Engineering Optics

Lecture 18

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by

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Module 2

LASER Basics

Laser operation, Absorption, Spontaneous Emission and Stimulated Emission, Population & Inversion, Three- and Four Level Laser Systems, Laser Characteristics- Types of Lasers: Solid-State Lasers, Gas Lasers, Semiconductor Lasers.

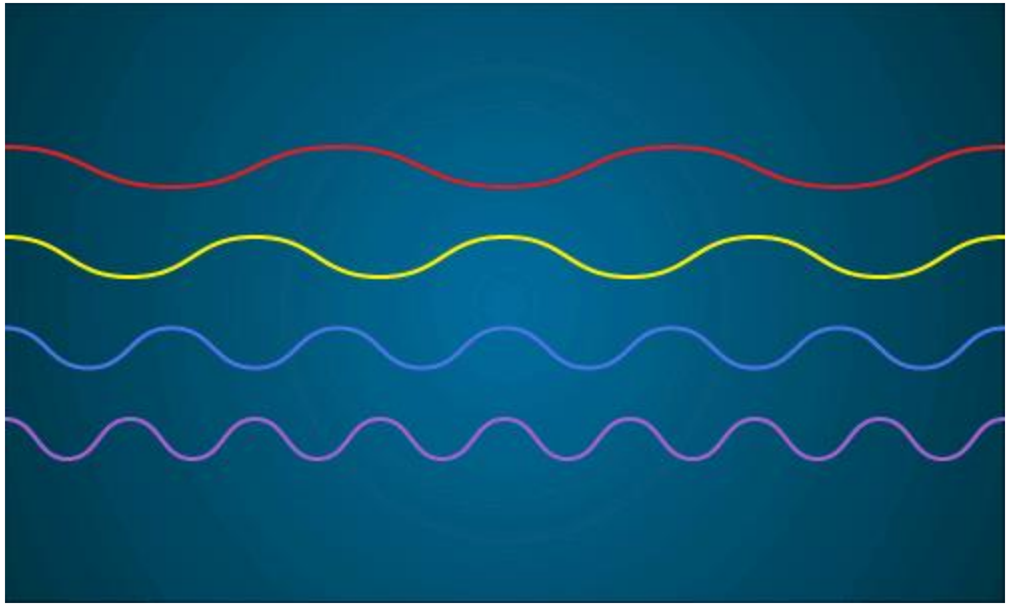
L A S E R

Light Amplification by Stimulated Emission of Radiation

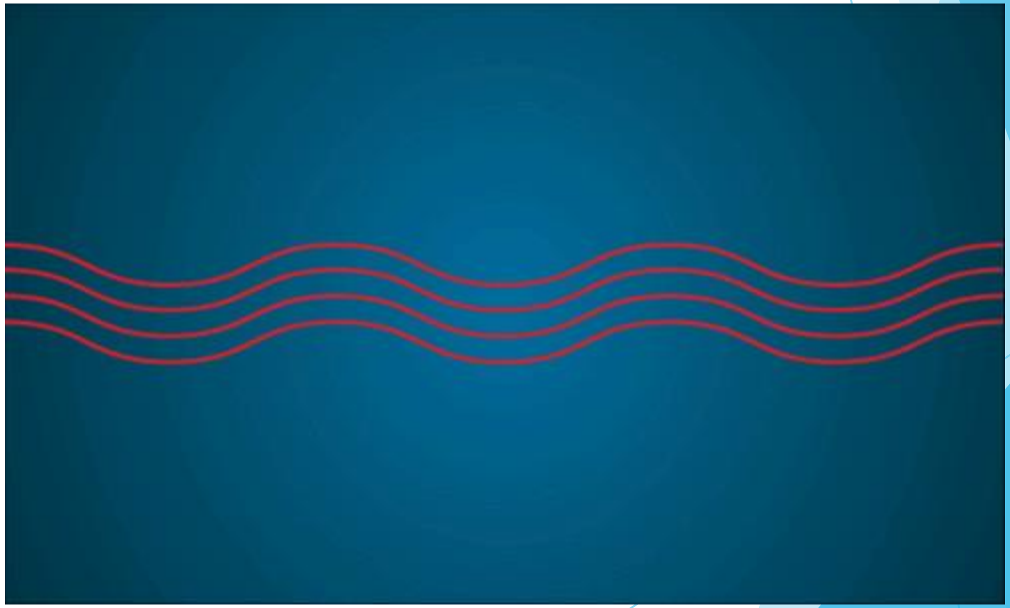
LASER is different!

