

# Making Waves



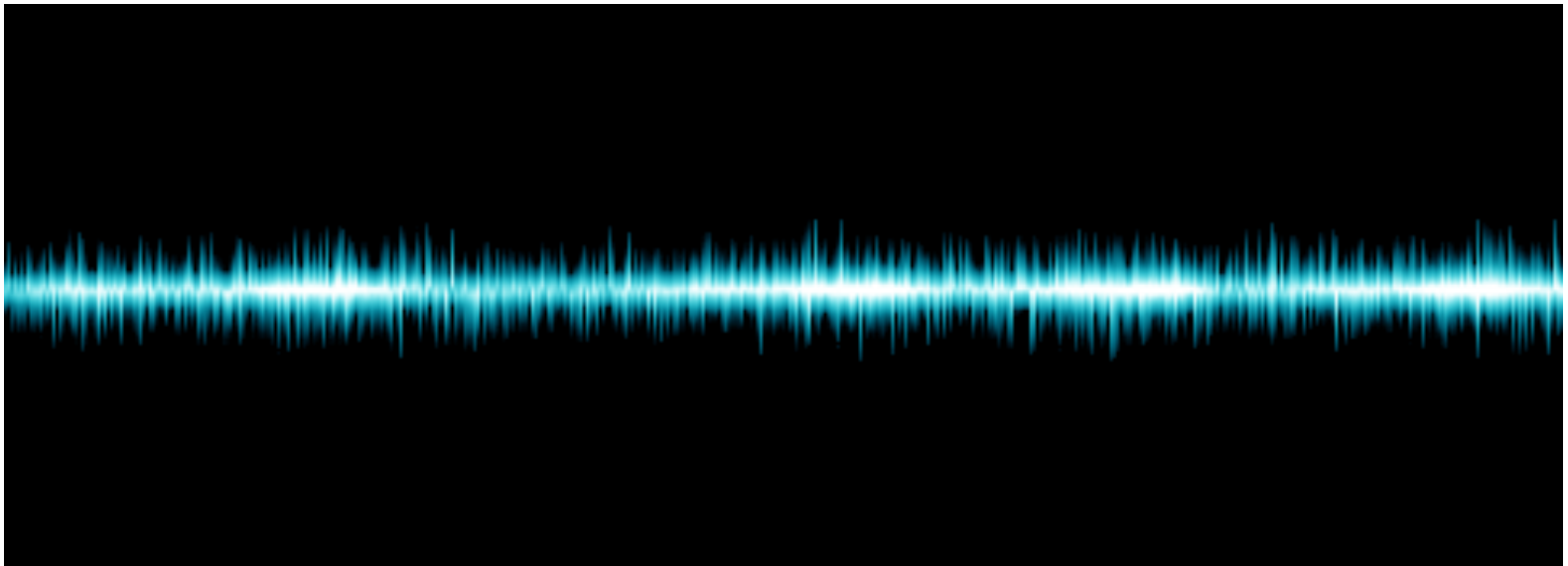
## Interferometry through the Ages

# You Know Waves



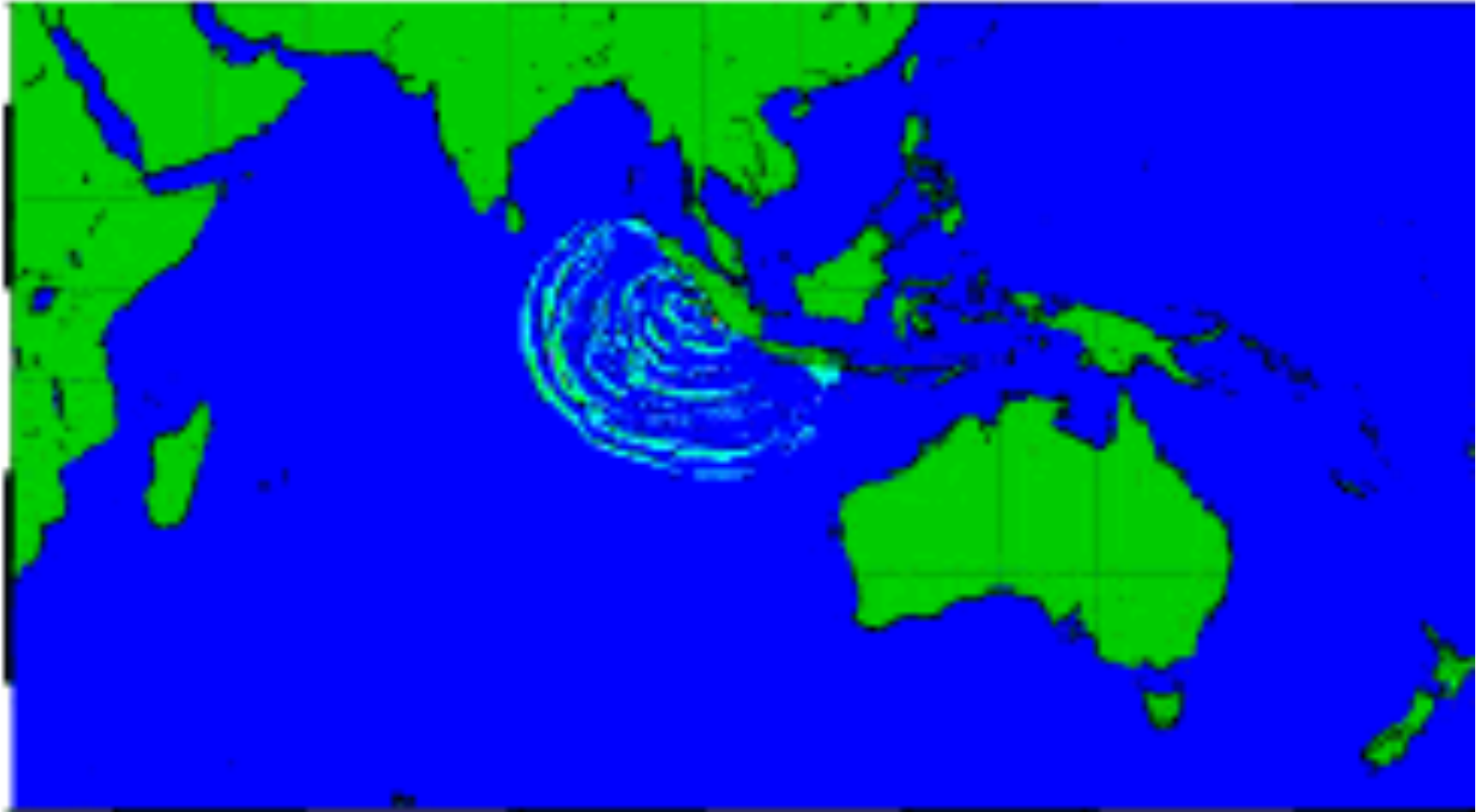
Water waves

# You Know Waves



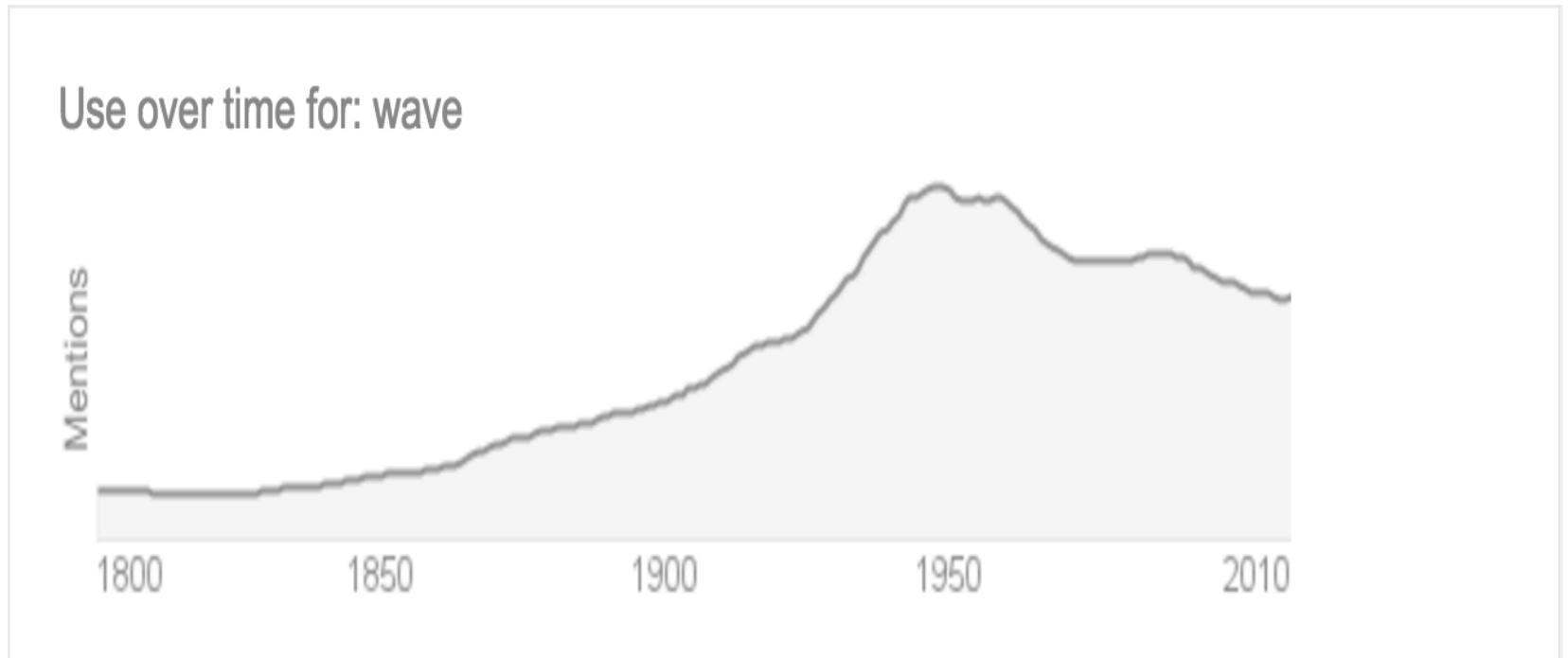
Sound waves

# You Know Waves



Water allows us to observe the spread of seismic waves in a tsunami

# You Know Waves



The frequency of use of the word “wave” over time is also a wave 😊

So what *is* a wave?

A **disturbance** that is moves through space or matter

