

SCHRÖDINGER'S CLUB

AT SAMUELI ACADEMY

# Introduction to Quantum

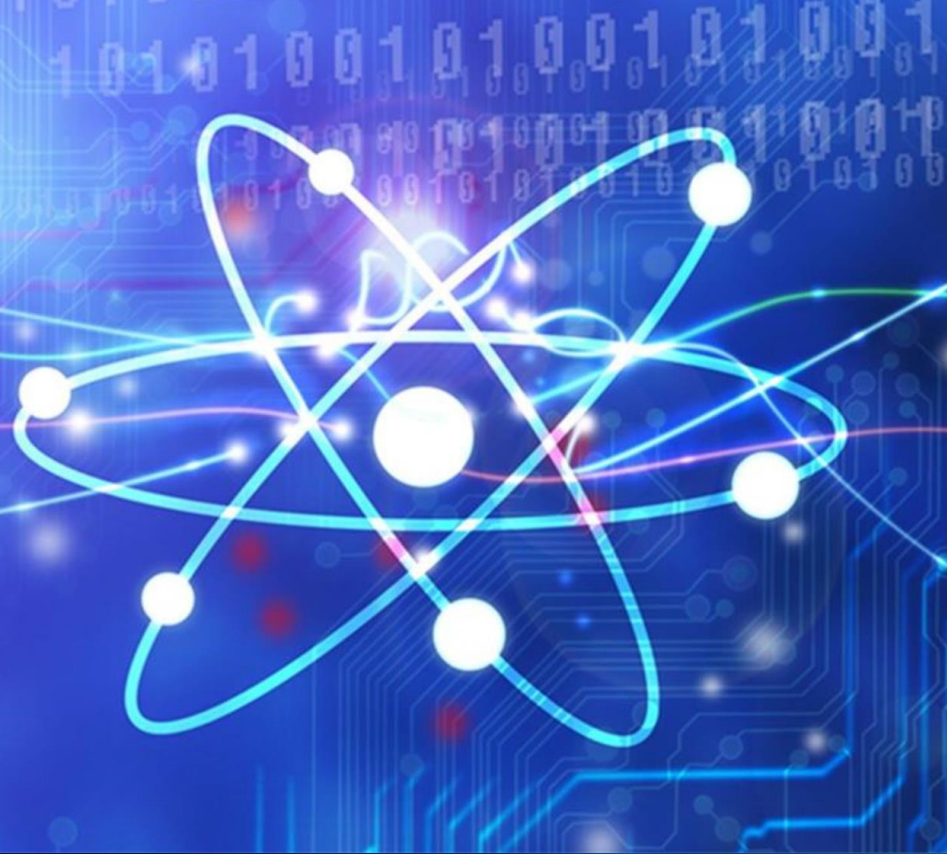
with hands-on laser & spectroscopy labs

## Today's Agenda:

1. What is Quantum & Why should you care?
2. Light is an Electromagnetic Wave
3. Measurements using polarization
4. Laser Light & Diffraction Gratings
5. Atomic Spectroscopy & Diffraction Gratings
6. Summary – What is this really all about ??

**Donn Silberman**  
Mentor





# What is Quantum & why should you care?

Things at the Atomic Scale are very different than at the human scale.

- The Quantum World underlies our modern civilization.
- And Quantum is about take humanity to the next level.
- You can help make it happen.

This web page has the article below and links to all the references.

## Quantum Theory with Computer & Cyber Security Applications

Donn M. Silberman, Fellow of the OSSC & SPIE



SOLVAY CONFERENCE 1927

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Adapted from W.H. BRAGG, H. DESLANDRES and E. VAN AUDEL

Here are the first two paragraphs of the article. [Click on the link below to download the full article.](#)