LASER: Lasers produce a very narrow beam of light → ***unusual***

Sunlight or a lightbulb—is made up of light with many different wavelengths. Each color of light has a different wavelength. $\lambda_V < \lambda_R$ Our eyes see this mixture of wavelengths as white light.



This Fig. shows a representation of the different wavelengths present in sunlight. When all of the different wavelengths (colors) come together, you get white light. Image credit: NASA

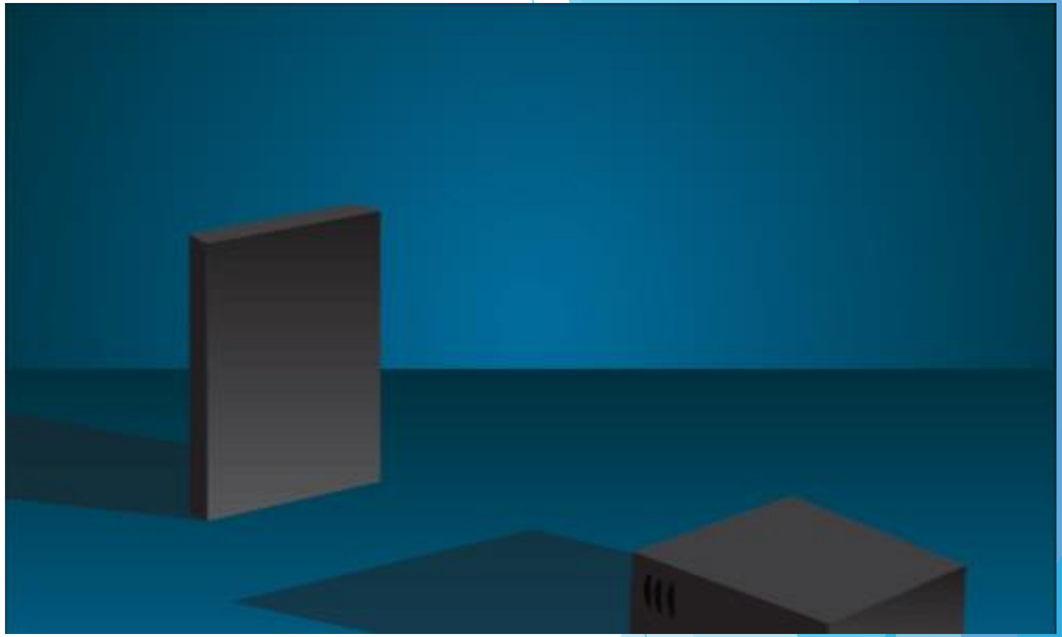


This Fig. is a representation of in phase laser light waves. Image credit: NASA

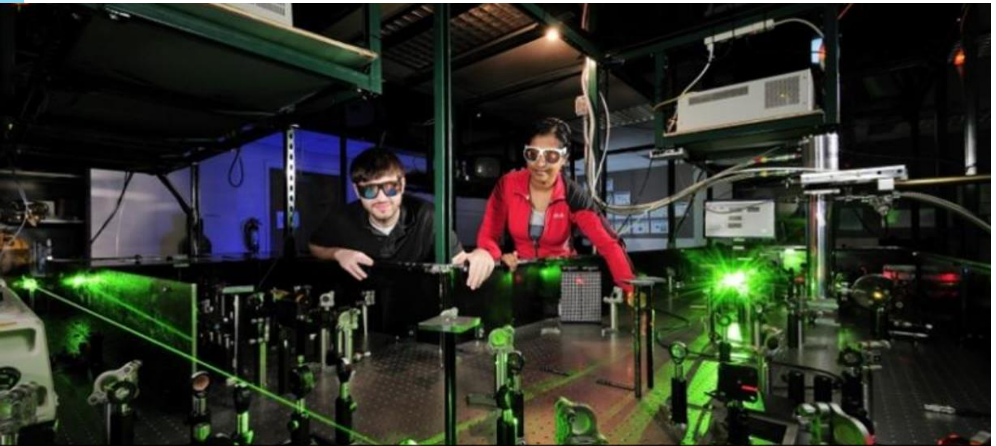
LASER light

Properties:

- **Directionality:** highly directional, divergence < 10^{-5} rad
- **High power:** Continuous wave lasers having power levels of ~10^5 W and pulsed lasers having a total energy of ~50,000 J
- **Tight focusing:** as highly directional, laser can be focused to areas of approximately few micrometers squared
