Directed-energy weapon

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A **directed-energy weapon** (**DEW**) is a type of weapon which emits energy in an aimed direction without the means of a projectile. It transfers energy to a target for a desired effect. Some of these weapons are real or practicable; some are science fiction. The energy is in various forms:

- Electromagnetic radiation (typically lasers or masers).
- Particles with mass (particle beam weapons).
- Fictional weapons often use some sort of radiation or energetic particle that does not exist in the real world; or where the physical nature of the energy and its means of transmission is not detailed and the visible effects would be impossible in the real world.

Some of these weapons are known as **death rays** or **rayguns** 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, but most examples appear in science fiction (or non-functional toys and film props).

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Types

Broadly defined, directed-energy weapons can be categorised according to the type of energy used (sound, radio, light, particles, plasma, etc) and the intended effects on the target (physical damage, interference with senses and guidance, disorientation, disabling machinery, incapacitating people, etc).

This article restricts itself to weapons designed to cause physical damage with electromagnetic or particle beams. For some other weapons see:-

- For weapons to interfere with communications, i.e. jamming, see Electronic countermeasures, Electronic warfare, Radio jamming, and Radar jamming.
- For weapons to blind or disorient or interfere with the human eye or electronic sensors see Dazzler

(weapon). This is the first verifiable use of directed-energy as a weapon (as opposed to jamming) and dates from World War II.
- For particle beams see also Particle beam weapon.
- For laser weapons see this article and Laser applications.
- For sonic and ultrasonic beam weapons see Sonic weaponry.

For devices which can be confused with (but are not) directed-energy weapons see:-

- Laser designators are usually infrared lasers used for selective illumination of a target for navigating a laser-guided bomb. They are relatively high-power, often using a solid-state laser, eg Nd:YAG or Eu:YAG.
- The term electroshock gun includes two sorts of weapons, but neither of these is a directed-energy weapon, despite its name:
  - The electric shock prod administers an electric shock on contact. It is not strictly a gun, as it does not cause any effect at a distance.
  - Guns which fire an electrified projectile.
- Occasionally science fiction authors misuse the name "thermic lance" to mean a raygun, but the real thermal lance is not a gun.

For directed-energy weapons in fiction see this article and Raygun.

Tactical considerations & problems

Lasers have four main advantages over conventional weaponry:

- Laser beams travel at the 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.
- Light's short transit time also nearly eliminates the influence of gravity, so long range projection does not require compensation for such.
- Some lasers run on electricity which can be cheaply generated, reducing the need for expensive and finite ammunition. However, getting portable electric power sources of sufficient energy capacity is a problem.
- Because light has a practically nil ratio (exactly $1 / c$) of momentum to energy, lasers produce negligible recoil.

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 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 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.

Blooming

Laser beams begin to cause plasma breakdown in the air at energy densities of around a megajoule per square centimeter. This effect, called "blooming", causes the laser to defocus and to lose energy to 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. For the usual laser wavelengths this method would need billions of micrometre-size antennas, 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). See (http://projectrho.com/rocket/rocket3x.html#laser).
- 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 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.
- Tailoring the pulse timing, power, and/or wavelength of the laser to induce a shockwave that evacuates the path between the target and the weapon. Without air in the laser's path, blooming will not occur. However, it is difficult to achieve the amount of power needed to blast the air out of the way.
- Limiting these weapons to use in vacuum, for example space.

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 cloud. The shockwave 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 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 when the device can be safely activated again. These problems, which severely limit laser weapon practicality at present, might be offset by:

1. Cheap high-temperature superconductors 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 by using energy released in a suitable chemical reaction instead. Chemical oxygen iodine laser (hydrogen peroxide with iodine) and deuterium fluoride laser (atomic fluorine reacting with 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, 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 to an atmosphere.

Lack of indirect fire capabilities

Because light is only marginally affected by gravity, and indirect fire requires the use of gravity to strike an enemy from behind cover or not in line-of-sight, lasers cannot be used for indirect fire. However, mounting lasers on airborne or space-based platforms may circumvent this limitation simply by getting around or above an obstruction that provides cover or blocks line-of-sight.

