**Directed-energy weapon**

A **directed-energy weapon** (**DEW**) is a type of weapon that emits [energy](http://en.wikipedia.org/wiki/Energy) in an aimed direction without the means of a [projectile](http://en.wikipedia.org/wiki/Projectile). It transfers energy to a target for a desired effect. Some of these weapons are real or in development; others are at present only [science fiction](http://en.wikipedia.org/wiki/Science_fiction).

The energy can come in various forms:

* [Electromagnetic radiation](http://en.wikipedia.org/wiki/Electromagnetic_spectrum) (typically [lasers](http://en.wikipedia.org/wiki/Laser) or [masers](http://en.wikipedia.org/wiki/Maser)).
* Particles with [mass](http://en.wikipedia.org/wiki/Mass) ([particle beam weapons](http://en.wikipedia.org/wiki/Particle_beam_weapon)).
* [Sound](http://en.wikipedia.org/wiki/Sound) ([sonic weaponry](http://en.wikipedia.org/wiki/Sonic_weaponry))

In science fiction, these weapons are sometimes known as **death rays** or [**rayguns**](http://en.wikipedia.org/wiki/Raygun) and are usually portrayed as projecting energy at a person or object to kill or destroy.

Some lethal directed-energy weapons are under active [research and development](http://en.wikipedia.org/wiki/Research_and_development), but most examples appear in [science fiction](http://en.wikipedia.org/wiki/Science_fiction) (non-functional [toys](http://en.wikipedia.org/wiki/Toy), [film props](http://en.wikipedia.org/wiki/Theatrical_property) or [animation](http://en.wikipedia.org/wiki/Animation)).

**Tactical considerations and problems**

Lasers have several main advantages over conventional weaponry:

* Laser beams travel at the [speed of light](http://en.wikipedia.org/wiki/Speed_of_light), unlike projectile weapons, so there is no need in terrestrial applications to aim ahead to allow for the target moving while the shot travels as the transit time over such distances is virtually zero.
* The speed of delivery means that the target has no chance to detect or evade (as with enemy aircraft targeted with anti-aircraft missiles), and that some third object does not have the time to accidentally move into the trajectory while the energy is delivered.
* Light's short transit time also nearly eliminates the influence of gravity, so long range projection does not require compensation for such. Other aspects such as [wind](http://en.wikipedia.org/wiki/Wind) speed can be ignored.
* Lasers can provide a level of pin-point accuracy that cannot be matched by a projectile.
* Some lasers run on electricity which can be cheaply generated, reducing the need for expensive and finite ammunition, possibly replacing it with smaller batteries that would hold many more shots. However, building portable electric power sources of sufficient energy capacity is a problem.
* Because light has a practically nil ratio (exactly 1 / *c*) of [momentum](http://en.wikipedia.org/wiki/Momentum) to [energy](http://en.wikipedia.org/wiki/Energy), lasers produce negligible [recoil](http://en.wikipedia.org/wiki/Recoil).
* Laser beams do not "betray" themselves when emitted, either by eyesight or by sound. Unlike missiles ( e.g. [ICBMs](http://en.wikipedia.org/wiki/Intercontinental_ballistic_missile)) there is no system to track and contain them.
* Design of laser weapons does not have to consider forces that the classic ammunition causes during firing.
* The laser could have much longer range than firearms without need of a long barrel or rifling

Since lasers can theoretically defeat artillery and missile attacks, any group fielding an effective laser system will gain decisive advantages in ground, air and space combat. Under [radar](http://en.wikipedia.org/wiki/Radar) control, lasers have shot artillery shells in flight, including mortar rounds. This suggests that a primary application of lasers might be as part of a defensive system.

The main difficulty with currently practical lasers is the high expense and fragility of their mirrors and mirror-pointing systems.

Some believe that [mirrors](http://en.wikipedia.org/wiki/Mirror) or other countermeasures can reduce the effectiveness of high energy lasers. This has not been demonstrated. Small defects in mirrors absorb energy, and the defects rapidly expand across the surface. Protective mirroring on the outside of a target could easily be made less effective by incidental damage and by dust and dirt on its surface. However protective measures have been considered that would evaporate off the surface and reduce the intensity of the beam, such as [ablative armor](http://en.wikipedia.org/wiki/Ablative_armor).

**Blooming**

Laser beams begin to cause [plasma](http://en.wikipedia.org/wiki/Plasma_(physics)) breakdown in the air at energy densities of around a [megajoule](http://en.wikipedia.org/wiki/Joule) per cubic centimeter. This effect, called "blooming," causes the laser to defocus and disperse energy into the atmosphere. It can be more severe if there is fog, smoke, or dust in the air.