# The Wave Equation

$$\frac{\partial^2 U}{\partial x^2} = \frac{1}{c_0^2} \frac{\partial^2 U}{\partial t^2}$$

Energy

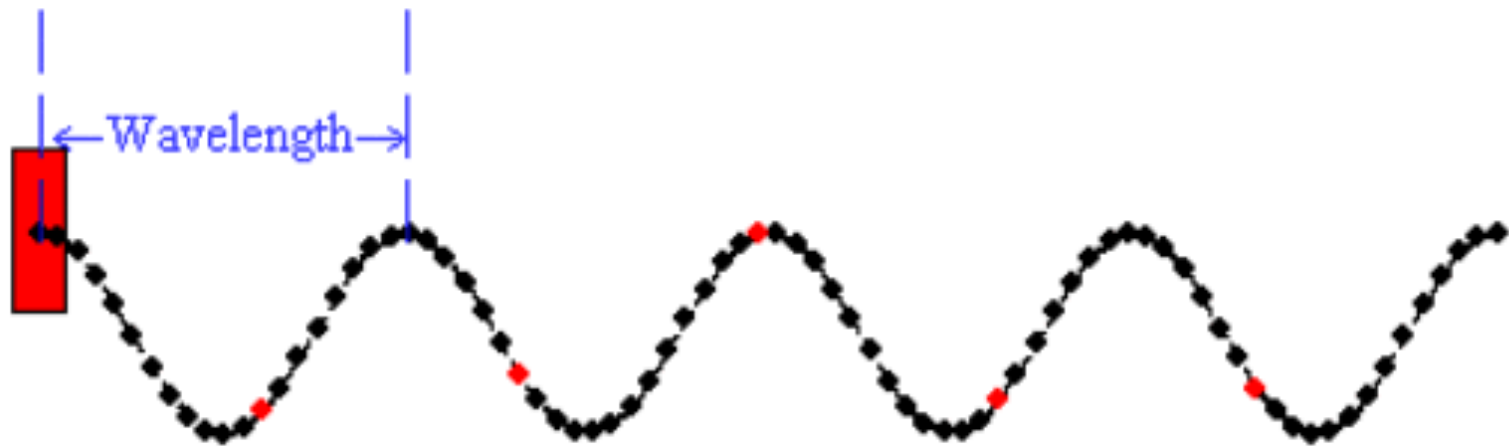
Change in space

Speed of wave

Change in time

# Transverse Waves

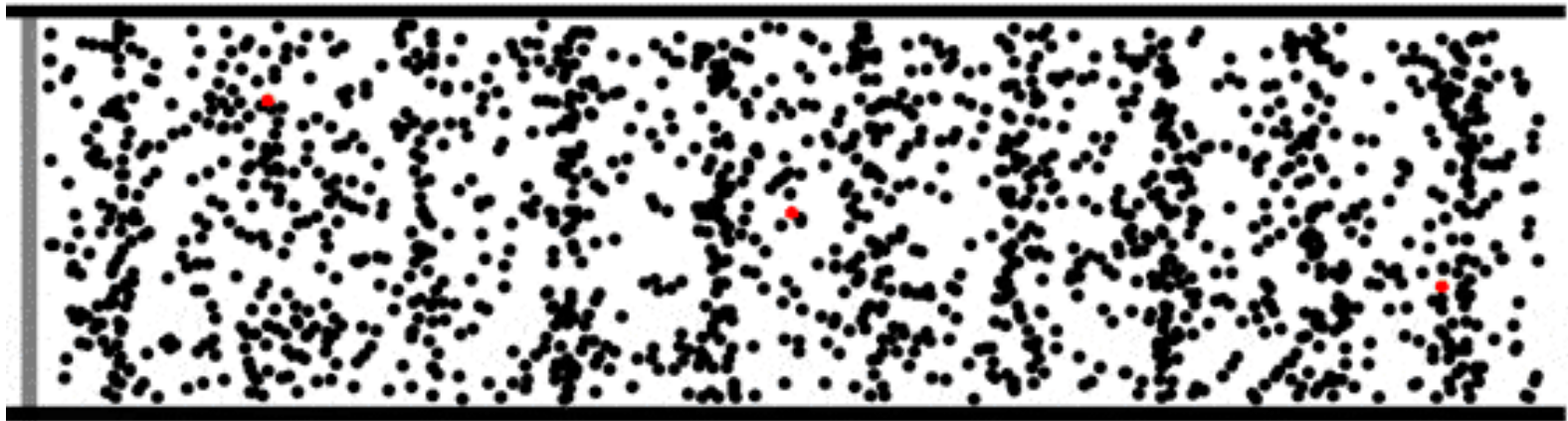
Transverse Wave



*isvr*



# Longitudinal Waves



©2011. Dan Russell



Transverse Wave



Longitudinal Wave

MAKE GIFS AT [GIFSOUP.COM](http://GIFSOUP.COM)

Waves, unlike matter, can overlap

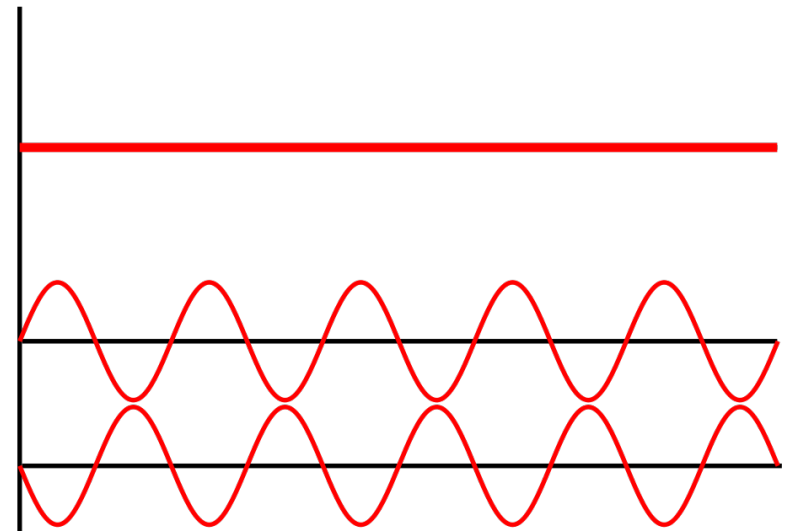
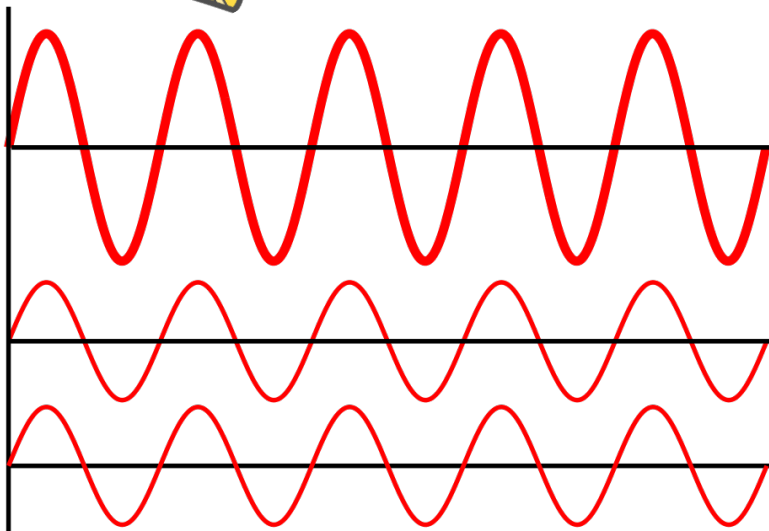


