

Engineering Optics

Lecture 26

16/05/2023

by

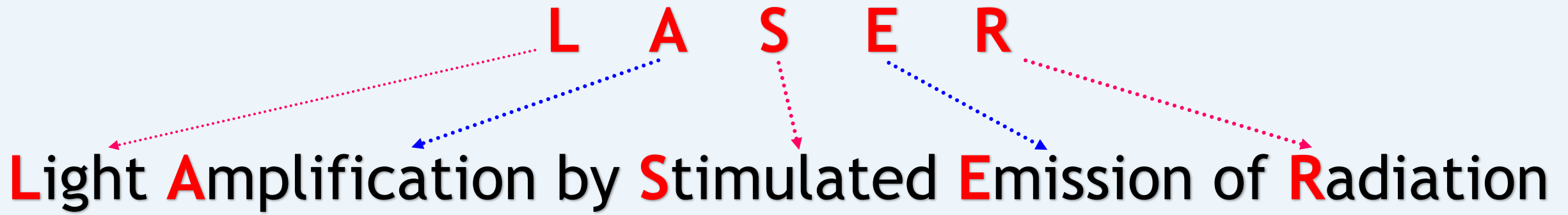
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Module 2

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.



The diagram illustrates the acronym LASER and its full name. The letters L, A, S, E, and R are arranged in a horizontal line at the top. Below them, the full name "Light Amplification by Stimulated Emission of Radiation" is written. Red dotted arrows point from the letters L, S, and R to the corresponding words "Light", "Stimulated", and "Radiation" respectively. Blue dotted arrows point from the letters A and E to the words "Amplification" and "Emission" respectively.

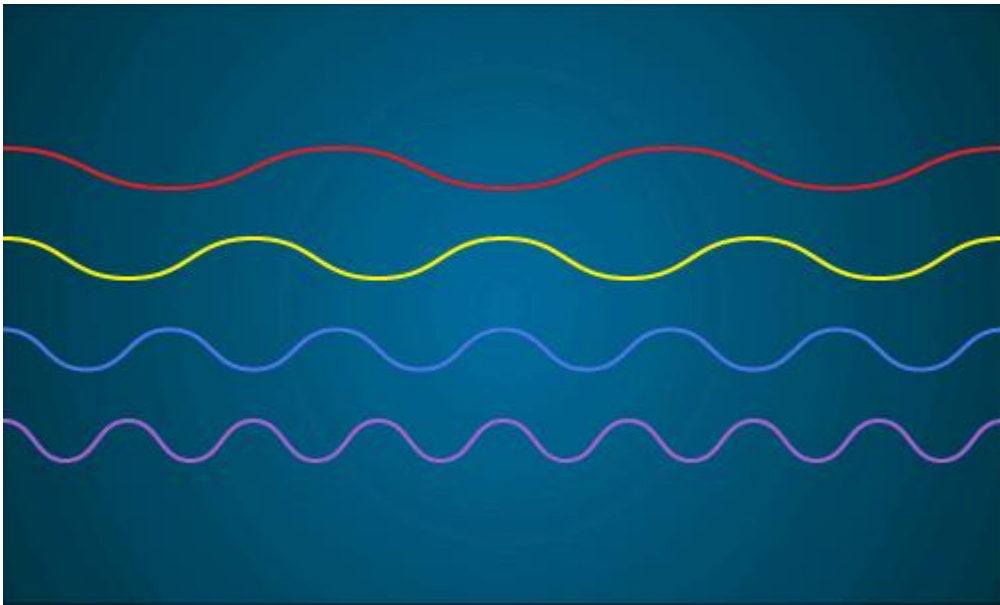
L A S E R

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

LASER is different!

