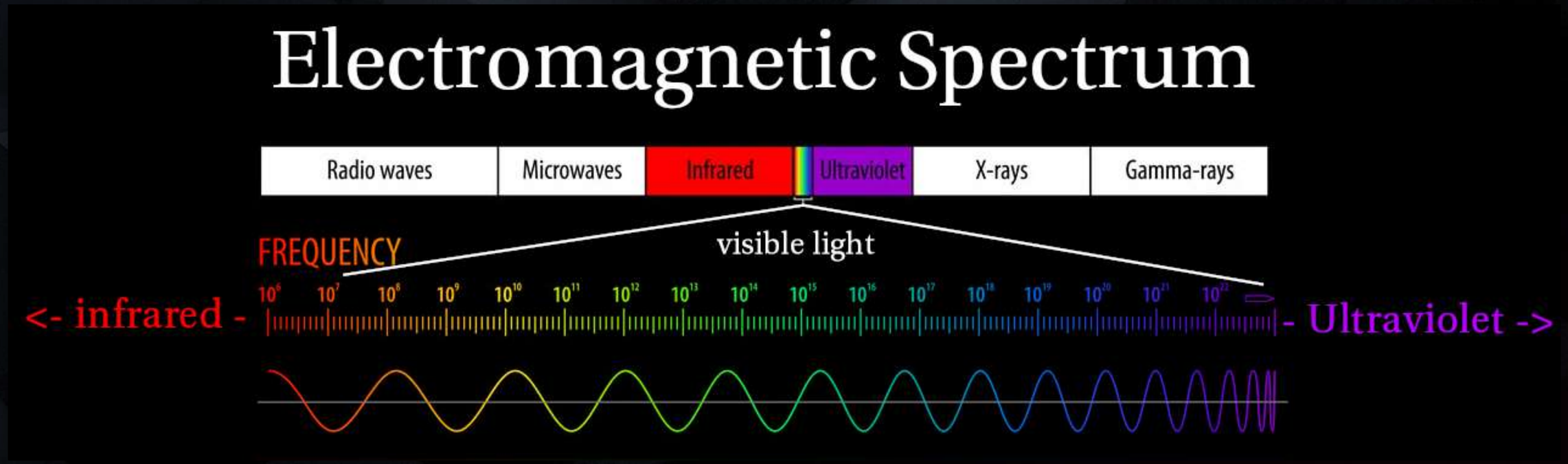
Lighting Concepts:

Cross Polarization Photography

Diffuse | Specular

Lighting Concepts:
Electromagnetic Spectrum

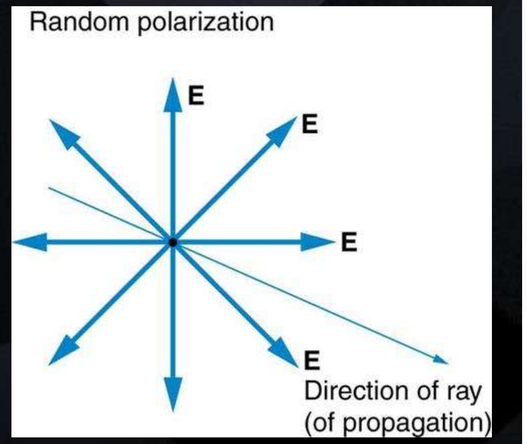
- Visible Light is a section of the Electromagnetic Spectrum
- Light / Color is represented in 2D as a Sine Wave with a specific frequency



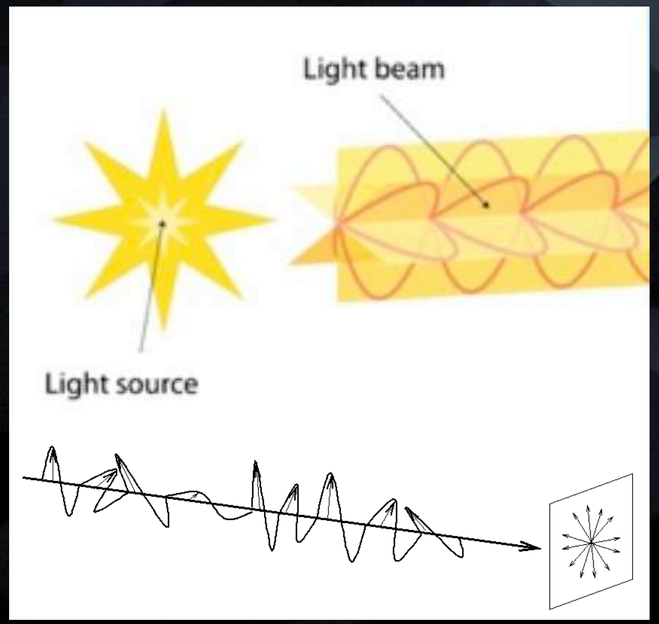
Lighting Concepts:
3D Light Wave Representation

- The 2D representation looks a bit different in 3D space, since the light waves could be oriented in any and all directions along it's forward axis
- A light beam with randomly oriented Light Waves is referred to as an Unpolarized Light

Front View



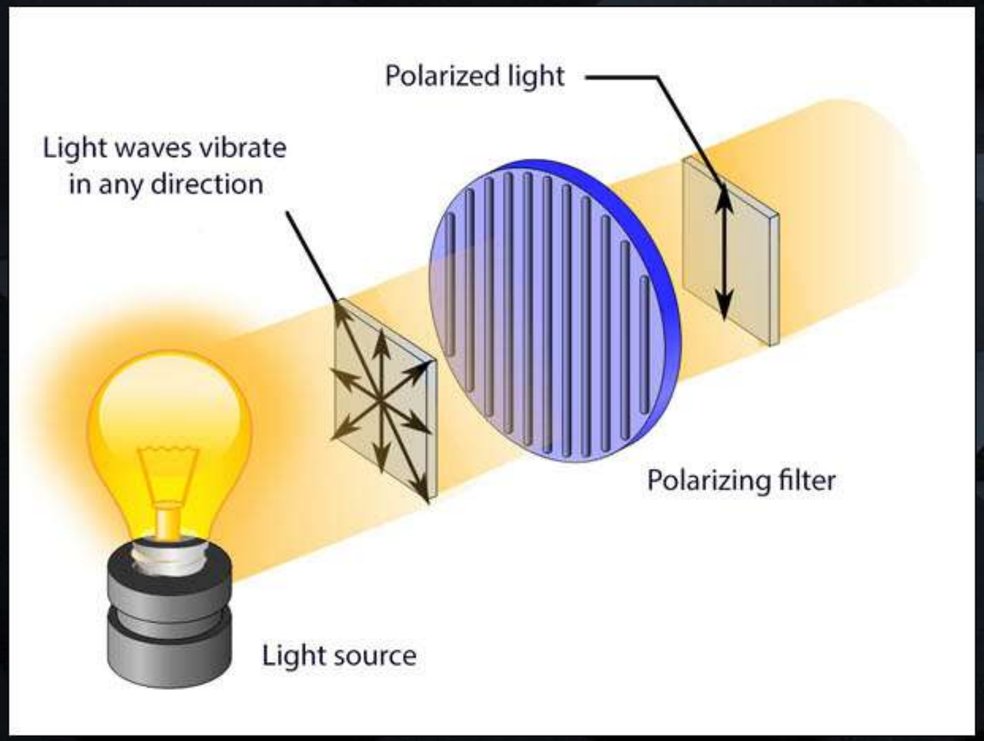
https://physics.stackexchange.com/questions/461699/how-can-non-polarised-light-exist



