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

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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.

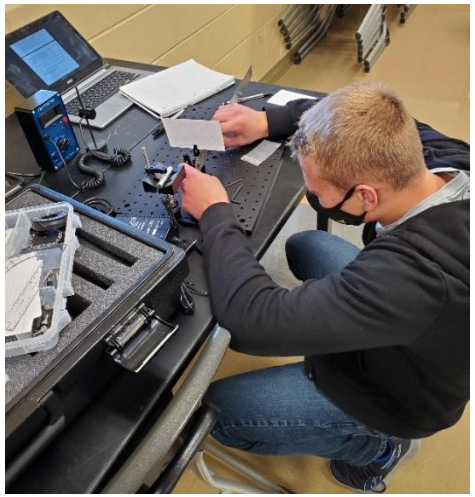
Motivation

Albia High School

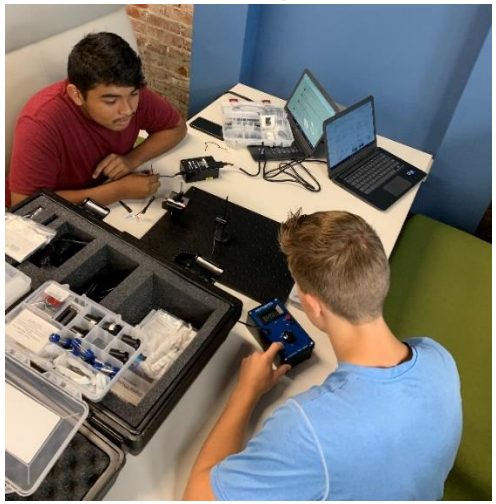
Centerville High School

Davis County High School

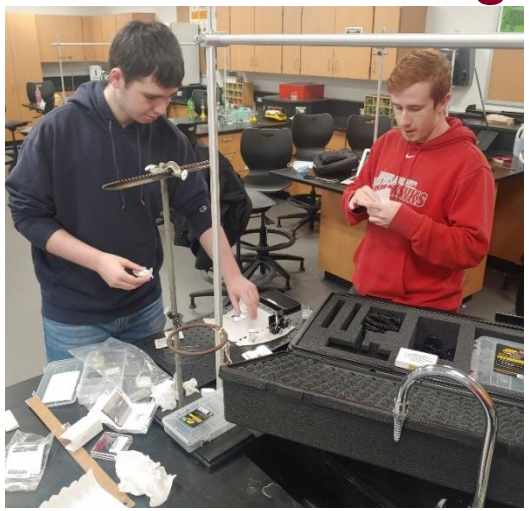
Hybrid (online & hands-on) High School Photonics Training



Davis County High School



Ottumwa High School

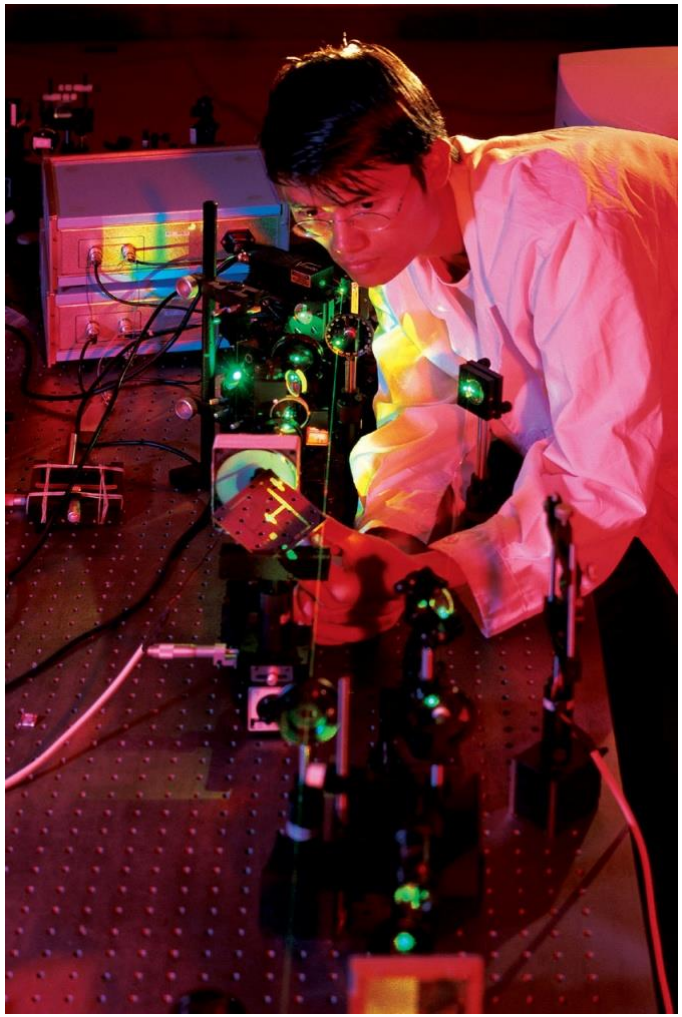


North Mahaska High School

Overview of Nature & Properties of Light

- **Photonics Occupations and Industries**
- **Light & Properties of Light**
  - Wavelength
  - Frequency
  - Speed
  - Period
  - Amplitude
  - Energy
  - Phase
  - Coherence
  - Polarization
- **Nature of Light**
  - Dual Nature of Light
  - Electro Magnetic Radiation
  - Scatter
  - Transmission
  - Absorption
  - Reflection
  - Refraction
  - Diffraction
  - Interference

Photonics Occupations



- Laser Technician
- Optics Technician
- Research & Development Technician
- Field Service Engineer
- Applications Technician
- Sales Engineer
- Plus a plethora or others

IHCC Laser and Optics Alumni

Please take time watch this 4.3 minute video featuring two IHCC's Laser & Optics Alumni.
https://youtu.be/iX56o0TnSsY
Thank you.

Photonics Industries

- Aerospace
- Agriculture
- Communication
- Computers
- Energy
- Entertainment
- Environmental
- Manufacturing
- Medicine, Bio-Medicine
- Nanoscience
- National/Public Defense
- Research & Development
- Transportation
- Plus a plethora of others

DRS DAYLIGHT SOLUTIONS
Mid-IR Lasers, Sensors & Systems

BAE SYSTEMS

ADAPT LASER SYSTEMS

IDEX HEALTH & SCIENCE

LUMENIS
Enhancing Life. Advancing Technology.