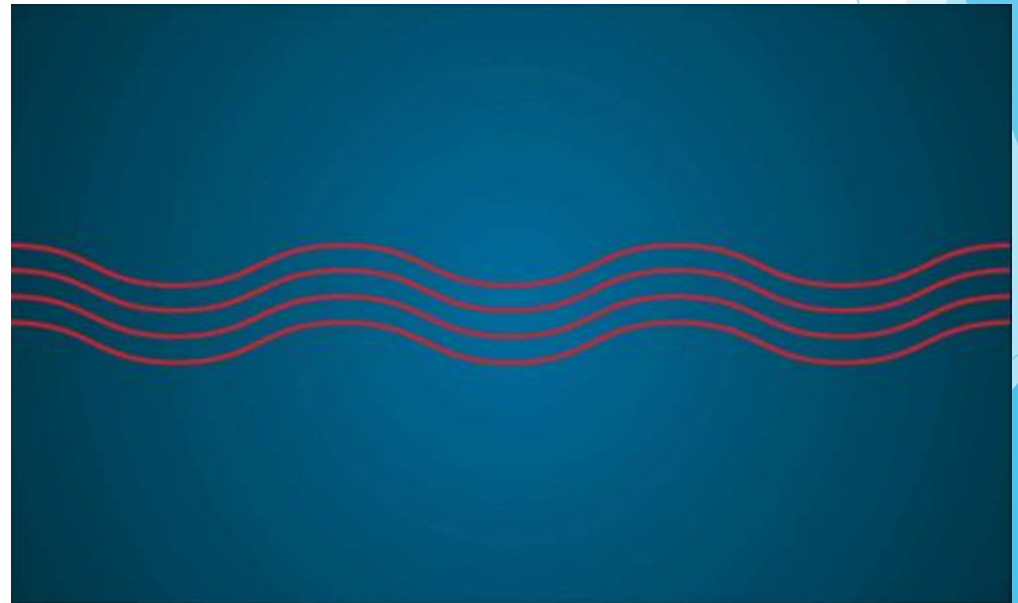
LASER: Lasers produce a very narrow beam of light

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

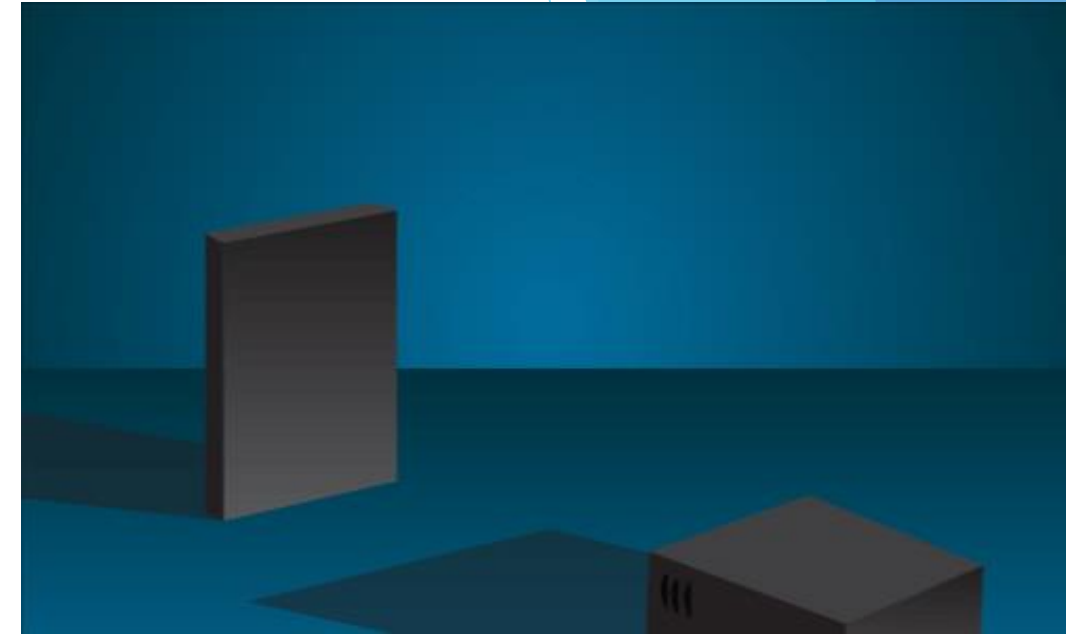


This Fig. is a representation of in phase laser light waves. Image credit: NASA

LASER light

Properties:

