

Applications of LASER

Spectroscopy

Most types of laser are an inherently pure source of light; they emit near-[monochromatic](#) light with a very well defined range of [wavelengths](#). By careful design of the laser components, the purity of the laser light (measured as the "[linewidth](#)") can be improved more than the purity of any other light source.

This makes the laser a very useful source for [spectroscopy](#). The high intensity of light that can be achieved in a small, well collimated beam can also be used to induce a nonlinear optical effect in a sample, which makes techniques such as [Raman spectroscopy](#) possible. Other spectroscopic techniques based on lasers can be used to make extremely sensitive detectors of various molecules, able to measure molecular concentrations in the parts-per- 10^{12} (ppt) level. Due to the high power densities achievable by lasers, beam-induced atomic emission is possible: this technique is termed [Laser induced breakdown spectroscopy](#) (LIBS).

Heat treatment

Heat treating with lasers allows selective surface hardening against wear with little or no distortion of the component. Because this eliminates much part reworking that is currently done, the laser system's capital cost is recovered in a short time. An inert, absorbent coating for laser heat treatment has also been developed that eliminates the fumes generated by conventional paint coatings during the heat-treating process with CO₂ laser beams.

One consideration crucial to the success of a heat treatment operation is control of the laser beam irradiance on the part surface. The optimal irradiance distribution is driven by the thermodynamics of the laser-material interaction and by the part geometry.

Typically, irradiances between 500-5000 W/cm² satisfy the thermodynamic constraints and allow the rapid surface heating and minimal total heat input required. For general heat treatment, a uniform square or rectangular beam is one of the best options. For some special applications or applications where the

heat treatment is done on an edge or corner of the part, it may be better to have the irradiance decrease near the edge to prevent melting.

Weather

Research shows that scientists may one day be able to induce [rain](#) and [lightning](#) storms (as well as micro-manipulating some other weather phenomena) using [high energy lasers](#). Such a breakthrough could potentially eradicate [droughts](#), help alleviate weather related [catastrophes](#), and allocate weather resources to areas in need. [\[3\]\[4\]](#)

Lunar laser ranging

Main article: [Lunar laser ranging experiment](#)

When the Apollo astronauts visited the moon, they planted [retroreflector](#) arrays to make possible the [Lunar Laser Ranging Experiment](#). Laser beams are focused through large [telescopes](#) on Earth aimed toward the arrays, and the time taken for the beam to be reflected back to Earth measured to determine the distance between the Earth and Moon with high accuracy.

Photochemistry

Some laser systems, through the process of [mode locking](#), can produce extremely brief pulses of light - as short as picoseconds or femtoseconds (10^{-12} - 10^{-15} seconds). Such pulses can be used to initiate and analyse chemical reactions, a technique known as *photochemistry*. The short pulses can be used to probe the process of the reaction at a very high temporal resolution, allowing the detection of short-lived intermediate molecules. This method is particularly useful in [biochemistry](#), where it is used to analyse details of protein folding and function.

Laser scanner

Laser barcode scanners are ideal for applications that require high speed reading of linear codes or stacked symbols.

Laser cooling

A technique that has recent success is *laser cooling*. This involves [atom trapping](#), a method where a number of atoms are confined in a specially shaped

arrangement of [electric](#) and [magnetic fields](#). Shining particular wavelengths of light at the ions or atoms slows them down, thus *cooling* them. As this process is continued, they all are slowed and have the same energy level, forming an unusual arrangement of matter known as a [Bose–Einstein condensate](#).

Nuclear fusion

Some of the world's most powerful and complex arrangements of multiple lasers and optical amplifiers are used to produce extremely high intensity pulses of light of extremely short duration, e.g. [laboratory for laser energetics](#), [National Ignition Facility](#), [GEKKO XII](#), [Nike laser](#), [Laser Mégajoule](#), [HiPER](#). These pulses are arranged such that they impact pellets of [tritium](#)–[deuterium](#) simultaneously from all directions, hoping that the squeezing effect of the impacts will induce atomic [fusion](#) in the pellets. This technique, known as "[inertial confinement fusion](#)", so far has not been able to achieve "breakeven", that is, so far the fusion reaction generates less power than is used to power the lasers, but research continues.