## PRE-QUANTUM MYSTERIES

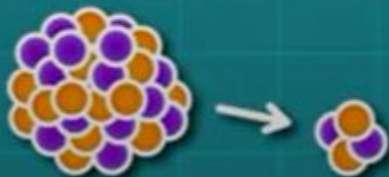
### ATOMIC SPECTRA



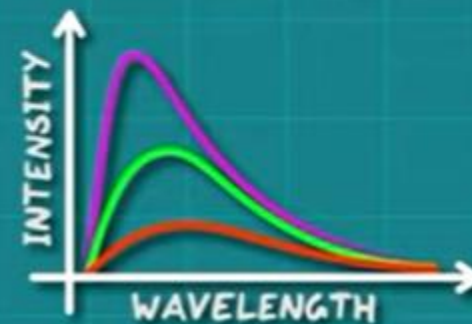
### THE STABLE ATOM



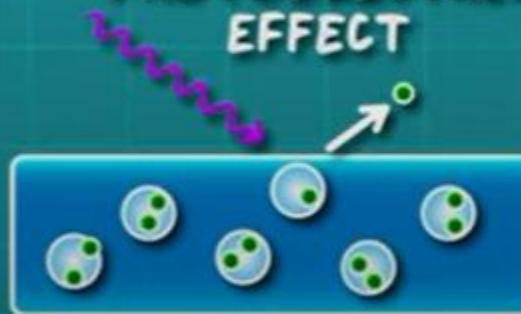
### RADIOACTIVITY



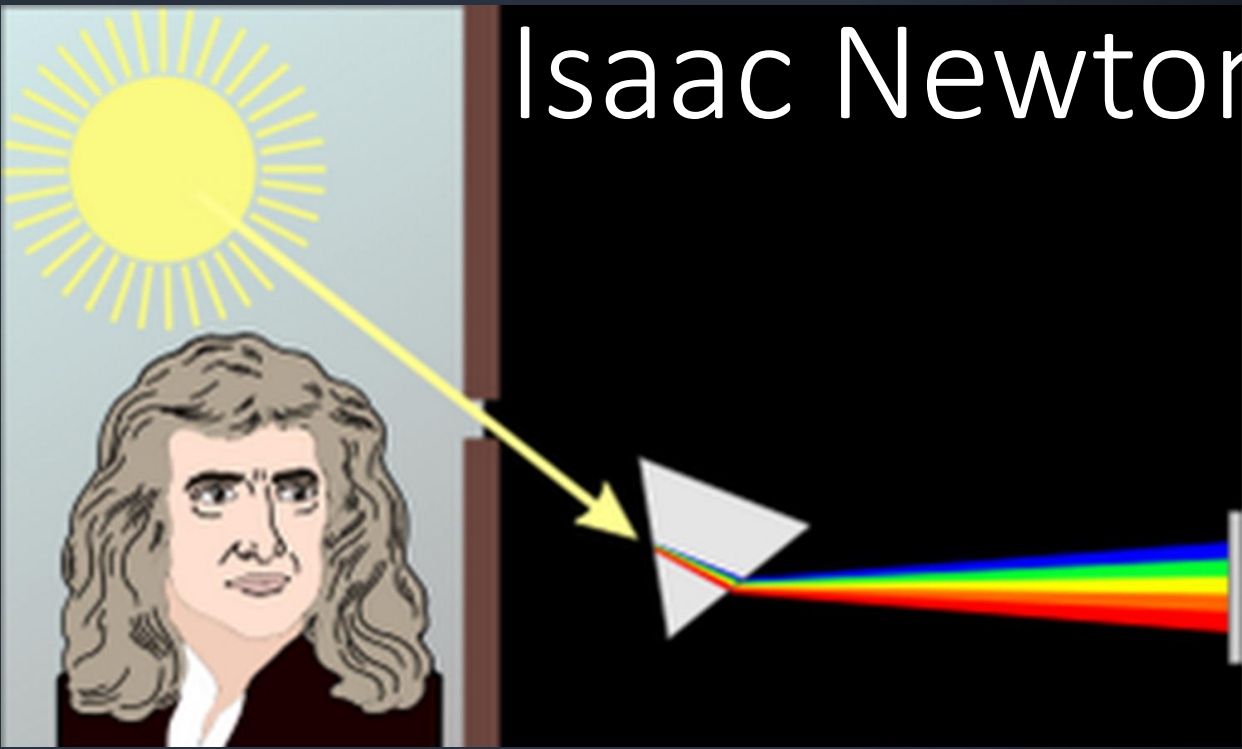
### BLACKBODY RADIATION



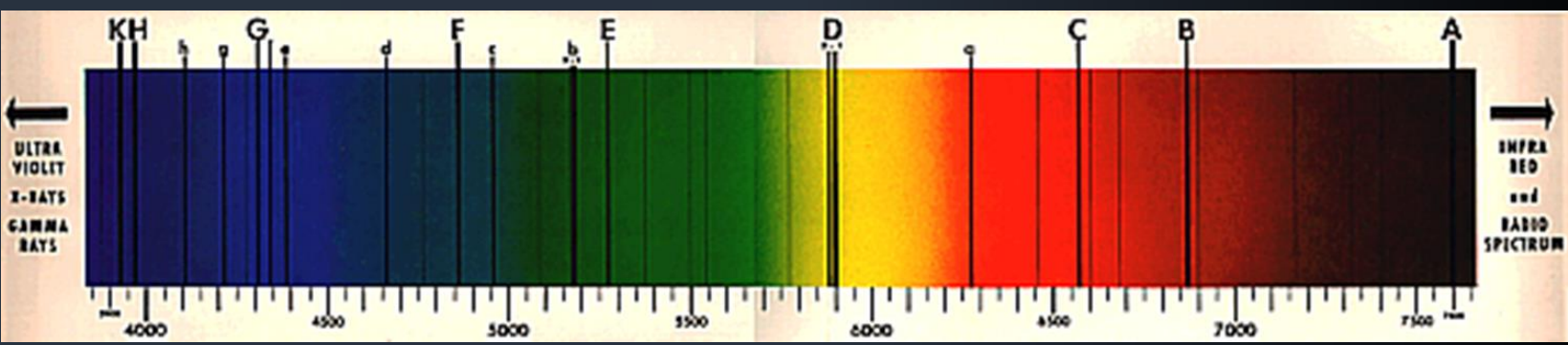
### PHOTOELECTRIC EFFECT



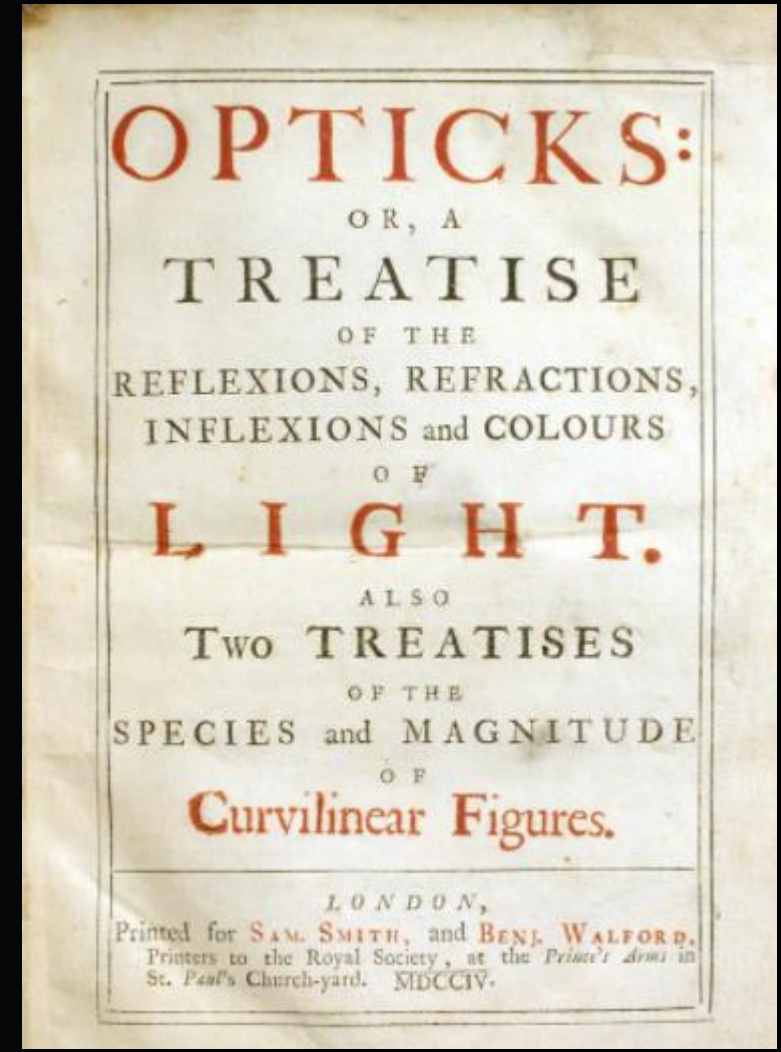
# Isaac Newton & the Prism



## The Solar Spectrum with Fraunhofer Lines



Discrete spectral lines correspond to the energy levels of various atoms that are burning in the Sun.



The first, 1704, edition of *Opticks: or, a treatise of the reflexions, refractions, inflexions and colours of light.*

# Light is an Electromagnetic Wave

- **Amplitude** → Size of each vibration
- **Direction** → Path of each vibration
- **Length** → Separation between vibrations

Scientists study the properties of things.

Properties of waves include:

**Amplitude, Direction, Length**

# Light is an Electromagnetic Wave

- **Amplitude** → Size of each vibration → *Power*
- **Direction** → Path of each vibration
- **Length** → Separation between vibrations



dim light  
small vibrations

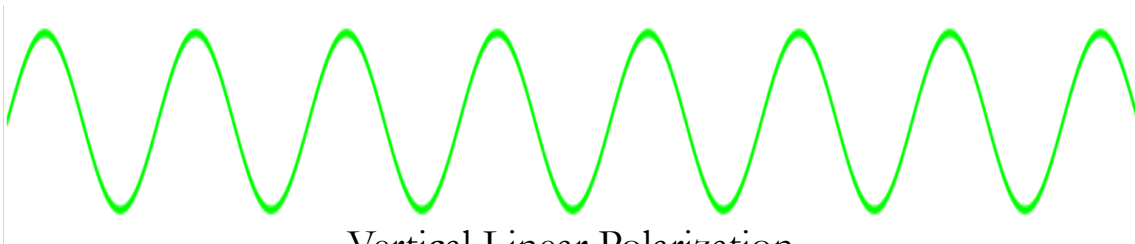


**Bright Light**  
**LARGE VIBRATIONS**

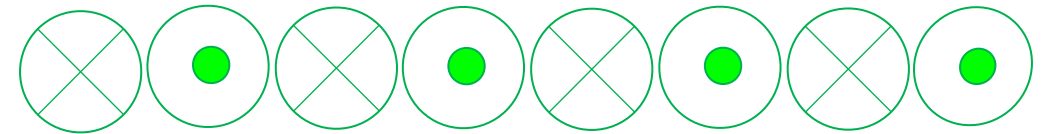


# Light is an Electromagnetic Wave

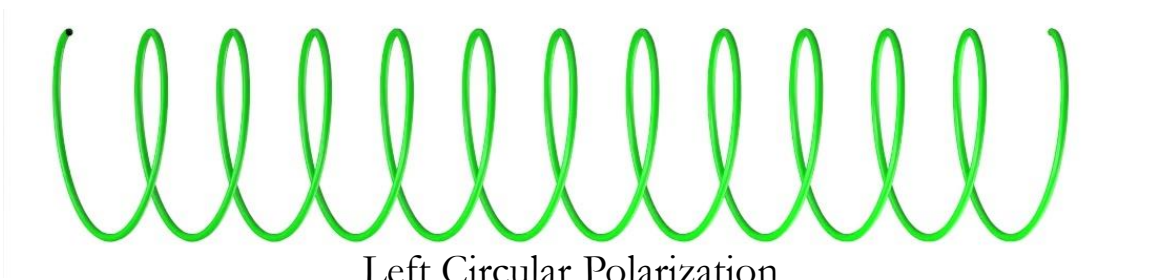
- **Amplitude** → Size of each vibration → *Power*
- **Direction** → Path of each vibration → *Polarization*
- **Length** → Separation between vibrations



