Indian Hills Community College presents the series Basics of Photonics Fundamentals (lasers & optics)

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"This material is based upon work supported by the National Science Foundation under Grant No. 1800935.“ "Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation."

Life. Changing.

WELCOME & THANK YOU FOR YOUR INTEREST

Greetings

- I am Frank Reed, Indian Hills's Grant Director & Principal Investigator for the *Developing Photonics Education in Iowa's Rural Secondary Schools* National Science Foundation Grant.
- I have been in the photonics (**lasers and optics**) field since 1989 when I graduated from Indian Hills and have been with IHCC since 1996.
- I do hope you enjoy and learn from these presentations.

- The presentations will cover the following.
  1. Motivation, Light and the Nature & Properties of Light
  2. Optical Components
  3. Basic Laser Safety
  4. Geometrical (RAY) Optics
  5. **Physical (WAVE) Optics**
  6. Principles of Lasers

Motivation

- Currently the U.S. laser & optics industry is growing by leaps and bounds,
  - Or as we like to say “at the speed of light”.
- The medical/bio-science area is the fastest growing followed closely by manufacturing.
  - These two areas will impact each of us on a personal basis.
- Nationally, there are ~2000 entry level photonics technician positions per year with ~20% filled.
- IHCC’s Laser & Optics 2020 graduates received an average starting salary of $61,800.00.
- To increase the number of these technicians, WE must market lasers & optics to our students.
- 70% of technicians working in U.S. photonics industry say that their jobs are intellectually challenging and have no worries about joblessness.
- IHCC’s NSF ATE Grant has the main objective of increasing the number of Photonics Techs in the U.S.
- One way to do that is to introduce teachers to the world of photonics.
  - Therefore, this opportunity is provided for you to learn more about lasers & optics with hope that you will include it in your course work.

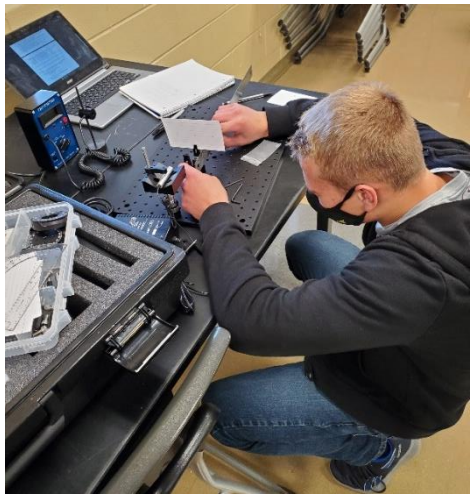
Motivation

Albia High School

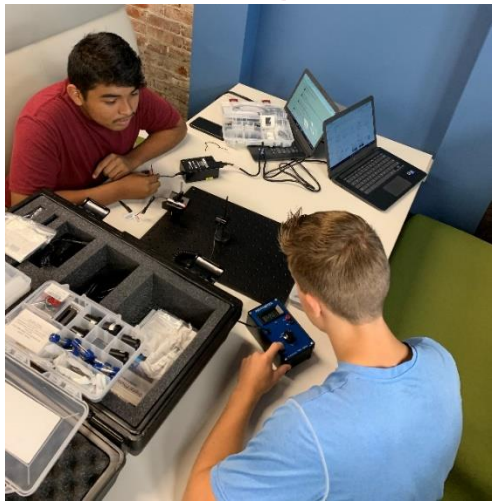
Centerville High School

Davis County High School

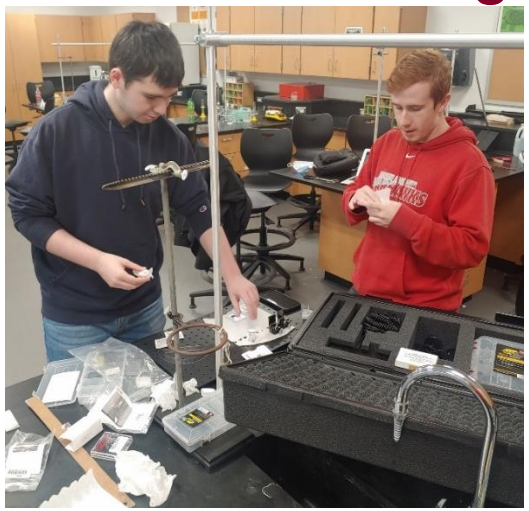
Hybrid (online & hands-on) High School Photonics Training