There are several ways to stop or reduce blooming:

* The beam can be distributed over a large mirror that focuses the power on the target, to keep energy density in the air too low for blooming to happen. This requires a large, very precise, fragile mirror, mounted somewhat like a searchlight, requiring bulky machinery to slew the mirror to aim the laser.
* A [phased array](http://en.wikipedia.org/wiki/Phased_array). For the usual laser [wavelengths](http://en.wikipedia.org/wiki/Wavelength) this method would need billions of [micrometre](http://en.wikipedia.org/wiki/Micrometre)-size [antennae](http://en.wikipedia.org/wiki/Antenna_(radio)), and no way to make these is known. Phased arrays could theoretically also perform phase-conjugate amplification (see below). Another advantage is that phased arrays do not require mirrors or lenses, can be made flat and thus do not require a turret-like system (as in the first approach) to be aimed, though range will suffer at extreme angles (that is, the angle the beam forms to the surface of the phased array).[[1]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-0#cite_note-0)
* A phase-conjugate laser system. Here, a "finder" or "guide" laser illuminates the target. Any mirror-like ("specular") points on the target reflect light that is sensed by the weapon's primary amplifier. The weapon-power amplifier then amplifies inverted waves in a positive feedback loop, destroying the target with [shockwaves](http://en.wikipedia.org/wiki/Shock_wave) as the specular regions evaporate. This avoids the blooming problem because the waves from the target passed through the blooming, and therefore show the most conductive optical path; this automatically corrects for the distortions caused by blooming. Experimental systems using this method usually use special chemicals to form a "phase conjugate mirror." In most systems, the mirror overheats dramatically at weaponized power levels.
* A very short pulse that finishes before blooming interferes.

**Evaporated target material shading the target**

Another problem with weaponized lasers is that the evaporated material from the surface of the target begins to shade the surface. There are several approaches to this problem:

* One is to induce a standing shockwave in the [ablation](http://en.wikipedia.org/wiki/Ablation) cloud. The [shockwave](http://en.wikipedia.org/wiki/Shock_wave) then continues to perform damage.
* Another scheme is to scan the target faster than the shockwave.
* Another theoretical possibility is to induce plasmic optical mixing at the target. In this scheme, the transparency of the target's ablation cloud to one laser is modulated by another laser, perhaps by tuning the laser to the absorption spectra of the ablation cloud, and inducing [population inversion](http://en.wikipedia.org/wiki/Population_inversion) in the cloud. The other laser then induces local lasing in the ablation cloud. The beat frequency that results can induce frequencies that penetrate the ablation cloud.

**High power consumption**

One major problem with laser weapons (and directed-energy weapons in general) is their high energy requirements. Existing methods of storing, conducting, transforming, and directing energy are inadequate to produce a convenient hand-held weapon. Existing lasers are inefficient and waste much energy as heat, and thus need much power and bulky cooling equipment to avoid damage by overheating. Simple air cooling could leave an impractical amount of time between shot cycles. These problems, which severely limit laser weapon practicality at present, might be offset by:

1. Cheap high-temperature [superconductors](http://en.wikipedia.org/wiki/Superconductivity) to make the weapon more efficient.
2. A new method of conveniently storing and/or generating large amounts of electricity needed to power the weapon.

If only #2 is available, part of the energy could be used to cool the device.

This problem of storing and/or supplying electrical energy is offset in [chemical lasers](http://en.wikipedia.org/wiki/Chemical_laser) by using energy released in a suitable [chemical reaction](http://en.wikipedia.org/wiki/Chemical_reaction) instead. [Chemical oxygen iodine laser](http://en.wikipedia.org/wiki/Chemical_oxygen_iodine_laser) ([hydrogen peroxide](http://en.wikipedia.org/wiki/Hydrogen_peroxide) with [iodine](http://en.wikipedia.org/wiki/Iodine)) and [deuterium fluoride laser](http://en.wikipedia.org/wiki/Hydrogen_fluoride_laser) (atomic [fluorine](http://en.wikipedia.org/wiki/Fluorine) reacting with [deuterium](http://en.wikipedia.org/wiki/Deuterium)) are two examples of laser types capable of megawatt-range output of a continuous beam. Storing and transporting the chemical fuel presents its own problems with these lasers, and the problems of cooling and overall inefficiency remain.

This problem could also be lessened if the weapon were mounted either as at defensive position near a power plant, or on board a large, possibly [nuclear powered](http://en.wikipedia.org/wiki/Nuclear_propulsion), naval or space ship.

**Beam absorbed by obscuration in the air**

A laser beam or particle beam passing through air can be absorbed or scattered by rain, snow, dust, fog, smoke, or similar visual obstructions that a bullet would easily brush aside. This effect adds to blooming and worsens the efficiency of the weapon by wasting more energy into the atmosphere.

The energy that is wasted can cause significant disruption to cloud development since the impact wave creates a "tunnelling effect". Engineers from [MIT](http://en.wikipedia.org/wiki/Massachusetts_Institute_of_Technology) and the [U.S. Army](http://en.wikipedia.org/wiki/United_States_Army) are looking into ways that this weapon can be used against [weather](http://en.wikipedia.org/wiki/Weather).

**Lack of indirect fire capabilities**

[Indirect fire](http://en.wikipedia.org/wiki/Indirect_fire), as used in artillery warfare to allow the shelling of a target behind a hill, is not feasible with line-of-sight laser weapons. Possible alternatives are to mount the lasers (or perhaps just reflectors) on airborne or space-based platforms or [unmanned aerial vehicles](http://en.wikipedia.org/wiki/Unmanned_aerial_vehicle).