Medtronic

COHERENT

mks

LAWRENCE LIVERMORE NATIONAL LABS:
National Ignition Facility

TRUMPF

Light

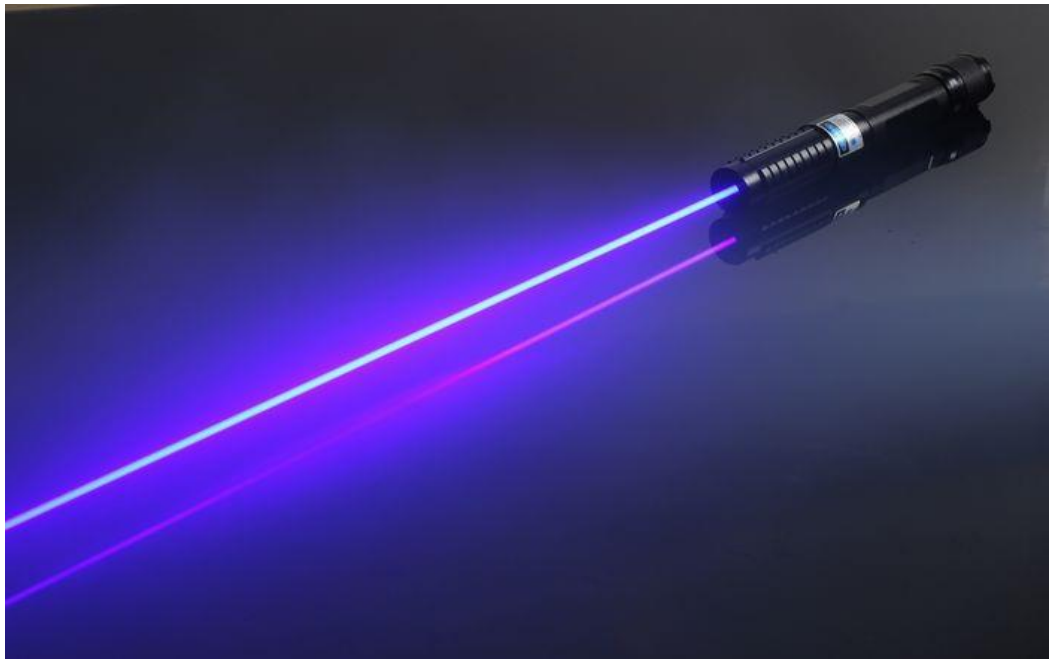
- Photons (particles of light) exists everywhere at the same time.

- It is a form of energy emitted from a source that reacts with all materials in one way or another.

Light

Laser Light

- Monochromatic: Single frequency or single color
- Collimated: very low in divergence and unidirectional
- Coherent: photons travel in phase
- High Intensity or radiant power per unit area (irradiance)
  - Creates a demand for laser safety.



Properties of Light

- Wavelength
- Frequency
- Speed
- Period
- Amplitude
- Energy
- Phase
- Coherence
- Polarization

Wavelength

- Distance over which a wave repeats
- Measured in meters.
- Wavelengths are on the order of a few hundred Nanometers (10^{-9})
- A value not visible to the naked eye

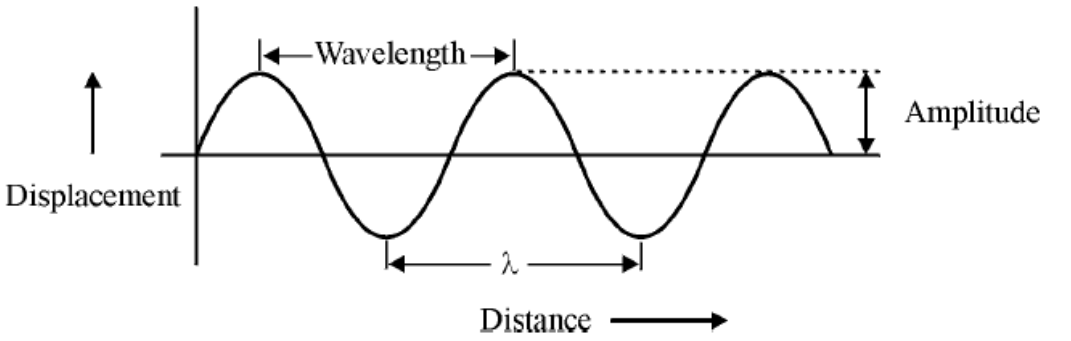
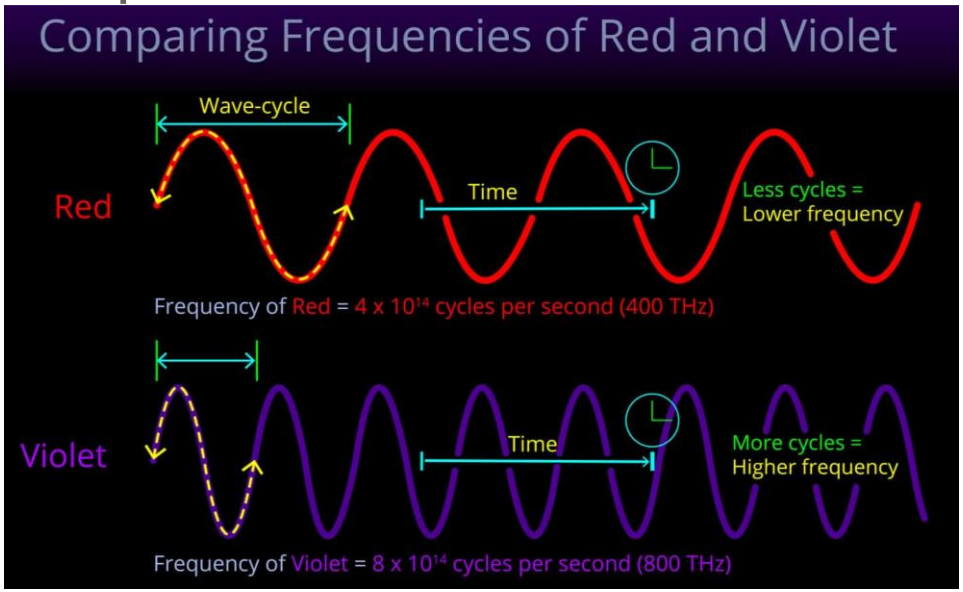


Figure 1-1 *Displacement versus distance along a wave at an instant of time*

Frequency

- The number of times a wave repeats itself in one second.
  - # of cycles per time
- Never changes
  - Wavelength and speed of light can change
- Frequency and color are directly correlated
  - 566 THz is green light at 530 nm at 3.0 X 10^8 m/s
- Represented by Hertz or cycles per second.



