

## How Lasers Work

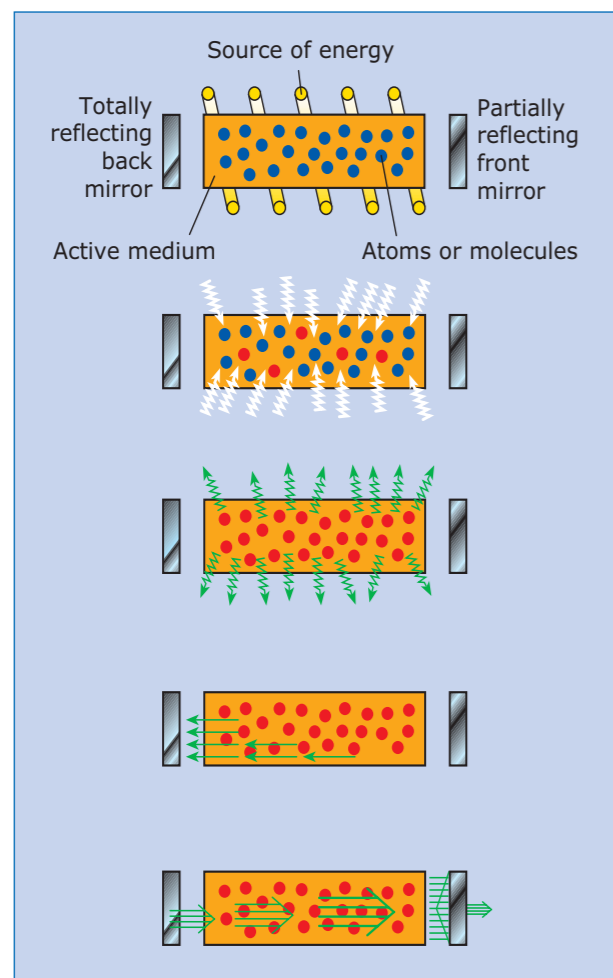
Energy from a flashlamp, an electrical discharge or another source is pumped into a material called the **active medium**, which is contained in the laser cavity.

As this energy is absorbed, the individual atoms in the active medium move into an 'excited' state.

The energy is re-emitted from the active medium as optical radiation.

Mirrors are placed at either end of the cavity to reflect the radiation back into the active medium. This stimulates the active medium into producing more radiation, called **laser radiation**.

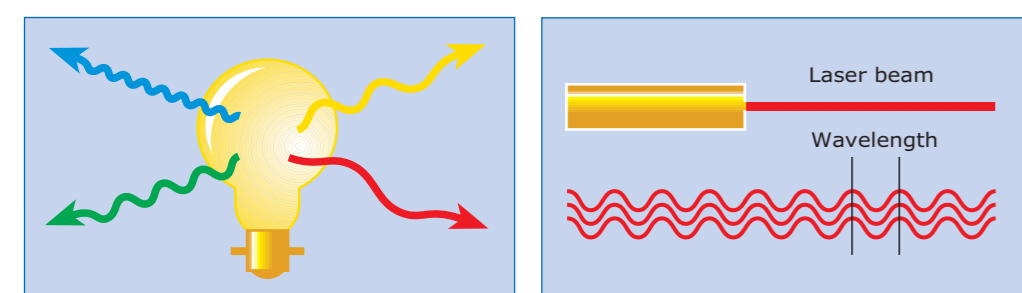
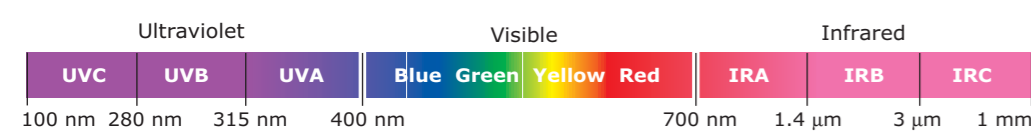
The laser radiation is amplified by the process of stimulation. If one of the mirrors is partially transmitting, some of the laser radiation will be emitted as the laser beam.