# Key: Waves, unlike matter, can overlap



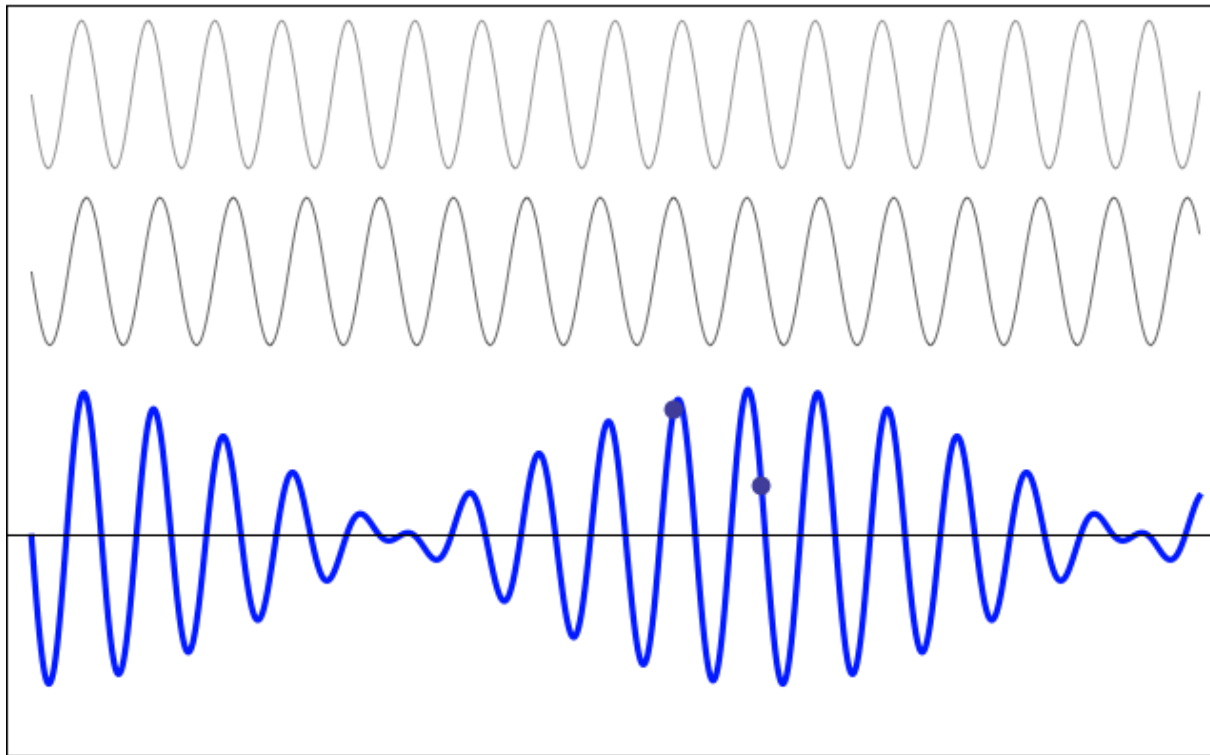
If they are in phase, interference is **constructive**

If perfectly out of phase – **destructive**



# Waves, unlike matter, can overlap

- In between we have beats



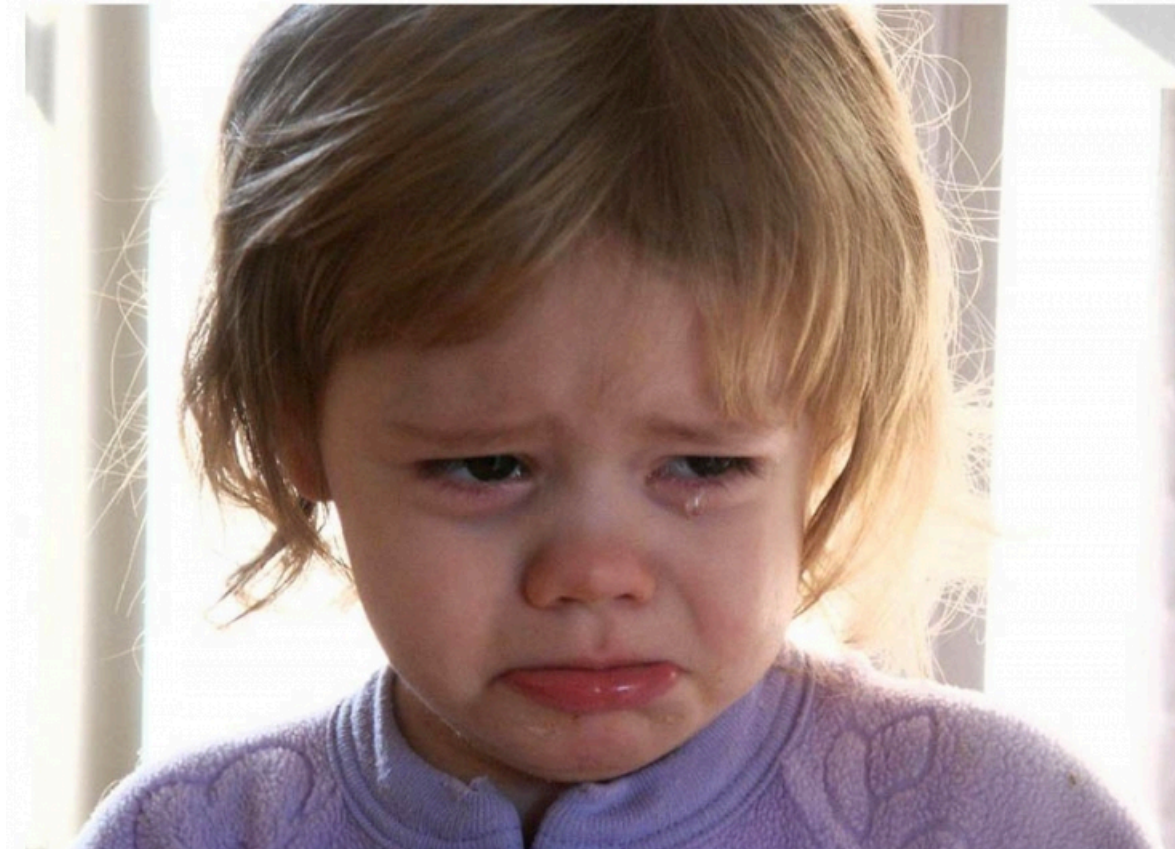
# The Power of the Beat

- The frequency of a beat is equal to the difference between the frequencies of the two interfering waves
- **This is how you tune a guitar!**



# Beats of Light?

- Light has frequency millions of times that of sound
- So we can't see or hear light beats