Speed

- Wave velocity is distance traveled per unit of time

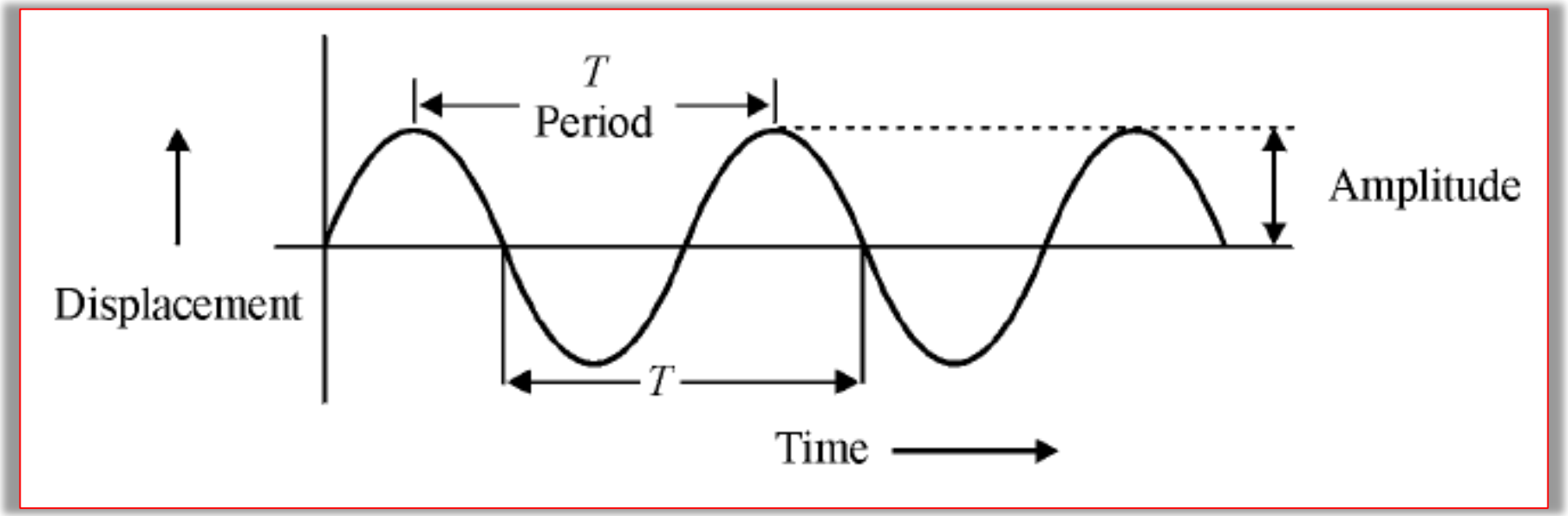
- When ALL light is traveling through a vacuum it travels at the same speed, the speed of light.

- 300 million meters per second or 186,284 miles per second which is around 670 million mph.

- Light from the Sun takes a little over 8 minutes to reach Earth.

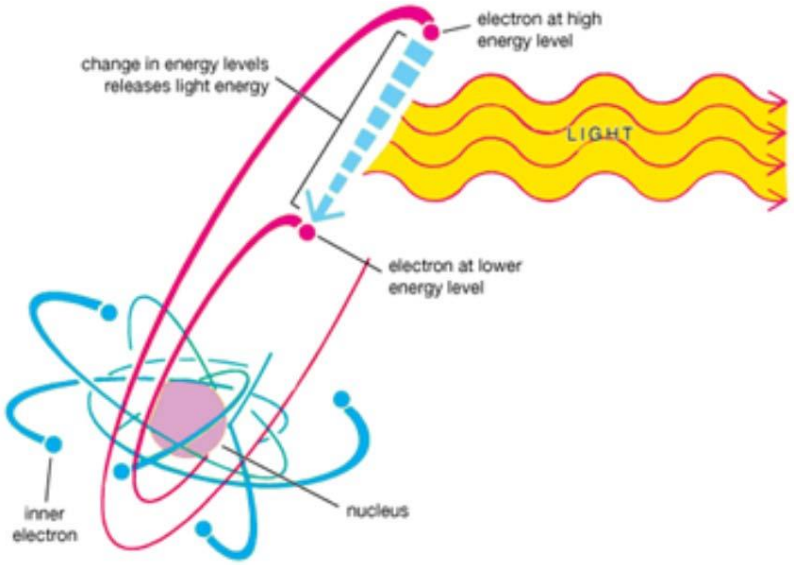
Period - Amplitude

- Period - time over which a wave repeats itself
- Amplitude - maximum displacement of the wave from a certain reference point.

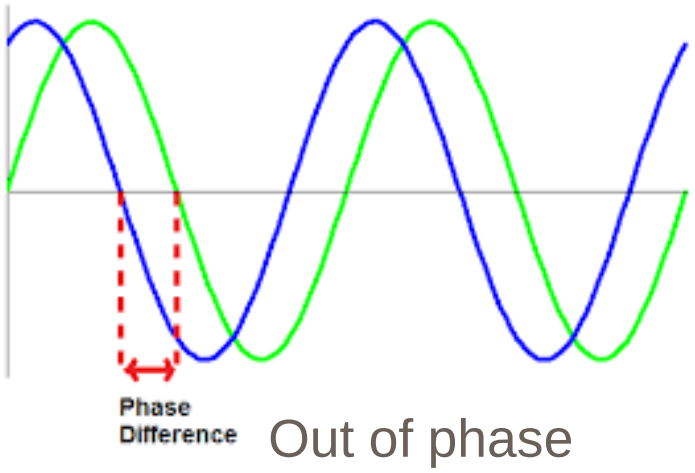


Energy - Phase

- Each photon generated has a specific direction, *energy*, frequency, polarization, wavelength, and phase.
- The higher the frequency, the greater the energy.
- Light energy is the only form of energy visible to the human eye