**LASER**  
Light Amplification by the Stimulated Emission of Radiation

## Laser Beams

A laser beam is electromagnetic radiation, as is the light emitted by a light bulb. The beam produced by a laser may be in the infrared, visible or ultraviolet regions of the spectrum.



Light from a light bulb is emitted at many wavelengths in all directions.

A laser emits a beam of only one wavelength (or a small number of wavelengths). This wavelength is determined by the active medium.

The individual waves of a laser beam are 'in phase', ie they all go up and down at the same time. A laser beam is therefore said to be 'coherent'.

Most laser beams have a low divergence, so they do not spread out, even over very long distances.



## Laser Applications

The use of new active media has given rise to lasers which operate at new wavelengths, increasing their applications.

Semiconductor (diode) lasers now compete with traditional laser technology. These small but efficient lasers can produce beams at up to several watts of power.

### Materials processing

A high powered CO<sub>2</sub> or Nd:YAG laser beam will produce enough heat to etch, weld or even cut metals. Ultraviolet lasers are used to drill very precise holes and in semiconductor manufacturing.



### Research

Research at universities and other establishments plays a key role in finding and developing new laser applications. Laser beams are also valuable research tools.

### Medicine

Lasers play an important role in medicine from the removal of diseased tissue to the treatment of birthmarks. Eye surgeons use lasers to treat many conditions including long and short sightedness. Dentists use laser beams to drill teeth.

Laser beams are also used to investigate living material and for diagnosing medical conditions.



### Entertainment

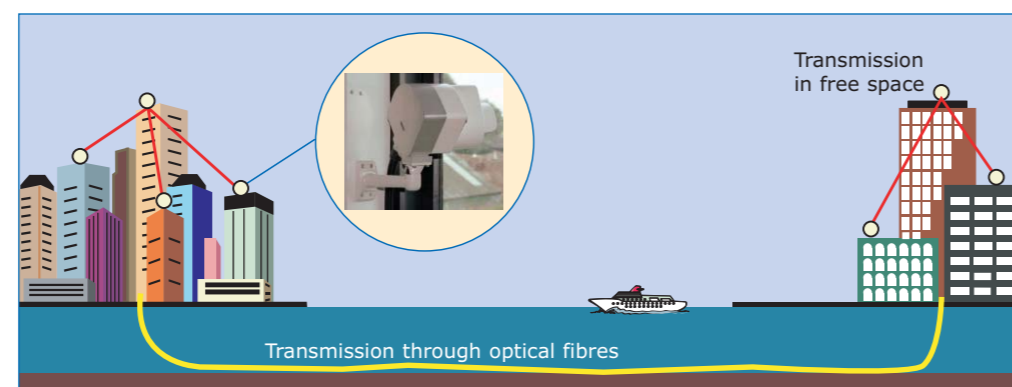
Low divergence allows laser beams to be projected over long distances and scanned into images using a system of oscillating mirrors.

### Military

Laser beams are used to measure distance and to mark out targets for weapons.

### Communications

Tiny lasers are used to transmit voice and digital information through optical fibres and the air.



### DEFINITIONS

**Accessible emission limit (AEL)** The maximum accessible output of a laser in a specific laser class.

**Active medium** The active medium determines the wavelength of the laser radiation. It also gives the laser its name, eg

argon fluoride	193 nm	neodymium:YAG	1064 nm
helium neon	633 nm	carbon dioxide	10600 nm

**Irradiance** The power density of a laser beam incident at 90° to a surface, measured in watts per square metre (W m<sup>-2</sup>).

**Maximum permissible exposure (MPE)** The level of exposure below which biological damage is unlikely to occur. Laser products should be engineered so that people are exposed to levels below the MPE.

**Radiant energy** The energy of a laser beam pulse, measured in joules (J).

**Radiant exposure** The energy density of a laser beam incident at 90° to a surface, measured in joules per square metre (J m<sup>-2</sup>).

**Radiant power** The power of a laser beam, measured in watts (W).

**Wavelength** The length of a single cycle in a wave, generally measured in nanometres (nm) or micrometres (μm). Lasers emit beams which are made up of only one or a few wavelengths. For visible laser beams, the wavelength determines the colour.