Davis County High School



Ottumwa High School



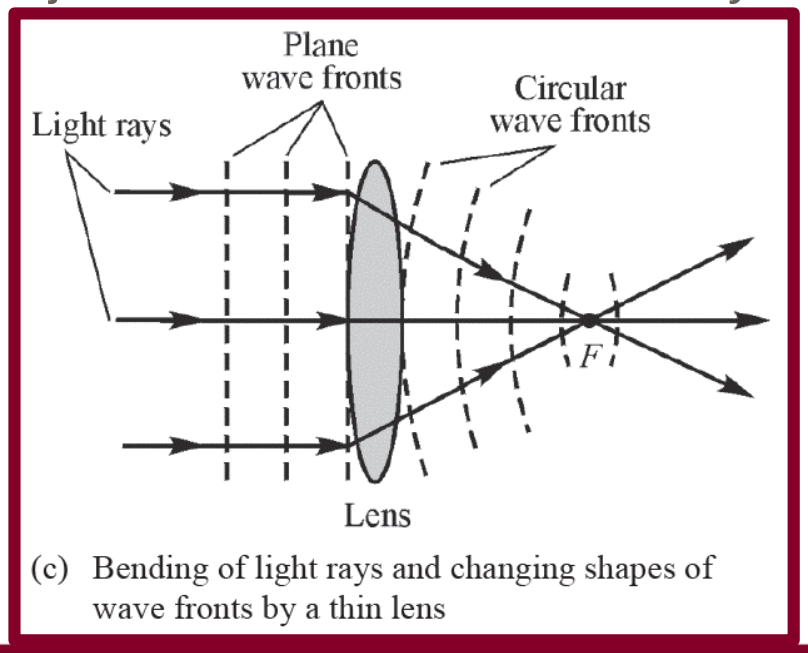
North Mahaska High School

Basic Physical (Wave) Optics

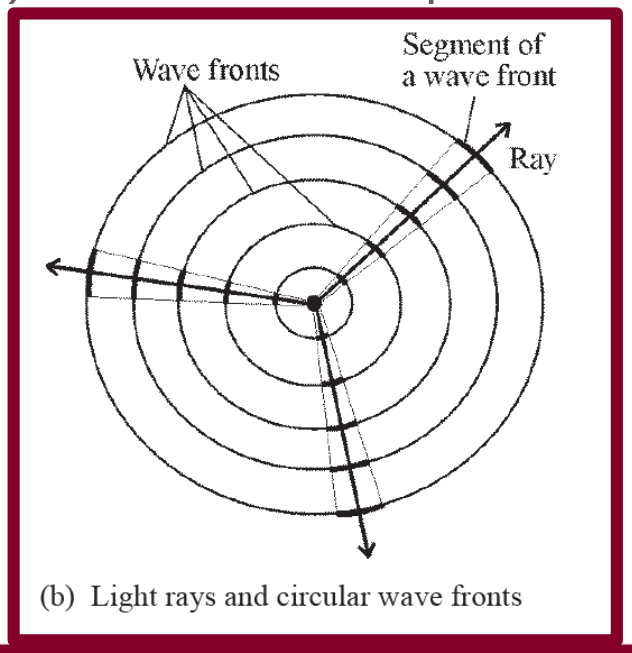
- Wave Motion & Wave Fronts
- Principle of Superposition
- Interference: 2 - Coherent Sources
- Diffraction: 1 – Coherent Source
- Diffraction & Interference
- Diffraction Gratings
- Polarization
- Polarization Methods
- Brewster Angle
- Brewster Window

Wave Motion & Wave Fronts

- Geometrical or ray optics *cannot* account for the light patterns produced on a screen beyond objects such as a 100μm diameter human hair, or through small openings, such as a 50μm pinhole
- Therefore, we now move from the *propagation* of light energy along a straight-line to one that includes the *spreading* of light energy; a fundamental behavior of all wave motion.
- The figures below show *electromagnetic* wave fronts moving in conjunction with a laser beam/ray and (c) how a lens manipulates both.



(c) Bending of light rays and changing shapes of wave fronts by a thin lens



(b) Light rays and circular wave fronts

Wave Motion & Wave Fronts

- This picture shows water wave motion travelling radially outward from center.
- These wave motions are mostly up and down or *transverse* vibrations, propagating in a direction *perpendicular* to the vibrations as wave fronts.
- A *wave front* is defined as a series of adjacent points along which all motions of the wave are identical.

Wave Motion & Wave Fronts

- The solid circles in Figure 1 indicate the wave *crests*—maximum displacements up (+amplitude); the dashed circles indicate the wave *troughs*—maximum displacements down (-amplitude).
- Crest to crest or trough to trough is the *wavelength*.
- If we were able to look along the surface of the pond, we would see a *sine wave-like* profile of the traveling wave such as that shown in Figure 2.