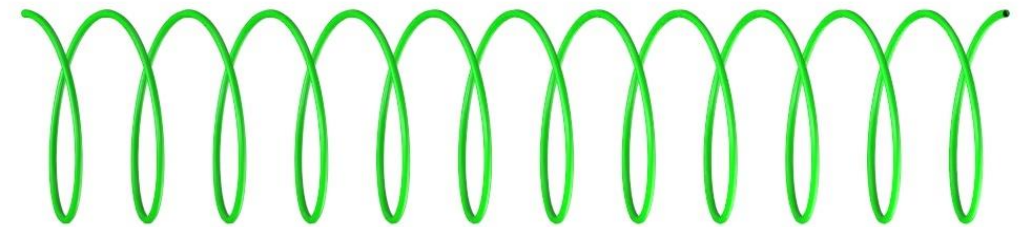
Vertical Linear Polarization



Horizontal Linear Polarization



Left Circular Polarization

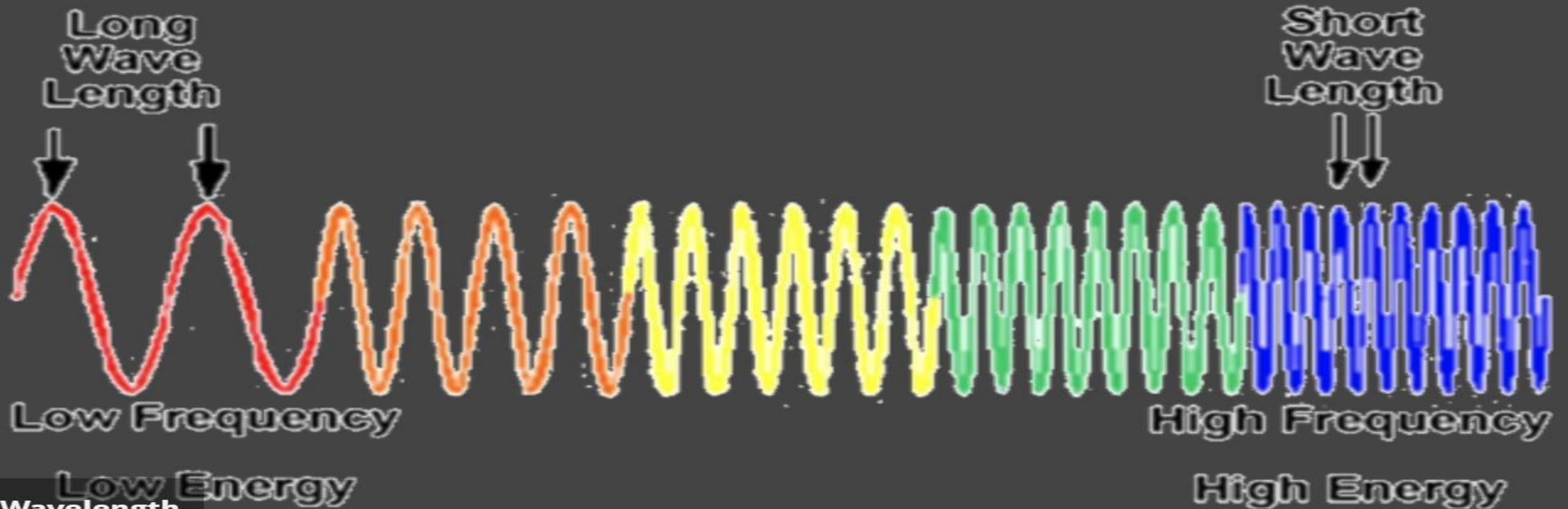


Right Circular Polarization



# Light is an Electromagnetic Wave

- Amplitude → Size of each vibration → *Power*
- Direction → Path of each vibration → *Polarization*
- Length → Separation between vibrations → *Color*



# Linear Polarizers

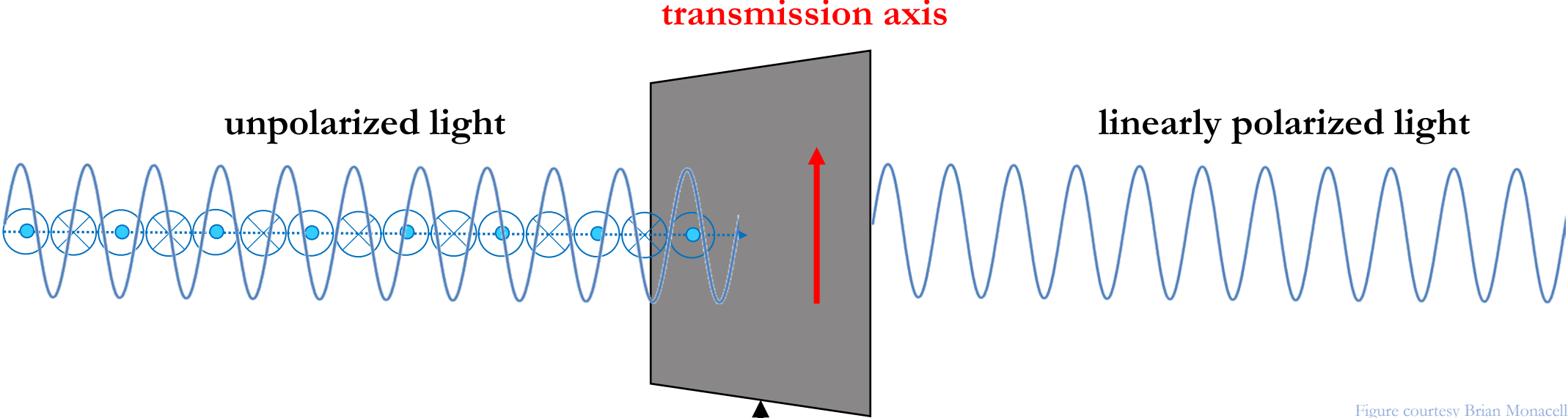
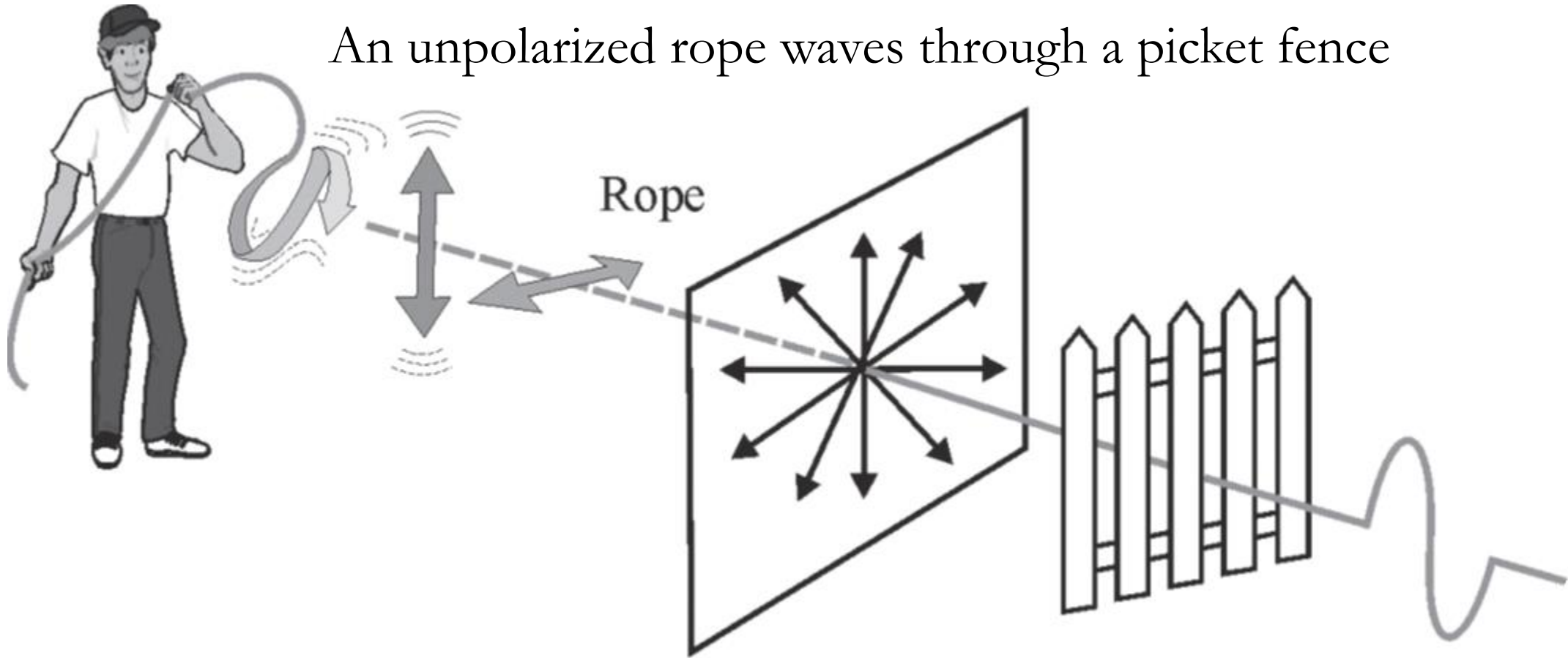