- **Spectral purity:** Laser beams can have an extremely small spectral width Δλ ~ 10^{-6} Å



This animation shows how a laser can focus all of its light into one small point. Credit: NASA



** It is quite safe to look at a 500 W bulb, it is very dangerous to look directly into a 5 mW laser beam → damage retina*

https://ultrafast.ku.edu/

https://scitechdaily.com/images/Bright-Sunlight.jpg

https://www.homestratosphere.com/types-of-flashlights/

Applications

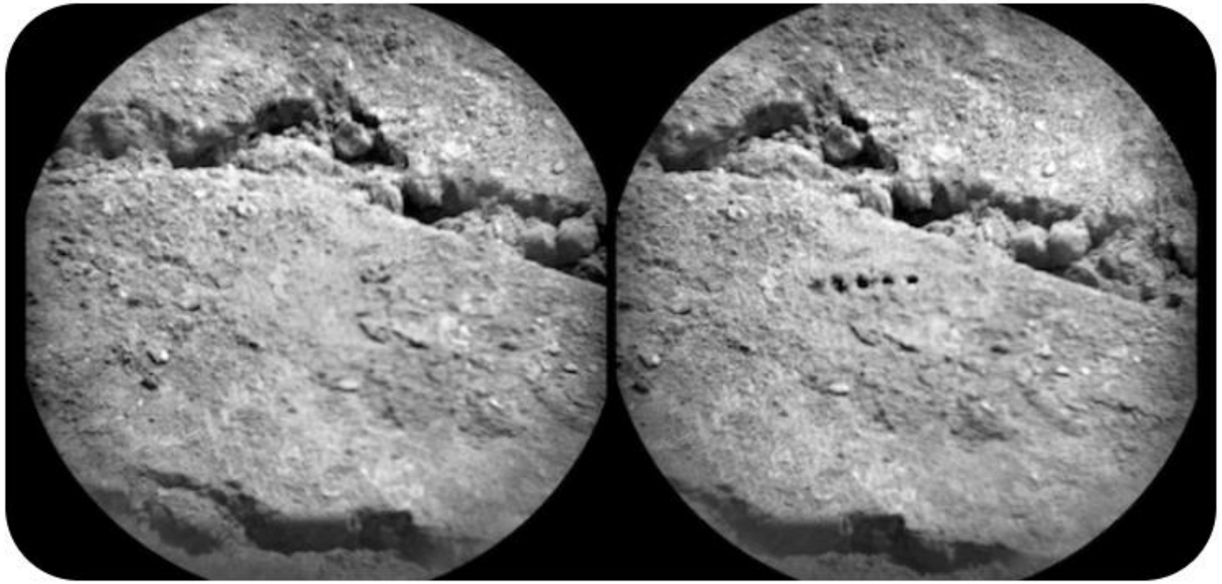
Because of such unique properties of the laser beam, it finds important applications in many diverse areas

- can cut through diamonds or thick metal
- delicate surgeries → eye surgeries
- recording and retrieving information
- surveying, remote sensing
- communications and in carrying TV and internet signals (Laser pulses having very small cross-sectional area (and high energy) can be guided through special fibers
- laser printers, bar code scanners
- They also help to make parts for computers and other electronics.