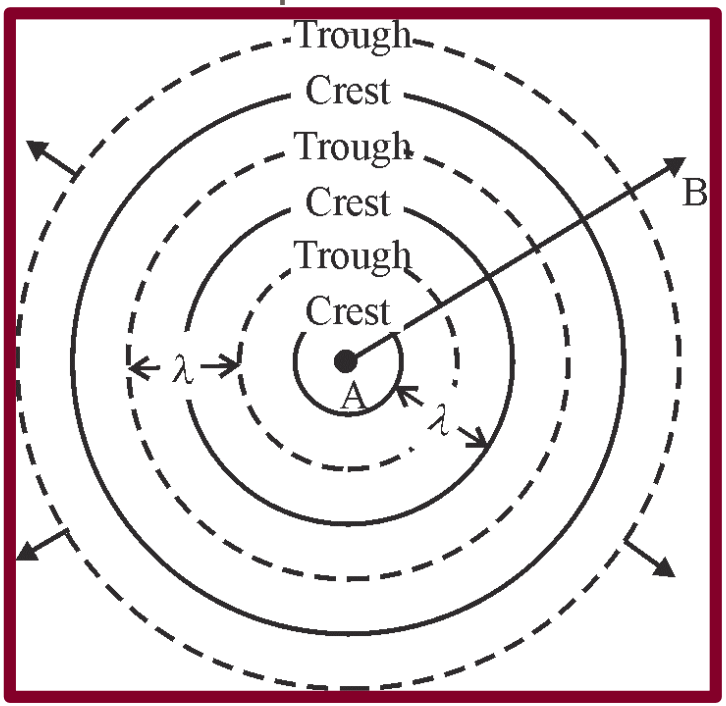


Figure 1

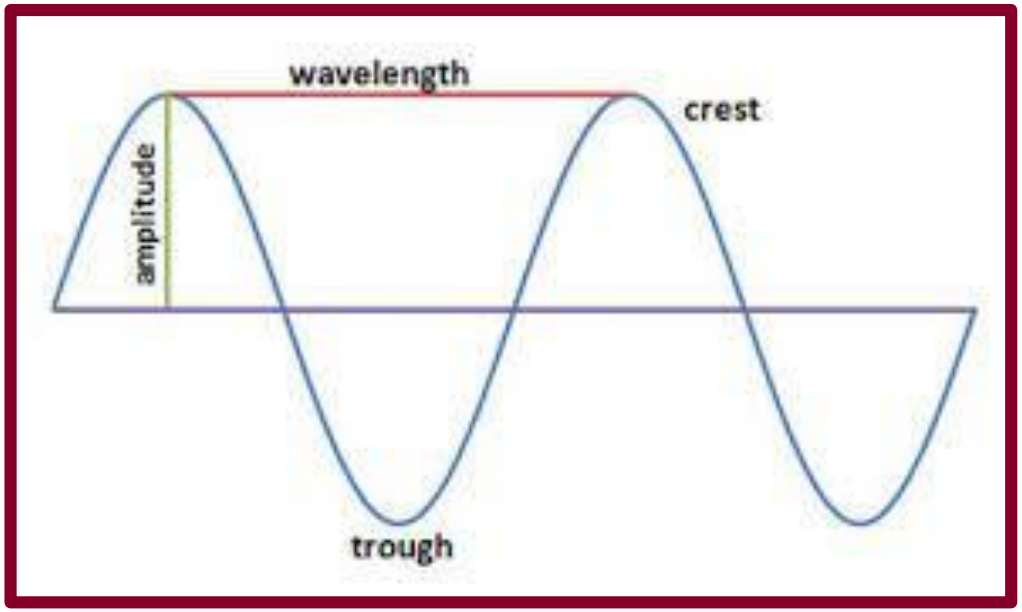
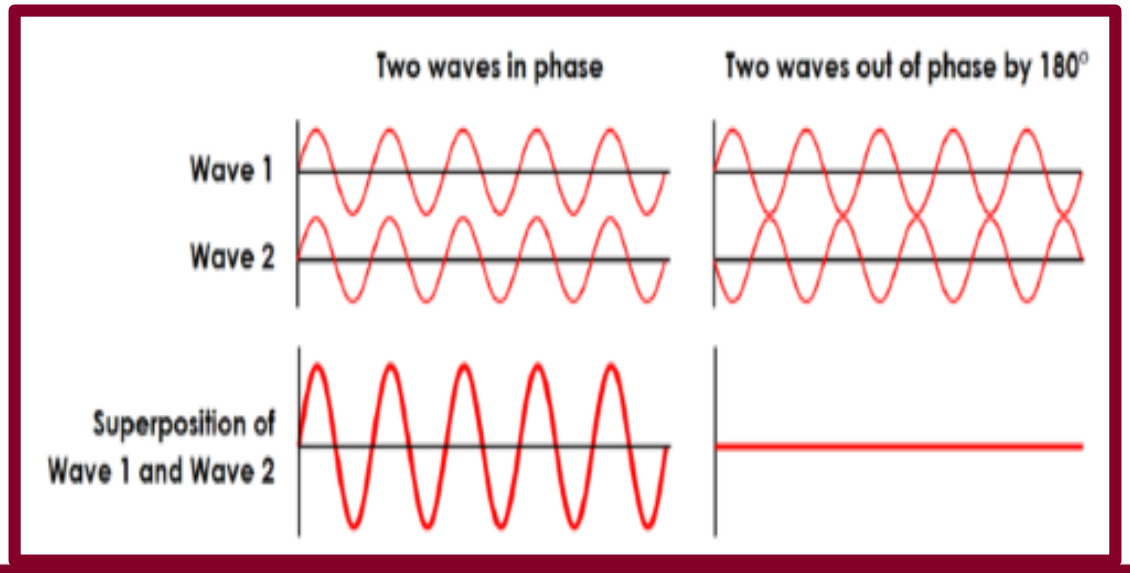