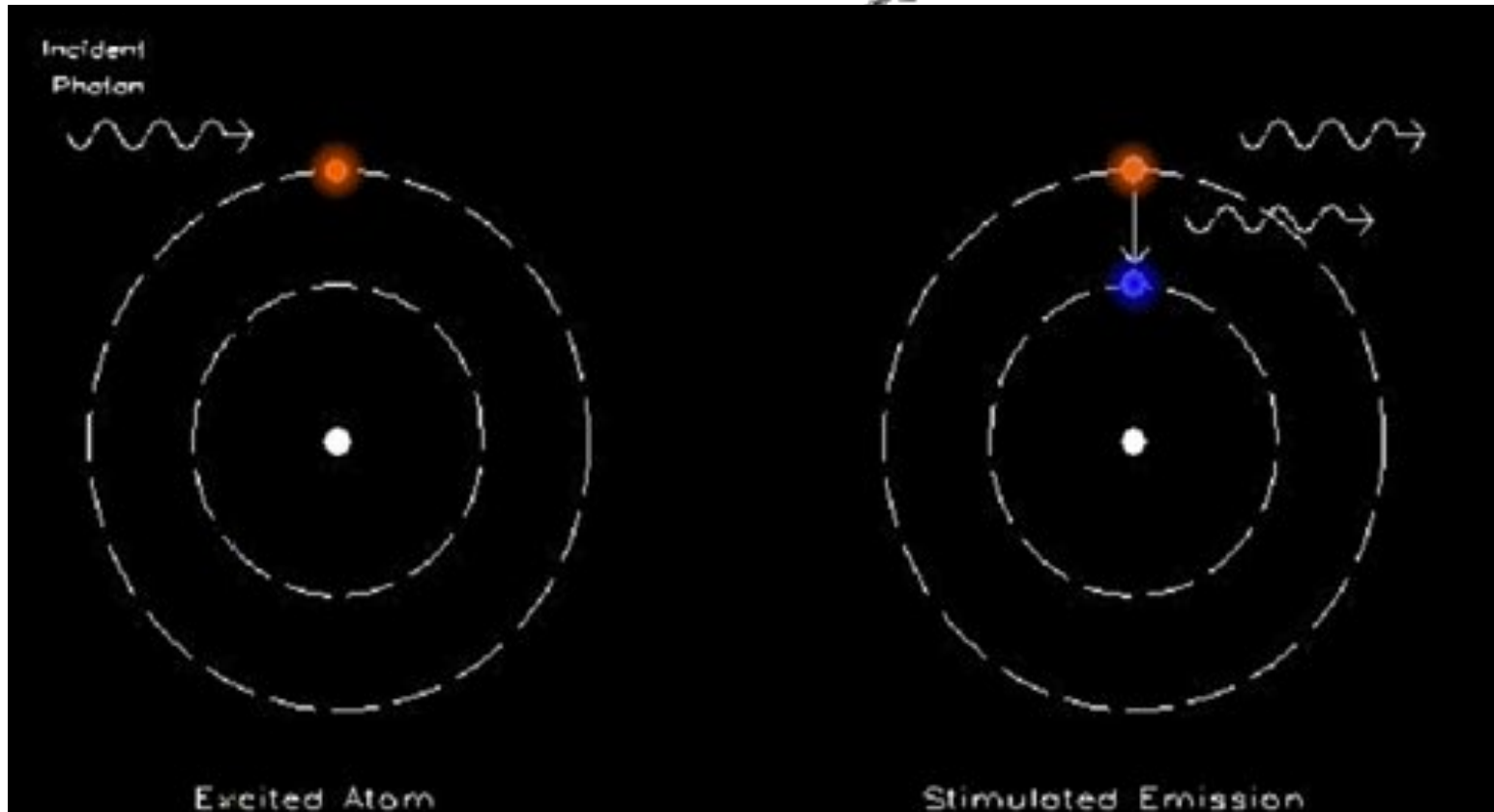


## Lasers to the Rescue!



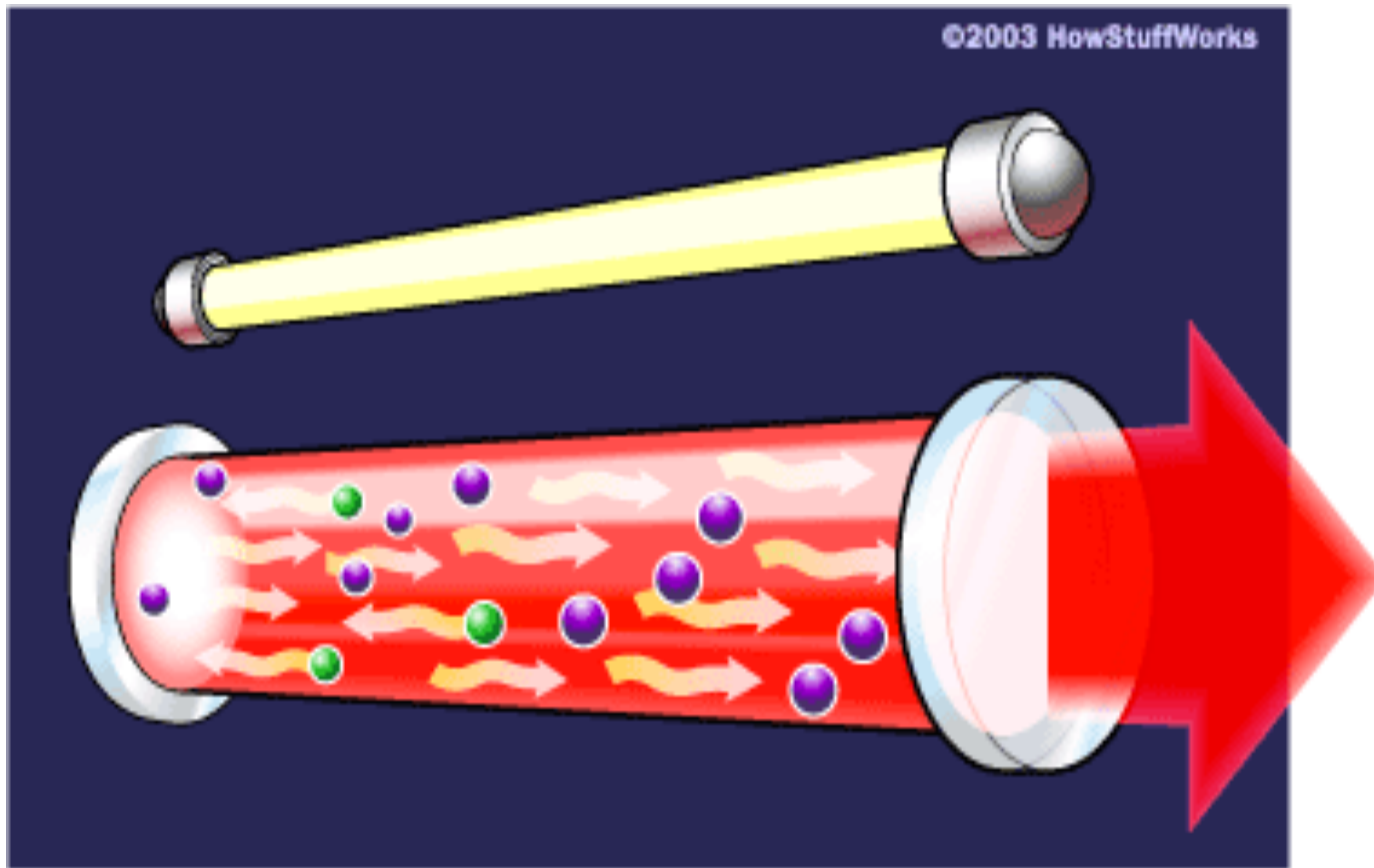
# Polarization: Building Lasers

Light **A**mplification by **S**timulated **E**mission of **R**adiation



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# Polarization: Building Lasers