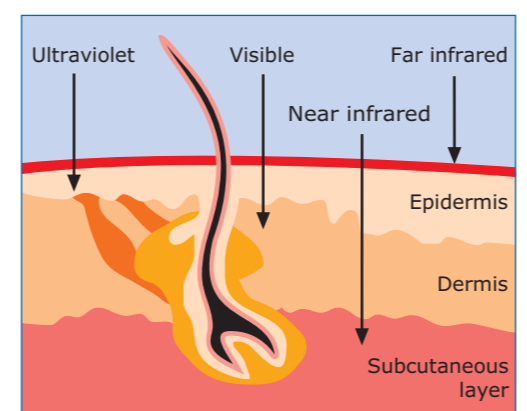
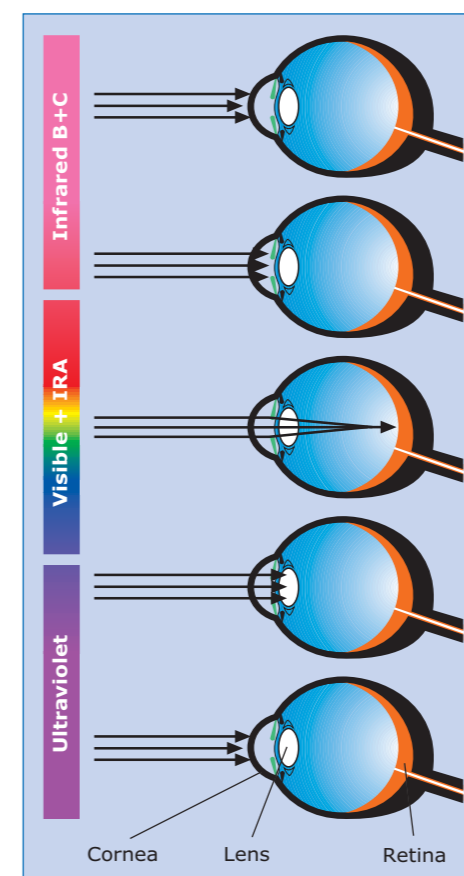
## Laser Hazards

When a laser beam strikes a person, the damage it causes will depend on the power and wavelength of the laser beam, and the organ or tissue exposed. The eyes and skin are most at risk to damage from a laser beam.

### Eye damage

Different laser wavelengths penetrate to different parts of the eye. The cornea and the lens will focus visible and near infrared (IRA) laser beams on to the retina at the back of the eye, where damage may occur.

IRB, IRC and ultraviolet invisible laser beams do not penetrate to the retina, but may cause damage to the cornea, the lens and other parts at the front of the eye.



### Skin damage

High powered lasers present a hazard to the skin. As with the eye, different laser wavelengths penetrate to different parts of the skin.

### CLASSIFICATION

The laser standard BS EN 60825-1 classifies laser products according to the beam hazard.

- Class 1** Safe under reasonably foreseeable conditions of operation.
- Class 1M** As Class 1 but not safe when viewed with optical aids such as eye loupes or binoculars.
- Class 2** (Visible laser beams only) The eye is protected by the aversion responses, including the blink reflex and head movement.
- Class 2M** As Class 2 but not safe when viewed with optical aids such as eye loupes or binoculars.
- Class 3R** More likely to cause harm to the eye than lower class lasers but do not need as many control measures as higher class lasers.
- Class 3B** Eye damage likely to occur if the beam is viewed directly or from shiny reflections.
- Class 4** Eye and skin damage likely from the main laser beam and reflected beams. These lasers may cause fires.

