobe to provide enough light in moving part applications – in combination with a larger lens aperture



Calculating Strobe Pulse Width

- RULES OF THUMB
- **Standard machine vision inspection or gauging:**
  - Keep the motion during strobe time to < = 1/10th Pixel
- **Data Matrix reading**:
  - Keep motion to < = 1 Pixel

Just those three parameters!

- Calculate the time to move one pixel:
  - **FOV Dimension** / (**Speed of Part** * **Number of Pixels**)
  - [inch] * [secs/inch] * [1/pixels] = secs/pixel
  - Example: 1 ins FOV; 2 ins/sec; 1000 pixels in direction of motion
    1/(2 * 1000) = 0.0005 seconds (500 microseconds) to move 1 pixel

Suggested strobe/shutter duration = 50 microseconds for gauging
= 500 microseconds for DM read

Summary Number 1 - 8 Things to Know

Red – Examples in everyday life

1. **The difference between bright field and dark field lighting** – BF a light right next to you in front of the TV. DF- The dust that appears on the floor when the sun comes in low in the evening.
2. **How to draw or imagine the "W"** – all the things you could see if you stood in front of an infinitely long flat mirror and looked through an empty picture frame
3. **What is takes to smother ambient light** - a TV screen so bright that room lights or sun makes no difference
4. **Follow the photons – think about ray tracing** – play with a laser pointer and a disco ball
5. **Understand the difference between matt and specular surfaces** - what changes when you get condensation on a mirror?
6. **Know that most materials are somewhere in between** - most print on paper is at least a bit glossy
7. **Know how to calculate how long it takes a part/image to move one pixel**. Time and distance calculation – Driving speed and distance -> time of travel
8. **Think in terms of signal to noise ratio** - bars on your cell phone

Summary 2

1. Use the scientific method and 3 step approach to identify correct lighting solutions:

   Step 1-Think about how light will interact with the object

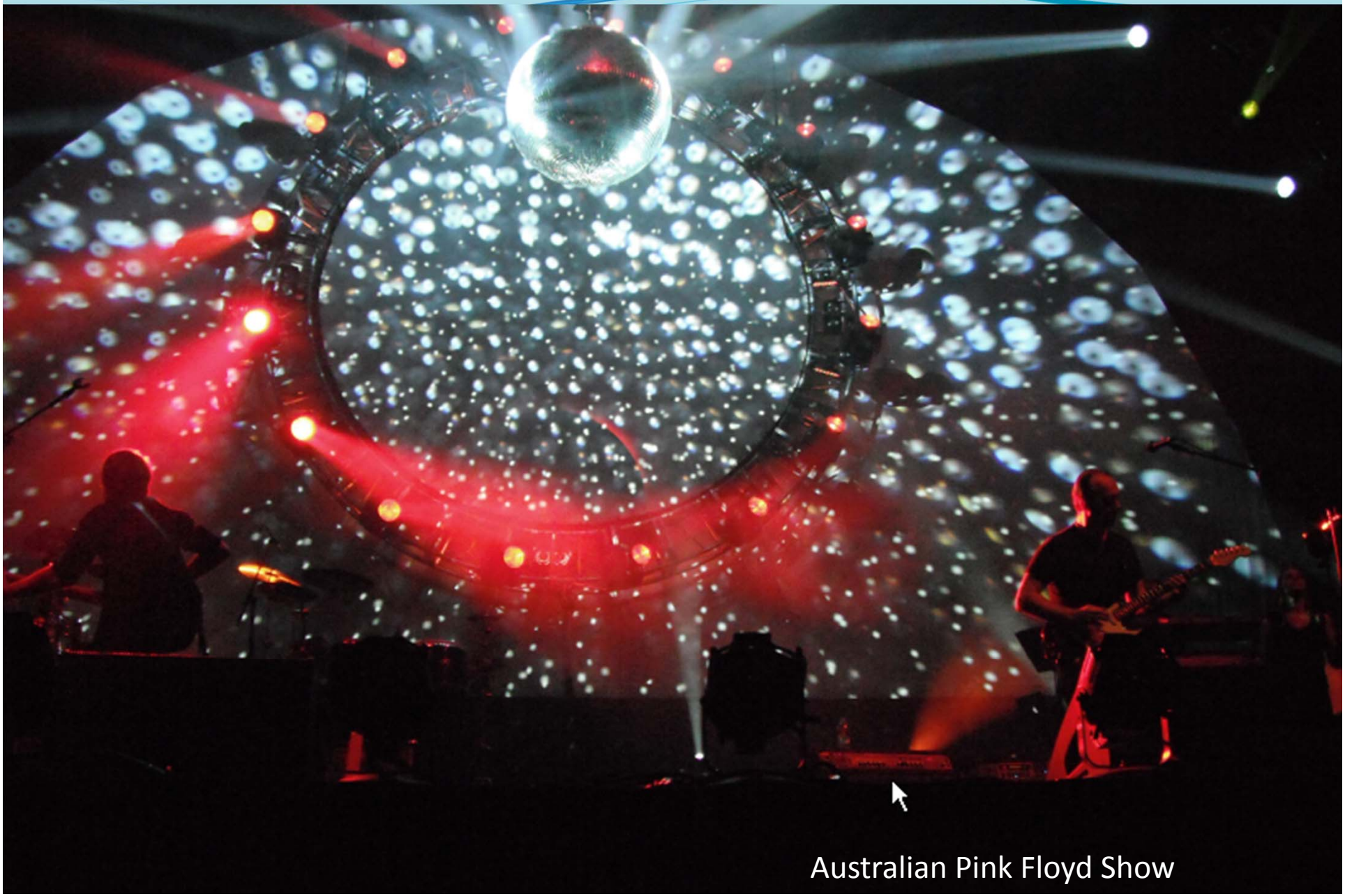
   Step 2-Understand the "W" and use ray tracing to determine where light should be present / absent

   Step 3-Select the right geometry to get maximum SNR

2. Use advanced lighting techniques to fit geometry needs (co-axial through continuous diffused illumination), and keep structured lighting in mind.
3. Use ball bearing / mirror techniques to determine uniformity of light source.
4. Consider polarization to eliminate reflections as a last resort.
5. Consider color regarding absorption / reflection and relative to the source used.
6. Use strobing to stop motion where required and get the maximum intensity.

……and Have Fun with Lights……like these guys

Having Fun With Lights!



Australian Pink Floyd Show

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