- ▶ **Directionality:** highly directional, divergence $< 10^{-5}$ rad
- ▶ **High power:** Continuous wave lasers having power levels of $\sim 10^5$ W and pulsed lasers having a total energy of $\sim 50,000$ 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 $\Delta\lambda \sim 10^{-6}$ Å

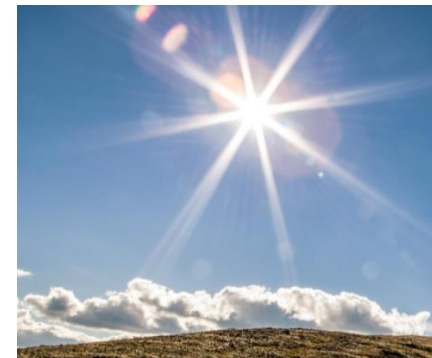


This animation shows how a laser can focus all of its light into one small point. Credit: NASA



** 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

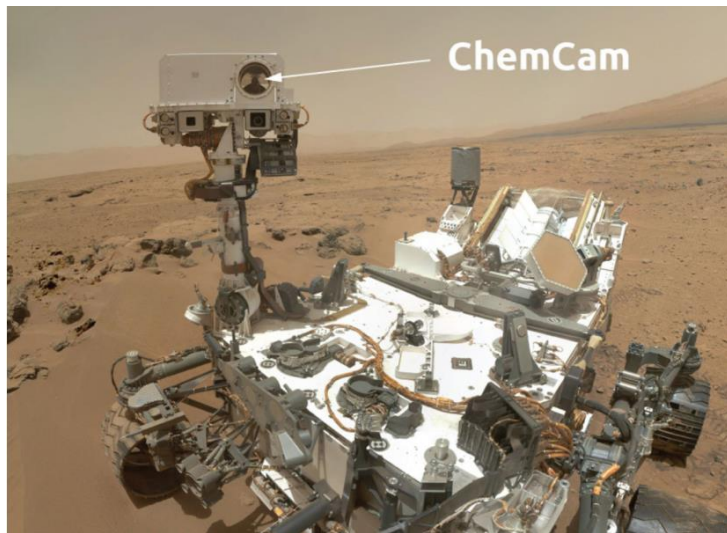
Because of such unique properties of the laser beam, it finds important applications in many diverse areas

- ▶ 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.