**EM radiation beam weapons**

[Lasers](http://en.wikipedia.org/wiki/Laser) are very well known in [science fiction](http://en.wikipedia.org/wiki/Science_fiction) as a type of raygun. In the real world, lasers are often used for sighting, ranging and targeting for guns; but the laser beam is not the source of the weapon's firepower.

Laser weapons usually generate brief high-energy pulses. A million [joules](http://en.wikipedia.org/wiki/Joule) delivered as a laser pulse is roughly the same energy as 200g of high explosive, and has the same basic effect on a target. The primary damage mechanism is mechanical shear, caused by reaction (like a [rocket](http://en.wikipedia.org/wiki/Rocket)) when the surface of the target is explosively evaporated.[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)]

Most existing weaponized lasers are [gas dynamic lasers](http://en.wikipedia.org/wiki/Gas_dynamic_laser). Fuel, or a powerful turbine, pushes the lasing media through a circuit or series of orifices. The high-pressures and heating cause the medium to form a plasma and lase. A major difficulty with these systems is preserving the high-precision mirrors and windows of the laser resonating cavity. Most systems use a low-powered "oscillator" laser to generate a coherent wave, and then amplify it. Some experimental laser amplifiers do not use windows or mirrors, but have open orifices, which cannot be destroyed by high energies.[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)]

For research on real lasers as [non-lethal weapons](http://en.wikipedia.org/wiki/Less-lethal_weapon), see [Dazzler](http://en.wikipedia.org/wiki/Dazzler_(weapon)).

**Electrolaser**

Main article: [Electrolaser](http://en.wikipedia.org/wiki/Electrolaser)

An electrolaser lets [blooming](http://en.wikipedia.org/wiki/Directed-energy_weapon#Blooming) occur, and then sends a powerful electric current down the conducting [ionized](http://en.wikipedia.org/wiki/Ionization) track of plasma so formed, somewhat like [lightning](http://en.wikipedia.org/wiki/Lightning). It functions as a giant high energy long-distance version of the [Taser](http://en.wikipedia.org/wiki/Taser) or [stun gun](http://en.wikipedia.org/wiki/Electroshock_weapon).

**Radio frequency**

[HERF](http://en.wikipedia.org/wiki/High-energy_radio-frequency_weapons) cannons (high-energy radio-frequency weapons), which work on the same principles as [microwave](http://en.wikipedia.org/wiki/Microwave) ovens, have also shown potential.

On January 25, 2007 the US Military unveiled a device mountable on a small armored vehicle ([HMMWV](http://en.wikipedia.org/wiki/High_Mobility_Multipurpose_Wheeled_Vehicle)). It resembles a planar array. It can make people feel as if the air temperature is around 130 °F (54 °C) from around 500 yards (460 m) away. Full scale production of such a weapon is not expected until at least 2010. It is probably most usefully deployed as an [Active Denial System](http://en.wikipedia.org/wiki/Active_Denial_System).

**Microwaves**

Microwave guns powerful enough to injure humans are possible.

* [Active Denial System](http://en.wikipedia.org/wiki/Active_Denial_System) is a millimeter wave source, to heat the water in the target's skin and thus cause incapacitating pain. It is being developed by the [U. S. Air Force Research Laboratory](http://en.wikipedia.org/wiki/United_States_Air_Force_Research_Laboratory) in [New Mexico](http://en.wikipedia.org/wiki/New_Mexico) by researchers working with [Raytheon](http://en.wikipedia.org/wiki/Raytheon) for riot-control duty in [Iraq](http://en.wikipedia.org/wiki/Iraq). Though intended to cause severe pain while leaving no lasting damage, some concern has been voiced as to whether the system could cause irreversible damage to the eyes. There has yet to be testing for long-term side effects of exposure to the microwave beam. It can destroy [unshielded](http://en.wikipedia.org/wiki/TEMPEST) [electronics](http://en.wikipedia.org/wiki/Electronics). [CBS](http://en.wikipedia.org/wiki/CBS) broadcast a "[60 Minutes](http://en.wikipedia.org/wiki/60_Minutes)" piece on the technology in 2008. [[2]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-1#cite_note-1)

The device comes in various sizes including attached to a [humvee](http://en.wikipedia.org/wiki/Humvee).

Microwave weapons also have considerable anti-material applications, as they are capable of disabling or destroying unhardened electronics. The components of a microwave weapon—a power source, microwave generator and an antenna—are all readily available, and civilians have successfully built and tested simple devices in this category.

* The United States, in cooperation with the Canadian Government, built and successfully tested a microwave gun. It was shown working on a willing soldier on American and Canadian television.[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)]

**Pulsed Energy Projectile**

Main article: [Pulsed Energy Projectile](http://en.wikipedia.org/wiki/Pulsed_Energy_Projectile)

Pulsed Energy Projectile or PEP systems emit an infrared laser pulse which creates rapidly expanding [plasma](http://en.wikipedia.org/wiki/Plasma_(physics)) when meeting the target. The resulting sound, shock and electromagnetic waves stun the target and cause pain and temporary paralysis. The weapon is under development and is intended to be used as a non-lethal weapon in crowd control.