EM radiation beam weapons

Lasers are very well known in 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 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) when the surface of the target is explosively evaporated.

Most existing weaponized lasers are gas dynamic lasers. 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.

There is research on real lasers as non-lethal weapons. See Dazzler.

Electrolaser

An electrolaser lets blooming occur, and then sends a powerful electric current down the conducting ionized track of plasma so formed, somewhat like lightning. It functions as a giant high energy long-distance version of the Taser or stun gun.

Radio frequency

HERF cannons (high-energy radio-frequency weapons), which work on the same principles as microwave ovens, have also shown potential.

On January 25, 2007 the US Military unveiled a device mountable on a small armored vehicle (hummer). It

resembles a satellite dish. It can make people feel around 130 degrees from around 500 yards away, hotter if closer. It is not clear yet if the weapon has the capability to burn or kill. Full scale production of such a weapon is not expected until at least 2010. It is probably the Active Denial System.

Microwaves

Microwave guns powerful enough to injure humans are possible.

- Active Denial System is a microwave source, to heat the water in the target's skin and thus cause incapacitating pain. It is being developed by the Air Force Research Laboratory in New Mexico by researchers working with Raytheon for riot-control duty in Iraq. Though intended to cause severe pain while leaving no lasting damage, some concern has been voiced as to if the system could cause irreversible damage to the eyes. However, such damage, being non-lethal, would still be preferable to the damage caused by conventional munitions. There has yet to be testing for long-term side effects of exposure to the microwave beam. It can destroy unshielded electronics.
- See VMADS (Vehicle-Mounted Active Denial System)

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 (a Canadian) on American and Canadian television.

Pulsed Energy Projectile

Pulsed Energy Projectile or PEP systems emit an infrared laser pulse which creates rapidly expanding plasma 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

The Mid-Infrared Advanced Chemical Laser is an experimental U.S. Navy deuterium fluoride laser and was tested against an Air Force satellite in 1997.

THEL

THEL (Tactical High Energy Laser) is a weaponized deuterium fluoride laser developed in a joint research project of Israel and the U.S. It is designed to shoot down aircraft and missiles. See also National Missile Defense.

Airborne Laser

The U.S. Air Force's Airborne Laser, or Advanced tactical laser, is a plan to mount a CO2 gas laser or COIL chemical laser on a modified Boeing 747 and use it to shoot down missiles. [1] [1] (http://www.militarypictures.info/airplanes/boeing_abl.jpg.html)

Ultraviolet laser

HSV Technologies of San Diego is developing a laser weapon to paralyze animals (testing for later use on

humans) by an electric charge generated by the laser beam. It is described as an ultraviolet laser and not an electrolaser. [2] (http://www.hsvt.org/)

Particle beam weapons

Particle beam weapons can use charged or neutral particles, and can be either endoatmospheric or exoatmospheric. Particle beams 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 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 or bolt or stream of plasma, which is an excited state of matter consisting of atomic electrons & nuclei and free electrons if ionized, or other particles if pinched, not to be confused with plasma stealth. Examples are:

- The 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/articles/163_ballsoffire.shtml) explains theories about 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
- The plasma rifle is a staple of science fiction. There may have been influence from the real plasma torch used to cut metal.
- The discontinued 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 (**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, a specialized 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 [3] (http://www.p2pnet.net/story/12661) for more details; the many lethal and peaceful uses of the device is discussed.

Electric beam in a vacuum

In a vacuum (e.g. in 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 and electronic parts of satellites and 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.

Low-powered lasers

This is not a weapon, but is included here for completeness. There is an imitation 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 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.

History

Mythology

Before modern technology developed, many mythologies described gods or demons using weapons that make lightning, such as Zeus's/Jupiter's thunderbolts, Thor's hammer Mjolnir, and the Hindu god Indra's spear (the vajrā).

Ancient inventors

According to mythology, the concept of the "burning mirror" or *death ray* began with 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 fleet as they invaded Syracuse, 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 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 television program). In particular, an experiment by students at MIT showed that a mirror-based weapon was at least possible, if not necessarily practical.[2]

Grindell-Matthews

After the astonishing technological advancement during World War I, many such schemes began to appear credible. Harry Grindell-Matthews tried to sell such a ray to the British Air Ministry after that war. He failed to appear to demonstrate his apparatus, however. It was apparently taken to France but has not resurfaced, leading to various 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 asked Robert Watson-Watt of the Radio Research Station whether a "death ray" was possible. He and colleague Arnold Wilkins 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 in Britain. See: 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, 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 (Jones 1978).