Medical

- Cosmetic surgery ([removing tattoos](#), scars, stretch marks, sunspots, wrinkles, birthmarks, and hairs): see [laser hair removal](#). Laser types used in [dermatology](#) include [ruby](#) (694 nm), [alexandrite](#) (755 nm), pulsed diode array (810 nm), [Nd:YAG](#) (1064 nm), [Ho:YAG](#) (2090 nm), and [Er:YAG](#) (2940 nm).
- [Eye surgery](#) and [refractive surgery](#)
- [Soft tissue surgery](#): [CO₂](#), [Er:YAG laser](#)
- [Laser scalpel](#) (General surgery, gynaecological, urology, laparoscopic)
- [Photo biomodulation](#) (i.e. laser therapy)
- "No-Touch" removal of tumors, especially of the brain and spinal cord.
- [Intelligent laser speckle classification](#) for skin health assessments (especially regarding damage caused through ageing)
- In [dentistry](#) for [caries](#) removal, [endodontic/periodontic](#) procedures, [tooth whitening](#), and [oral surgery](#)
- [Cancer treatment](#)

- Burn and surgical scar management: scar contracture [CO2](#) (especially the newer fractionated CO2 lasers), redness and itch (Pulsed Dye laser - PDL), post-inflammatory hyper-pigmentation (Q-switched lasers :Ruby, Alexandrite), burn scar unwanted hair growth and trapped hairs (Ruby, IPL and numerous hair removal lasers)

Industrial Applications

- A detailed list of industrial and commercial laser applications includes:
- [Laser cutting](#)
- [Laser welding](#)
- [Laser drilling](#)
- [Laser marking](#)
- [Laser cleaning](#)
- [Laser cladding](#), a surface engineering process applied to mechanical components for reconditioning, repair work or [hard facing](#)
- [Photolithography](#)
- [Optical communications](#) over [optical fiber](#) or in [free space](#)

- [Laser peening](#)
- [Guidance systems](#) (e.g., [ring laser gyroscopes](#))
- [Laser rangefinder](#) / [surveying](#),
- [Lidar](#) / pollution monitoring,
- [Digital minilabs](#)
- [Barcode readers](#)
- [Laser engraving](#) of printing plate
- [Laser bonding](#) of additive marking materials for decoration and
identification,
- [Laser pointers](#)
- [Laser mice](#)
- [Laser accelerometers](#)
- [OLED display](#) manufacturing
- [Holography](#)
- [Bubble grams](#)
- [Optical tweezers](#)
- Writing [subtitles](#) onto [motion picture](#) films.^[13]

- [Power beaming](#), which is a possible solution to transfer energy to the climber of a [Space elevator](#)
- [3D laser scanners](#) for accurate 3D measurement
- [Laser line levels](#) are used in surveying and construction. Lasers are also used for [guidance for aircraft](#).
- Extensively in both consumer and industrial imaging equipment.
- In [laser printers](#): gas and diode lasers play a key role in manufacturing high resolution printing plates and in image scanning equipment.
- [Diode lasers](#) are used as a light switch in industry, with a laser beam and a receiver which will switch on or off when the beam is interrupted, and because a laser can keep the light intensity over larger distances than a normal light, and is more precise than a normal light it can be used for product detection in automated production.
- [Laser alignment](#)
- [Additive manufacturing](#)
- [Plastic welding](#)

- [Metrology](#) - handheld and robotic laser systems
for [Aerospace](#), [Automotive](#) and [Rail](#) applications
- To store and retrieve data in [optical discs](#), such as [CDs](#) and [DVDs](#)
- Blu-ray

Entertainment and recreation

- [Laser lighting displays](#) accompany many music concerts
- [Laser tag](#)
- [Laser harp](#): a musical instrument where the strings are replaced with laser beams
- As a light source for [digital cinema projectors](#)^[14]