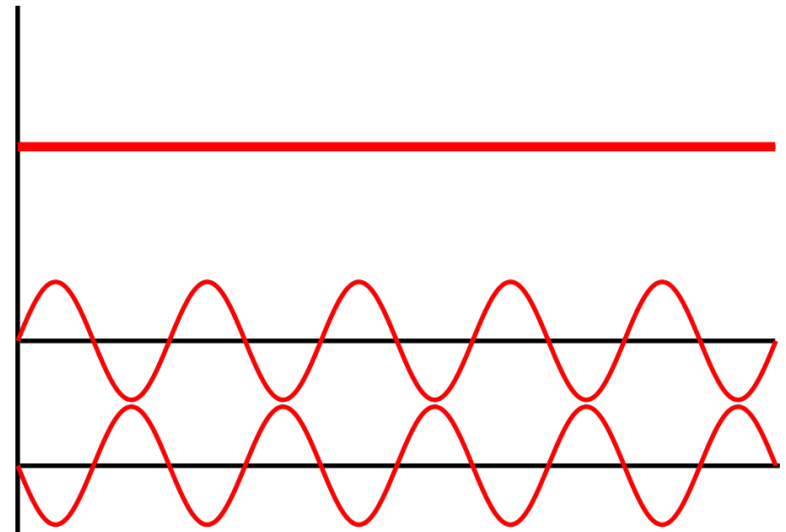
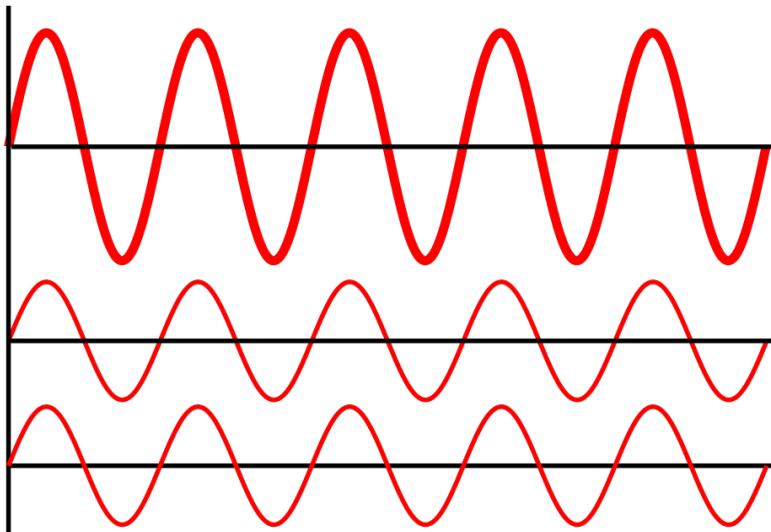
Light **A**mplification by **S**timulated **E**mission of **R**adiation



# Key: Polarization



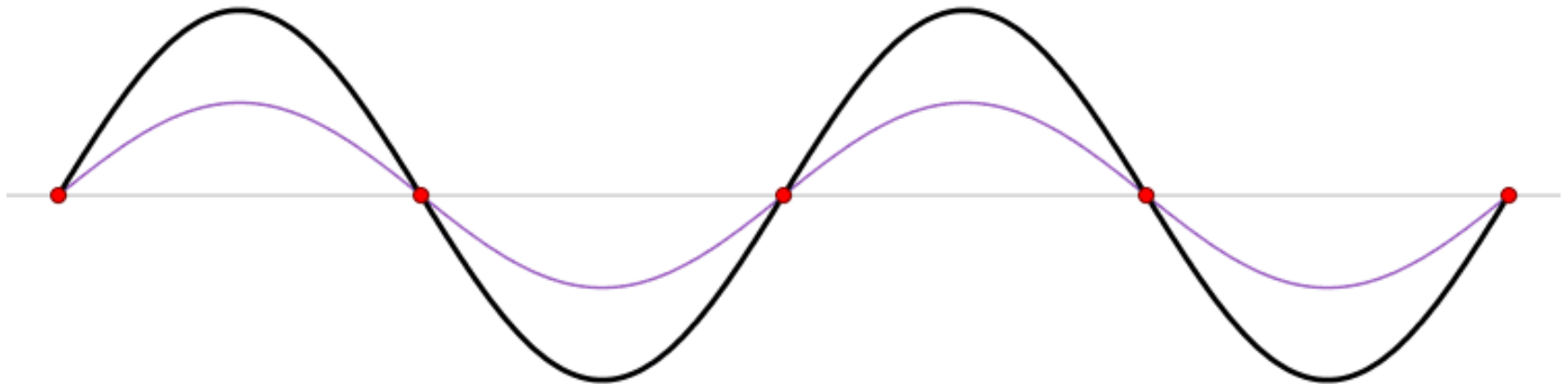
**Stimulated waves all have the same polarization**



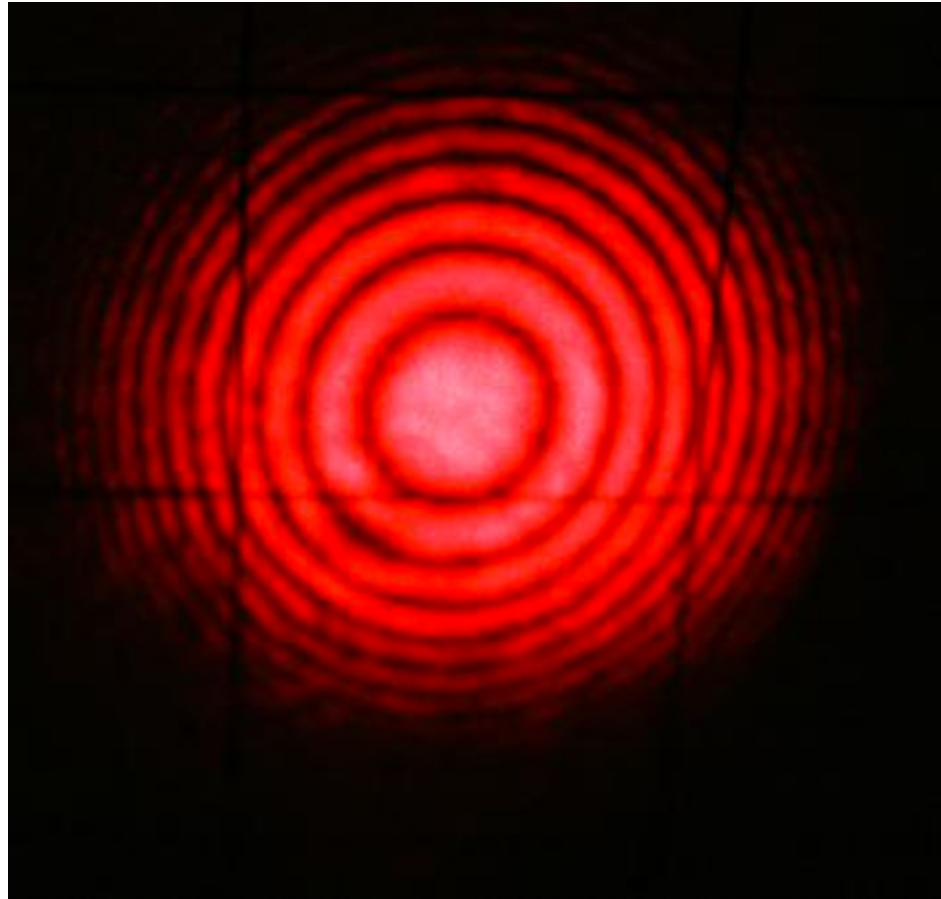
# Last key: Standing Waves



When waves are not perfectly in or out of phase,  
partial constructive + destructive interference = standing wave