**MIRACL**

Main article: [MIRACL](http://en.wikipedia.org/wiki/MIRACL)

The Mid-Infrared Advanced Chemical Laser is an experimental [U.S. Navy](http://en.wikipedia.org/wiki/United_States_Navy) [deuterium fluoride laser](http://en.wikipedia.org/wiki/Hydrogen_fluoride_laser) and was tested against an [Air Force](http://en.wikipedia.org/wiki/United_States_Air_Force) [satellite](http://en.wikipedia.org/wiki/Satellite) in 1997.

**[PHaSR](http://en.wikipedia.org/wiki/PHaSR" \o "PHaSR)**

Personnel Halting and Stimulation Response, or PHaSR, is a non-lethal hand-held weapon developed by the [United States Air Force](http://en.wikipedia.org/wiki/United_States_Air_Force) [[3]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-usafphasr-2#cite_note-usafphasr-2) Its purpose is to "dazzle" or stun a target. It was developed by Air Force [Directed Energy Directorate](http://en.wikipedia.org/w/index.php?title=Directed_Energy_Directorate&action=edit&redlink=1).

**THEL**

Main article: [Tactical High Energy Laser](http://en.wikipedia.org/wiki/Tactical_High_Energy_Laser)

[Tactical High Energy Laser](http://en.wikipedia.org/wiki/Tactical_High_Energy_Laser) (THEL) is a weaponized deuterium fluoride laser developed in a joint research project of [Israel](http://en.wikipedia.org/wiki/Israel) and the [U.S.](http://en.wikipedia.org/wiki/United_States) It is designed to shoot down aircraft and missiles. See also [National missile defense](http://en.wikipedia.org/wiki/National_missile_defense).

**Airborne laser**

Main article: [Boeing YAL-1](http://en.wikipedia.org/wiki/Boeing_YAL-1)

The U.S. Air Force's [Airborne Laser](http://en.wikipedia.org/wiki/Boeing_YAL-1), or [Advanced Tactical Laser](http://en.wikipedia.org/wiki/Advanced_Tactical_Laser), is a plan to mount a [CO2](http://en.wikipedia.org/wiki/Carbon_dioxide_laser) [gas laser](http://en.wikipedia.org/wiki/Gas_laser) or [COIL](http://en.wikipedia.org/wiki/Chemical_oxygen_iodine_laser) [chemical laser](http://en.wikipedia.org/wiki/Chemical_laser) on a modified [Boeing 747](http://en.wikipedia.org/wiki/Boeing_747) and use it to shoot down [missiles](http://en.wikipedia.org/wiki/Missile).[[4]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-3#cite_note-3)[[5]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-4#cite_note-4)

**FIRESTRIKE**

Main article: [FIRESTRIKE](http://en.wikipedia.org/wiki/FIRESTRIKE)

[Northrop Grumman](http://en.wikipedia.org/wiki/Northrop_Grumman) has announced the availability of a high-energy [solid-state laser](http://en.wikipedia.org/wiki/Solid-state_laser) weapon system that they call [FIRESTRIKE](http://en.wikipedia.org/wiki/FIRESTRIKE). The system is modular, using 15KW modules that can be combined to provide various levels of power.

**Low-powered laser**

This is not a weapon, but is included here for completeness. There is an imitation [shotgun](http://en.wikipedia.org/wiki/Shotgun) which fires a low-powered laser beam at a target which is covered with reflective 90° corners designed to send the beam back where it came from to be detected by a detector on the gun. This is only for target practice without using up ammunition; it has the disadvantage (for a shotgun user) that the beam travels at the [speed of light](http://en.wikipedia.org/wiki/Speed_of_light) and in a straight line, without teaching the shooter to allow for the effects of wind deflecting the fired shot and the target moving while the shot travels (i.e. [windage](http://en.wikipedia.org/wiki/Windage)).

**Particle beam weapons**

[Particle beam weapons](http://en.wikipedia.org/wiki/Particle_beam_weapon) can use charged or neutral particles, and can be either endoatmospheric or exoatmospheric. [Particle beams](http://en.wikipedia.org/wiki/Particle_beam) as beam weapons are theoretically possible, but practical weapons have not been demonstrated. Certain types of particle beams have the advantage of being self-focusing in the atmosphere.

[Blooming](http://en.wikipedia.org/wiki/Directed-energy_weapon#Blooming) is not limited to lasers, but is also a problem in particle beam weapons. Energy that would otherwise be focused on the target spreads out; the beam becomes less effective.

* Thermal blooming occurs in both charged and neutral particle beams, and occurs when particles bump into one another under the effects of thermal vibration, or bump into air molecules.
* Electrical blooming occurs only in charged particle beams, as ions of like charge repel one another.