Figure courtesy Brian Monacelli



Image courtesy Erin Monacelli

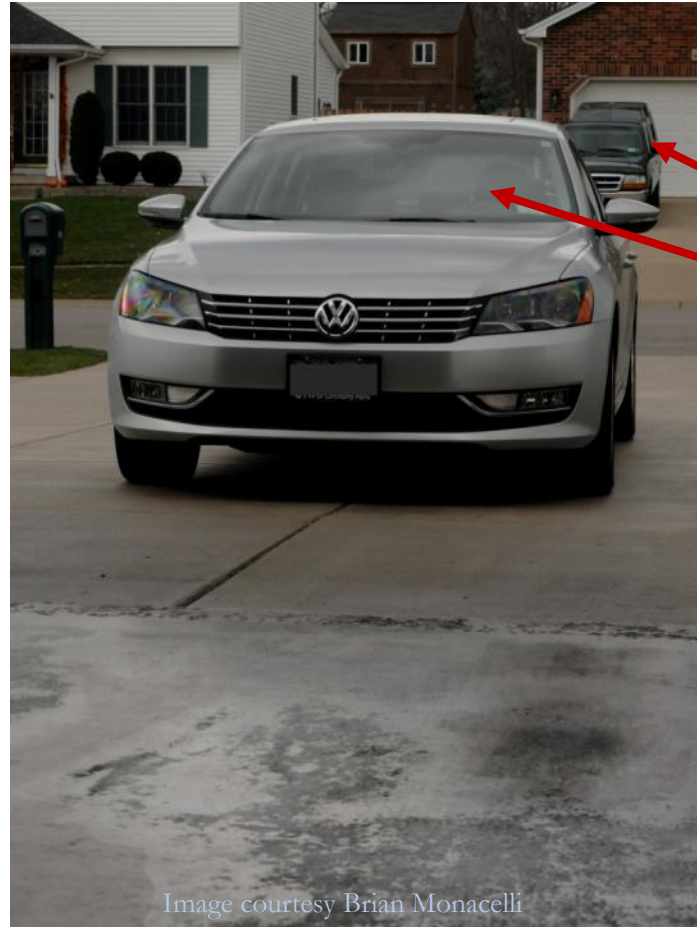
# Polarization Analogy



On the other side of the picket fence, the rope's motion is polarized along the slats

# Polarized Sunglasses Block Glare

without polarized sunglasses



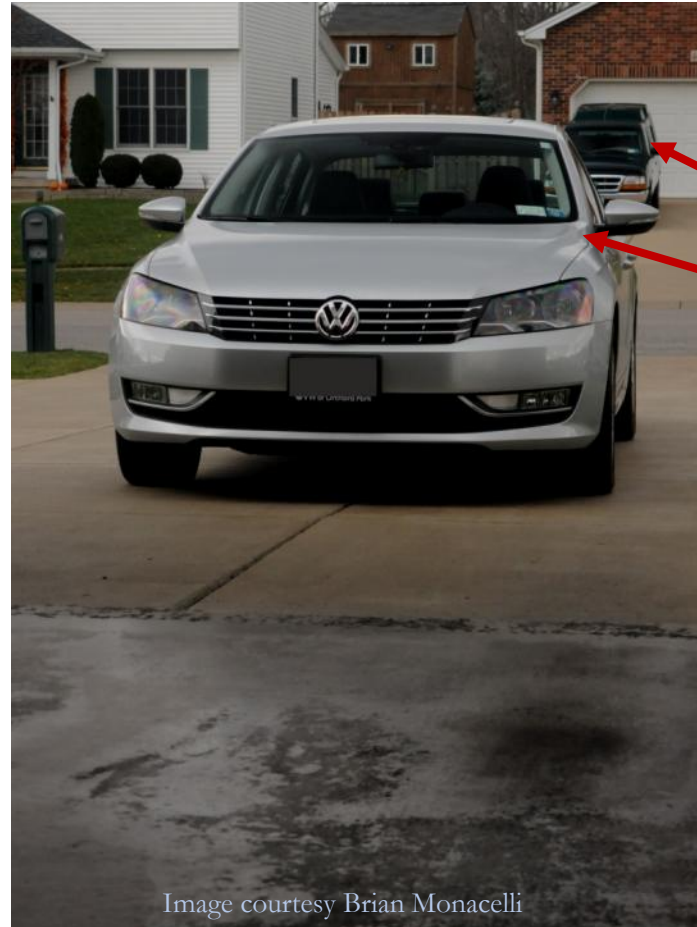
Watch the car windshields and hood

Polarizers block horizontally s-polarized light, and transmit vertically p-polarized light