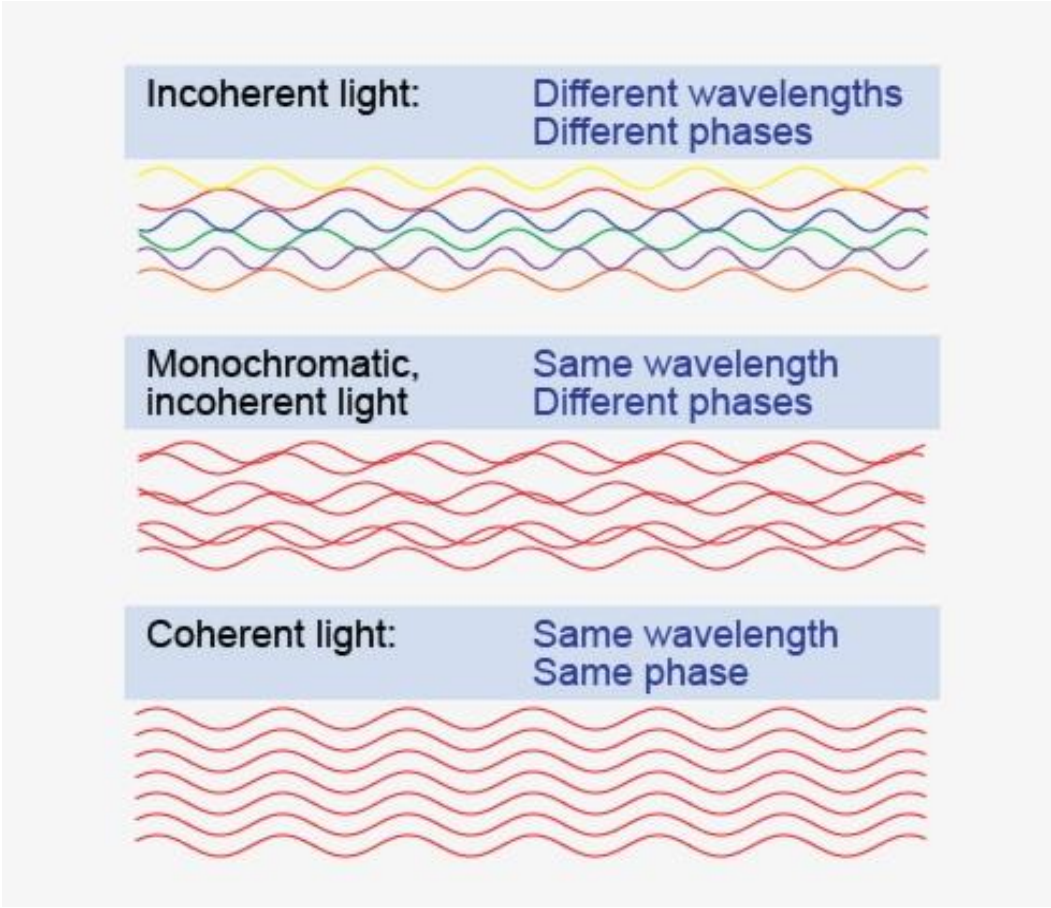
- Phase: point of angular displacement in radians or degrees at a particular time.
- Involves the position relationship of two waveforms.
- In phase: When the peaks of two waveforms with the same frequency are in exact alignment at the same time



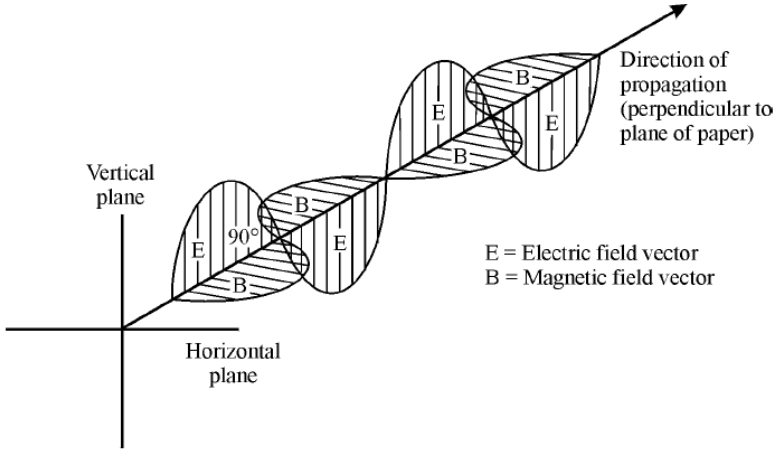
Out of phase

Coherence

- Occurs when most of the light is in step or in phase
- Coherent light is necessary to focus light to create a clear image
- Why we can create holograms and measure chemical makeup of the atmosphere

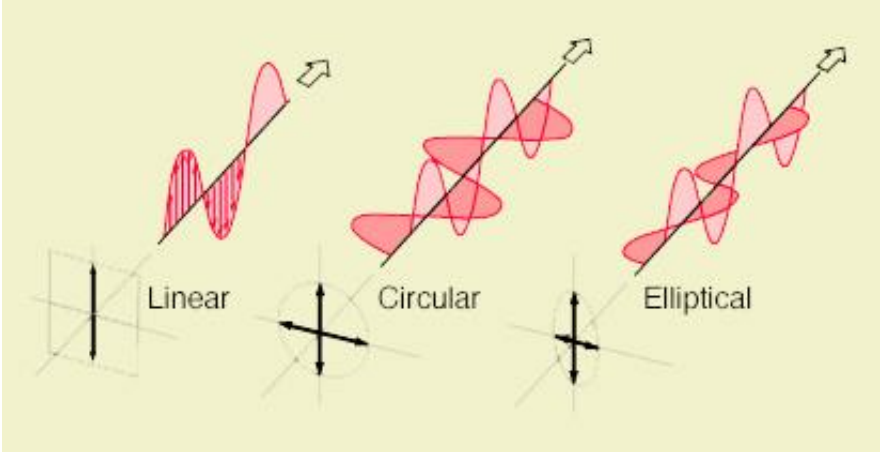


Polarization



Three dimensional view of an electromagnetic wave.