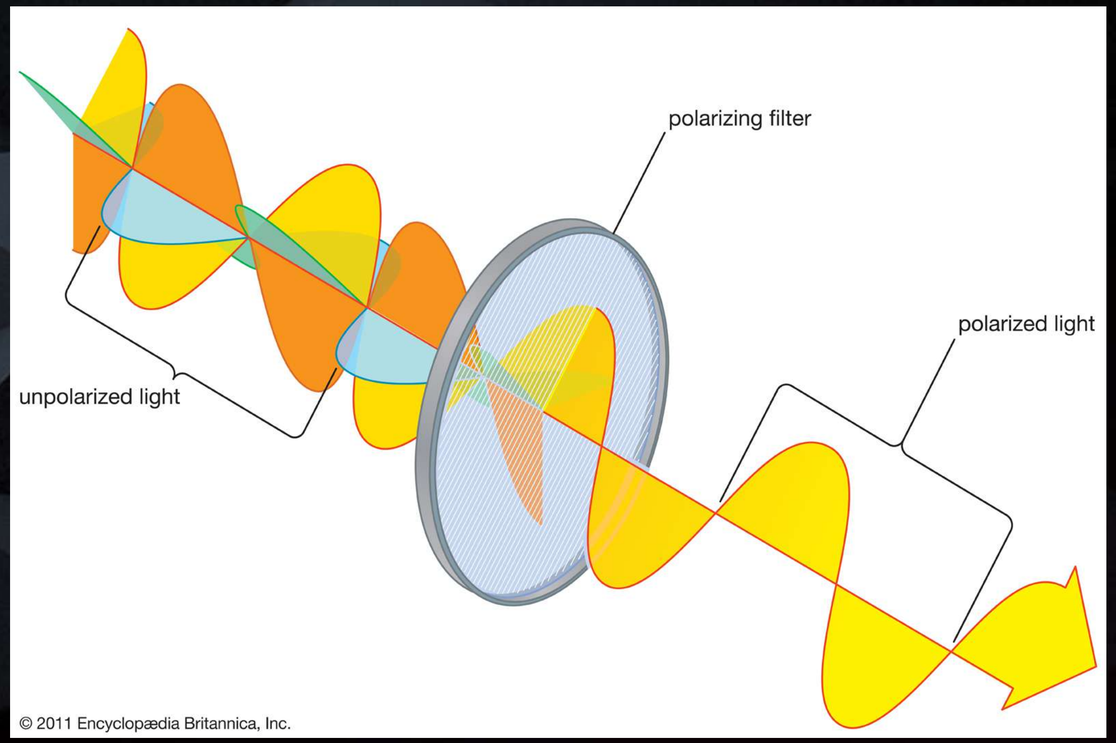
https://physics.stackexchange.com/questions/447441/unpolarized-light-spherical-wavelets-and-photons

Lighting Concepts:
Linear Polarization of Light

- Linear Polarization isolates one specific angle of the light wavelength, only allowing a portion of the light waves that were oriented in the that direction, through the filter



https://skyandtelescope.org/observing/polarized-light-from-blue-sky-to-egg-nebula/



https://astrobites.org/2022/10/23/astrobites-guide-to-polarimetry/

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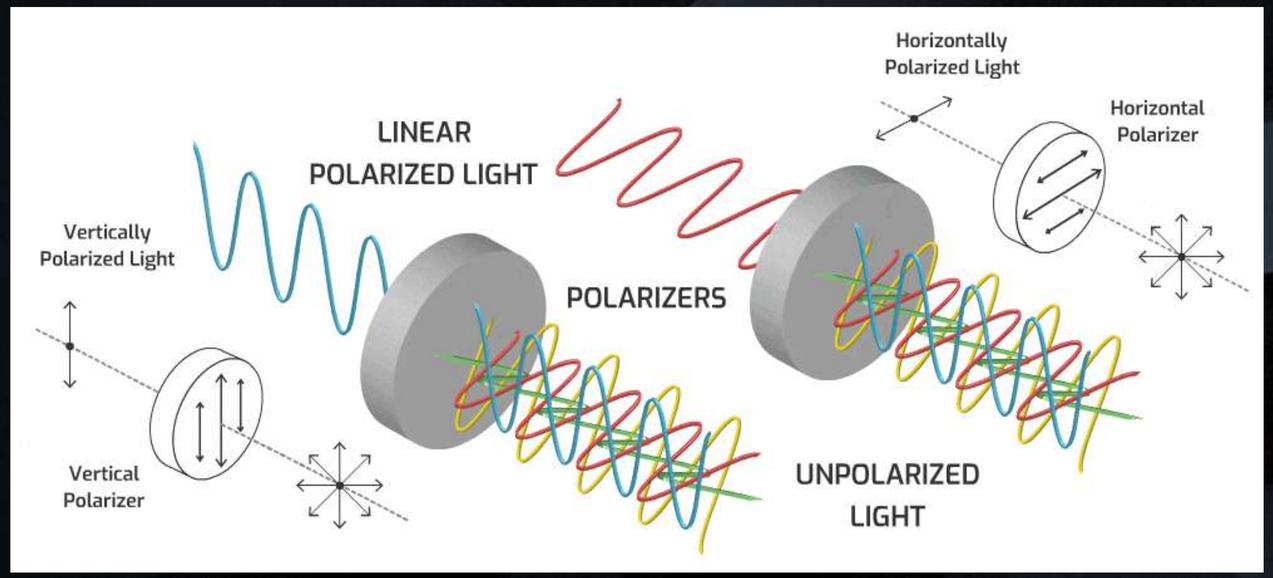
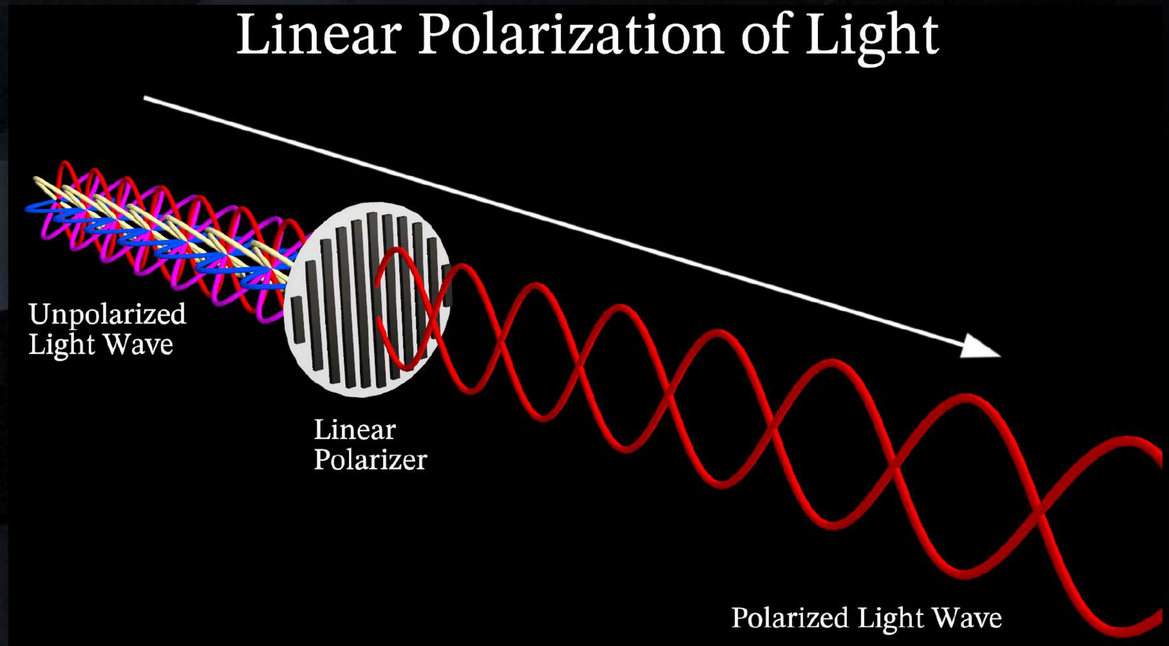
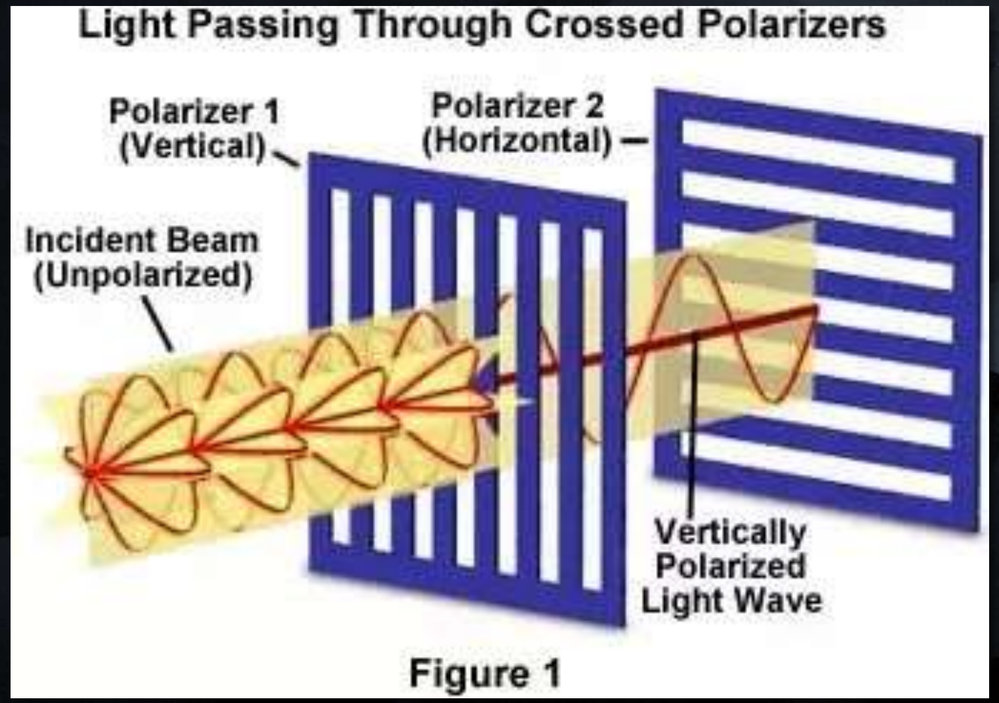