# Polarized Sunglasses Block Glare

with polarized sunglasses



Watch the car windshields and hood

Light reflecting off the ground is horizontally s-polarized

# Polarization Filters – Hands-on Experiment



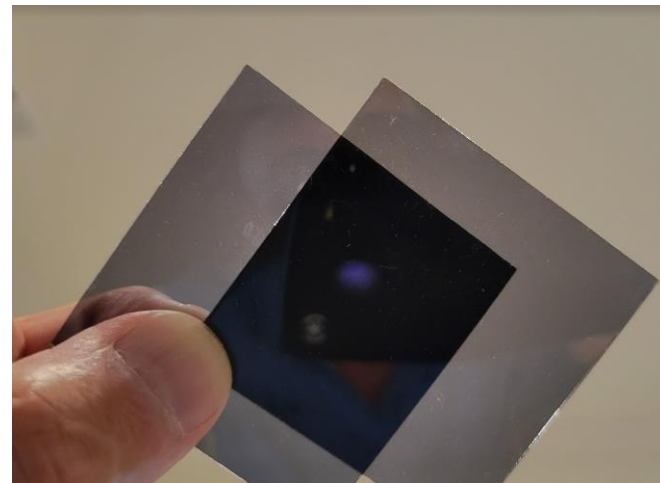
Ceiling light – no **P** filters



Ceiling light – one **P(h)** filter

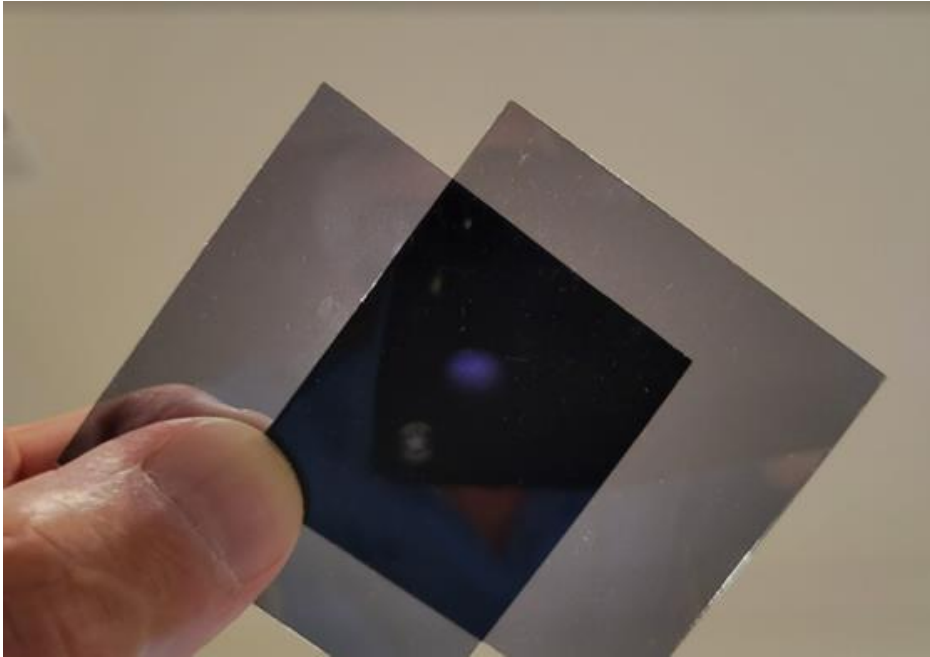


Ceiling light – one **P(v)** filter

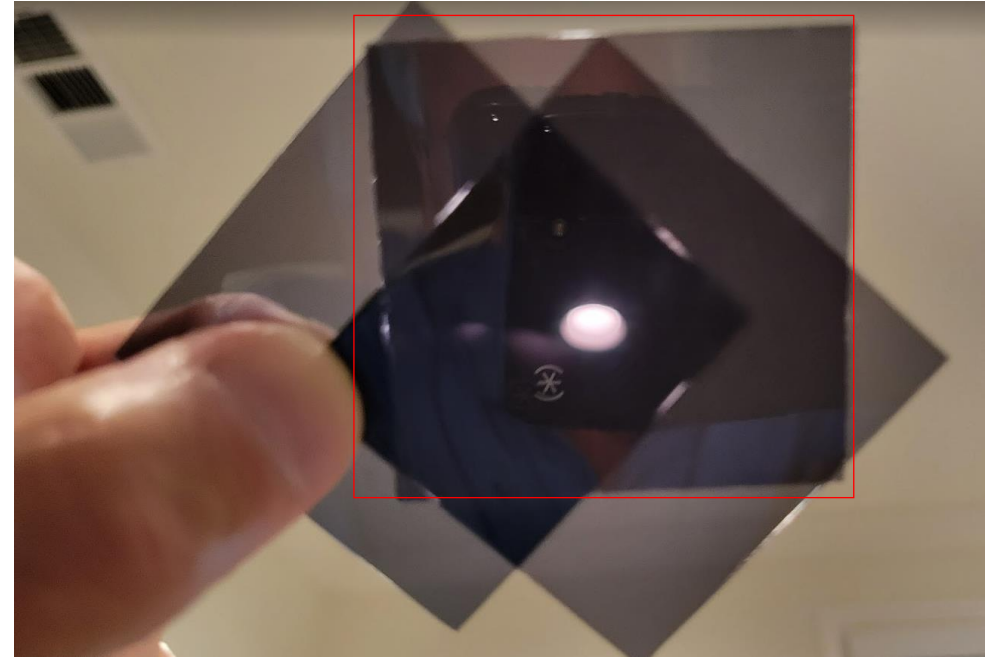


Ceiling light – both **P(h & v)** filters

# Polarization Filters



Ceiling light – both **P(h & v)** filters



Ceiling light – both **P(h & v)** filters  
Plus a third **P** filter at 45 deg !!!  
(sandwiched in-between)

# Polarization Filters with a Polarized Laser



Laser with no P filter



Laser with P(h) filter



Laser with P(h+v) filters



# Polarization Filters with a Polarized Laser



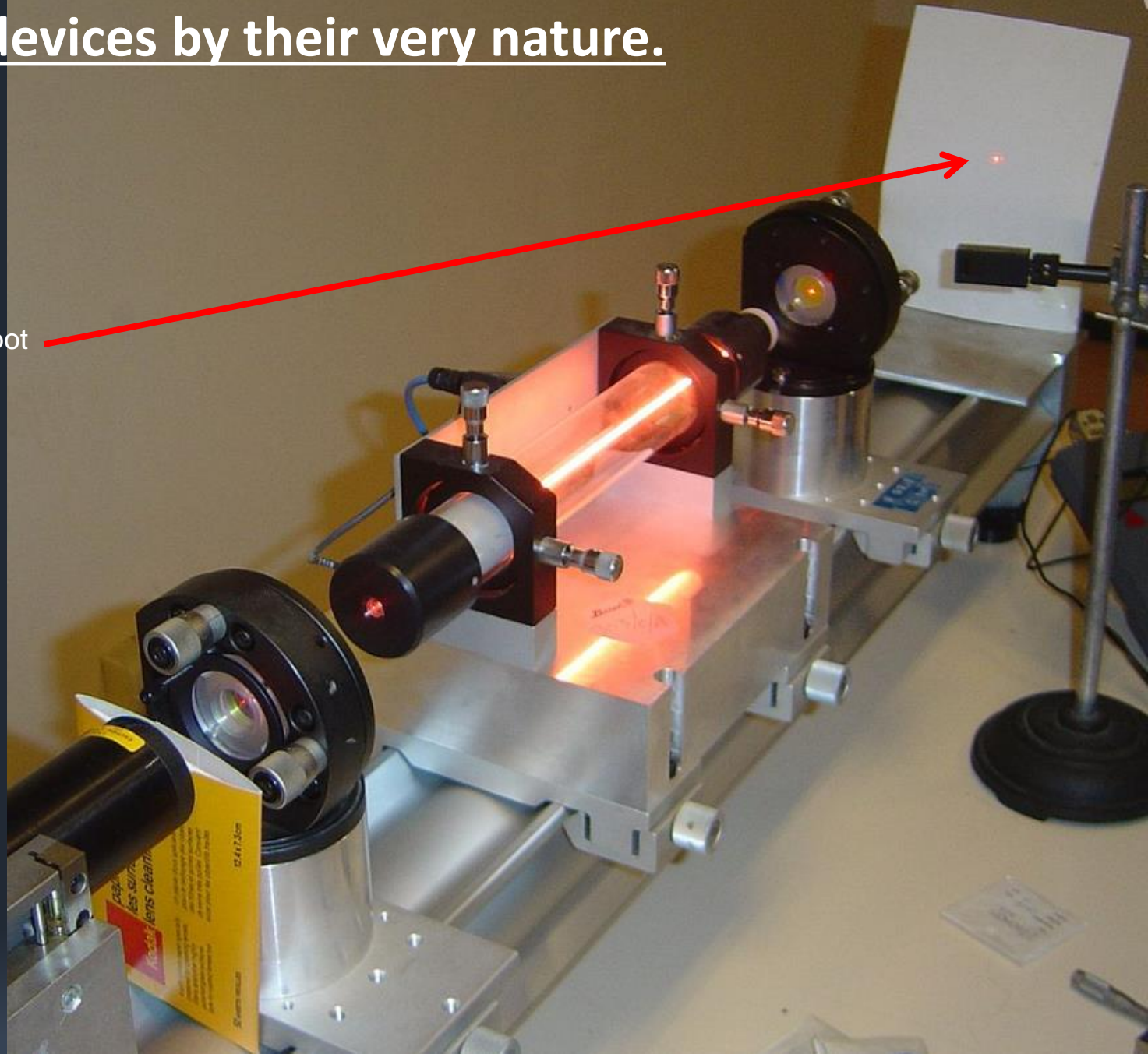
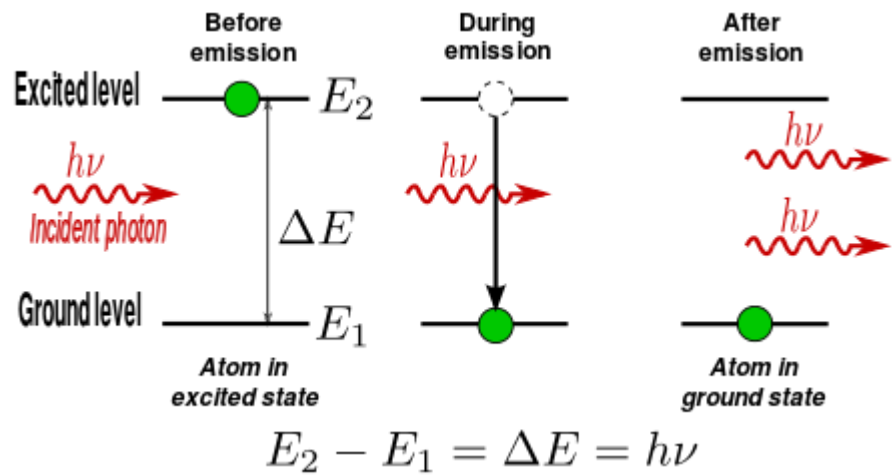
Laser with P(h+v) filters



Laser with P(h+ v + 45) filters

# Lasers are intrinsically quantum devices by their very nature.

A helium–neon laser demonstration. The glow running through the center of the tube is an electric discharge. This glowing plasma is the gain medium for the laser. The laser produces a tiny, intense spot on the screen to the right. The center of the spot appears white because the image is overexposed there.