Figure 2

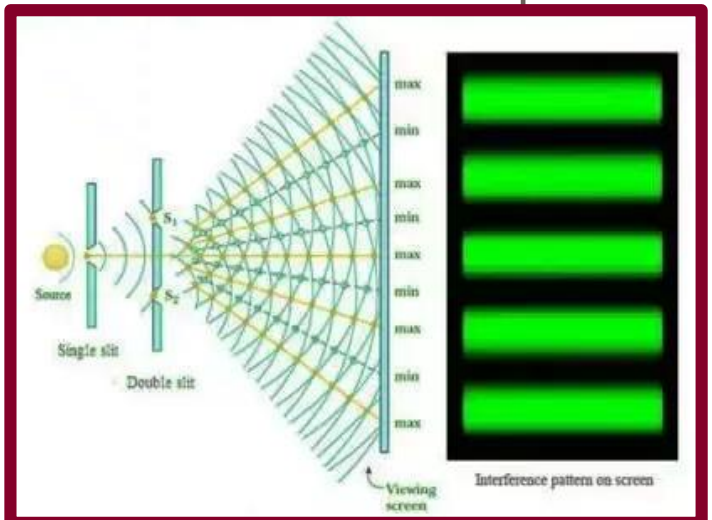
Principle of Superposition

- When two or more waves move simultaneously through a region of space, each wave proceeds independently.
- The resulting wave “displacement” at any point and time is the vector sum of the “displacements” of the individual waves.
- The result of superposition of 2 - waves when they are in phase (constructive interference) and when they are 180° out of phase (destructive interference.



Interference

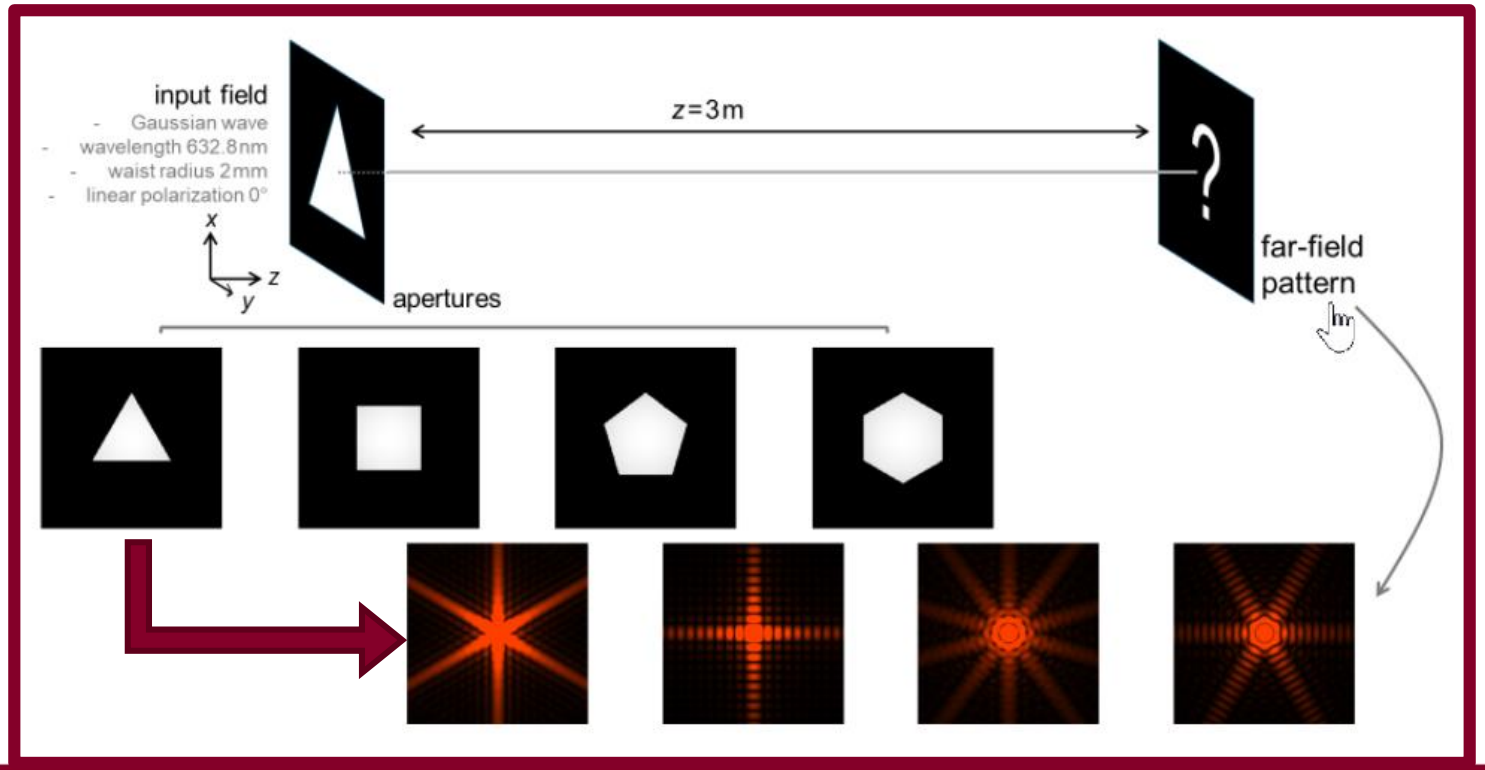
- It is possible to show the interference of overlapping light waves coming from two nearby coherent sources.
- In this graphic, the waves from the two sources reinforce (add to, max) each other and where they weaken (subtract from, min) each other.
- Notice the **two** “point” sources of light, *S*1 and *S*2, whose radiating waves maintain a *fixed wavelength and fixed phase relationship* with each other as they travel outward.
- This is a “coherence of sources” which is a stringent requirement for interference to be observed.
- The *solid* circles represent crests (max), the *dashed* circles, troughs (min).