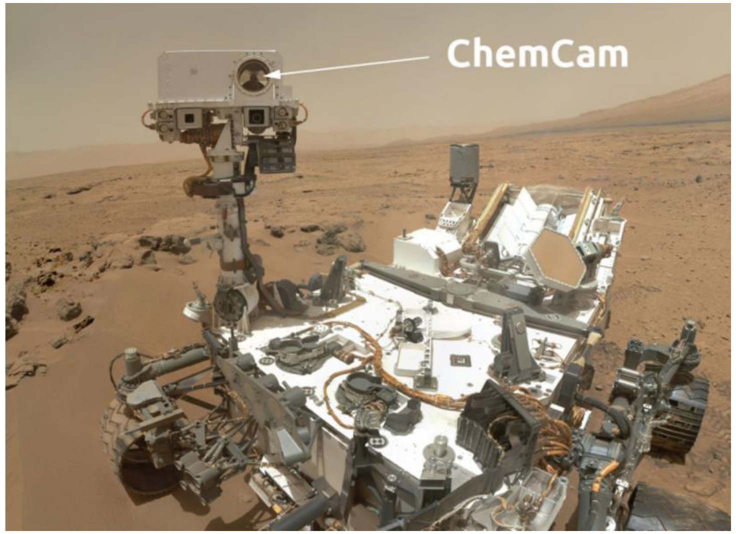
Applications continued

- Lasers are also used in spectrometers. Spectrometers can help scientists figure out what things are made of.

For example, the *Curiosity rover* uses a laser spectrometer to see what kinds of chemicals are in certain rocks on Mars.

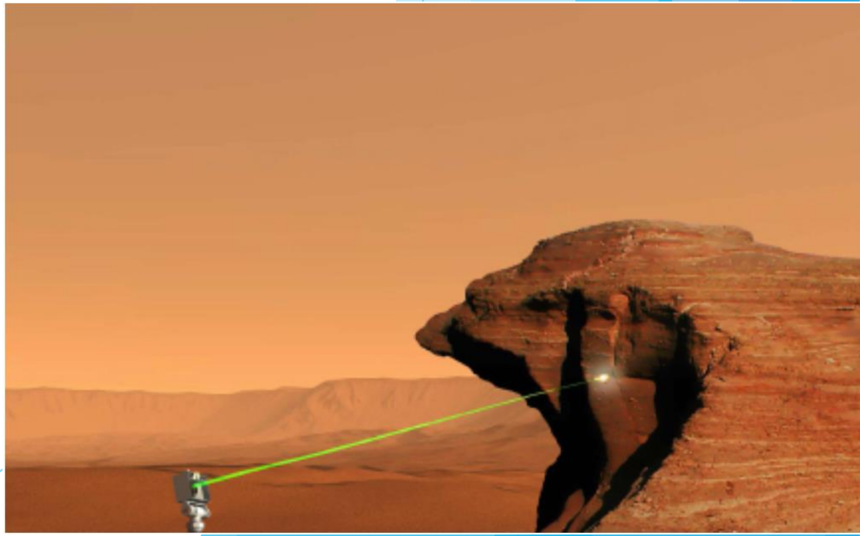


This is a picture of Martian soil before (left) and after (right) it was zapped by the Curiosity rover's laser instrument called ChemCam. By zapping tiny holes in Martian soil and rock, ChemCam can determine what the material is made of. Image credit: NASA/JPL-Caltech/LANL/ CNES/IRAP/LPGN/CNRS



https://www.nasa.gov/lasercomms
https://mars.nasa.gov/msl/spacecraft/instruments/chemcam/

The Chemistry and Camera tool is known as **ChemCam**.
Looking at rocks and soils from a distance, *ChemCam fires a laser* and analyzes the elemental composition with the help of camera and spectrograph to identify the chemical and mineral composition of rocks and soils.