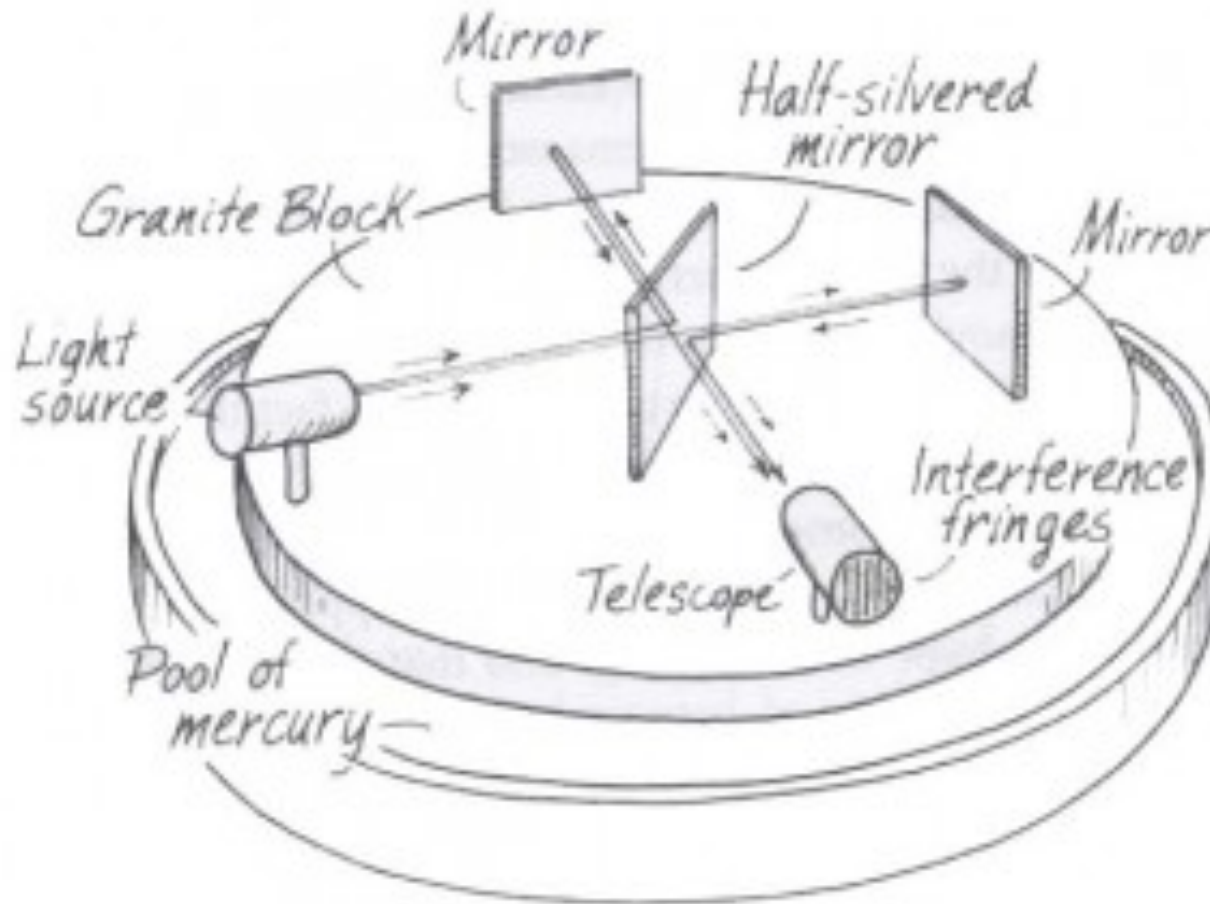


# In 2D – Bingo! A Fringe Pattern



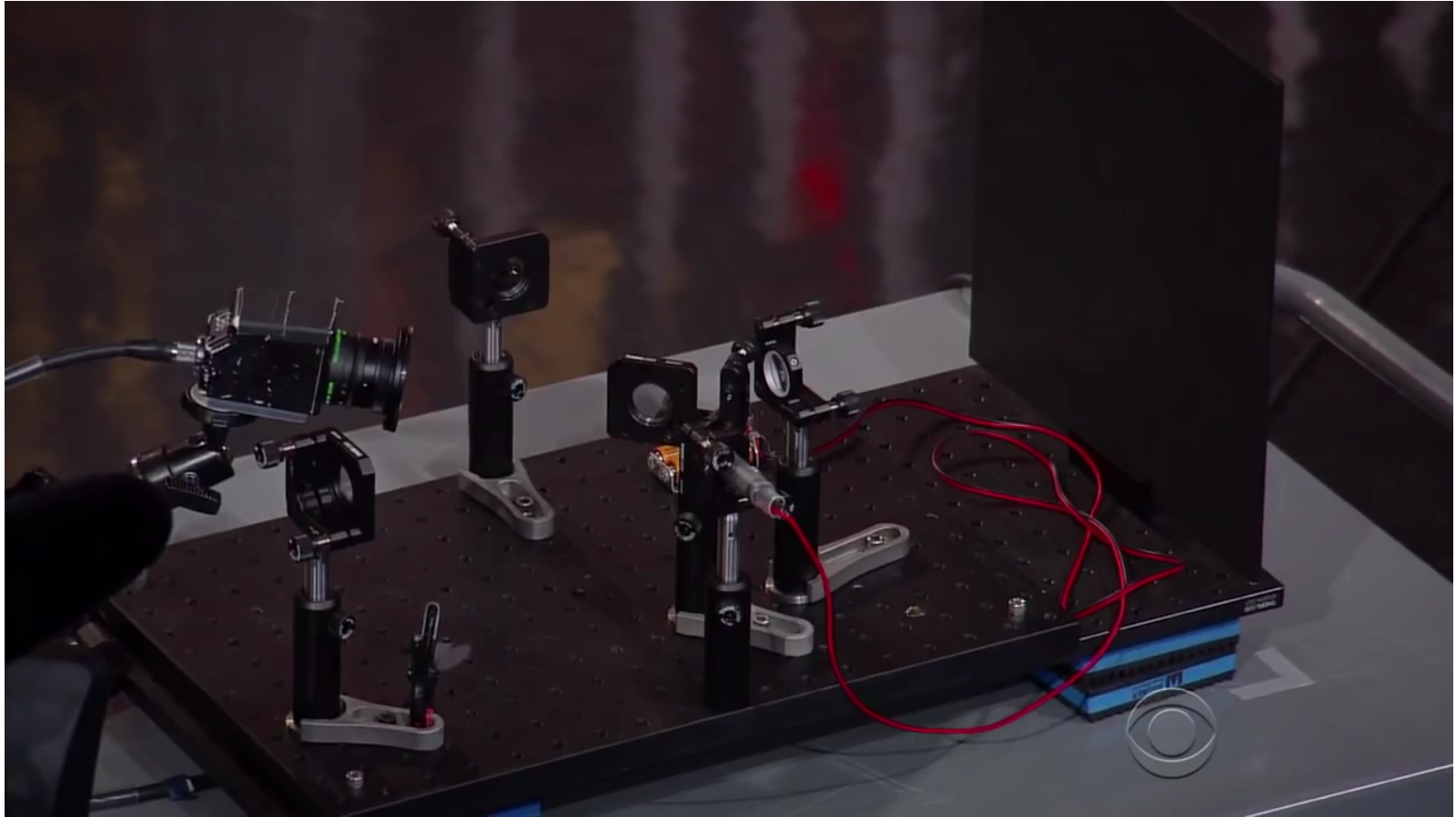
Result of 2D interference

# How do we make such a pattern?



Michelson-Morley Interferometer

# Action!



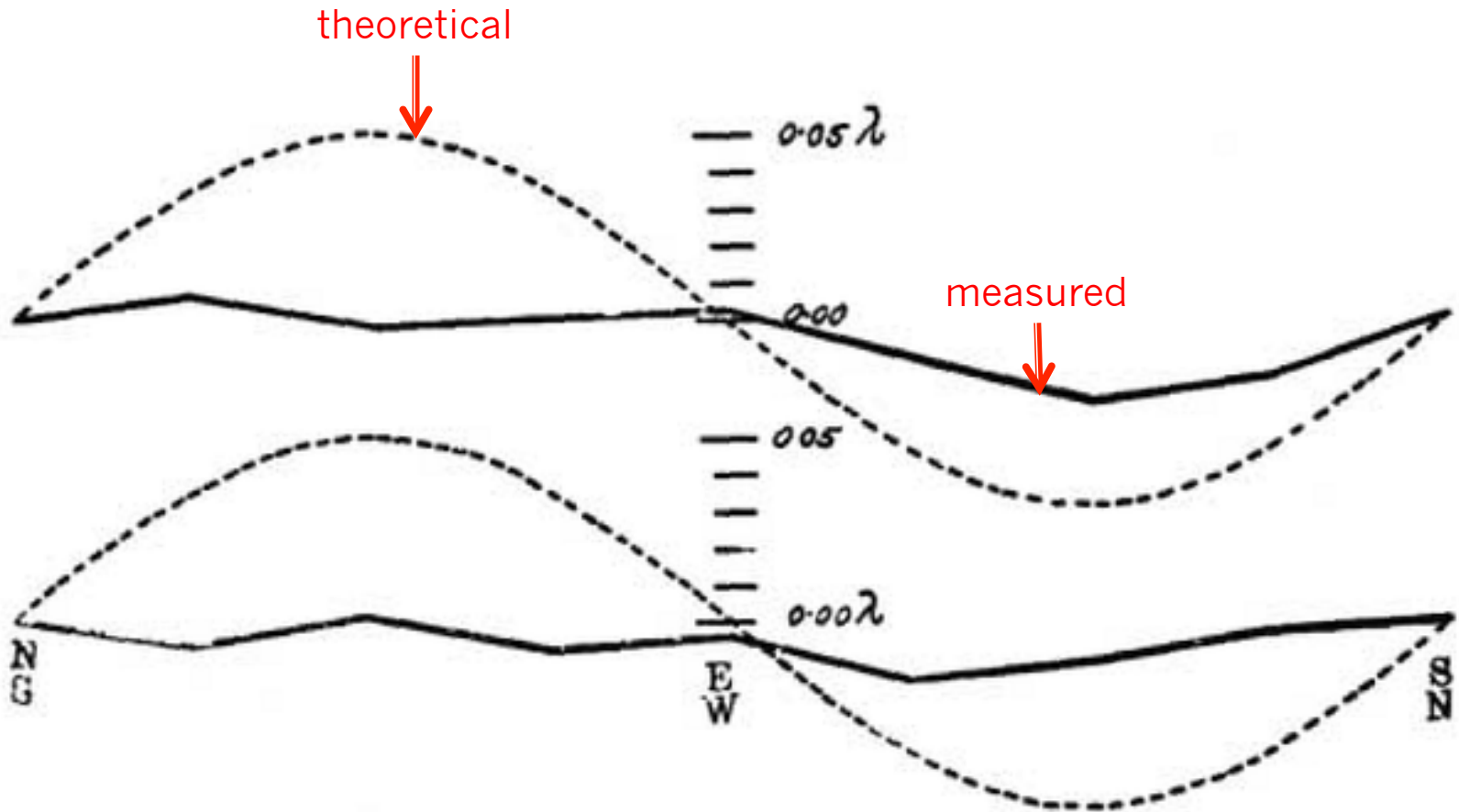


We have one, too!

# Applications: There is no (A)ether

- Michelson and Morley 1887
- If the universe were filled with ether, the earth would have a motion relative to it in some direction
- **Speed** of light increases along one arm as  $\sin(i)$ , other as  $\cos(i)$ 
  - $i$  is inclination of arm w.r.t. proposed **ether wind**
