# NASA Facts

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**Langley Research Center**
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# Laser Technology: Shedding Some Light

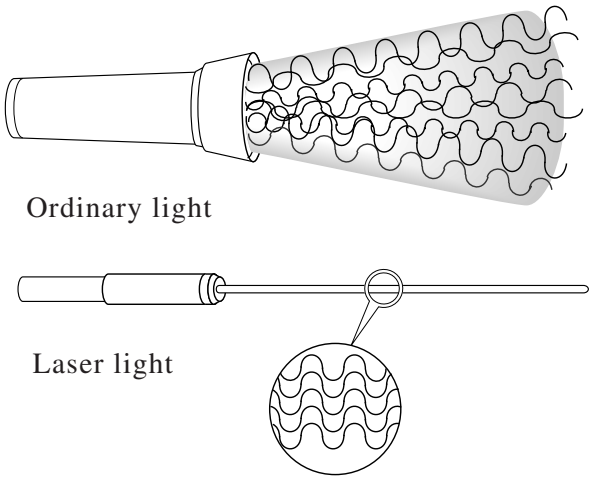
Imagine knowing enough about a hurricane to get the right people evacuated. Or knowing enough about Earth's atmosphere to predict climate trends and to stop negative human impacts. Consider a time when advances in medical procedures retire the scalpel to the museum. And think about precision-oriented manufacturing which brings consumer costs down because of its efficiency.

One advance in technology can enable these 21st century goals — it is the laser. The laser is already integrated into our daily lives, in supermarket scanners, video and compact disks, as a tool to make dental work, in cosmetic plastic and general surgery, and in industry where it is used to align equipment and even cut out fabric for clothes.

Lasers are also changing how scientists conduct research, and they are an important tool for atmospheric studies at NASA Langley Research Center.

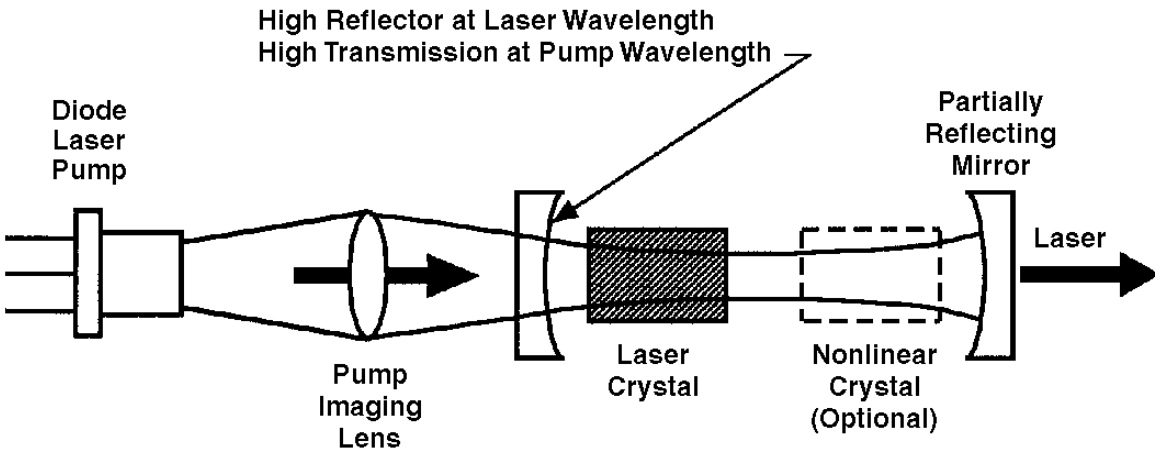
## What is a laser?

A laser* is a unique kind of light, more intense and concentrated than anything in nature. Laser light differs from white light (such as sunlight, the light we use in lamps or flashlights) in several ways. Light from most sources spreads out as it travels so that much less of it hits a given area as it moves farther from its source. Traveling as a tight, unbroken beam, the laser light does not disperse as much as it moves away from its origin. Also, while white light is a mix of colored light waves, laser light is monochromatic, having a single wavelength which corresponds to one specific color. Identical wavelengths travel parallel to one another for reinforcement, creating a strong beam that can be focused down to less than 0.001 inch in diameter. Laser light can be controlled very precisely as a steady, continuous beam or in bursts or pulses.