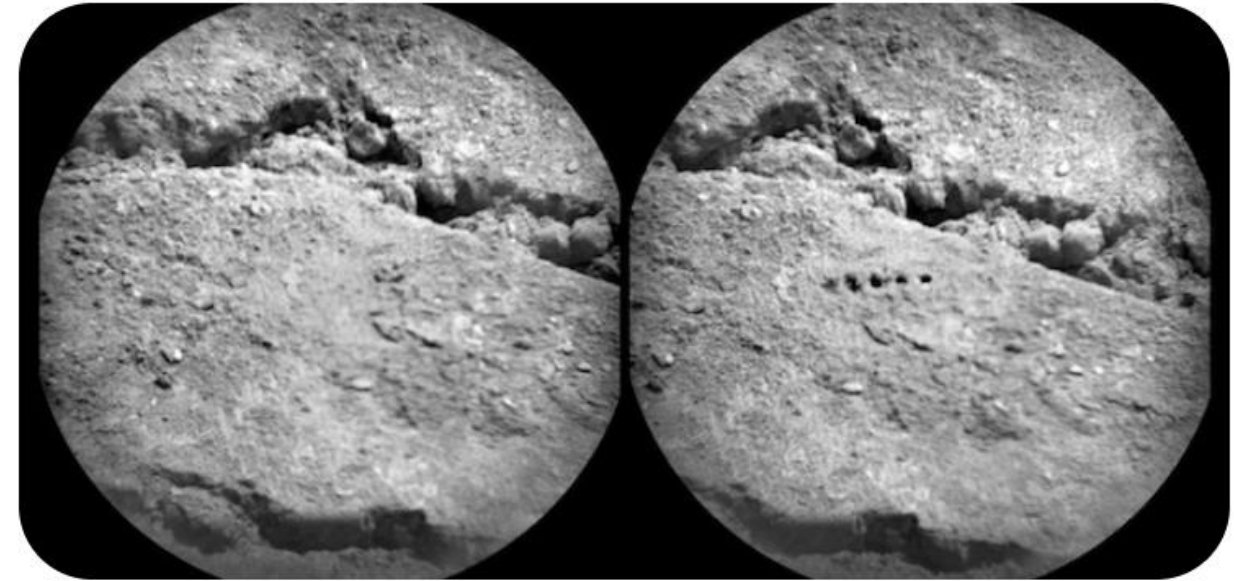
Applications continued

- ▶ 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*.



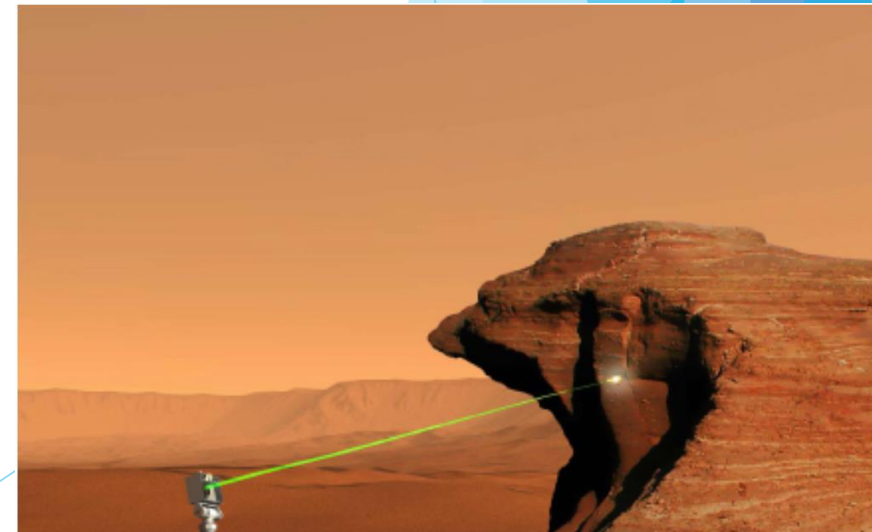
<https://www.nasa.gov/lasercomms>
<https://mars.nasa.gov/msl/spacecraft/instruments/chemcam/>



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

*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.

