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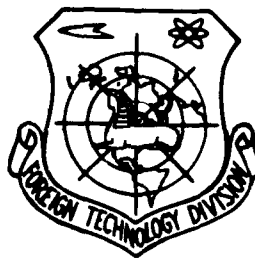
FOREIGN TECHNOLOGY DIVISION



APPLICATIONS OF LASERS

by

Hsiang Chun

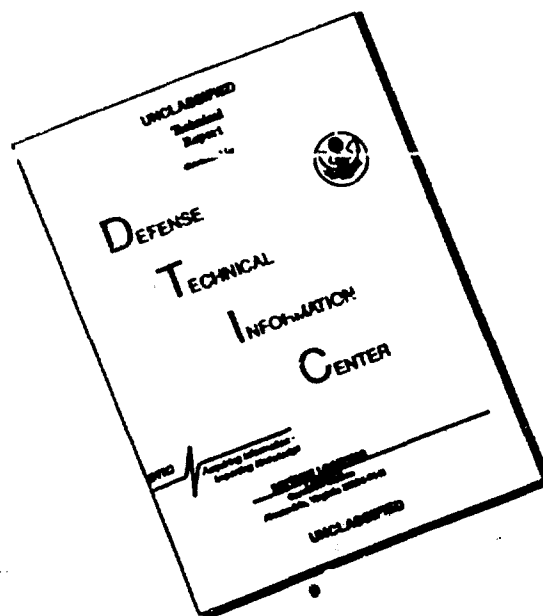


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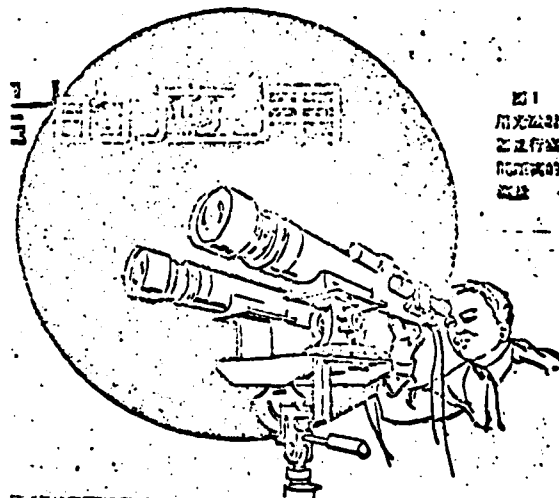
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ABSTRACT: Lasers can produce a light beam having excellent directivity and an intensity several million times the intensity of the sun. Experiments proved that laser beams have a beam spread less than 30 cm for every 1.5-km propagation. Research is underway to use lasers in space, surface, and underwater communications. Lasers will be used in military detection, mapping, computing technology, and space navigation and also as weapons. When lasers are used in communications, the audio signals to be transmitted are used to modulate the light beams. The modulated beams are then transmitted by an optical transmitter. The optical receiver at the receiving end will receive and demodulate the incoming light signals. An optical system for space communications using solar energy for laser pumping is in process of development. Optical radars require a lower input power than microwave radars. Research shows that an optical radar having an average output power of 66 w is capable of detecting 2 spaceships 16,000 km apart with an accuracy approaching 1×10^{-4} . A ground optical radar having a 10-km detecting range weighs only 10 kg. Lasers emitting blue light beams are used for underwater tracking and intersubmarine communications. Lasers having a power density of 1-1000 Mw/cm² can raise the temperature of carbon to 8000C in 5×10^{-3} sec. Such lasers can be used as countermeasure weapons. The use of a laser as an accelerator to produce an energy of 100 Mev is believed possible. "Uses of lasers in metal machining, medicine, and biology will appear in K'o hsueh hua pao, no. 2, 1963." Orig. art. has: 6 figures. English translation: 8 pages.