Here is a four part app that can be manipulated to show waves, interference, slits and diffraction: https://phet.colorado.edu/sims/html/wave-interference/latest/wave-interference_en.html

Diffraction

- The ability of light to bend around corners is fundamental to both interference (2 - coherent light sources) and diffraction (1 - coherent light source).
- Therefore diffraction of a single coherent light source occurs when propagating through small openings, around obstacles, or past sharp edges.
- Each obstacle creates a unique diffraction pattern.
  - This graphic and the website/app from the previous slide are examples.



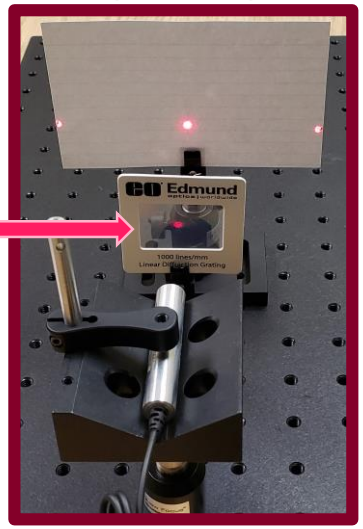
Diffraction & Interference

- The youtube site compares diffraction and interference patterns.
  - Variable width Single Slit diffraction with red light laser.
  - Pinhole diffraction with yellow light laser.
  - Double Slit Interference with red, yellow & green light lasers.
    - Note the differences per wavelength.
    - A double slit in front of a single laser beam which is monochromatic and coherent, constitutes 2 - coherent light sources.

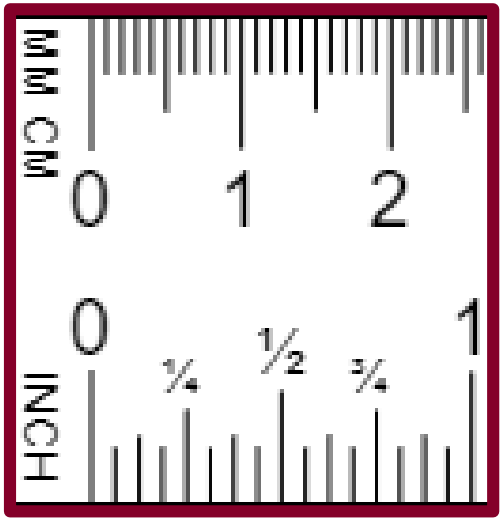
Diffraction & Interference:
https://www.youtube.com/watch?v=9D8cPrEAGyc

Diffraction Gratings

- An optical device with close, equidistant, and parallel lines for the purpose of resolving (diffracting) light into its spectral components.
- The diffracting angles are strongly dependent on both the slit spacing and wavelength of the incident light.
- Transmission Grating: lines on or in a transmissive medium.
- Reflection Grating: lines on a reflective medium.
- Typically consisting of a large number of parallel grooves or lines representing slits with a specified spacing.
- The diffraction grating in the picture has 1000 lines/mm. Think about it.