**Light waves from the flashlight are different colors and different lengths; however, the laser light waves are all of the same wavelength and have only one color.**

*Light Amplification by Stimulated Emission of Radiation




**Typical diode-pumped solid-state laser**

While they can bore holes in the hardest substance of all — a diamond — lasers can also perform delicate operations such as surgery.

The early lasers grew out of an experiment in the 1960s when a German scientist, Theodore Maiman, discovered that one could separate and concentrate wavelengths of light. Various materials and designs have been used to do this.

## Lasers at NASA Langley

Scientists at NASA Langley Research Center have been researching and developing lasers for remote sensing (monitoring and measuring) of Earth's atmosphere since the technology was in its infancy. In recent years, they have incorporated lasers into atmospheric studies as part of NASA's Mission to Planet Earth program. The goal of this long-term global research is to study the interaction of all the environmental components — air, water, land, life — that make up the Earth system. While a variety of remote sensing techniques have been used, advances in laser technology are opening up new views of the Earth's atmosphere and placing the laser at the forefront of research tools.

In 1985, NASA Langley performed its first airborne laser mission: to study water vapor and the density of aerosols (small particles) in our atmosphere.

Less than 10 years later, in 1994, NASA Langley joined with industry to put an atmospheric laser sensor in space to probe the atmosphere. The **L**idar **I**n-Space **T**echnology **E**xperiment (**LITE**) was flown aboard the Space Shuttle Discovery (STS-64). During its 12-day mission, LITE measured the Earth's cloud cover and tracked aerosols in the atmosphere. The laser used on this mission was a component of a **Lidar** (**LI**ght **D**etection **A**nd **R**anging). Lidar is similar to radar, but instead of bouncing radio waves off its target, a lidar uses short pulses of laser light to bounce or reflect off particles — even molecules — in the atmosphere. The reflected light comes back to a telescope where it is collected and measured.

The LITE data is being analyzed and archived and has proven so effective in presenting a global picture of the Earth's atmosphere that NASA Langley scientists are now exploring the feasibility and potential advantages of using lidar instruments on satellites.

That same year NASA Langley accomplished another lidar mission. Flown on the high-altitude ER-2 aircraft, which is a modified U-2 spy plane, the **L**idar **A**tmospheric **S**ensing **E**xperiment (**LASE**) used the first tunable laser to function autonomously. The lidar used in this mission was designed to measure atmospheric elements which are typically hard to detect, such as water vapor and pollutants. This **DI**fferential **A**bsorption **L**idar (**DIAL**) uses two laser beams pulsed at different wavelengths, one tuned to a specific particle or gas which absorbs it, and one tuned to remain unabsorbed. By measuring the difference between the two beams as they come back to the telescope — one partially absorbed and one intact — scientists can determine the amount of a particle or gas present.

NASA Langley's work in the development of laser technology has naturally found application in medicine and manufacturing. NASA Langley engineers were instrumental in the development of the diode pump laser which is currently state of the art because of its efficiency, reliability and long life. In response to an industrial need for such a laser, NASA Langley teamed with others to take the diode semi-conductor from being a lab curiosity to a product which industry has since commercialized.

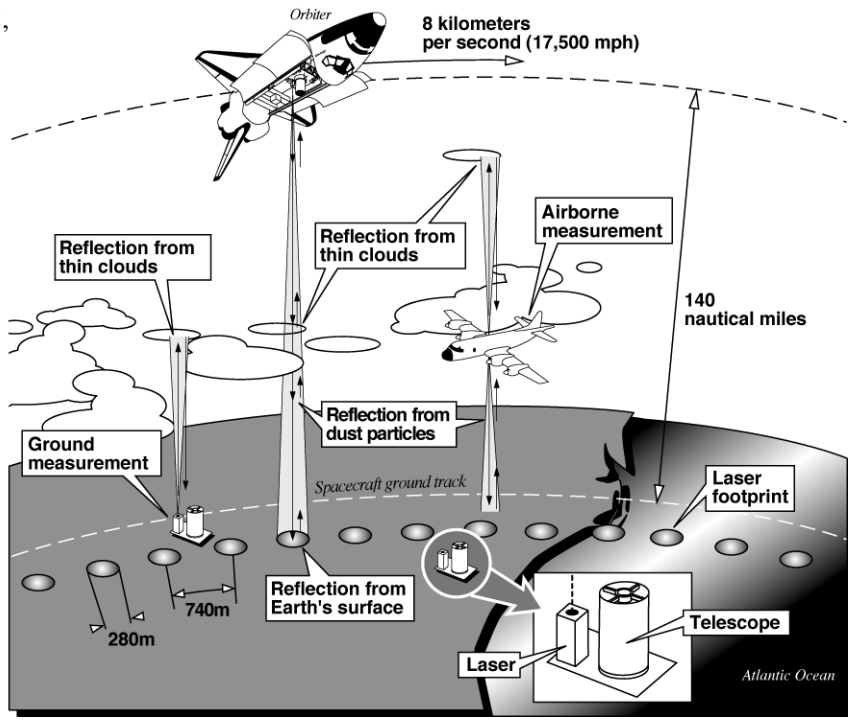
NASA Langley also contributed greatly to the development of a more efficient laser for special medical applications, such as incisions and arterial repairs.