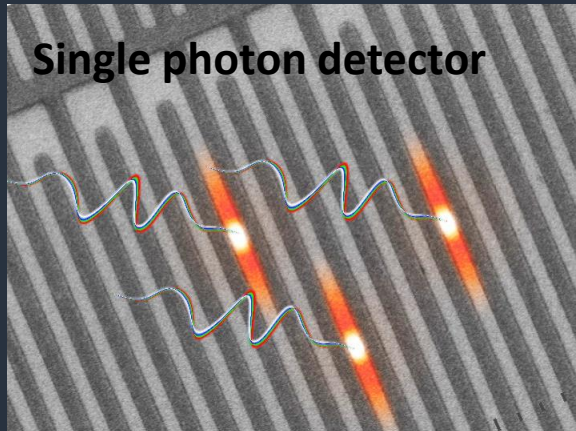


In physics, a quantum is the minimum amount of any physical entity involved in an interaction. The fundamental notion that a physical property can be "quantized" is referred to as "the hypothesis of quantization".

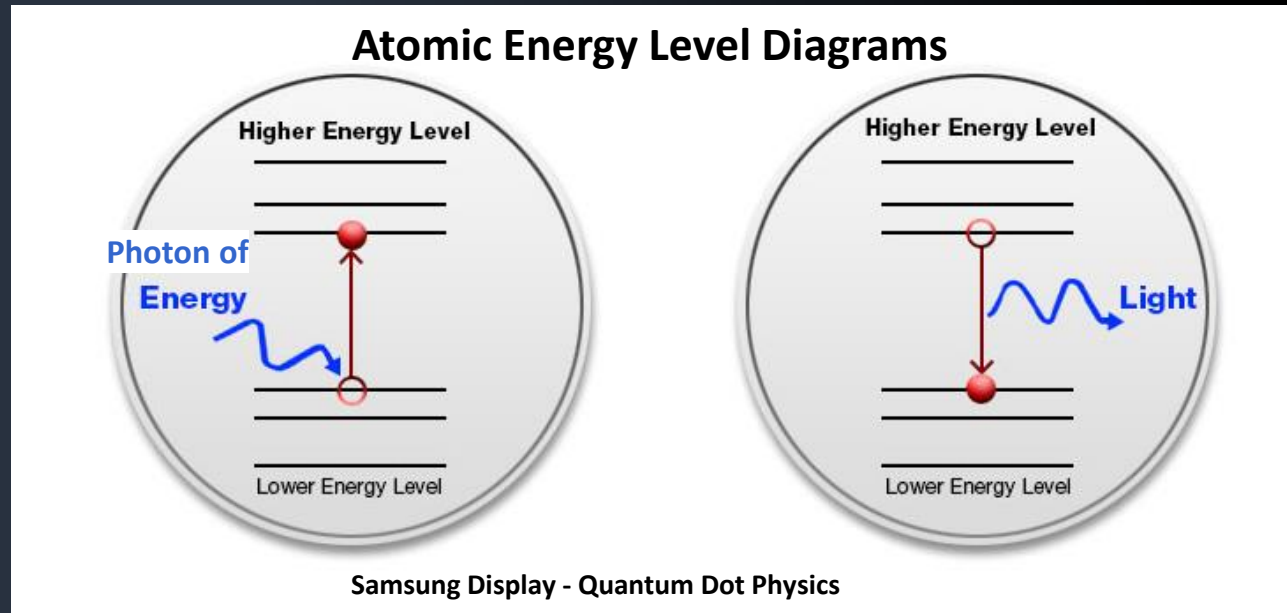
[1] This means that the magnitude of the physical property can take on only **discrete values** consisting of integer multiples of one quantum.

Can't have 1 1/2 photons  
Or 3/4 of an electron

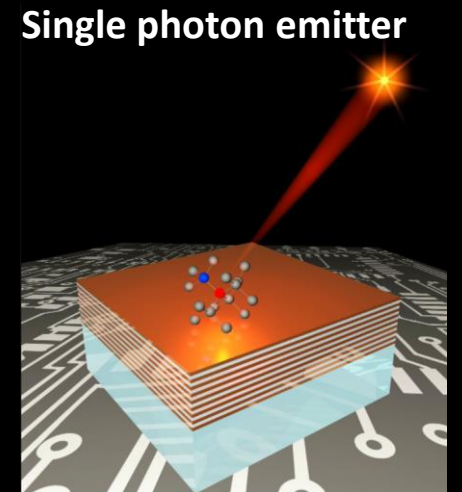
Graphic representation of an **electron (red O)** moving from one energy level to another, emitting or absorbing a **photon (Energy)** of light.



1-singlephoton.jpg (716x536) (b-cdn.net)



Samsung Display - Quantum Dot Physics



singlephoton.jpg (1000x1413) (b-cdn.net)

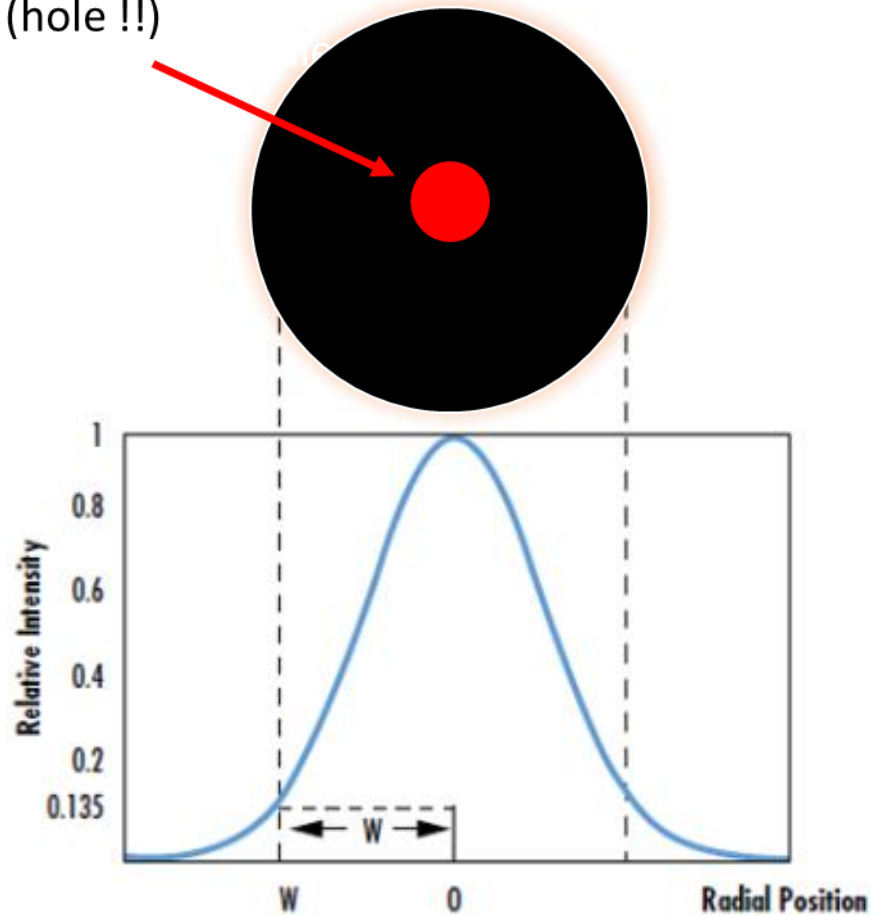
$E = h\nu$  Quantum energy of a photon.  $h = \text{Planck's constant} = 6.626 \times 10^{-34} \text{ Joule}\cdot\text{sec} = 4.136 \times 10^{-15} \text{ eV}\cdot\text{s}$

$E = mc^2$

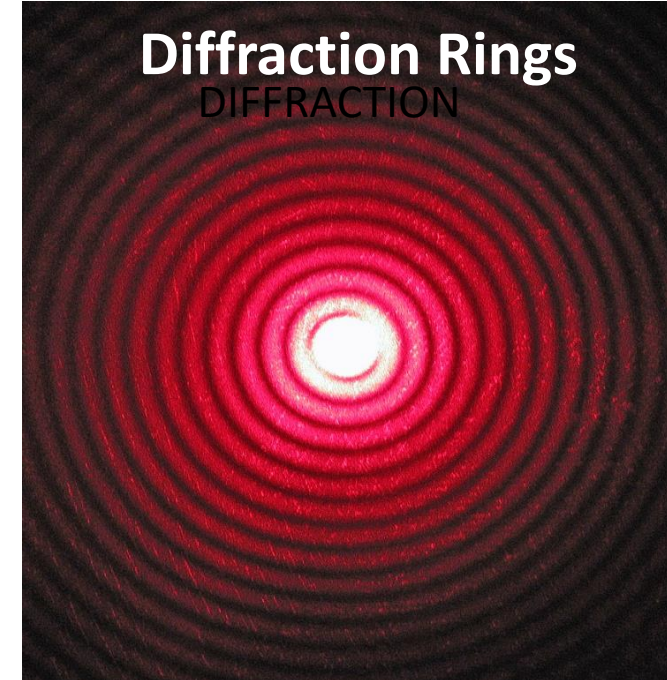


# Laser Light Distribution Patterns

Small Aperture  
(hole !!)