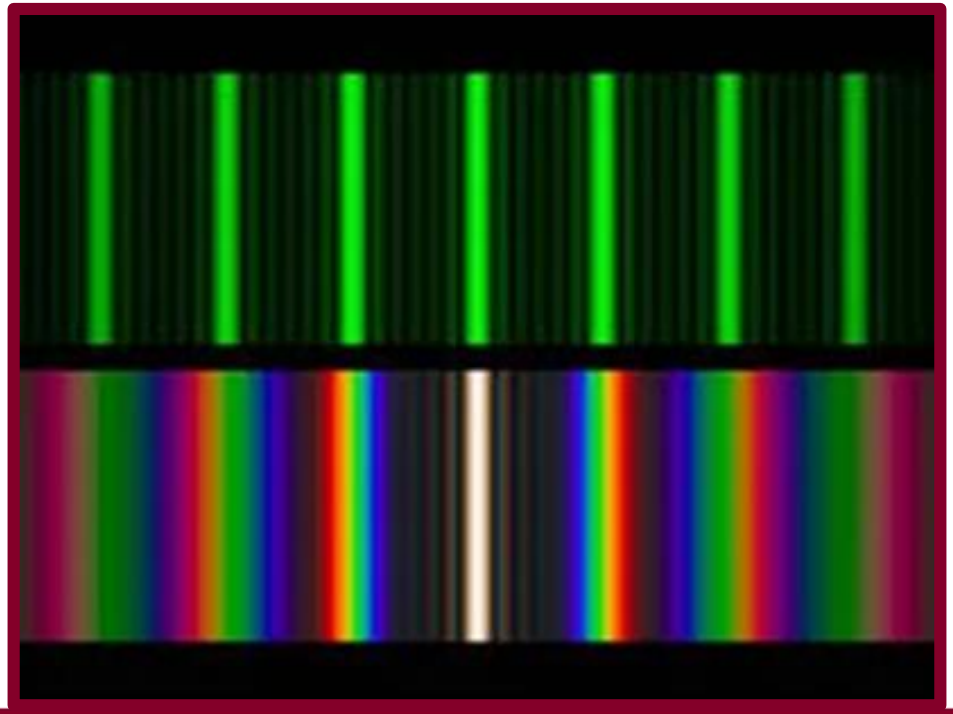


Red Laser Light



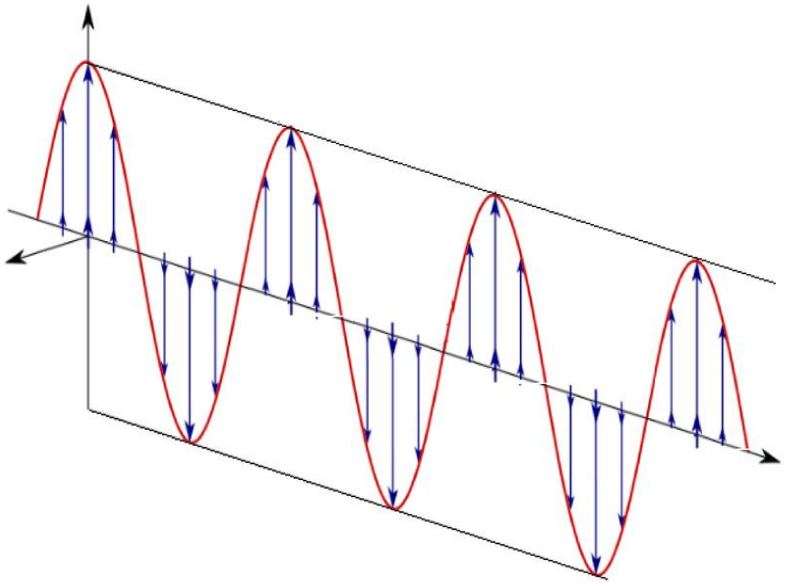
Diffraction Gratings

- Graphic compares a green light diffraction pattern with one of white light.
- Green light pattern corresponds to the location of the green-light fringe within the “rainbow” fringe.
- Notice the white light central fringe is white, with the composite color fringes to either side.
- The “rainbows” are oriented with the blue end towards the center because it is the shortest wavelength shown.