- Aligning or Controlling the orientation of the E-vectors
- Liner, Circular, and Elliptical polarization

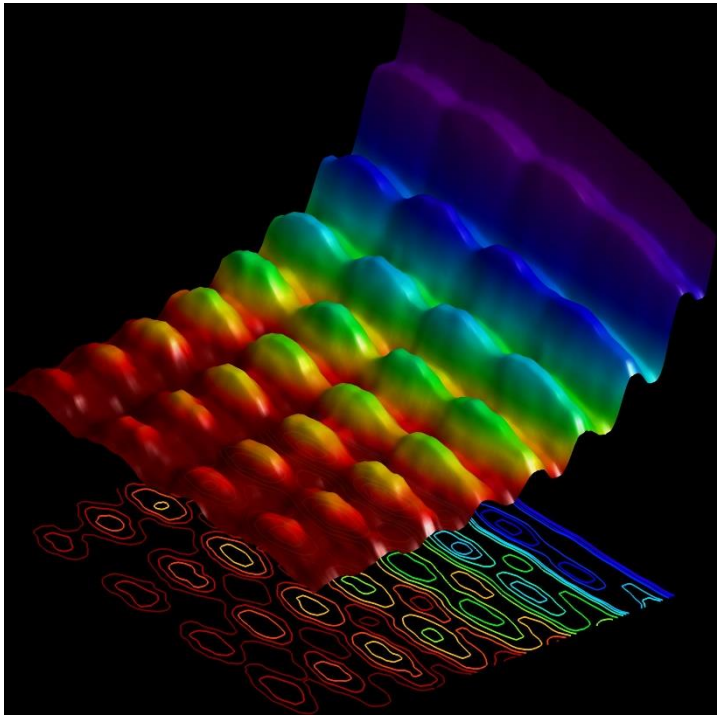


Nature of Light

- Dual Nature of Light
- Electro Magnetic Radiation
- S.T.A.R.R.
- Diffraction
- Interference

Dual Nature of Light

- Light can be modeled and predicted as a particle or a wave.
- Particle
  - Photon or packet of energy,
- Wave
  - Photons travel in wavelets creating a wave front
- Every photon has a specific energy, phase, frequency, polarization, and direction.

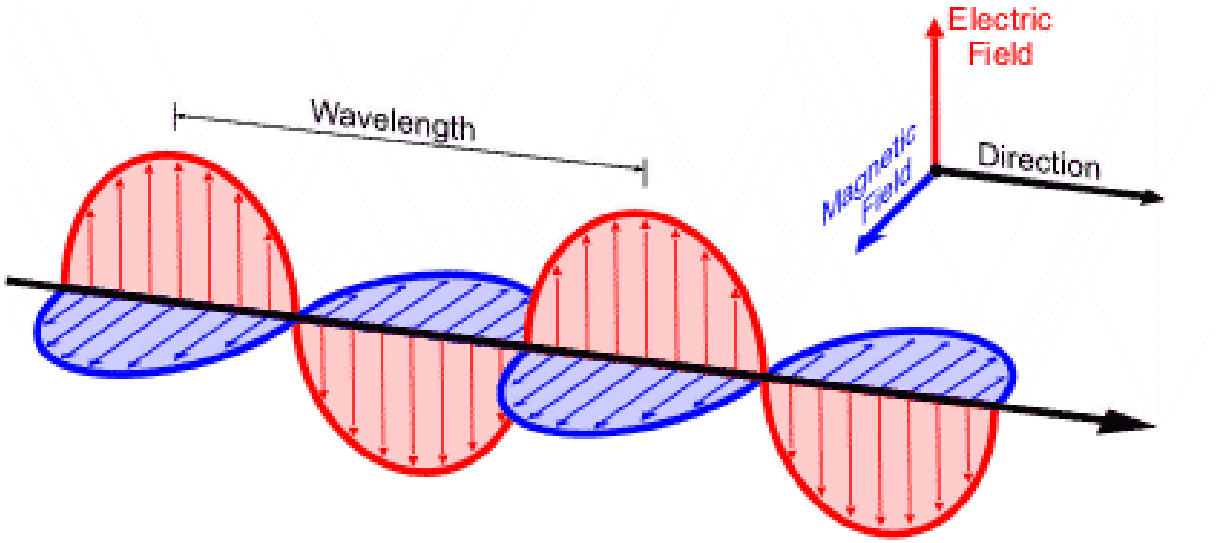


Electro-Magnetic Radiation

- Light Energy moves or propagates via changing electric and magnetic fields

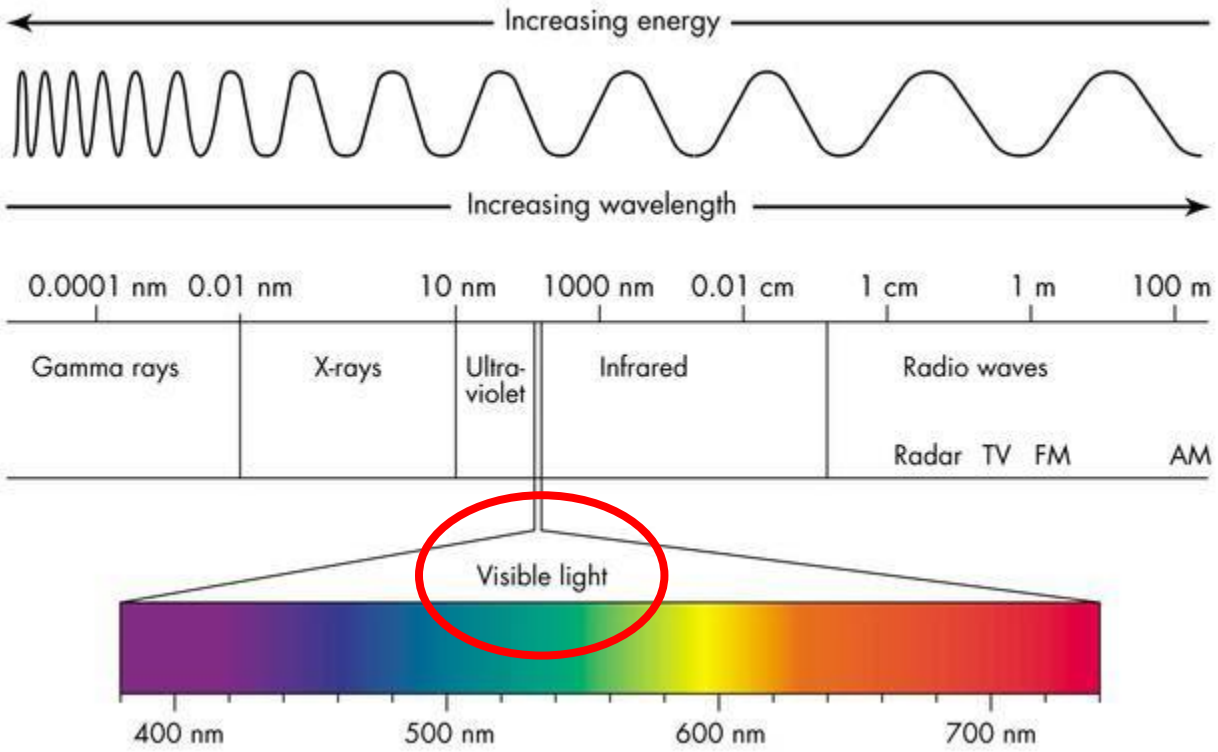
- Oscillations in electric and magnetic fields working together, 90 degrees from each other, and 90 degrees from the direction of propagation