*Figure 1: The waist of a Gaussian beam is defined as the location where the irradiance is  $1/e^2$  (13.5%) of its maximum value*

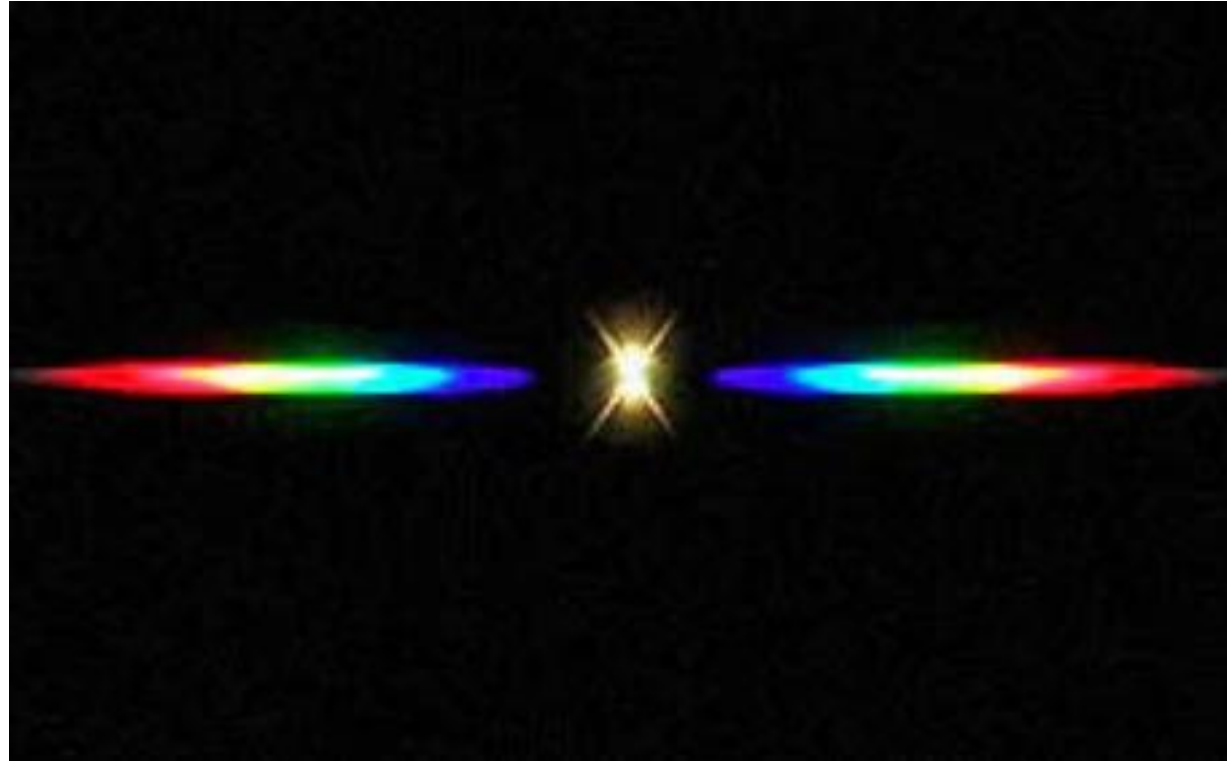
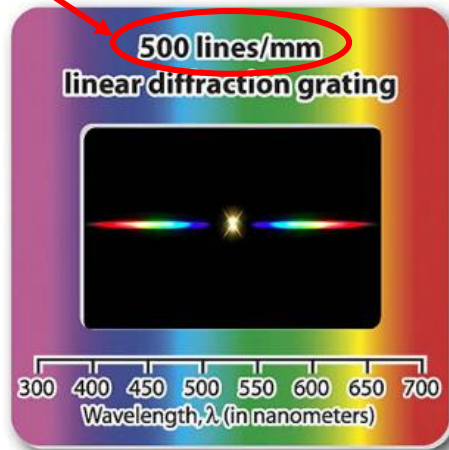
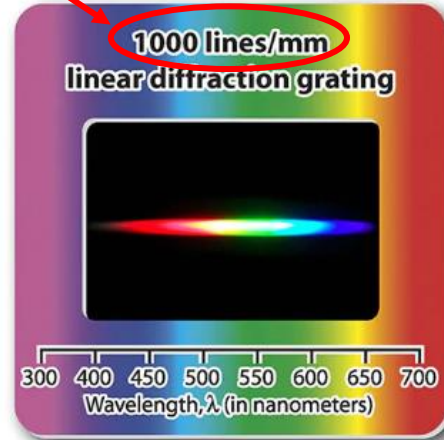


A diffraction pattern of a red laser beam projected onto a plate after passing through a small circular aperture in another plate

[Laser Interference - Diffraction - Wikipedia](#)



# Diffraction Gratings



The grid of bumps in the plastic **diffract** the colors of the white light into the **visible spectrum**.

# Diffraction Gratings



Photo by Donn Silberman

## 17. DETERMINING LASER WAVELENGTH USING GRATING

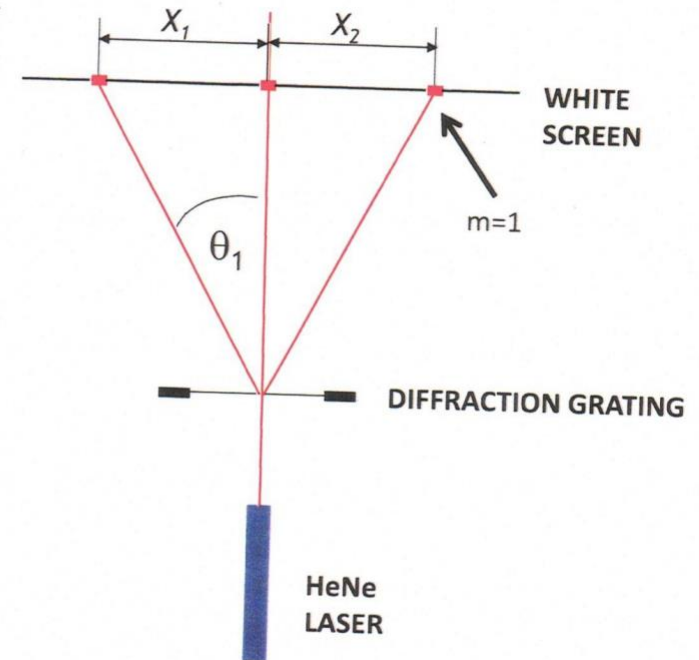
Perform the calculations below (see the figure).