- As interferometer rotated, effect of interference should be sinusoidal

# Applications: There is no (A)ether



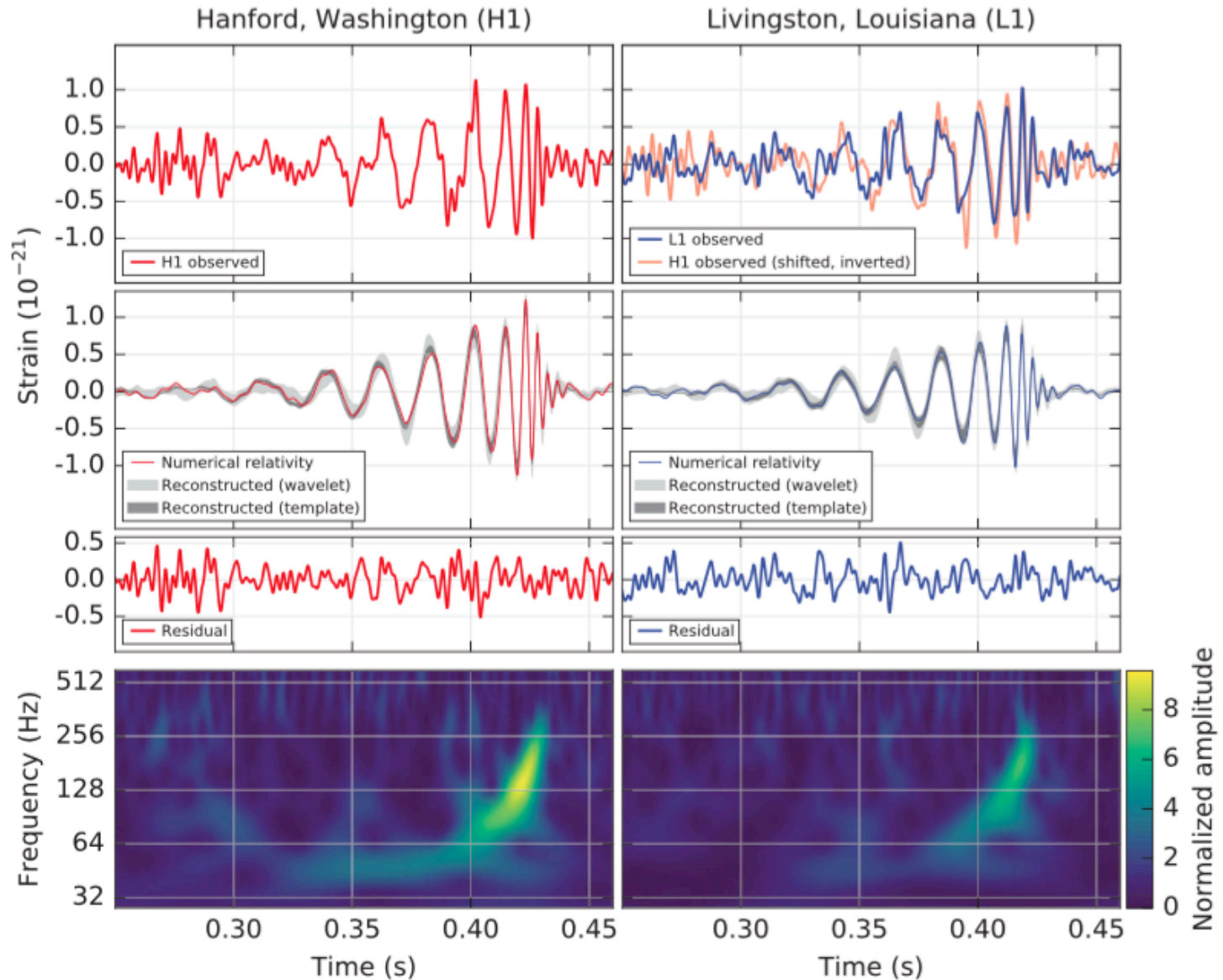
# Applications: There ARE gravitational waves

- LIGO collaboration 2015
- Here 4km arms are rigid
- If a gravitational wave passes by, increases **length** of one arm and not other

$$\textit{strain} = \frac{\Delta\textit{length}}{\textit{length}}$$

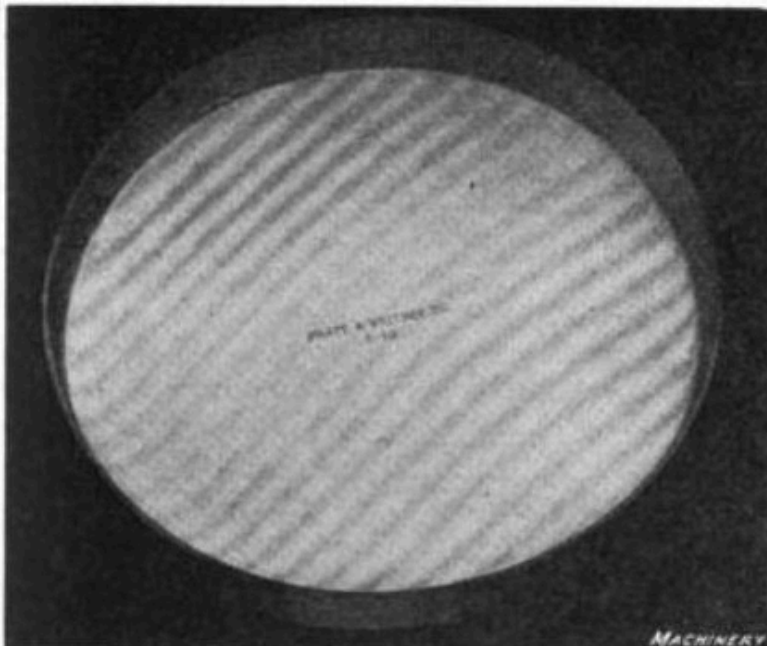
- Two identical detectors – one in Louisiana, one in Washington (state)
- So if not noise, same signal should show up in both