- It travels with no medium required



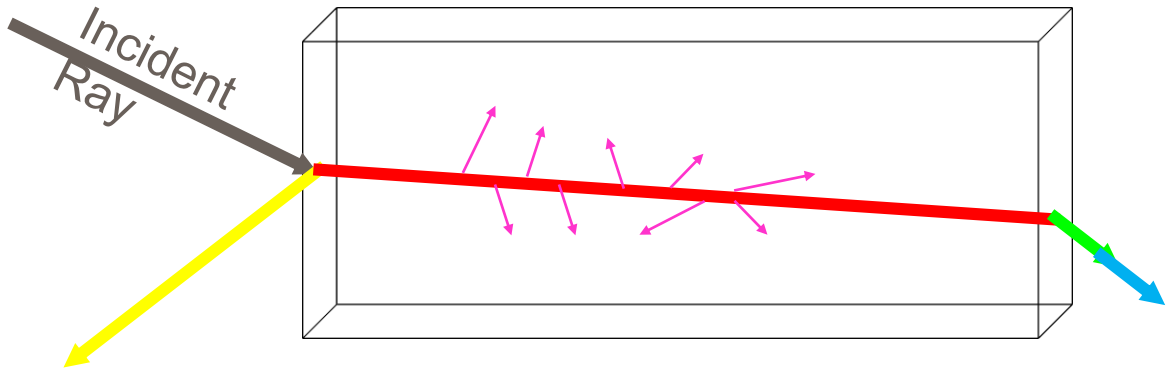
Electro-Magnetic Radiation Spectrum

- In photonics, white light is a mixture of the wavelengths/colors of red, green and blue (RGB).
- Shorter wavelengths = higher frequencies



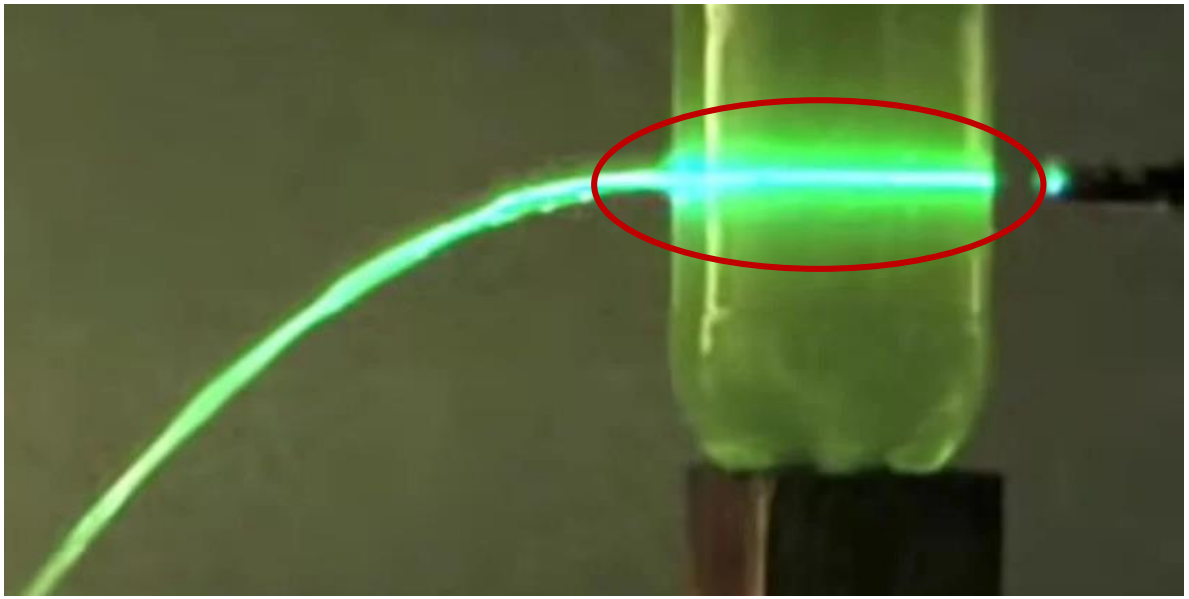
S.T.A.R.R.