https://thinklucid.com/tech-briefs/polarization-explained-sony-polarized-sensor/

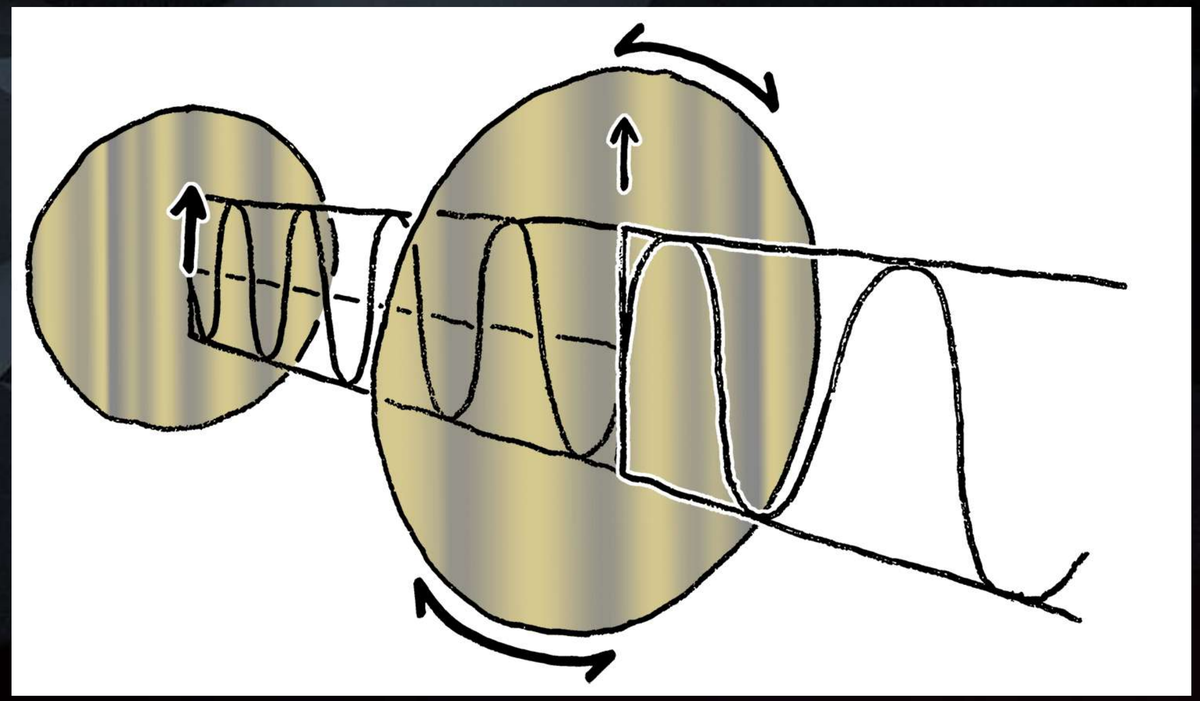


Lighting Concepts:
Cross Polarization of Light

- Cross Polarization uses 2 Polarizers that are perpendicular to each other, effectively eliminating the light wave passing through.
- The first polarizer isolates the light wave to only one orientation
- The second polarizer, if parallel to the first, continues to allow the polarized light through, but as it becomes more perpendicular, the light gets dimmer, and eventually blocked entirely



https://www.olympus-lifescience.com/en/microscope-resource/primer/lightandcolor/polarization/



https://commons.wikimedia.org/wiki/File:Cross_linear_polarization.gif

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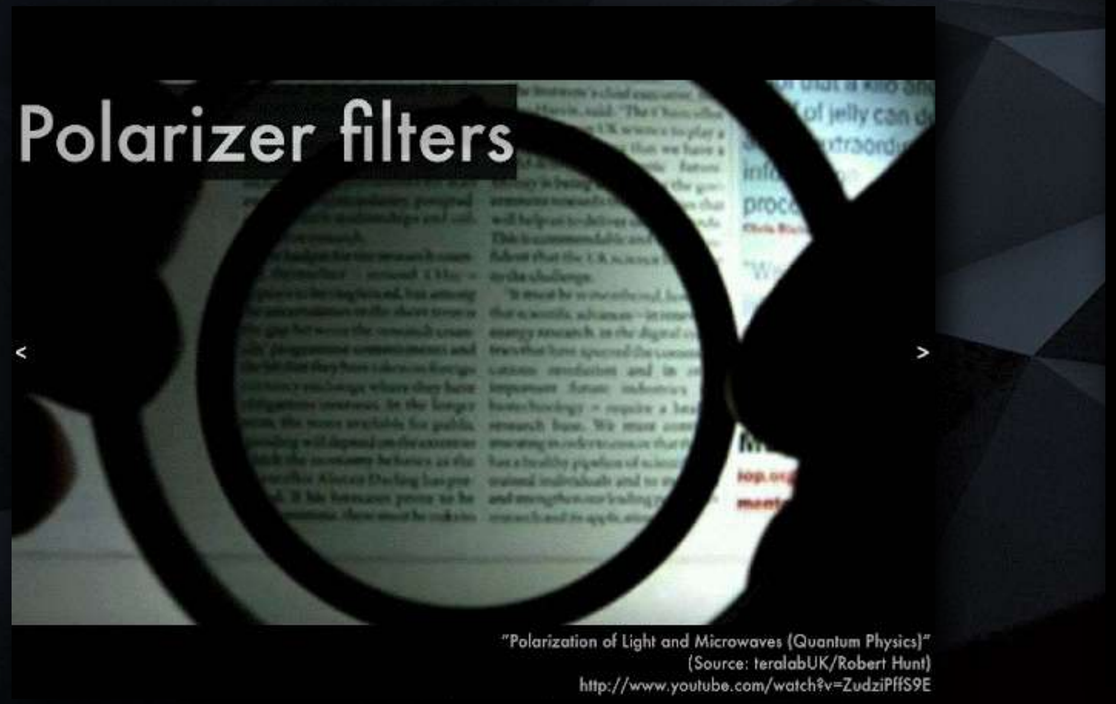
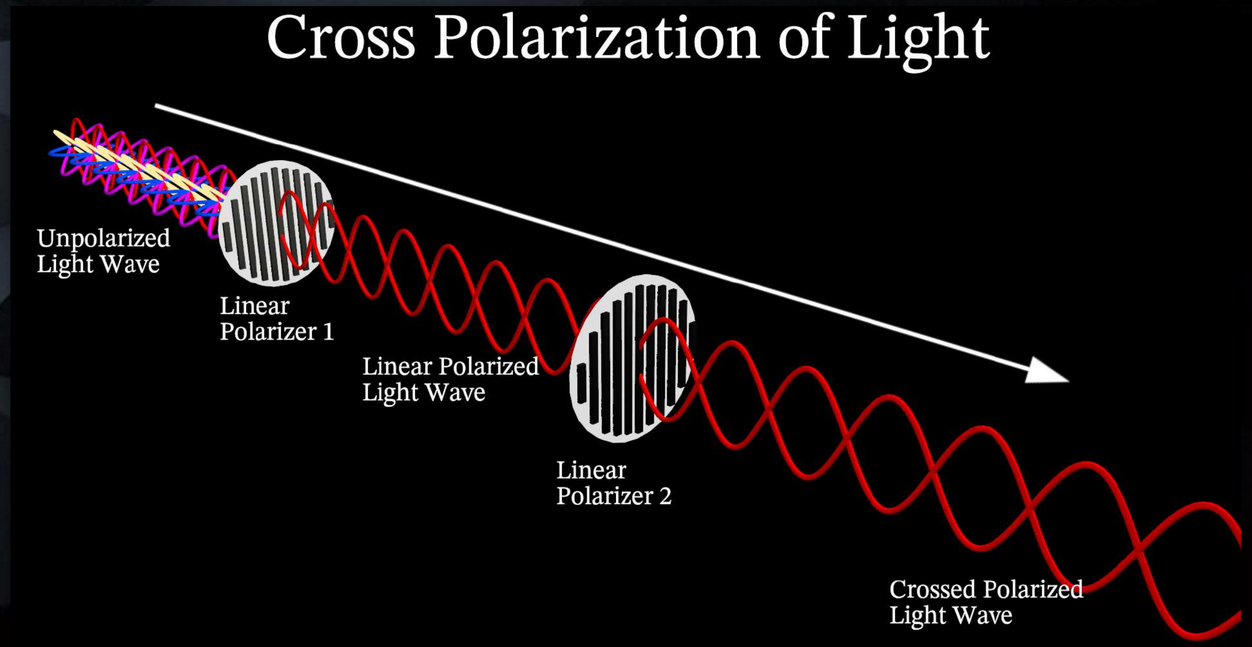
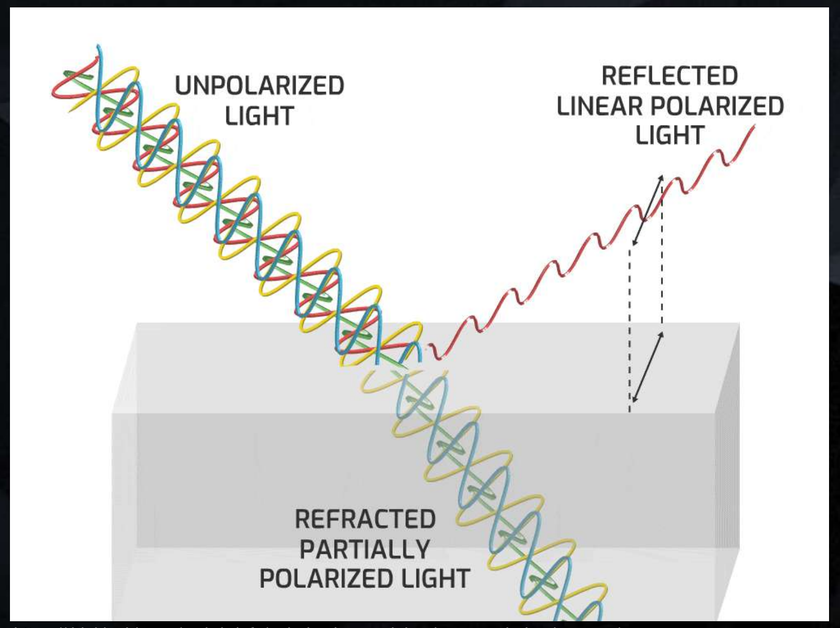