A shoulder-mounted engine-stopping weapon was a central plot element in episode 303 of BBC espionage drama serial Bugs, in which it was referred to as an "engine killer".

See electromagnetic pulse, which is known for its engine-stopping effect, but is an indirect-energy weapon.

Tesla

Nikola Tesla (1856 - 1943) was a noted inventor, scientist and electrical engineer. He invented Tesla coils, transformers, alternating current electrical generators and was a major early pioneer of radio technology.

He was also noted for making some outlandish claims, among them that he had developed what he called a "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 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 and to several European countries without success. Various conspiracy theories persist regarding the nature of this device and the whereabouts of Tesla's model or schematics for it.

H.G. Wells

H. G. Wells, in his book *The War of the Worlds*, for the first time used a "death ray" like laser in science fiction, in the form of the Martians "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 WWII, Nazi Germany increasingly put its hopes on research into technologically revolutionary secret weapons, the *Wunderwaffen*.

Among the directed-energy weapons the Nazis investigated were sonic weaponry, using parabolic reflectors to project sound waves of destructive force.

This Nazi research included searching in India in the hope that some of the powerful weapons and flying craft described in the Mahabharata and other old Indian books were the real products of supposed ancient technology, rather than mythology based on lightning and other destructive natural forces.

"Star Wars"

In the 1980s, Ronald Reagan proposed his Strategic Defense Initiative program, which was immediately nicknamed "Star Wars". It suggested that lasers, perhaps including space-based X-ray lasers, could destroy ICBMs in flight. Due to political opposition, this plan was never carried out. For a clearer explanation of SDI, see Strategic Defense Initiative.

See also

- High-energy radio-frequency weapons

External links

- Directed Energy Weapons @ Air Power Australia (http://www.ausairpower.net/dew-ebomb.html)

- Ionatron - Maker of directed-energy weapons (http://www.ionatron.com/)
- www.globalresearch.ca link to video of possible use in Iraq (http://www.globalresearch.ca/index.php?context=viewArticle&code=TOR20070405&articleId=527
- Wired News (AP) article on weapons deployment in Iraq, Active Denial System and Stunstrike, July 10, 2005 (http://www.wired.com/news/technology/0,1282,68152,00.html?tw=wn_7techhead)

References

1. ^ Wired News article "Weapons Freeze, Microwave Enemies" (http://www.wired.com/news/technology/0,1282,64437,00.html?tw=newsletter_topstories_html) (and copied in at least 661 other web pages including this link (http://www.foxnews.com/story/0,2933,127763,00.html))
2. ^ Archimedes Death Ray: Idea Feasibility Testing (http://web.mit.edu/2.009/www/lectures/10_ArchimedesResult.html)

- Jones, R.V. [1978]. *Most Secret War:British Scientific Intelligence 1939-1945*. Coronet, p84,124. ISBN 0-340-24169-1.

- US claims that China has used high-energy lasers to interfere with US satellites Janes Defence (http://www.janes.com/defence/air_forces/news/jdw/jdw061016_1_n.shtml)
- China jamming test sparks U.S. satellite concerns USA Today (http://www.usatoday.com/tech/news/2006-10-05-satellite-laser_x.htm)
- Beijing secretly fires lasers to disable US satellites The Telegraph (http://www.telegraph.co.uk/news/main.jhtml?xml=/news/2006/09/26/wchina226.xml)
- China Attempted To Blind U.S. Satellites With Laser Defense News (http://www.defensenews.com/story.php?F=2121111&C=america)
- China Has Not Attacked US Satellites Says DoD United Press International (http://www.upi.com/SecurityTerrorism/view.php?StoryID=20061025-120611-1464r) & SpaceWar (http://www.spacedaily.com/reports/China_Has_Not_Attacked_US_Satellites_Says_DoD_999.html)

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