- S-T-A-R-R: light incident on and traveling into or through a material will undergo S.T.A.R.R.
  - Scatter
  - Transmit
  - Absorb
  - Reflect
  - Refract



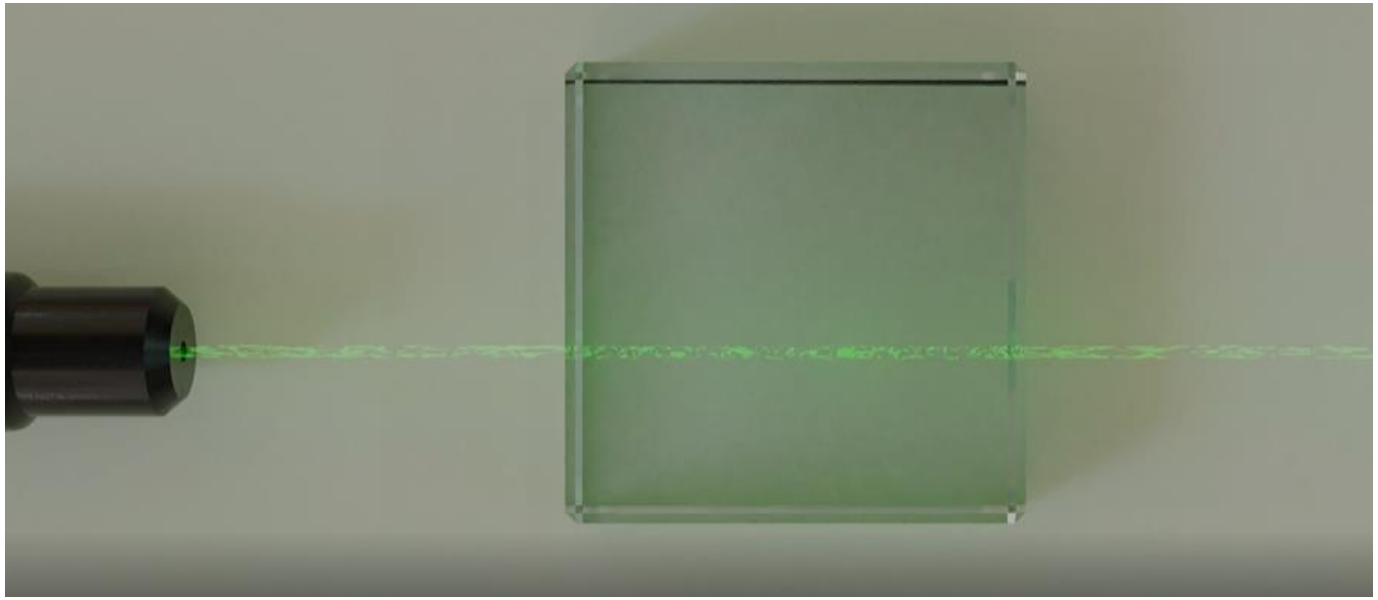
Scatter

- When a beam of light is attenuated by a physical deflection of a photon from the direct beam.
- Happens when light collides with a small molecule
- Wavelength dependent



Transmit

- When light transmits through one medium to another, it changes speed and wavelength, but not frequency
- The photo shows straight line transmission with reflection, absorption and scatter thereby decreasing the power out compared to the power in.



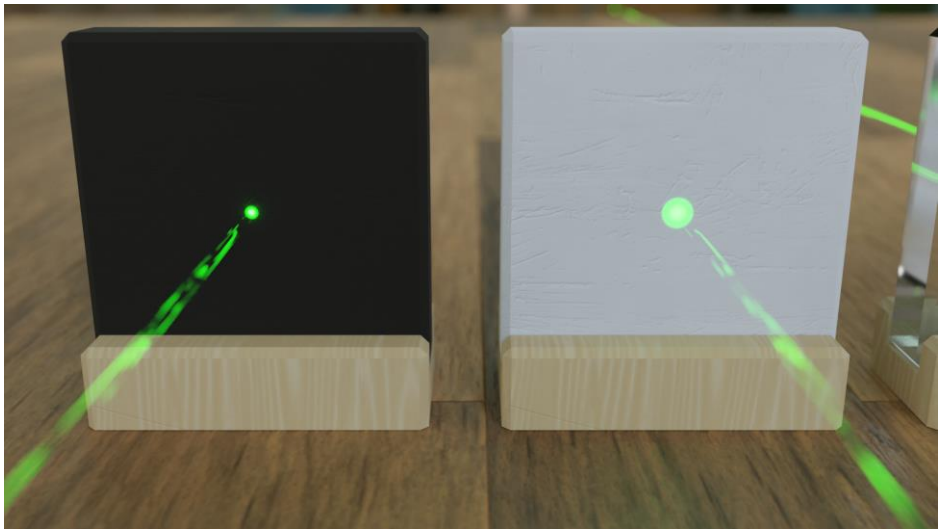
Absorb

Refers to the “taking up” of radiant energy by an irradiated object

On the left, the green light is strongly absorbed by the black surface and therefore its reflection is highly diminished.

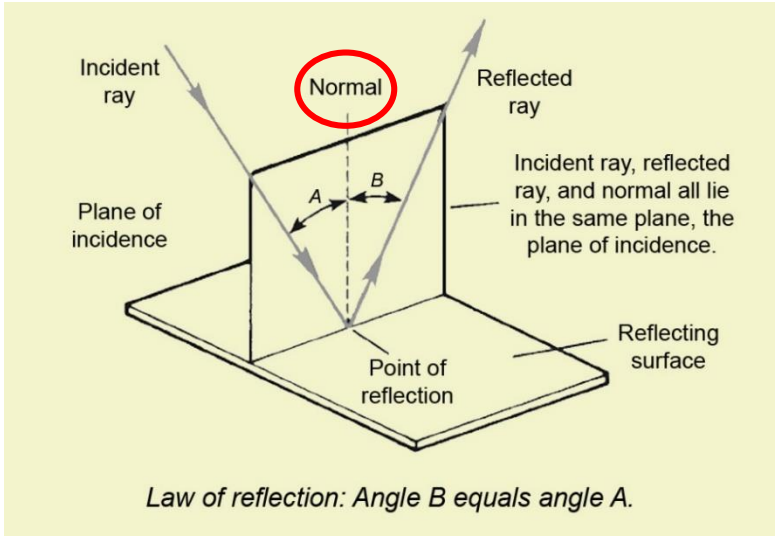
On the right, the white surface absorbs less light and therefore reflects more.

The light spot therefore appears larger and more intense.



Reflection

- If a laser beam is directed onto a mirror, the light beam is deflected with little loss of energy/power.
- Specular Reflection off of smooth surfaces such as mirrors or a calm body of water.
- Diffuse Reflection off of rough surfaces such as clothing, paper, and the asphalt roadway.