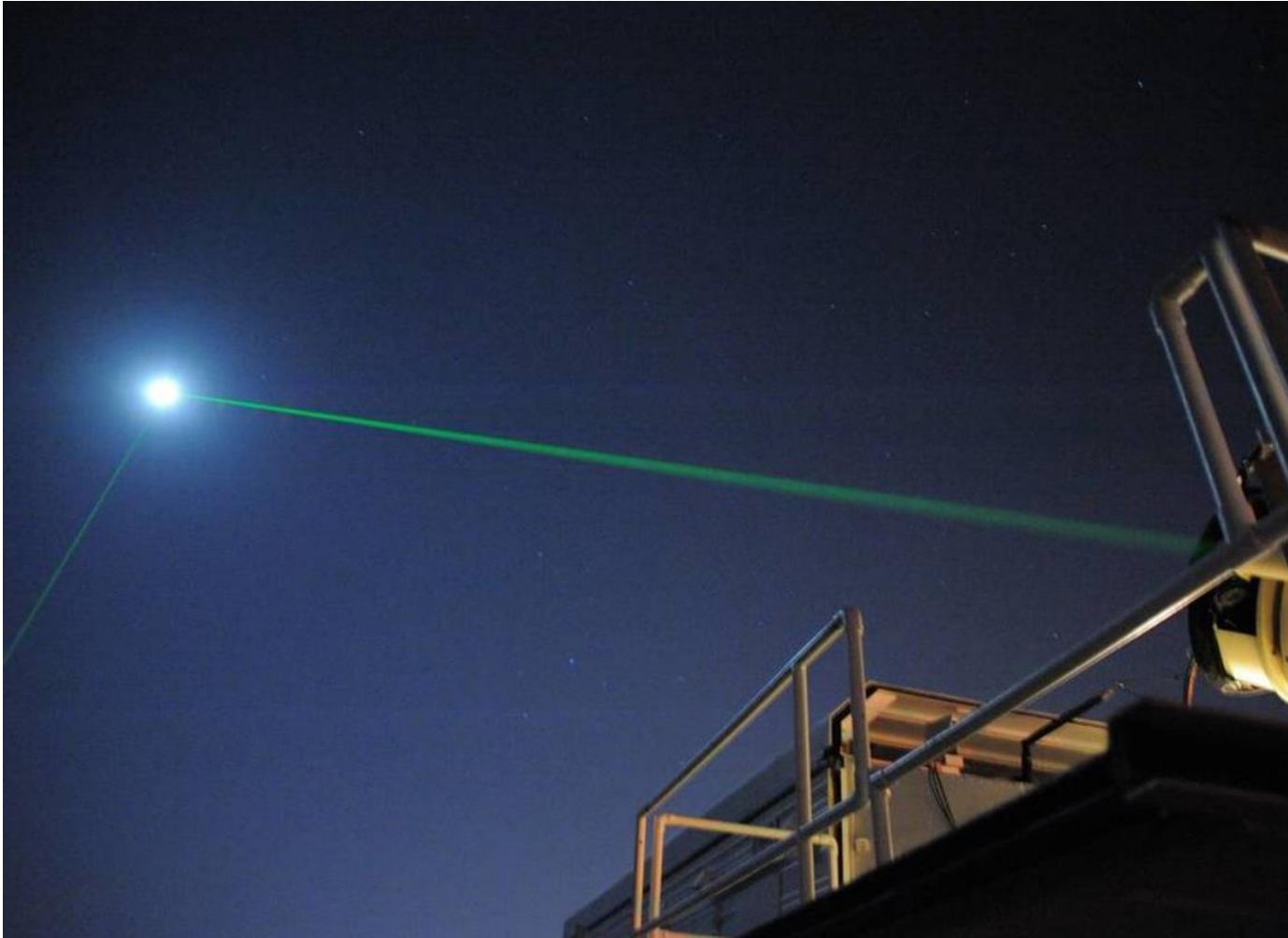
The reflector NASA scientists aimed for is mounted on the Lunar Reconnaissance Orbiter (LRO), a spacecraft that has been studying the Moon from its orbit since 2009. One reason engineers placed the reflector on LRO was so it could serve as a pristine target to help test the reflecting power of panels 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.

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 Communications Relay Demonstration (LCRD)

On Dec. 7, 2021, the [Laser Communications Relay Demonstration \(LCRD\)](#) launched into orbit, about 22,000 miles from Earth to test the capabilities of laser communications. LCRD is the agency's first technology demonstration of a two-way laser relay system. Now that LCRD is in orbit, NASA's laser communications [advancements](#) continue.

LCRD Experimenters Program

In May 2022, NASA certified that LCRD is ready to conduct experiments. These experiments are testing and refining laser systems — the mission's overall goal. Experiments provided by NASA, other government agencies, academia, and industry are measuring the long-term effects of the atmosphere on laser communications signals; assessing the technology's applicability for future missions; and testing on-orbit laser relay capabilities.

"We will start receiving some experiment results almost immediately, while others are long-term and will take time for trends to emerge during LCRD's two-year experiment period," said Rick Butler, project lead for the LCRD experimenters program at [NASA's Goddard Space Flight Center](#) in Greenbelt, Maryland. "LCRD will answer the aerospace industry's questions about laser communications as an operational option for high bandwidth applications."