**Plasma weapons**

Plasma weapons fire a beam, bolt, or [stream](http://en.wikipedia.org/wiki/Particle_beam) of [plasma](http://en.wikipedia.org/wiki/Plasma_(physics)), which is an excited [state of matter](http://en.wikipedia.org/wiki/State_of_matter) consisting of atomic electrons & nuclei and free electrons if [ionized](http://en.wikipedia.org/wiki/Ionization), or other particles if [pinched](http://en.wikipedia.org/wiki/Pinch_(plasma_physics)), not to be confused with [plasma stealth](http://en.wikipedia.org/wiki/Plasma_stealth). Examples are:

* The [MARAUDER](http://en.wikipedia.org/wiki/MARAUDER) (**M**agnetically **A**ccelerated **R**ing to **A**chieve **U**ltra-high **D**irected **E**nergy and **R**adiation). See [this link](http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=7369133) for more details; the antiaircraft potential of such a system is mentioned.
* [This article](http://www.forteantimes.com/features/articles/225/unfriendly_fire_ball_lightning_and_ufos.html) explains theories about [ball lightning](http://en.wikipedia.org/wiki/Ball_lightning), which may be a type of plasma, which if weaponized could produce beam weapons guided in the same sense as an [Anti-tank guided missile](http://en.wikipedia.org/wiki/Anti-tank_guided_missile)
* The [plasma rifle](http://en.wikipedia.org/wiki/Plasma_rifle) is a staple of science fiction. There may have been influence from the real [plasma torch](http://en.wikipedia.org/wiki/Plasma_torch) used to cut metal.
* The discontinued [Shiva Star](http://en.wikipedia.org/wiki/Shiva_Star) project was to be a system for shooting down incoming missiles with projectiles of plasma traveling at speeds from 3,000 kilometers per second to 10,000 kilometers per second.
* [MEDUSA](http://en.wikipedia.org/w/index.php?title=MEDUSA&action=edit&redlink=1) (**M**obile **E**nergy **D**evice **U**nited **S**tates of **A**merica). Normally, the electrons are collected or recaptured at the end of the [klystron](http://en.wikipedia.org/wiki/Klystron), a specialized [vacuum tube](http://en.wikipedia.org/wiki/Vacuum_tube). But by allowing them to stream freely to the high power microwave and high energy laser assembly, they become potentially lethal projectiles able to instantly destroy inorganic and organic material. See [[6]](http://www.p2pnet.net/story/12661) for more details; the many lethal and peaceful uses of the device are discussed.

**Electric beam in a vacuum**

In a [vacuum](http://en.wikipedia.org/wiki/Vacuum) (e.g. in [space](http://en.wikipedia.org/wiki/Space)), an electric discharge can travel a potentially unlimited distance at a velocity slightly slower than the speed of light. This is because there is no significant electric resistance to the flow of electric current in a vacuum. This would make such devices useful to destroy the [electrical](http://en.wikipedia.org/wiki/Electricity) and [electronic](http://en.wikipedia.org/wiki/Electronics) parts of [satellites](http://en.wikipedia.org/wiki/Satellite) and [spacecraft](http://en.wikipedia.org/wiki/Spacecraft). However, in a vacuum the electric current cannot ride a laser beam, and some other means must be used to keep the electron beam on track and to prevent it from dispersing: see [particle beam](http://en.wikipedia.org/wiki/Particle_beam).

**Speed of the weapon**

The speed of the energy weapon is determined by the density of the beam or laser. If it is very dense then it is very powerful, but a particle beam is much slower than the [speed of light](http://en.wikipedia.org/wiki/Speed_of_light), its speed being determined by mass, power, density, or particle or energy density.

**History**

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|  | This section **does not** [**cite**](http://en.wikipedia.org/wiki/Wikipedia:Citing_sources) **any** [**references or sources**](http://en.wikipedia.org/wiki/Wikipedia:Verifiability). Please help [improve this article](http://en.wikipedia.org/w/index.php?title=Directed-energy_weapon&action=edit) by adding citations to [reliable sources](http://en.wikipedia.org/wiki/Wikipedia:Reliable_sources). [Unverifiable](http://en.wikipedia.org/wiki/Wikipedia:Verifiability) material may be challenged and removed. *(November 2007)* |

**[**[**edit**](http://en.wikipedia.org/w/index.php?title=Directed-energy_weapon&action=edit&section=23)**] Mythology**

Before modern technology developed, many [mythologies](http://en.wikipedia.org/wiki/Mythology) described gods or demons using weapons that make [lightning](http://en.wikipedia.org/wiki/Lightning), such as [Zeus](http://en.wikipedia.org/wiki/Zeus)'s/[Jupiter's](http://en.wikipedia.org/wiki/Jupiter_(mythology)) [thunderbolts](http://en.wikipedia.org/wiki/Thunderbolt), [Thor](http://en.wikipedia.org/wiki/Thor)'s hammer [Mjöllnir](http://en.wikipedia.org/wiki/Mj%C3%B6llnir), and the [Hindu](http://en.wikipedia.org/wiki/Hinduism) god [Indra](http://en.wikipedia.org/wiki/Indra)'s [spear](http://en.wikipedia.org/wiki/Spear) (the [vajrā](http://en.wikipedia.org/wiki/Vajra)).