Laser Beams Reflected Between Earth and Moon

(10 Aug, 2020)

Dozens of times over the last decade NASA scientists have launched laser beams at a reflector the size of a paperback novel about 240,000 miles (385,000 kilometers) away from Earth. They announced today, in collaboration with their French colleagues, that they received signal back for the first time, an encouraging result that could enhance laser experiments used to study the physics of the universe.

The reflector NASA scientists aimed for is mounted on the Lunar Reconnaissance Orbiter (LRO), a spacecraft that has been studying the Moon from its orbit since 2009. One reason engineers placed the reflector on LRO was so it could serve as a pristine target to help test the reflecting power of panels left on the Moon's surface about 50 years ago. These older reflectors are returning a weak signal, which is making it harder to use them for science.

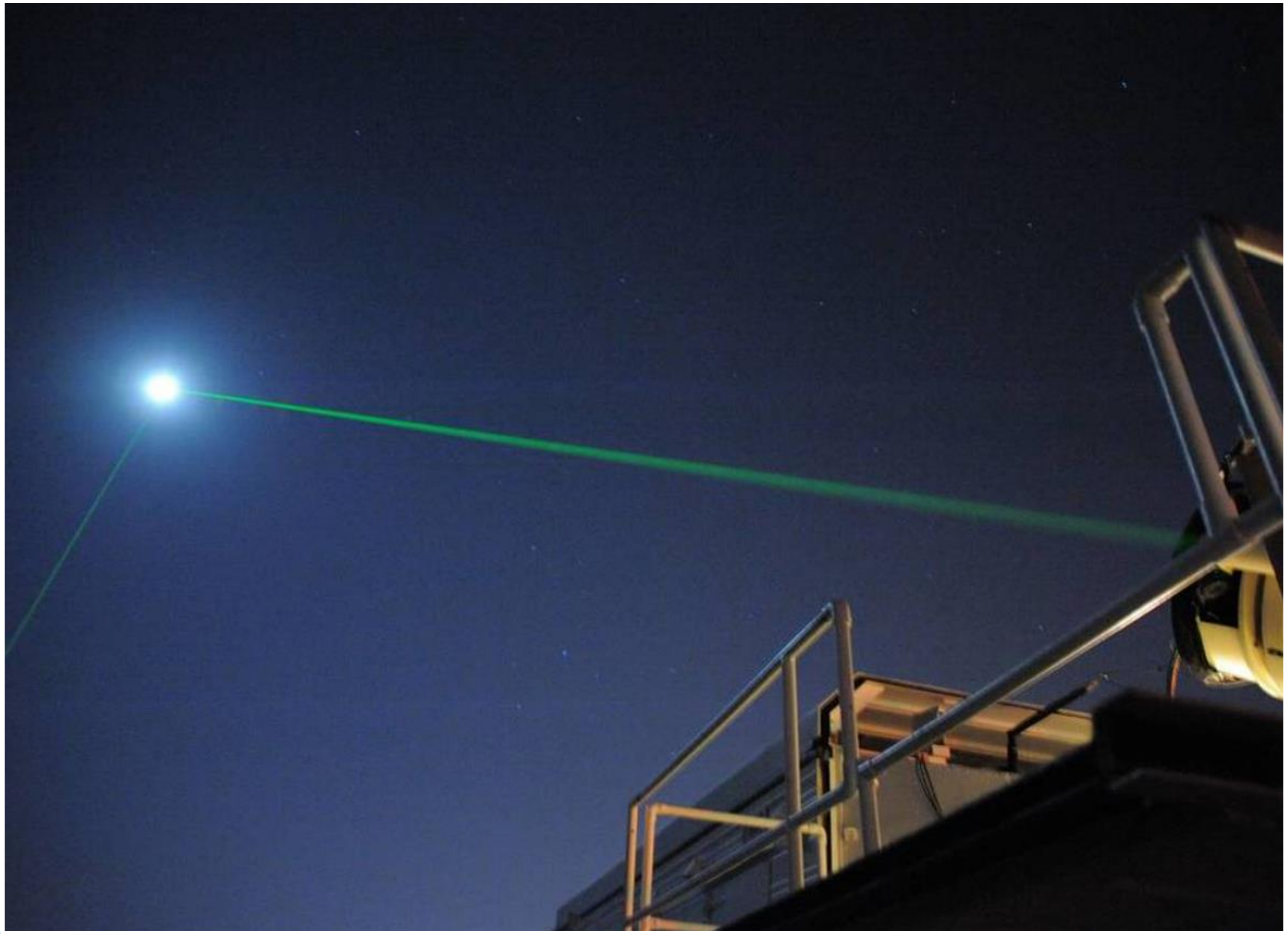
Scientists have been using reflectors on the Moon since the Apollo era to learn more about our nearest neighbor. It's a fairly straightforward experiment: Aim a beam of light at the reflector and clock the amount of time it takes for the light to come back. Decades of making this one measurement has led to major discoveries.