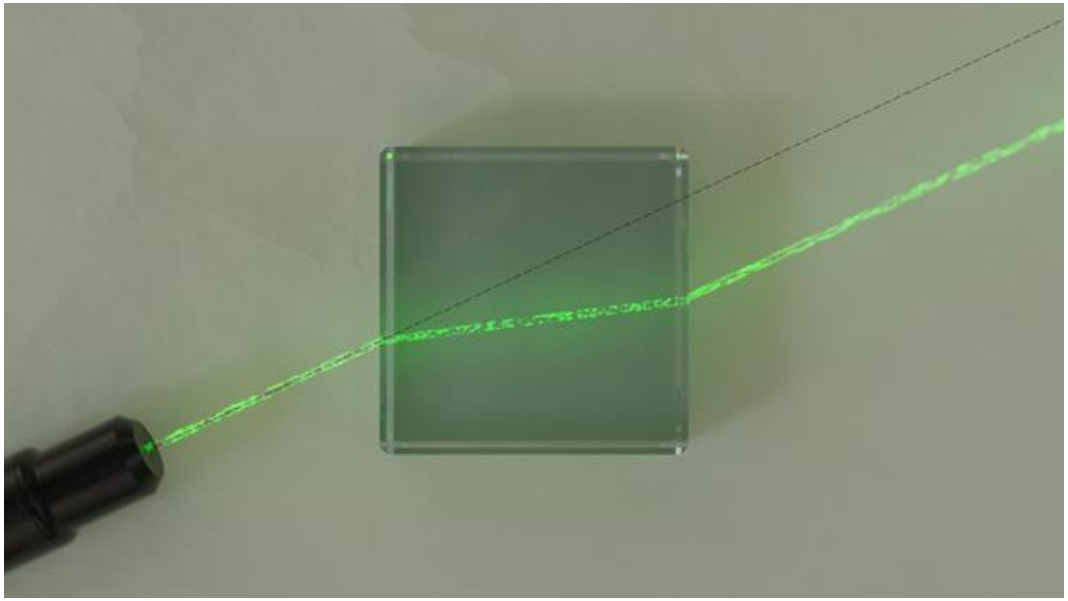


Law of reflection: Angle B equals angle A.

The Law of Reflection: when a ray of light reflects off a surface, the angle of reflection (B) equals the angle of incidence (A) when measured from the Normal.

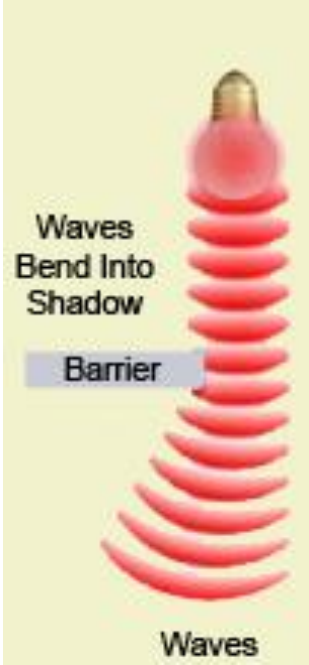
Refraction

- When a laser beam propagates from one transparent medium into another, its propagation direction will change or be bent therefore changing directions.



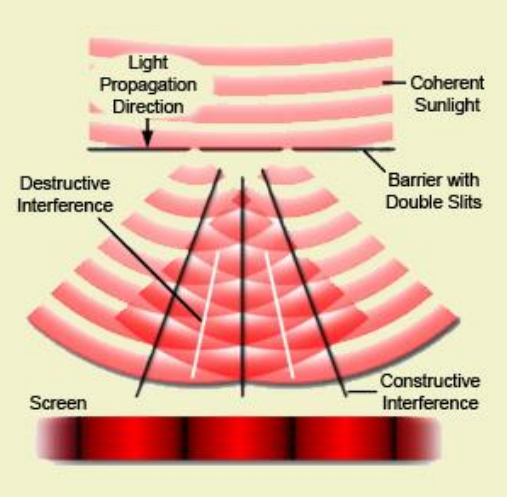
Diffraction

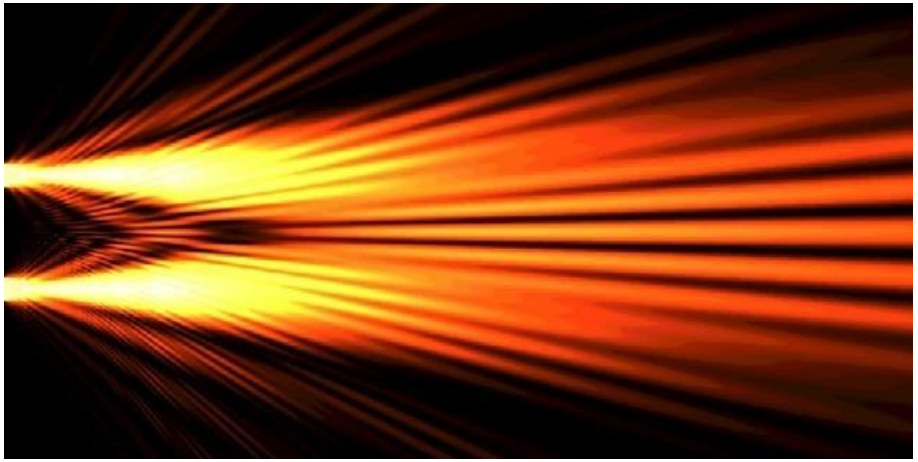
- Occurs when light grazes an opaque edge
- Some of the light turns the corner
- Cannot be eliminated

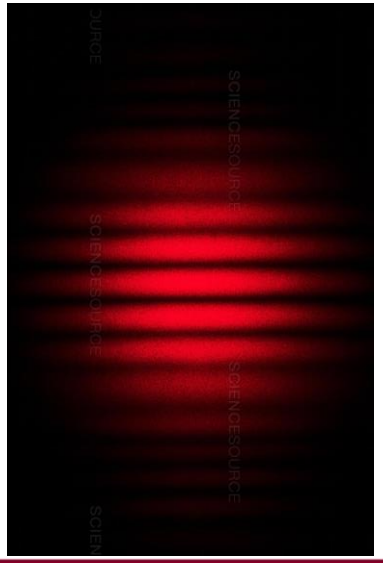


Interference

- Occurs when two coherent waves superimpose
- The result is bands of light and dark
- Constructive interference is the light
- Destructive interference is the dark







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