**Ancient inventors**

According to [legend](http://en.wikipedia.org/wiki/Legend), the concept of the "burning mirror" or *death ray* began with [Archimedes](http://en.wikipedia.org/wiki/Archimedes) who created a mirror with an adjustable focal length (or more likely, a series of mirrors focused on a common point) to focus sunlight on ships of the [Roman](http://en.wikipedia.org/wiki/Ancient_Rome) fleet as they invaded [Syracuse](http://en.wikipedia.org/wiki/Syracuse,_Sicily), setting them on fire. Historians point out that the earliest accounts of the battle did not mention a "burning mirror", but merely stated that Archimedes's ingenuity combined with a way to hurl fire were relevant to the victory. A [Byzantine](http://en.wikipedia.org/wiki/Byzantine_Empire) writer hundreds of years later is suggested to have imagined this 2200-year-old death ray, which is attributed to Archimedes. Some attempts to replicate this feat have had some success (though not the attempt by the [*MythBusters*](http://en.wikipedia.org/wiki/MythBusters) television program). In particular, an experiment by students at [MIT](http://en.wikipedia.org/wiki/Massachusetts_Institute_of_Technology) showed that a mirror-based weapon was at least possible, if not necessarily practical.[[6]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-5#cite_note-5)

Many alleged ancient reports of [Indian](http://en.wikipedia.org/wiki/India) flying technology and energy weapons derive from the [Vaimanika Shastra](http://en.wikipedia.org/wiki/Vaimanika_Shastra), which is a [forgery](http://en.wikipedia.org/wiki/Forgery) and was composed after 1900AD.

**Grindell-Matthews**

After the astonishing [technological advancement during World War I](http://en.wikipedia.org/wiki/Technology_during_World_War_I), many such schemes began to appear credible. [Harry Grindell Matthews](http://en.wikipedia.org/wiki/Harry_Grindell_Matthews) tried to sell such a ray to the British [Air Ministry](http://en.wikipedia.org/wiki/Air_Ministry) after that war. He failed to appear to demonstrate his apparatus, however. It was apparently taken to [France](http://en.wikipedia.org/wiki/France) but has not resurfaced, leading to various [conspiracy theory](http://en.wikipedia.org/wiki/Conspiracy_theory) ideas about what might have happened to it, or who might have developed it later.

**Robert Watson-Watt**

In 1935 the British [Air Ministry](http://en.wikipedia.org/wiki/Air_Ministry) asked [Robert Watson-Watt](http://en.wikipedia.org/wiki/Robert_Watson-Watt) of the [Radio Research Station](http://en.wikipedia.org/wiki/Radio_Research_Station) whether a "[death ray](http://en.wikipedia.org/wiki/Raygun)" was possible. He and colleague [Arnold Wilkins](http://en.wikipedia.org/w/index.php?title=Arnold_Wilkins&action=edit&redlink=1) quickly concluded that it was not feasible, but as a consequence suggested using radio for the detection of aircraft and this started the development of [radar](http://en.wikipedia.org/wiki/Radar) in Britain. See: [History of radar#Robert Watson-Watt](http://en.wikipedia.org/wiki/History_of_radar#Robert_Watson-Watt).

**Engine-stopping rays, urban legend made real**

Engine-stopping rays are a variant that occurs in fiction and myth. Such stories were circulating in Britain around 1938. The tales varied but in general terms told of tourists whose car engine suddenly died and were then approached by a German soldier who told them that they had to wait. The soldier returned a short time later to say that the engine would now work and the tourists drove off. A possible origin of some of these stories arises from the testing of the television transmitter in [Feldberg](http://en.wikipedia.org/wiki/Feldberg,_Baden-W%C3%BCrttemberg), Germany. Because electrical noise from car engines would interfere with field strength measurements, sentries would stop all traffic in the vicinity for the twenty minutes or so needed for a test. A distorted retelling of the events might give rise to the idea that a transmission killed the engine [[7]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-6#cite_note-6)

A shoulder-mounted engine-stopping weapon was a central plot element in episode 303 of BBC espionage drama serial [*Spooks*](http://en.wikipedia.org/wiki/Spooks), in which it was referred to as an "engine killer".

See [electromagnetic pulse](http://en.wikipedia.org/wiki/Electromagnetic_pulse), which is known for its engine-stopping effect, but is an indirect-energy weapon.

**Tesla**

[Nikola Tesla](http://en.wikipedia.org/wiki/Nikola_Tesla) (1856–1943) was a noted inventor, scientist and electrical engineer. He invented [Tesla coils](http://en.wikipedia.org/wiki/Tesla_coil), [transformers](http://en.wikipedia.org/wiki/Transformer), [alternating current](http://en.wikipedia.org/wiki/Alternating_current) [electrical generators](http://en.wikipedia.org/wiki/Electrical_generator) and was a major early pioneer of [radio](http://en.wikipedia.org/wiki/Radio) technology. Tesla worked on plans for a directed-energy weapon between the early 1900s until the time of his death. In 1937, Tesla composed a treatise entitled *The Art of Projecting Concentrated Non-dispersive Energy through the Natural Media* concerning charged particle beams.[[8]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-7#cite_note-7)