One of the biggest revelations is that the Earth and Moon are slowly drifting apart at the rate that fingernails grow, or 1.5 inches (3.8 centimeters) per year. This widening gap is the result of gravitational interactions between the two bodies.

"Now that we've been collecting data for 50 years, we can see trends that we wouldn't have been able to see otherwise," said Erwan Mazarico, a planetary scientist from NASA's Goddard Space Flight Center in Greenbelt, Maryland who coordinated the LRO experiment that was described on August 7 in the journal Earth, Planets and Space.

https://www.nasa.gov/feature/goddard/2020/laser-beams-reflected-between-earth-and-moon-boost-science

keeping track of orbiting satellites



This photograph shows the laser-ranging facility at the Goddard Geophysical and Astronomical Observatory in Greenbelt, Md. **The facility helps NASA keep track of orbiting satellites.** Both beams shown, coming from two different lasers, are pointed at **NASA's Lunar Reconnaissance Orbiter, which is orbiting the Moon.** Here, scientists are using the **visible, green wavelength of light**. The laser facility at the Université Côte d'Azur in Grasse, France, developed a new technique that uses **infrared light, which is invisible to the human eye, to beam laser light to the Moon.**

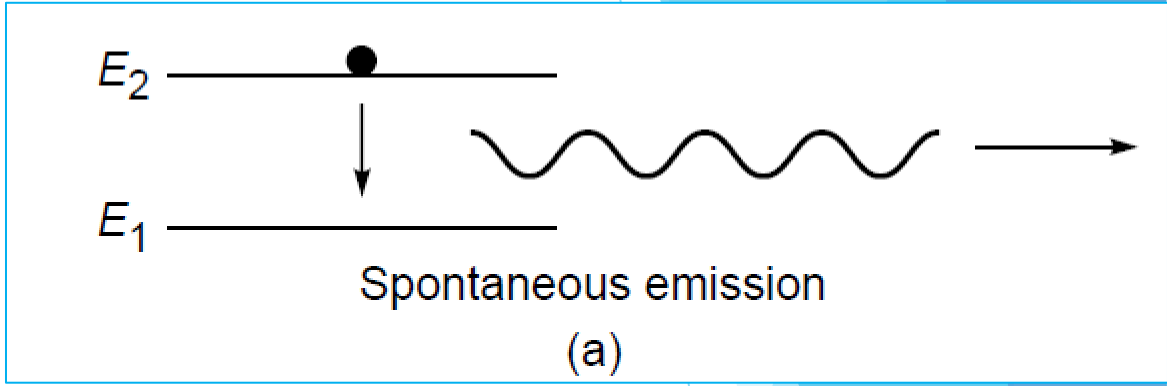
https://www.nasa.gov/feature/goddard/2020/laser-beams-reflected-between-earth-and-moon-boost-science