Lighting Concepts:
Polarization upon Reflection

- When unpolarized light hits a reflective surface (with a refractive index different than the surrounding medium, such as glass, snow, or water) the specular reflection is polarized or partially polarized to the angle perpendicular to the plane of incidence. (along the surface)
- How polarized the Reflection depends on many factors; angle of incidence, material type, etc.



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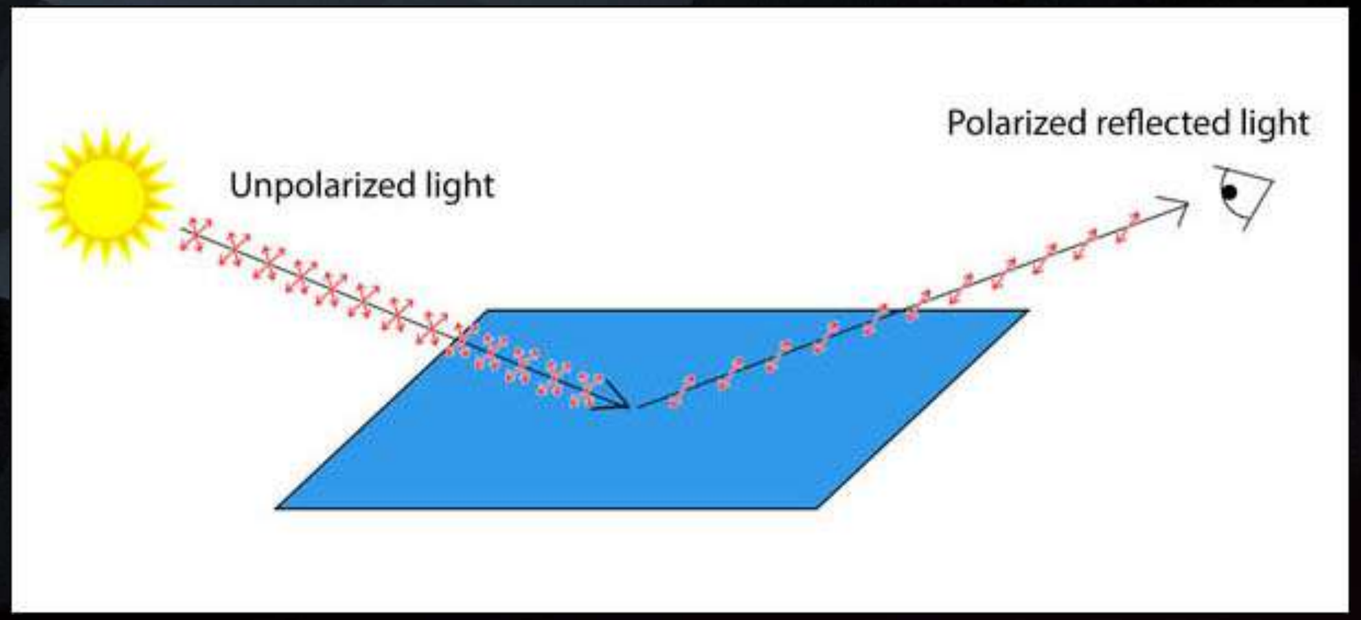
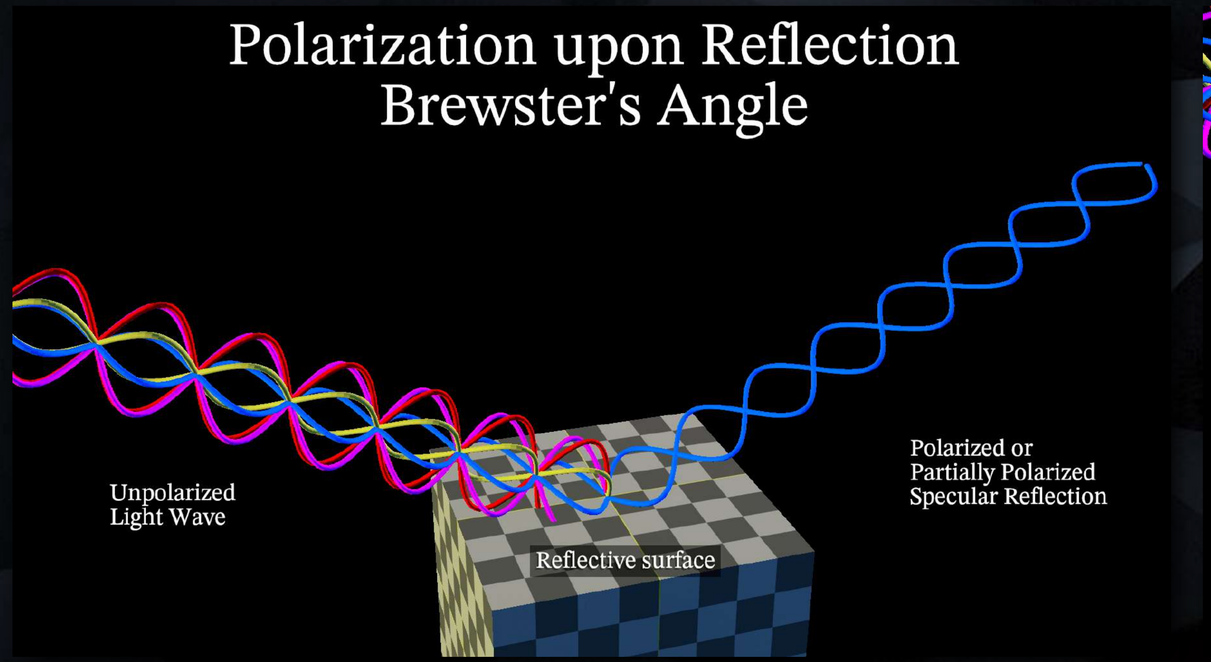
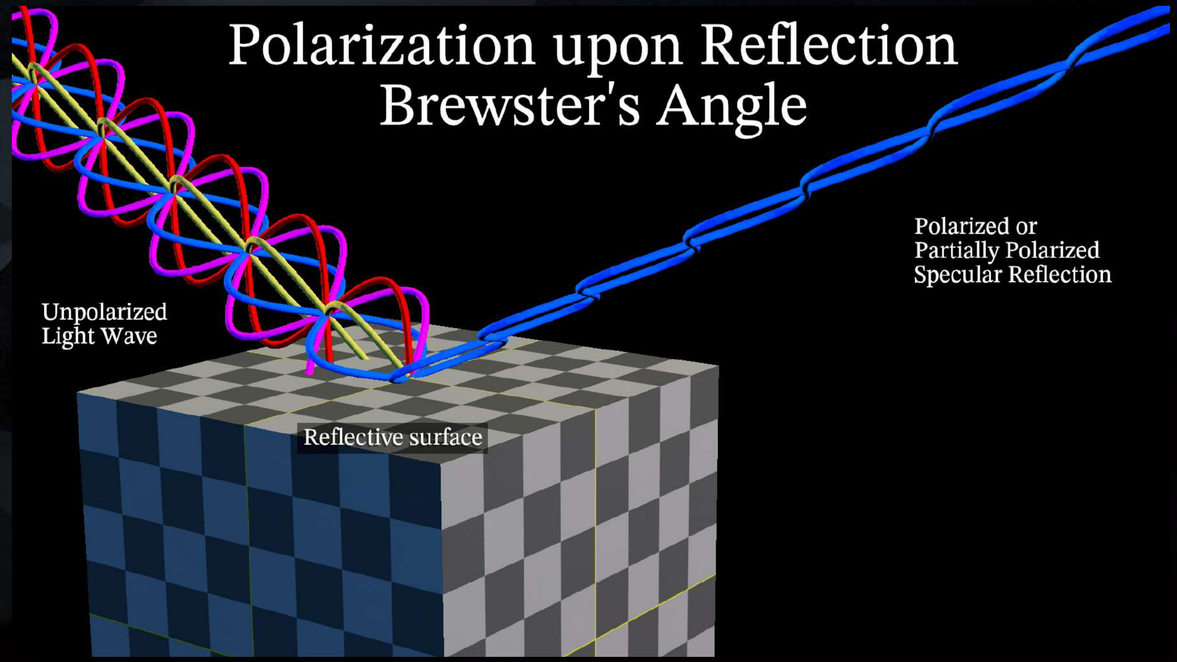