Tesla was noted for making a claim that he had developed what he called a "[teleforce](http://en.wikipedia.org/wiki/Teleforce)" weapon, or death ray. This death ray would "send concentrated beams of particles through the free air, of such tremendous energy that they will bring down a fleet of 10,000 enemy airplanes at a distance of 250 miles (400 km) from a defending nation's border and will cause armies of millions to drop dead in their tracks", as said in an article at the time. He offered this invention to the [U.S. War Department](http://en.wikipedia.org/wiki/United_States_Department_of_Defense) and to several European countries without success. Various [conspiracy theories](http://en.wikipedia.org/wiki/List_of_conspiracy_theories) persist regarding the nature of this device and the whereabouts of Tesla's model or schematics[[9]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-8#cite_note-8) for it. Tesla's 1917 proposal for Directed Energy submarine warfare [[10]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-9#cite_note-9) is eerily similar to a 2008 US Department of Defense proposal.

**H.G. Wells**

For the first time in science fiction, [H. G. Wells](http://en.wikipedia.org/wiki/H._G._Wells), in his [*The War of the Worlds*](http://en.wikipedia.org/wiki/The_War_of_the_Worlds) novel, described a "death ray"-like laser, in the form of the Martians' "[Heat-Ray](http://en.wikipedia.org/wiki/Heat-Ray)," which used a heat beam with many properties of the modern laser as a weapon. The weapon used a parabolic mirror to focus and direct a beam of pure heat that had many of the properties of light—this ultimately made 'death ray' like weapons popular in science fiction, which may have stimulated interest in developing real-life directed-energy weapons.

**Nazis**

In the later phases of [WW II](http://en.wikipedia.org/wiki/World_War_II), [Nazi Germany](http://en.wikipedia.org/wiki/Nazi_Germany) increasingly put its hopes on research into technologically revolutionary [secret weapons](http://en.wikipedia.org/wiki/Secret_weapon), the [*Wunderwaffen*](http://en.wikipedia.org/wiki/Wunderwaffe).

Among the directed-energy weapons the Nazis investigated were [sonic weaponry](http://en.wikipedia.org/wiki/Sonic_weaponry), using parabolic reflectors to project sound waves of destructive force.

**SDI**

In the 1980s, [U.S. President](http://en.wikipedia.org/wiki/President_of_the_United_States) [Ronald Reagan](http://en.wikipedia.org/wiki/Ronald_Reagan) proposed the [Strategic Defense Initiative](http://en.wikipedia.org/wiki/Strategic_Defense_Initiative) (SDI) program, which was nicknamed *Star Wars*. It suggested that lasers, perhaps space-based X-ray lasers, could destroy [ICBMs](http://en.wikipedia.org/wiki/Intercontinental_ballistic_missile) in flight. Though the strategic missile defense concept has continued to the present under the [Missile Defense Agency](http://en.wikipedia.org/wiki/Missile_Defense_Agency), most of the directed-energy weapon concepts were shelved.

**New claims**

In 1998 to provide independent assessment on human effects, data, and models for the use of 'non-lethal weapons' on the general population,[[11]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-10#cite_note-10) the TECOM Technology Symposium in 1997 concluded on non-lethal weapons, “Determining the target effects on personnel is the greatest challenge to the testing community,” primarily because "the potential of injury and death severely limits human tests." However, "directed energy weapons that target the central nervous system and cause neurophysiological disorders may violate the Certain Conventional Weapons Convention of 1980. And weapons that go beyond non-lethal intentions and cause “superfluous injury or unnecessary suffering” could violate the Protocol I to the Geneva Conventions of 1977."[[12]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-11#cite_note-11)

Some common bio-effects of electromagnetic or non-lethal weapons include:

* Effects to the human central nervous system resulting in physical pain
* Difficulty breathing
* [Vertigo](http://en.wikipedia.org/wiki/Vertigo_(medical))
* [Nausea](http://en.wikipedia.org/wiki/Nausea)
* [Disorientation](http://en.wikipedia.org/wiki/Orientation_(mental))
* Other systemic discomfort.

Interference with breathing poses the most significant, potentially lethal results.

Light and repetitive visual signals can induce [epileptic](http://en.wikipedia.org/wiki/Epilepsy) seizures. [Vection](http://en.wikipedia.org/wiki/Sensory_illusions_in_aviation) and [motion sickness](http://en.wikipedia.org/wiki/Motion_sickness) can also occur.

[Cavitation](http://en.wikipedia.org/wiki/Cavitation), which affects gas nuclei in human tissue, and heating, can result from exposure to ultrasound and can cause damage to tissue and organs.