LASER application
a few links

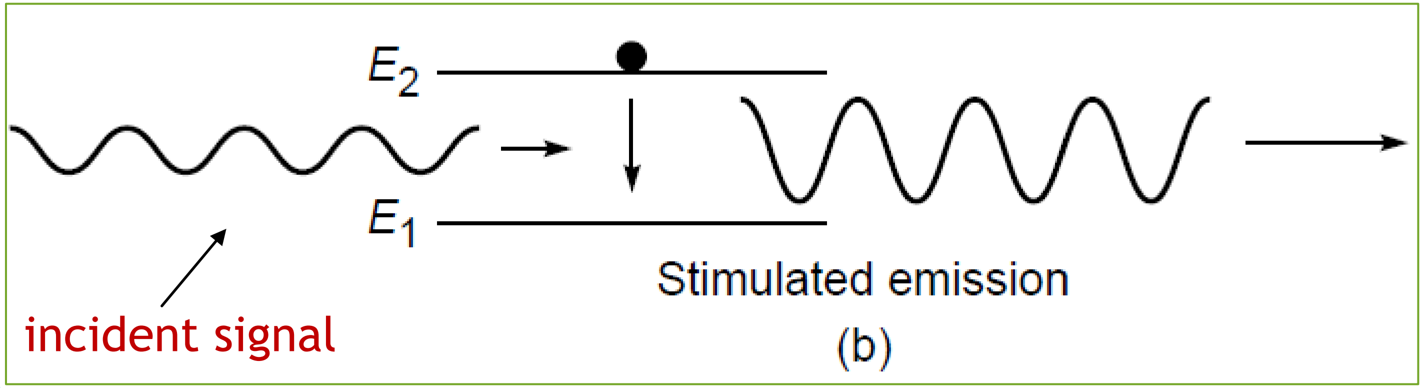
- https://www.nasa.gov/lasercomms
- https://www.nasa.gov/mission_pages/tdm/lcrd/index.html
- https://www.nasa.gov/mediacast/goddard/2022/bonus-lcrd-your-questions-answered-nasa-s-the-invisible-network-podcast

Spontaneous and Stimulated Emissions

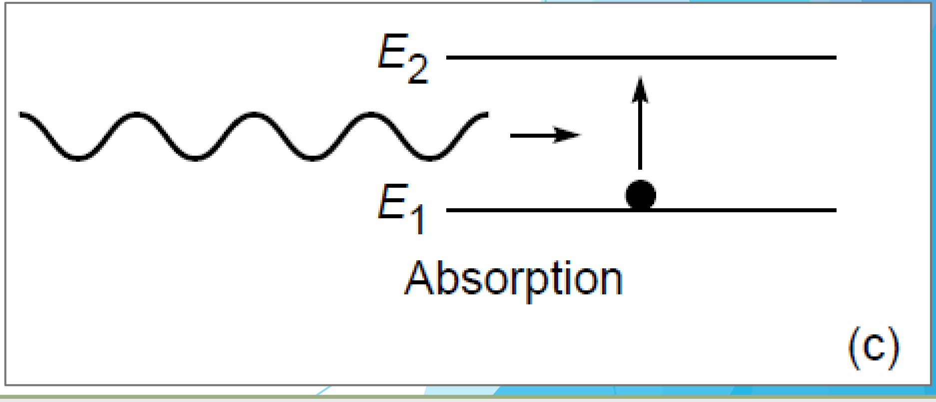
- Atoms → discrete energy states
- **Q: How does an atom interact with electromagnetic radiation??**
- Ans: according to Einstein → 3 different ways



The rate of spontaneous emission is proportional to the number of atoms in the excited state



The rate of stimulated emission depends on both the intensity of the external field and the number of atoms in the excited state



The rate of stimulated absorption depends both on the intensity of the external field and on the number of atoms in the lower energy state.

Optics, Ghatak

Thank You