https://skyandtelescope.org/observing/polarized-light-from-blue-sky-to-egg-nebula/

Lighting Concepts:
Brewster's Angle

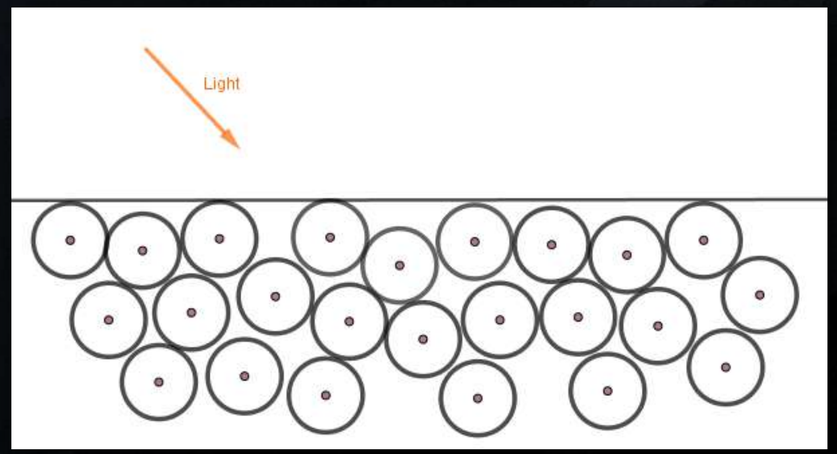
- At a specific angle, the specular reflection is completely polarized to the angle perpendicular to the plane of incidence.
- This angle is known as Brewster's Angle.





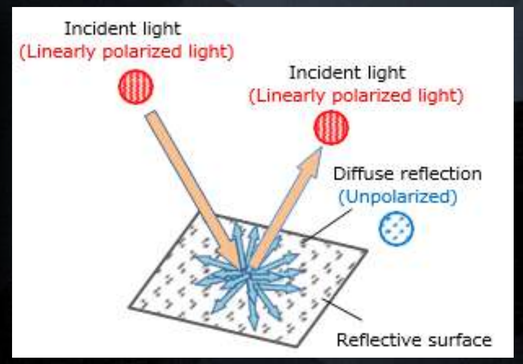
Lighting Concepts:
Unpolarized Diffuse Component

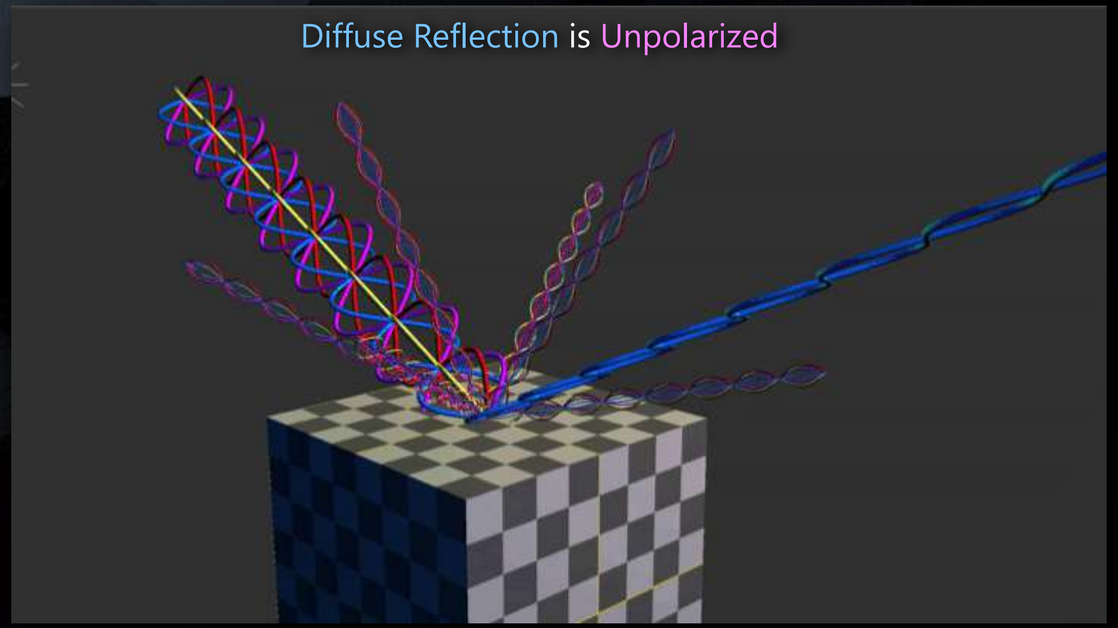
- Only the Specular Reflection has the effect of the Brewster's Angle Polarization
- The Diffuse Component is Unpolarized, because they are newly emitted photons from excited atoms
- This phenomenon only happens when the light is reflected off dielectric materials such as water or glass.
- When reflection occurs on a metallic surface, no Brewster Angle nor refracted light exist



Light photons hit and excite atoms which emit new photons and excite nearby atoms. Since it's a newly created light wave, it could be randomly oriented in any direction, meaning it is Unpolarized

https://cglearn.eu/pub/advanced-computer-graphics/physically-based-shading





Lighting Concepts:
Polarized Specular Reflections

- Placing a Linear Polarizer filter in front of the observer will Cross Polarize some Specular Reflections if angled correctly. It blocks the polarized reflection light wave from shining through it
- This is how Polarized Sunglasses are able to eliminate harsh glares and reflections from dielectric surfaces such as glass, water, snow, etc.