Studies have found that exposure to high intensity ultrasound at frequencies from 700 kHz to 3.6 MHz can cause lung and intestinal damage in mice. Heart rate patterns following vibroacoustic stimulation has resulted in serious negative consequences such as [arterial flutter](http://en.wikipedia.org/w/index.php?title=Arterial_flutter&action=edit&redlink=1) and [bradycardia](http://en.wikipedia.org/wiki/Bradycardia). Researchers have concluded that generating pain through the auditory system using high intensity sound resulted in a high risk of permanent hearing damage. Organizations in a research program which included:

* [Naval Submarine Medical Research Laboratory](http://en.wikipedia.org/wiki/Naval_Submarine_Medical_Research_Laboratory) ([Groton, Connecticut](http://en.wikipedia.org/wiki/Groton,_Connecticut))
* [Navy Experimental Diving Unit](http://en.wikipedia.org/wiki/Navy_Experimental_Diving_Unit) ([Panama City, Florida](http://en.wikipedia.org/wiki/Panama_City,_Florida))
* [SCC San Diego](http://en.wikipedia.org/w/index.php?title=SCC_San_Diego&action=edit&redlink=1)
* [Navy Medical Research and Development Command](http://en.wikipedia.org/w/index.php?title=Navy_Medical_Research_and_Development_Command&action=edit&redlink=1) ([Bethesda, Maryland](http://en.wikipedia.org/wiki/Bethesda,_Maryland))
* [Underwater Sound Reference Detachment of Naval Undersea Warfare Center](http://en.wikipedia.org/w/index.php?title=Underwater_Sound_Reference_Detachment_of_Naval_Undersea_Warfare_Center&action=edit&redlink=1) ([Orlando, Florida](http://en.wikipedia.org/wiki/Orlando,_Florida))
* Applied Research Laboratories: [University of Texas at Austin](http://en.wikipedia.org/wiki/University_of_Texas_at_Austin)
* Applied Physics Laboratory: [University of Washington](http://en.wikipedia.org/wiki/University_of_Washington)
* Institute for Sensory Research: [Syracuse University](http://en.wikipedia.org/wiki/Syracuse_University)
* [Georgia Institute of Technology](http://en.wikipedia.org/wiki/Georgia_Institute_of_Technology)
* [Emory University](http://en.wikipedia.org/wiki/Emory_University)
* [Boston University](http://en.wikipedia.org/wiki/Boston_University)
* [The University of Vermont](http://en.wikipedia.org/wiki/The_University_of_Vermont)
* [Applied Physics Laboratory](http://en.wikipedia.org/wiki/Applied_Physics_Laboratory)
* [Johns Hopkins University](http://en.wikipedia.org/wiki/Johns_Hopkins_University)
* [Jet Propulsion Laboratory](http://en.wikipedia.org/wiki/Jet_Propulsion_Laboratory)
* [University of Rochester](http://en.wikipedia.org/wiki/University_of_Rochester)
* [University of Minnesota](http://en.wikipedia.org/wiki/University_of_Minnesota)
* [University of Illinois system](http://en.wikipedia.org/wiki/University_of_Illinois_system)
* Loyola University
* [State University of New York](http://en.wikipedia.org/wiki/State_University_of_New_York) at Buffalo

involved high intensity audible sound experiments on human subjects. The extra-aural (unrelated to hearing) bioeffects on various internal organs and the central nervous system included auditory shifts, vibrotactile sensitivity change, muscle contraction, cardiovascular function change, central nervous system effects, vestibular (inner ear) effects, and chest wall/lung tissue effects. Researchers found that low frequency sonar exposure could result in significant cavitations, hypothermia, and tissue shearing. No follow on experiments were recommended. Tests performed on mice show the threshold for both lung and liver damage occurs at about 184 dB. Damage increases rapidly as intensity is increased. Noise-induced neurologic disturbances in humans exposed to continuous low frequency tones for durations longer than 15 minutes has involved in some cases development of immediate and long term problems affecting brain tissue. The symptoms resembled those of individuals who had suffered minor head injuries.

One theory for a causal mechanism is that the prolonged sound exposure resulted in enough mechanical strain to brain tissue to induce an injury.[[13]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-12#cite_note-12) “Project Pandora” conducted by the Walter Reed Army Institute of Research, WRAIR, included externally induced auditory input from pulsed microwave audiograms of words or oral sounds which create the effect of hearing voices that are not a part of the recipients own thought processes. Microwave pulses can also affect the epidermis (skin) and dermis, the thick sensitive layer of skin and connective tissue beneath the epidermis that contains blood, lymph vessels, sweat glands, and nerve endings, generating a burn from as far as 700 yards.[[14]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-13#cite_note-13) Directed energy weapons such as Boeing’s Airborne Laser which can be mounted on a 747 jet is able to burn the skin off enemy missiles.[[15]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-14#cite_note-14)

During the [Gulf War](http://en.wikipedia.org/wiki/Gulf_War), electromagnetic weapons, including high power microwaves were used to disrupt and destroy the enemy's electronic systems and may have been used for other effects. Types and magnitudes of exposure to electromagnetic fields is unknown.[[16]](http://en.wikipedia.org/wiki/Directed-energy_weapon#cite_note-15#cite_note-15)

**See also**

* [High-energy radio-frequency weapons](http://en.wikipedia.org/wiki/High-energy_radio-frequency_weapons)
* [Laser applications](http://en.wikipedia.org/wiki/Laser_applications)
* [Category:Rayguns](http://en.wikipedia.org/wiki/Category:Rayguns)

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