# Applications: There ARE gravitational waves

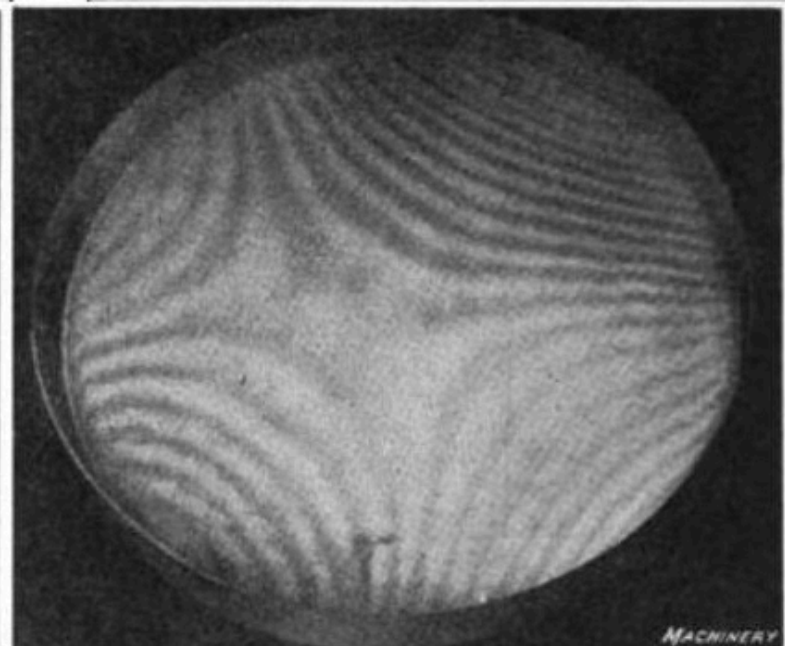


# Applications: Surface Smoothness Testing

Interference of monochromatic light  
Reflected from a reference flat surface and a sample



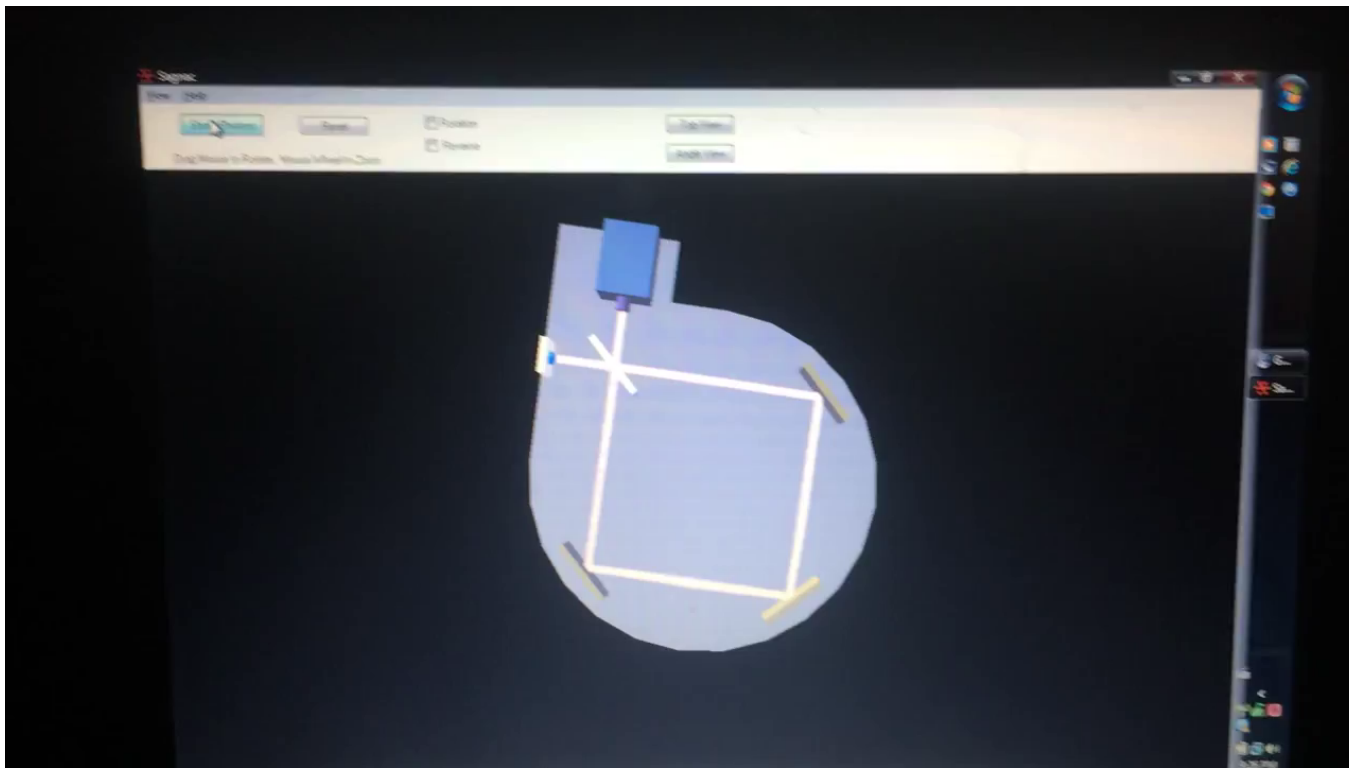
Smooth



Not yet smooth

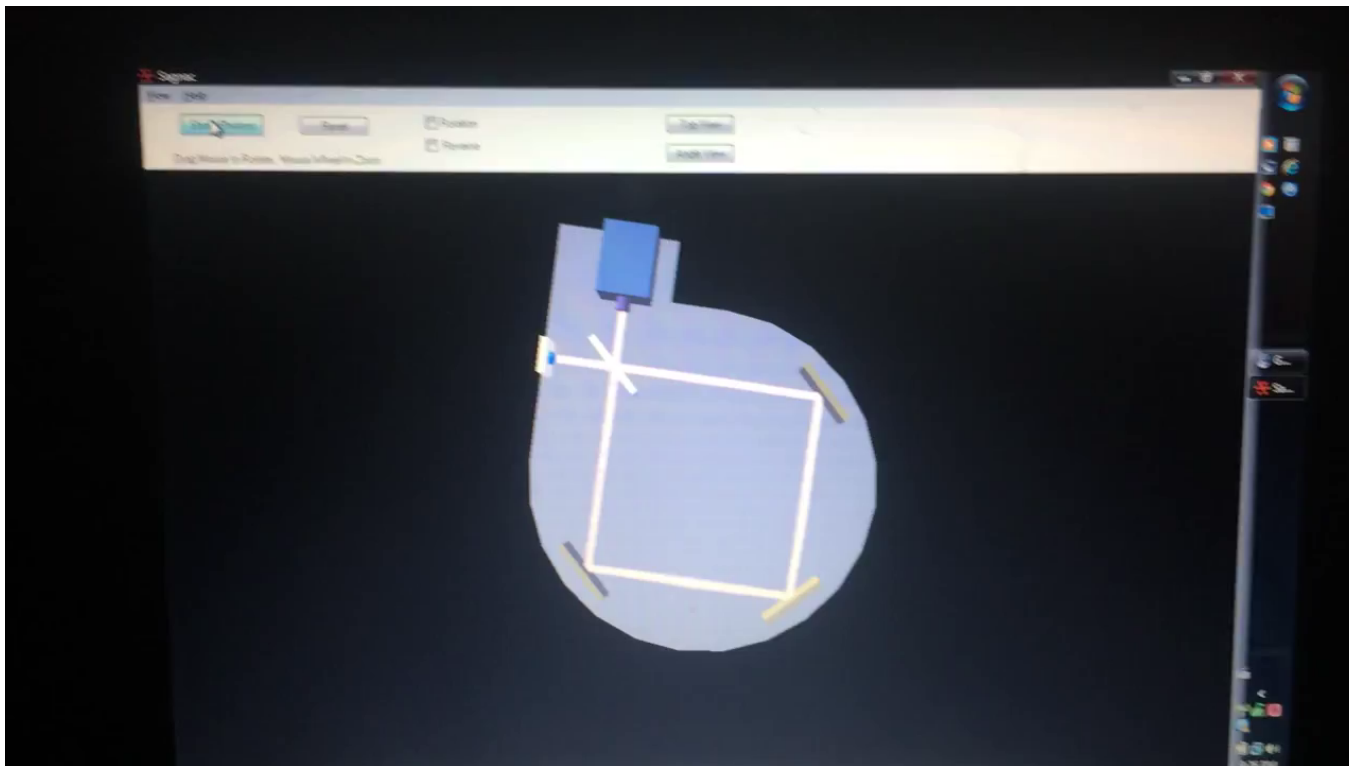
# Applications: GPS Navigation

The **Sagnac effect** measures rotation of the ring through which the two split beams travel



# How would you use an interferometer?

The **Sagnac effect** measures rotation of the ring through which the two split beams travel





How would you use an interferometer?



Questions?