https://specscart.co.uk/blog/are-polarized-lenses-bad-for-your-eyes

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https://www.onlineopticiansuk.com/polarised-lenses-sunglasses-explained-i150

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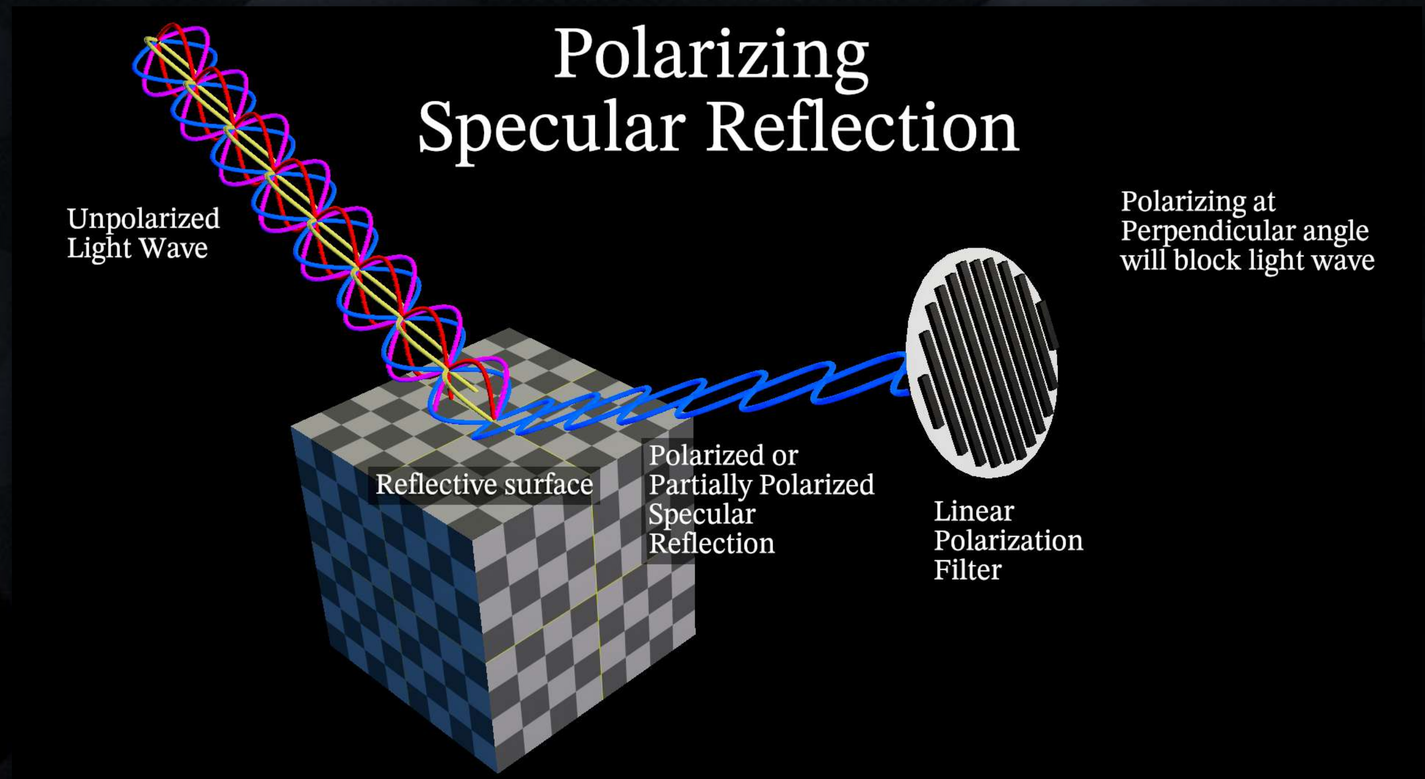
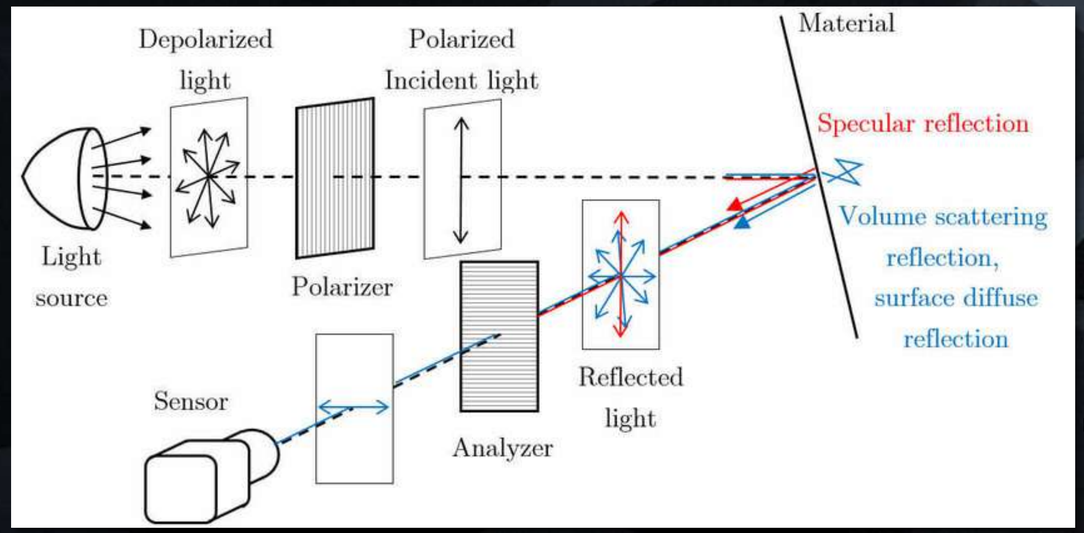
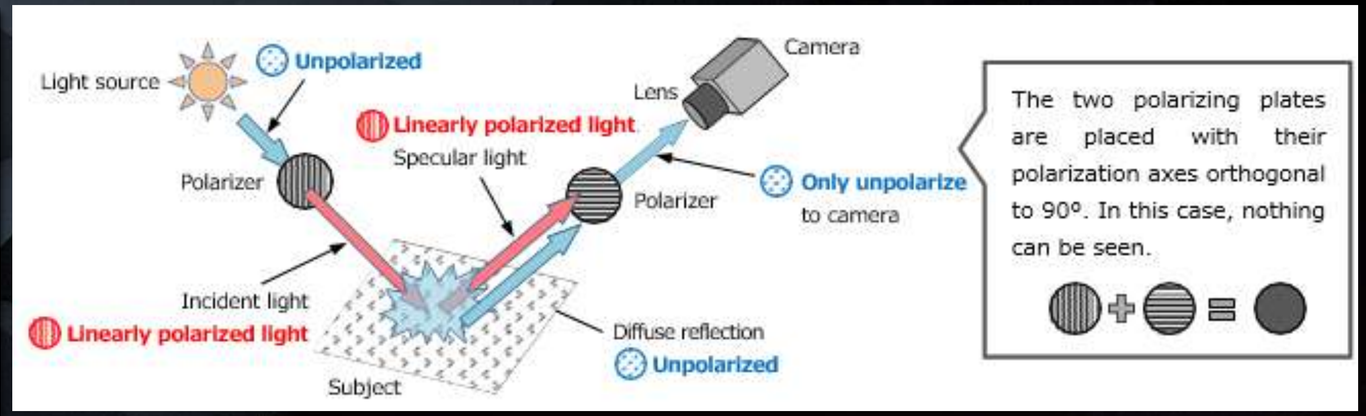


Lighting Concepts:
Cross Polarized Photography

- If you polarize the light source, the Specular Reflection is also polarized (because it's a mirror reflection of the light wave).
- The Diffuse Component is unpolarized light because it is newly created lightwaves oriented randomly. Adding a second polarizer on the Camera, means we can block the Specular Component entirely depending on the angle of the Polarizers. When the 2 polarizers are parallel, we see Specular + Diffuse , and when they are perpendicular we will see only Diffuse.



https://www.researchgate.net/figure/Principle-of-the-cross-polarization-CP-configuration-used-to-remove-the-specular_fig7_342491908



https://www.toshiba-teli.co.jp/en/technology/technical/t0011-Reflection-Polarization.htm