Polarization

- Polarization of light waves refers to the *transverse* direction of vibration of the ***electric field*** (E-field) vector of electromagnetic waves.
- *Transverse* means *E*-field vibrations *perpendicular* to the direction of wave propagation.
- If the electric field vector maintains that direction, the light is said to be *linearly polarized* and can be at any angle.
- The vibration here refers to the oscillation of the electric field in a particular transverse direction—at all given points along the propagation of the wave.



Watch this and change the parameters to see how to control or turn off a linearly polarized laser beam's intensity. https://micro.magnet.fsu.edu/primer/java/scienceopticsu/polarizedlight/filters/index.html

Polarization Methods

- Unpolarized light, the light we see around us, can be polarized through several methods.
- Dichroic materials (polarizers/analyzers) selectively *absorb* components of *E*-field vibrations along a given direction and largely *transmit* the components of the *E*-field vibration perpendicular to the absorption direction. Figure 1.
- Producing polarized light by *reflection*. Figure 2 and https://www.youtube.com/watch?v=JmSS924BM40
  - Unpolarized Light: Random E-fields.
  - Reflected Linear Polarized Light: E-field is parallel to reflecting surface (semi transparent surfaces, etc.) & considered horizontal.
  - Refracted/Partially Polarized Light: follows law of refraction.

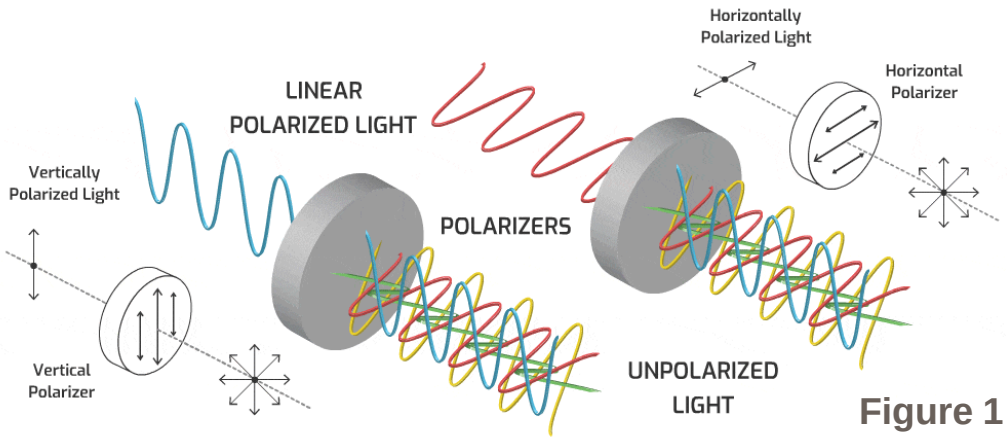


Figure 1

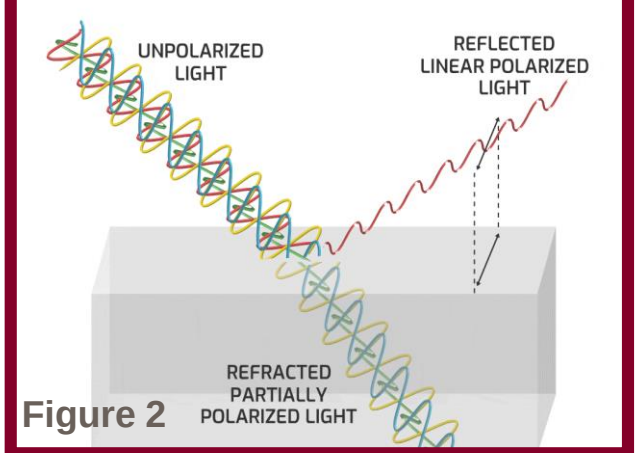
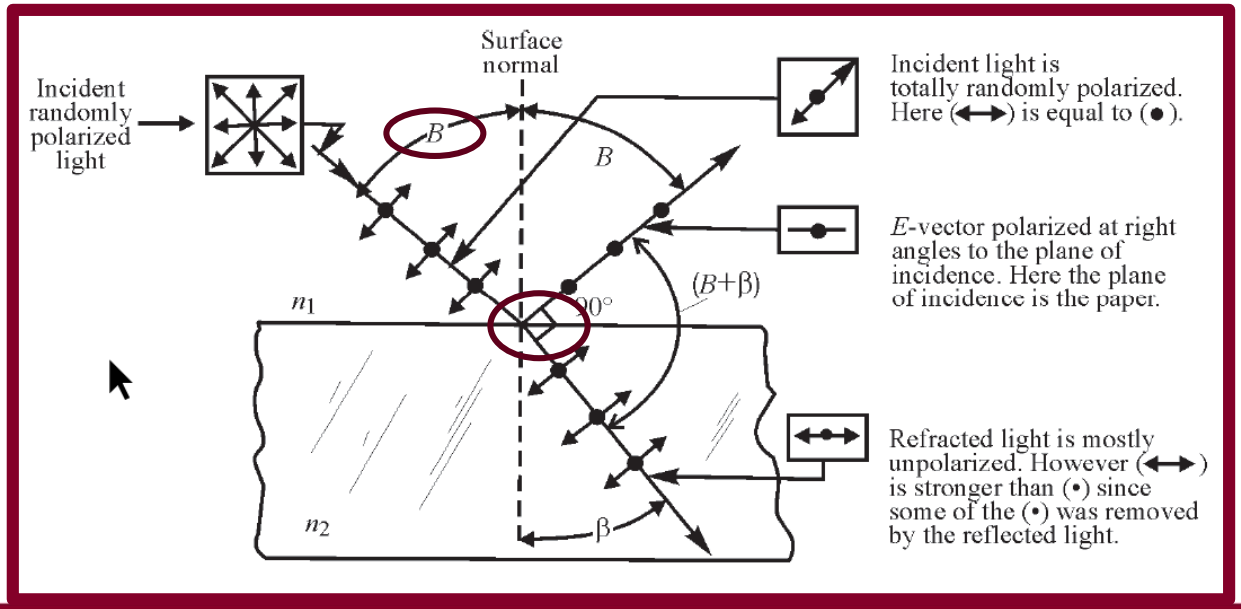