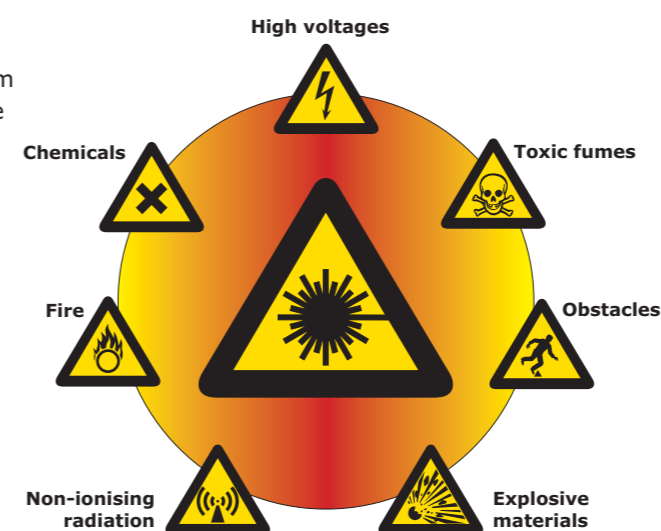


If a Class 4 laser is embedded within a product, and engineering controls prevent access to any direct or scattered beams, then the product itself may be classified as Class 1. The laser beams may be accessible if the engineering controls are defeated, eg during servicing.

This plate maker is an example of a Class 4 laser within a Class 1 product.

### Associated hazards

The hazards of the laser beam must be considered alongside other hazards. Sometimes the laser beam is not the most hazardous part of the equipment.



## Practical Laser Safety

### Engineering controls

The safest laser products rely upon engineered safety features.

Safety interlocks can isolate the laser if anyone enters an area of high risk.



This CO<sub>2</sub> cutting laser nozzle is surrounded by polycarbonate which is opaque to the laser beam and confines toxic byproducts.

### Administrative controls

Administrative safeguards are an important backup to engineering controls.

Lights or notices should warn people when they approach a laser hazard.



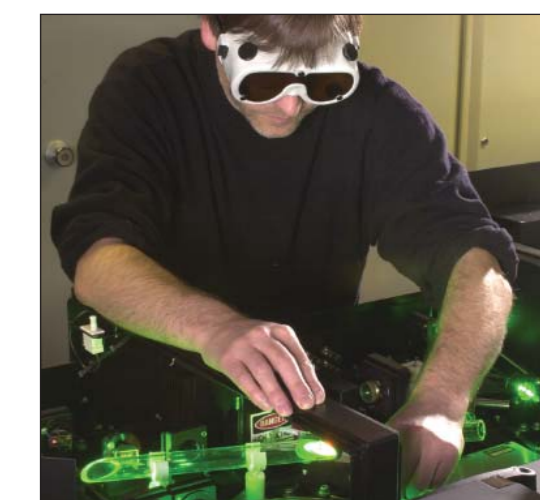
Anyone who works with a Class 3R, Class 3B or Class 4 laser should receive training covering both laser safety and the proper use of the equipment. In some cases training will also be required for users of Class 1M and Class 2M lasers.

Carefully planned schemes of work should give useful information to the operator for both normal work and emergency procedures.

### Personal protection

Personal protective equipment is used when other safety features are not feasible or sufficient.

Laser safety eyewear is designed to protect the user against accidental exposure. It must be suitable for the type of laser and should offer adequate protection against accidental exposure to the main beam. It must be kept clean and free from scratches. Skin protection may also be required.



### LEGISLATION

- There is no specific laser safety legislation, but general health and safety laws still apply, eg
- The Health and Safety at Work etc Act 1974
- The Management of Health and Safety at Work Regulations 1999
- The Provision and Use of Work Equipment Regulations 1998

Product supply legislation may also be relevant and many laser products require CE marking.

### LASER SAFETY STANDARDS

There are internationally agreed standards for laser products that also include guidance to users. BS EN 60825, which has several parts, is based on the International Electrotechnical Commission (IEC) standard of the same number. The laser safety standards also apply to light emitting diodes (LEDs). The standards in the USA have subtle differences and it is important that imported products comply with the British Standard.

### GUIDANCE DOCUMENTS

A number of industries have produced their own guidance documents, eg universities and the printing and medical sectors. Guidance has been published by the Civil Aviation Authority for the use of lasers out of doors and by the Health and Safety Executive for entertainment lasers.

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