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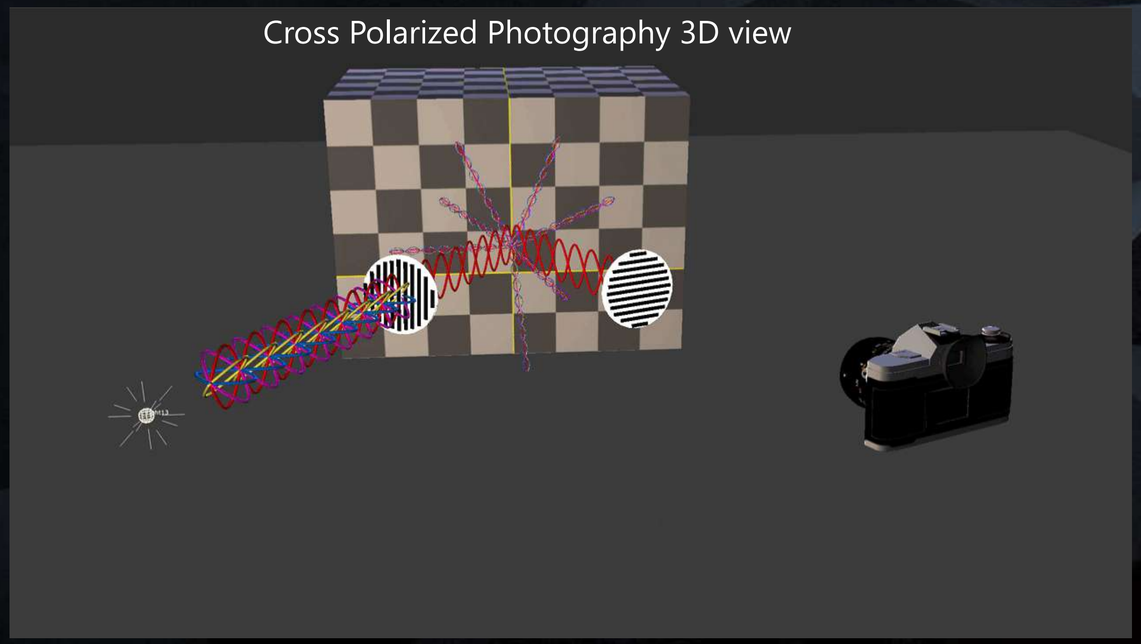

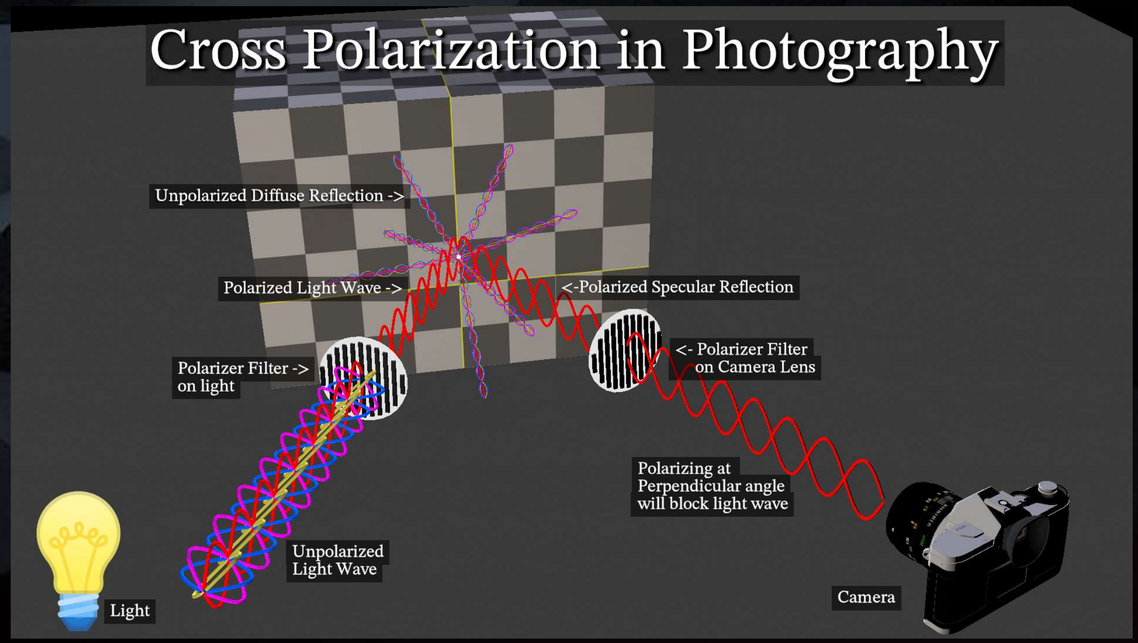

Lighting Concepts:
Cross Polarized Photography

- Adding both a Polarizer to the Light Source and a Polarizer to the Camera, we get 2 different results depending on the orientation of the Polarizers, either a Parallel Polarized Image or a Cross Polarized Image
- When the Polarizer are Parallel, You will see the Specular Component along with a Partially Polarized Diffuse Component
- When the Polarizers are Perpendicular or “Crossed”, the Specular Component is blocked, and all that remains is the other half of the Diffuse Component

YouTube - Jasper D - Photogrammetry - Creating Roughness Maps

YouTube - Classy Dog Studios - Cross Polarization Tutorial: Removing Specular Highlights and Reflections

Lighting Concepts:
Cross Polarized Photography

- The Parallel Polarized image gives use the Specular and Partial Diffuse (only Diffuse Component of that orientation)
- The Cross Polarized image, negates the Specular, and only shows the other half of the Diffuse Component
- To isolate the Specular Component, take Parallel Polarized image (Specular + Partial Diffuse) and minus the Cross Polarized image (Partial Diffuse). The Diffuse Components cancel out, and all that is left is the Specular Component

https://polycount.com/discussion/167507/alexs-texture-scans

minus

equals

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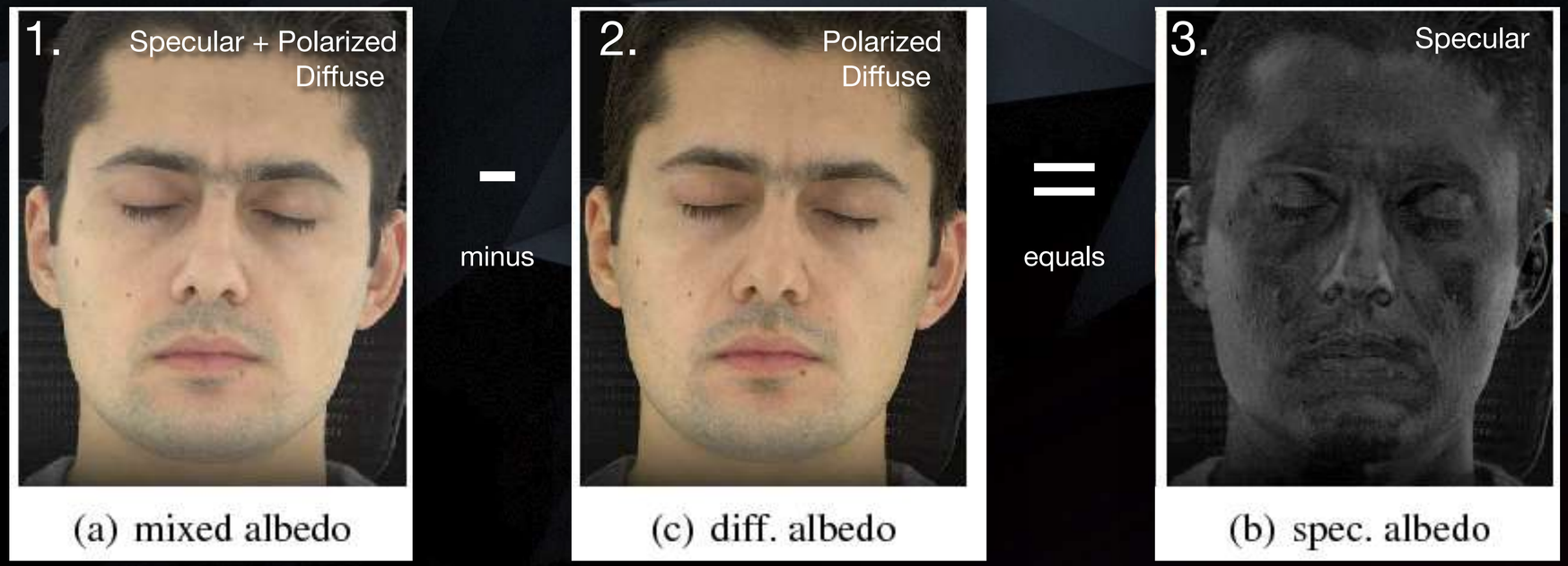


https://wp.doc.ic.ac.uk/rgi/project/diffuse-specular-separation-using-binary-spherical-gradient-illumination/