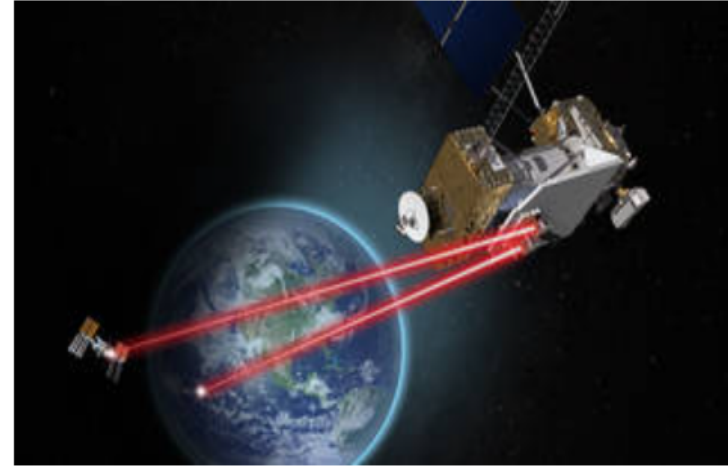


Illustration of LCRD relaying data from ILLUMA-T on the International Space Station to a ground station on Earth.

Credits: NASA's Goddard Space Flight Center/Dave Ryan

May 11, 2023

NASA, Partners Achieve Fastest Space-to-Ground Laser Comms Link

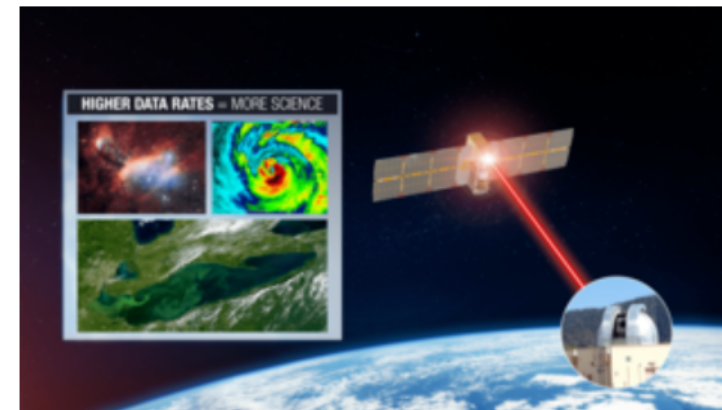


On April 28, NASA and its partners achieved another major milestone in the future of space communications – achieving 200 gigabit per second (Gbps) throughput on a space-to-ground optical link between a satellite in orbit and Earth, the highest data rate ever achieved by optical communications technology.

These data rates are made possible by using [laser communications](#), which packs information into the oscillations of light waves in lasers, instead of using radio waves like most space communications systems.

This communications link was achieved by the [TeraByte InfraRed Delivery \(TBIRD\)](#) system, carried into orbit by NASA's Pathfinder Technology Demonstrator 3 (PTD-3) satellite, and surpasses the previous 100 Gbps milestone previously demonstrated by the same team in June 2022. With this speedy connection, TBIRD can send down multiple terabytes of test data to Earth during a single six-minute pass over a ground station. A single terabyte is the equivalent of about 500 hours of high-definition video.

“Achieving 100 Gbps in June was groundbreaking, and now we’ve doubled that data rate – this capability will change the way we communicate in space,” said Beth Keer, the mission manager for TBIRD at [NASA's Goddard Space Flight Center](#) in Greenbelt, Maryland. “Just imagine the power of space science instruments when they can be



Laser communications offers more data back to Earth. More data = more discoveries.