## The Future

LASE and LITE collected data on a wide range of phenomena, from aerosols in the upper atmosphere to cloud droplets, pollutants, and Earth's protective layer of ozone. Future lidar instruments will be tailored to specific purposes.

NASA Langley engineers are currently building lasers with different characteristics for remote sensing needs. These lasers are very specialized, one-of-a-kind instruments which often require uncommon wavelengths and unusual pulse or light burst formats. They must be able to survive the rigors of launch and the harsh space environment and operate reliably for long periods. NASA Langley's goal is to have a laser operating unattended in space for five years, or an equivalent of five billion pulses. NASA Langley scientists have already tested a laser's ability to pulse that number of times. The next step is to have it do so in space.

NASA Langley engineers are designing a laser to measure wind velocity. Global wind-velocity measurements taken from space help determine air circulation. Such knowledge would improve weather forecasting and determine the path of severe storms more accurately. Local air or ground readings would enhance aircraft safety by




**In 1994 the LITE instrument flew aboard the Space Shuttle Discovery. An international team of scientists at over 50 locations around the world helped collect data to confirm the measurements taken from space.**

### *Why We Need to See*

*We all need to care about our atmosphere. It affects all of us. It affects our weather. It affects the ozone which protects us by absorbing harmful ultraviolet radiation. Global pollution affects the air we breath and the amount of sunlight which reaches us. Dust storms and volcanic eruptions also alter our atmosphere. If we can more accurately forecast natural occurrences, like the weather, we can be prepared. And if we can actually see the results of what we may be doing to hurt our planet's atmosphere, we can change our bad habits.*

determining hazardous wind conditions. Laser wind sensors can detect strong downdrafts called wind shear, which have been implicated in fatal airplane crashes. These lasers would also improve airport terminal efficiency by offering better information to those making air traffic decisions. This more sophisticated laser can determine vortices (horizontal tornadoes which are generated off the tips of larger airplane wings) which can upset smaller aircraft landing too close behind. These lasers can also determine when vortices are dispersed by local wind conditions which would allow smaller aircraft to land more efficiently.

NASA Langley engineers continue to develop more sophisticated lasers to measure atmospheric water content. These instruments would provide information for longer-term rain forecasts which could improve the allocation of already scarce water resources.

Laser technology is also being developed for potential future missions to measure ozone and other greenhouse gases which are main contributors to global warming and cooling. It is important to understand more about these atmospheric constituents in order to understand and respond to global climate changes. NASA Langley is helping the U.S. in a joint project with Canada to develop spaceborne laser missions to learn more about atmospheric ozone. This international effort comes after satellite data has recorded ozone depletion near both of the Earth's polar regions. An advanced lidar system called **ORACLE** (**O**zone **R**esearch with **A**dvanced **C**ooperative **L**idar **E**xperiments) will provide key information needed for understanding global change, atmospheric, chemistry, ozone depletion, meteorology and other environmental issues.

NASA Langley will join with other NASA centers to develop laser remote sensing instruments for possible future moon, Mars and other planetary exploration. Lasers designed for altimetry readings will aid in making planetary maps. Lasers also will be instrumental in determining winds and the amounts of atmospheric aerosols. This information will help designers know what conditions they would confront as they design future spacecraft for a mission to the moon or Mars.

In response to the increased concern for Earth's atmosphere, NASA Langley is researching new ways to collect and analyze this important data. As researchers develop the technology necessary to do this, they bring us closer to understanding how to protect our atmosphere.

For more information contact:

Office of Public Affairs
Mail Stop 115
NASA Langley Research Center
Hampton, VA 23681-0001
(757) 864-6123
http://www.larc.nasa.gov/org/pao