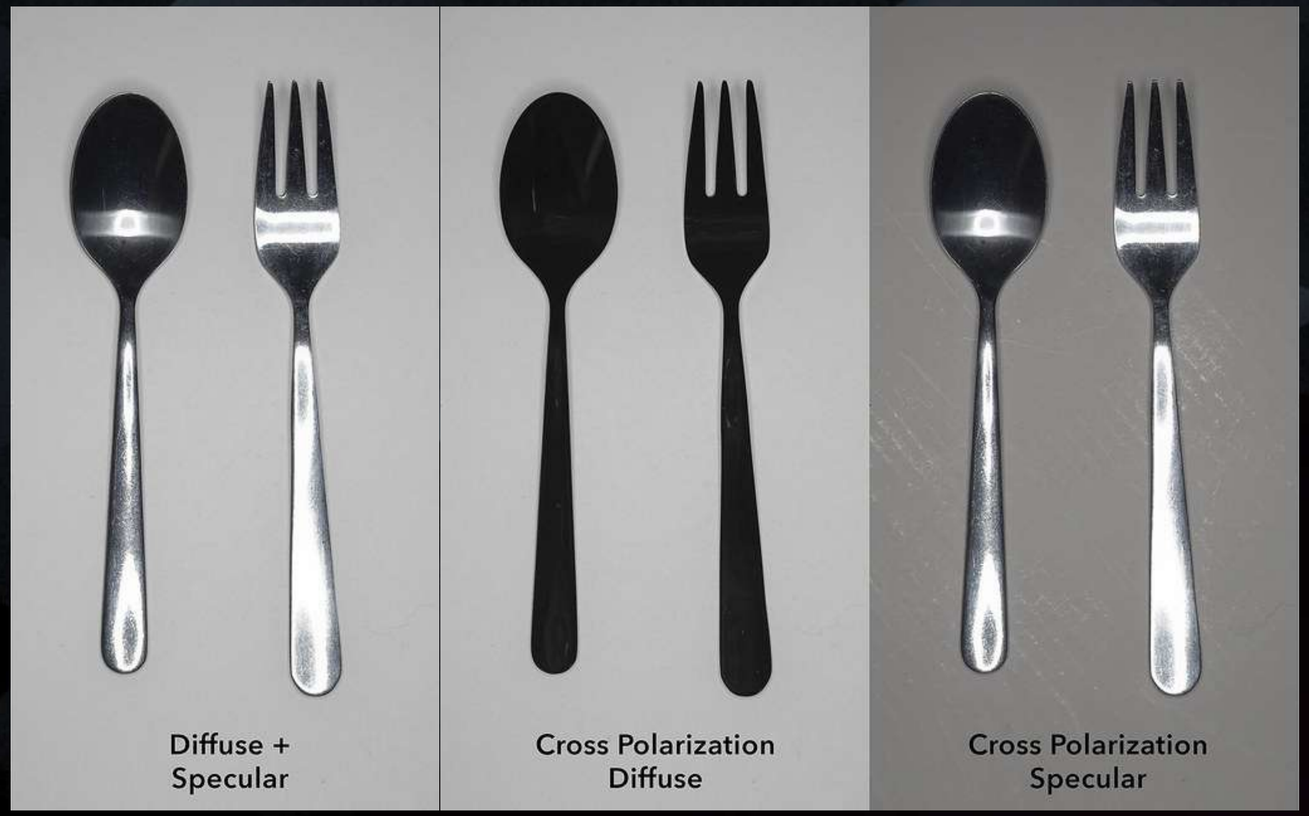
Lighting Concepts:
Cross Polarized Photography

- This Cross Polarization Photography allows CG Artists to collect photogrammetry data of everyday objects, and allows them to recreate these objects in 3D with accurate Diffuse and Specular Maps for Physically Based Rendering
- What seems just like theoretical Diffuse/Specular Render Pass separation in CG is actually a lighting phenomenon that can be separated into Diffuse and Specular Components in the real world

http://filmicworlds.com/blog/how-to-split-specular-and-diffuse-in-real-images/

Lighting Concepts:
Cross Polarized Photography

- Notice that Metallic Materials have no real Diffuse Color to them, They show up as completely black in the Cross Polarized result. Metals are entirely surface level Specular Reflections



https://www.flickr.com/photos/adanmq/44888076104

Lighting Concepts:
Cross Polarized Photography

- Occasionally, the Diffuse Components of the Parallel Polarized and Cross Polarized Images are slightly different, (brighter or a shift in color for example)
- In this case, when we minus the Cross Polarized result from the Parallel Polarized result, we are left with leftover color information or artifacts. The Specular Component can be desaturated to compensate for those color artifacts
- Remember that in Dielectric Materials the Specular Component is the same color as the light source, but Metals can sometimes tint the Specular color depending on the type of Metal

https://docs.sharktacos.com/photography/xpol.html

https://polycount.com/discussion/167507/alexs-texture-scans

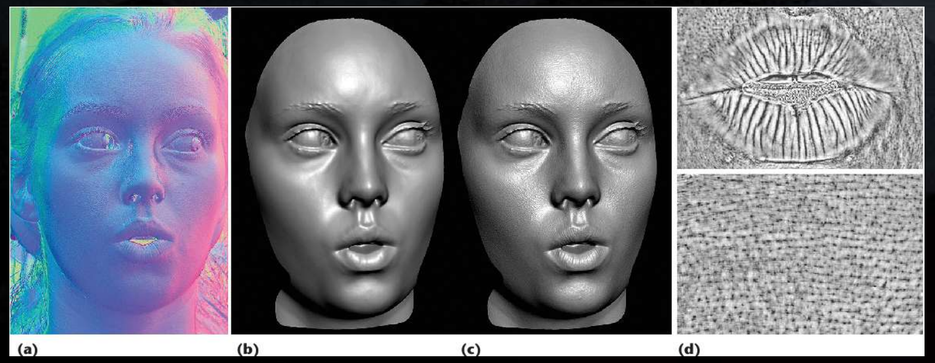
Lighting Concepts:

Light Stage: Cross Polarization

- The light stage used in films is capturing evenly lit, cross polarized textures of various facial expressions.
- This helps separate Diffuse and Specular and aids in tracking features of the face

Light Stage

https://vgl.ict.usc.edu/Research/DigitalEmily/



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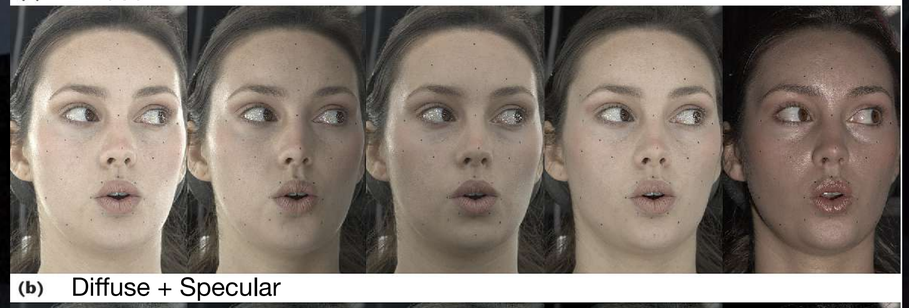

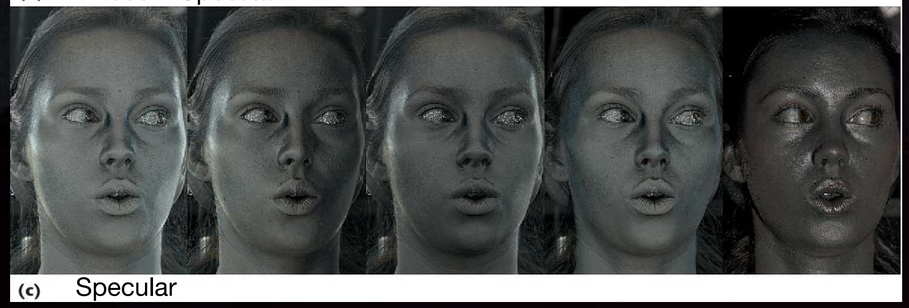

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