Credits: NASA



LASER application a few links

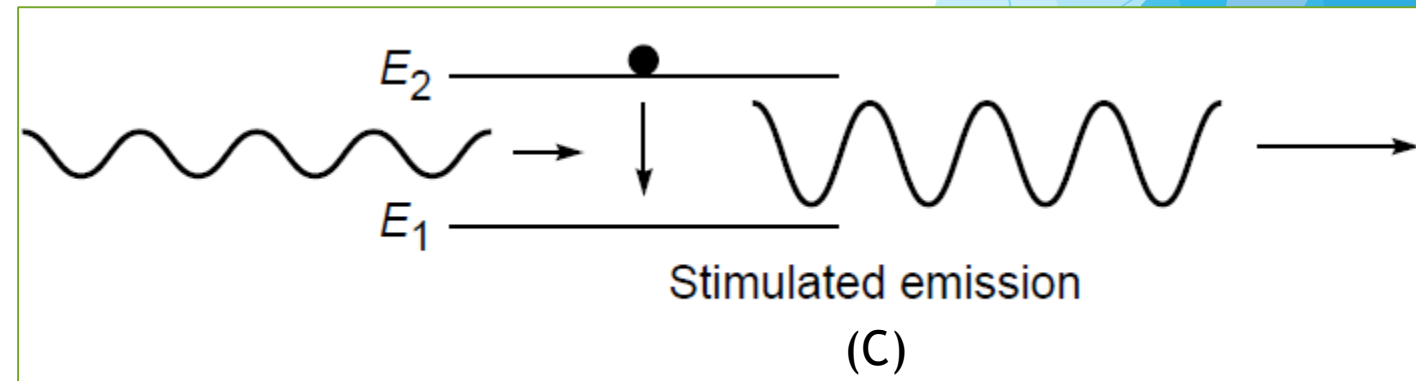
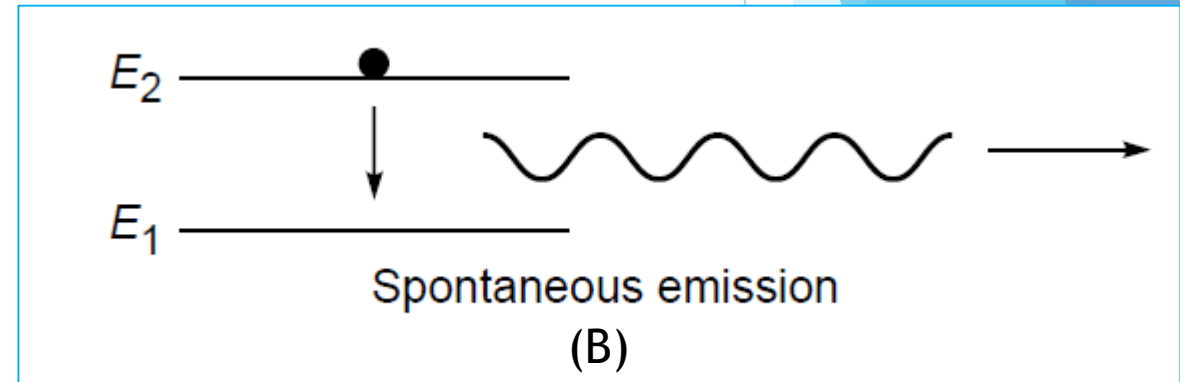
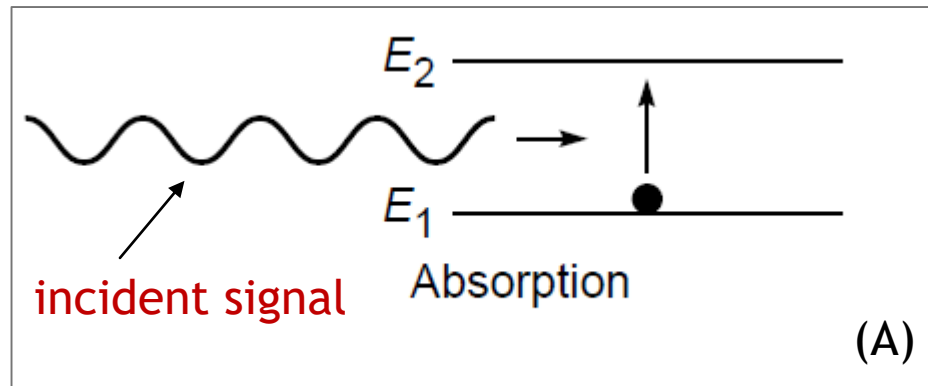
- ▶ <https://www.nasa.gov/lasercomms>
- ▶ https://www.nasa.gov/mission_pages/tdm/lcrd/index.html
- ▶ <https://www.nasa.gov/mediacast/goddard/2022/bonus-lcrd-your-questions-answered-nasa-s-the-invisible-network-podcast>

LASER

- ▶ **Q: How does an atom interact with electromagnetic radiation??**

Spontaneous and Stimulated Emissions

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



Thank You