Diffraction equation states the following:

$$m\lambda = d \sin\theta_m$$

where  $m$  is the order of the dot relative to the center,  $\theta_m$  is diffraction angle, and  $\lambda$  is wavelength of the laser beam light. In our case (since we are considering two dots immediately next to the center dot),  $m = 1$ :

$$\lambda = d \sin\theta_1$$



# Diffraction Gratings



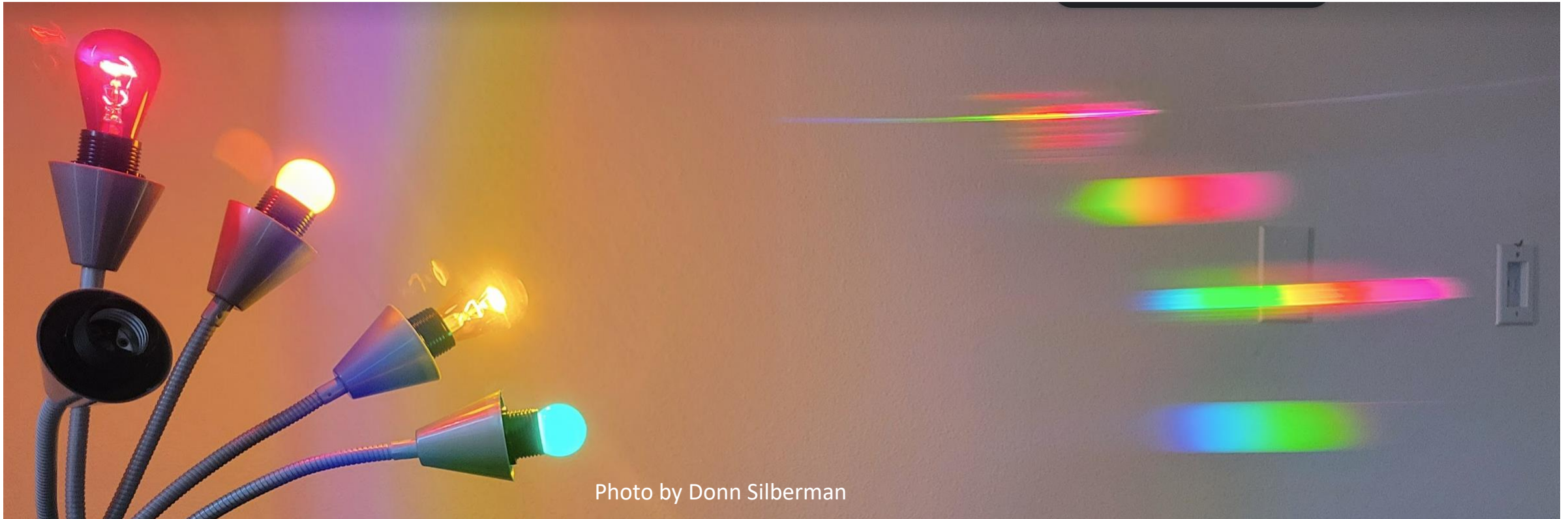
Photo by Donn Silberman

Now, we will analyze the diffraction formula  $m\lambda = d \sin\theta_m$ . What happens to the location of the first maxima (angle  $\theta$ , and distances  $X_1$  and  $X_2$ ) if we replace the red laser with the green one? Do they get closer or farther apart? Explain using the correlation in the diffraction formula. To verify your answer, if available, replace the red laser with green laser pointer.

**What happens for  $m > 1$  ? Like if  $m = 2$  ?**



# Spectroscopy & Diffraction Gratings



**Specialty Light Bulbs with photo taken through a diffraction grating.**

The images of the spectra are blurry compared to when you look through the grating with your eyes.

Try it on your own and draw what you see on the Spectroscopy worksheet.





# Spectroscopy & Diffraction Gratings

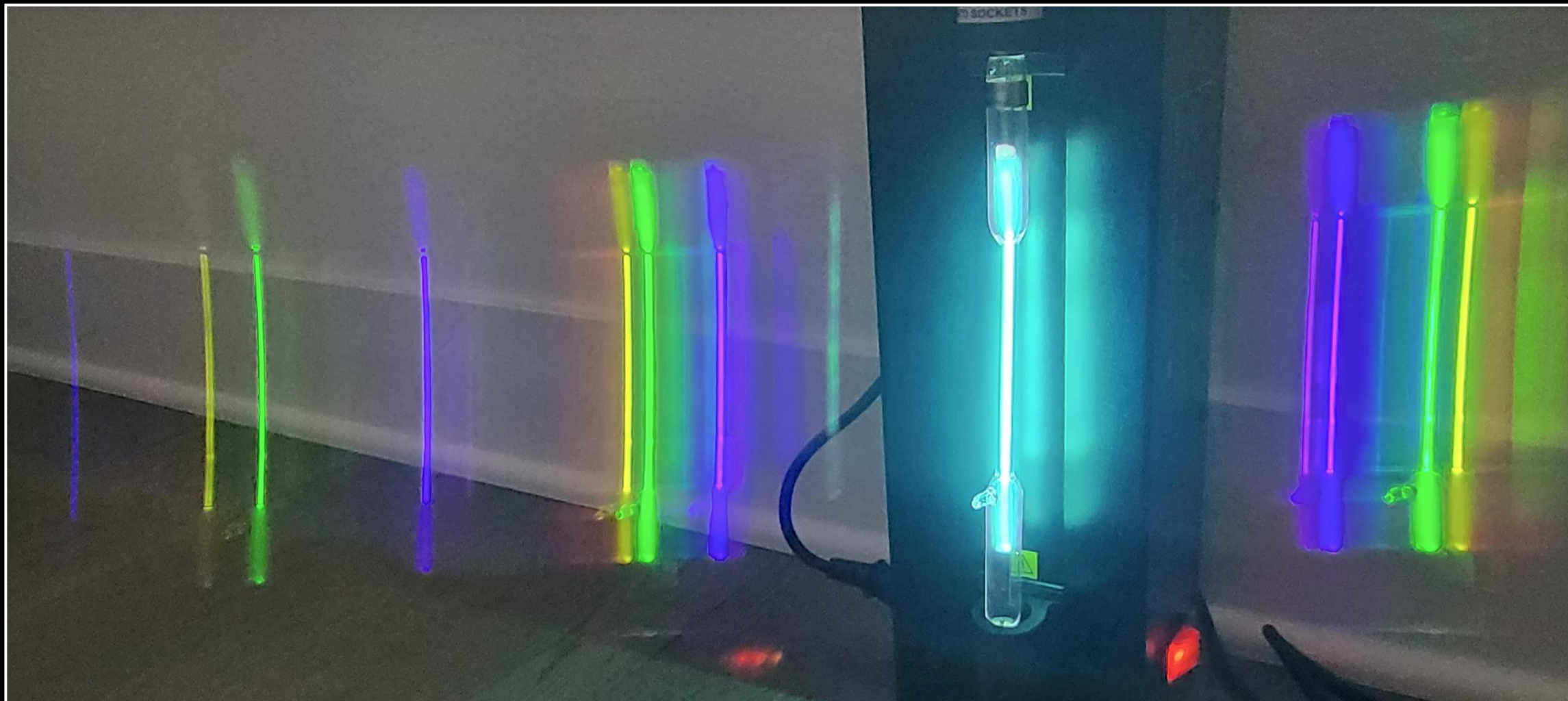
Use the Spectroscopy Worksheets to draw the spectra you see with your eyes when looking through the gratings.

Photos by Donn Silberman

# Spectroscopy & Diffraction Gratings







## Spectroscopy & Diffraction Gratings

Photo by Donn Silberman



Spectroscopy & Diffraction Gratings





# Spectroscopy & Diffraction Gratings

Photo by Donn Silberman

## What is this really all about??

### Quantum education & career pathways for you !!

#### Get involved with the Quantum World.

#### 1. Find good mentors

##### 1. Start with your Physics Teacher

#### 2. Take Action:

1. Go to my website, click on links and read articles
2. Watch YouTube videos on Quantum
3. Find hands-on workshops close to home
4. Take on-line courses
5. Got to a college that offers quantum courses
6. Take an internship that works in the field
7. Join a club or start one your self

Hybrid curriculum for upskilling photonics technicians in advanced optics, spectroscopy and quantum research enabled technologies

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**SPIE** Fellow



This project is supported by National Science Foundation grant DUE2055061



**OptoBotics<sup>SM</sup>**  
Robbts need eyes too

**PASADENA CITY COLLEGE**  
Laser Technology Program



**COLLEGE OF OPTICAL SCIENCES**  
COLLEGE OF ENGINEERING

THE UNIVERSITY OF ARIZONA

**Physics**

**HONORS COLLEGE**  
50<sup>TH</sup>  
FOUNDED 1962

**UCI** Division of Continuing Education  
Optical Engineering & Optical Instrument Design

**Donn Silberman**

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To learn more about Donn's related endeavors scan the QR code.

This is my business card – you can have one - FREE





Things at the Atomic Scale are very different than at the human scale.

## Summary

- The Quantum World underlies our modern civilization.
- And Quantum is about take humanity to the next level.
- You can help make it happen.

## Thank You

**Donn Silberman**

Optics Institute of Southern California

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