Figure 2

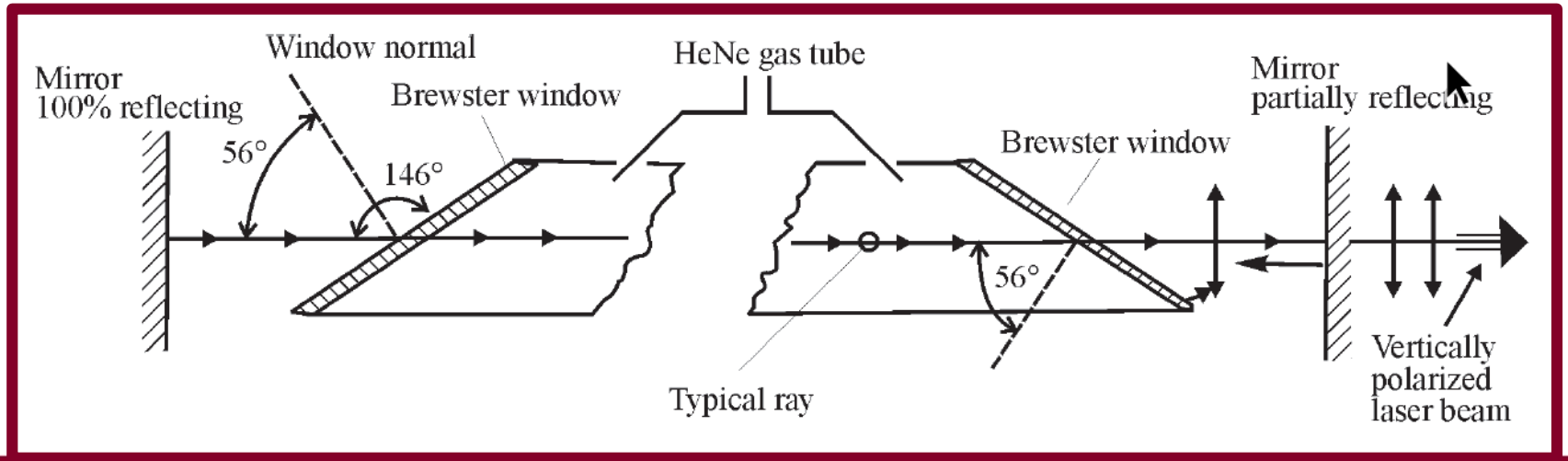
Brewster Angle

- This graphic shows the *complete* polarization of the *reflected light* at a *particular angle of incidence B*, called the *Brewster angle*.
- If light strikes an interface so that there is a 90º angle between the **reflected** ⟷ and **refracted** rays ⟷, the **reflected** light will be linearly **polarized**.
- The direction of **polarization** (the way the electric field vectors point) is parallel to the plane of the interface and considered horizontal.



Brewster Windows

- Polarized light consists of light waves all traveling in the same orientation and is very useful in a number of applications.
  - Such as microscopy (the examination of minute objects by means of a **microscope)**.
  - To prevent unwanted back reflections in an optical system.
  - Polarized sunglasses **(Safety Note: sunglasses should have full UV coating)**
- Monochromatic light in a laser beam is not necessarily polarized.
- ***Brewster windows*** are used in laser cavities to ensure that laser light, after bouncing back and forth between the cavity mirrors, emerges as linearly polarized light as shown below.



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