APPLICATIONS OF LASERS

Hsiang Chun

In lasers based on stimulating radiation of materials by formation of an optical resonance cavity consisting of two mutually parallel mirror surfaces of high reflectivity, repeated reflection of a light beam inside the cavity results in a great increase in the directivity of the beam by resonance. In this manner, one can obtain a light beam of very high intensity concentrated in one definite direction of propagation. If the luminous energy yield of this beam could be concentrated within one one-hundredth of one degree, its brightness would exceed that of a conventional light source of the same power by five hundred million times! Experiments show that for parallel beams from a laser, the area of dispersion is less than 30 cm over a transmission distance of 1.5 km. If the light of a solid laser were concentrated in a parallel beam 0.01 radian in width, then after covering a



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REPRODUCIBLE**

Fig. 1. Using the laser to determine distance in space.

distance of 250,000 mi to the moon, the area of the projection of that beam on the moon would be only less than 10 mi, but if the beam of a searchlight of identical power were projected onto the moon, the projection would have a width of over 25,000 miles. If we go a step further, to the gas laser, its dispersion would be

still smaller.

Next, if we use the wavelength of the output beam of a laser as a standard, and make a comparison in intensity of the various light beams of the same wavelength radiated by the sun, then the intensities of the laser radiation would be several million times stronger than those of the sun. Obviously, this beam of extreme intensity and low degree of dispersion would have great advantages when used in the optical transmission of messages and the exploration of extremely distant targets.

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Fig. 2. The laser beam causes the metal to vaporize; based on the spectrum of the white hot metal, its composition may be analyzed.

At present, the laser has been considered for use in space, ground and submarine communications. In the future, it will be used in the areas of military intelligence, weapons systems, cartography, medicine, computer technology and other basic scientific disciplines. It also has a tremendous future in applications to space navigation, high resolution spectrography, and other areas.

In the following, we shall present an introduction to the most important possible applications of the laser.

COMMUNICATIONS IN SPACE

When used in communications, the transmission station converts audio or other signals into amplified electrical energy and sends it directly to a modulator. Sounds of different strength fed to the modulator would modulate the output beam of the laser into light beams of different intensities. Finally, they are transmitted through optical transmitting systems. The advantages of this type of communications system are that the light beams originated from the transmission station could be propagated over an extremely large distance and when the receiving station receives this modulated light beam, even though it is very low in

intensity, it can be sent to a laser for amplification and then to the receiver, where, after amplification and demodulation, the sounds (or signals) reappear. Thus, the sensitivity is raised another step. Recently, this type of beam has been sent to the moon and a return signal from the moon received. According to present estimates, the communication range of the laser can be reckoned in light years! Figure 4 shows the experimental conditions of communication by light beams. The distance between the transmission and receiving terminals is 25 miles. Figure 3 shows the structures of the transmission and receiving systems.

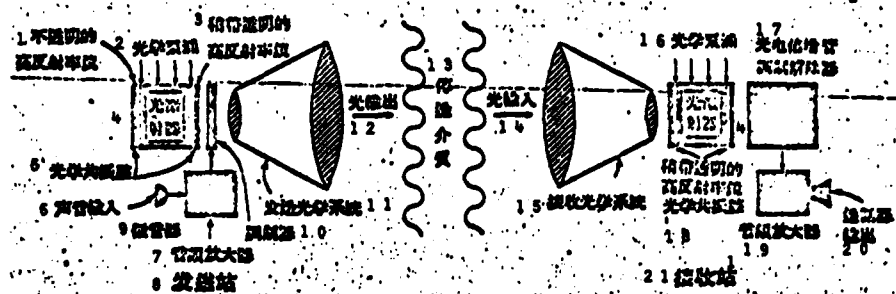


Fig. 3. The structure of light-wave transmission and receiving systems. 1) Opaque mirror of high reflectivity; 2) optical pump; 3) slightly transparent mirror of high reflectivity; 4) laser; 5) optical resonance cavity; 6) sound input; 7) audio frequency amplifier; 8) transmission station; 9) sound pickup; 10) modulator; 11) optical transmission system; 12) light output; 13) propagation medium; 14) light input; 15) optical receiving system; 16) optical pump; 17) photomultiplier; 18) slightly transparent mirror of high reflectivity; resonance cavity; 19) audio frequency amplifier; 20) loudspeaker; 21) receiving station.

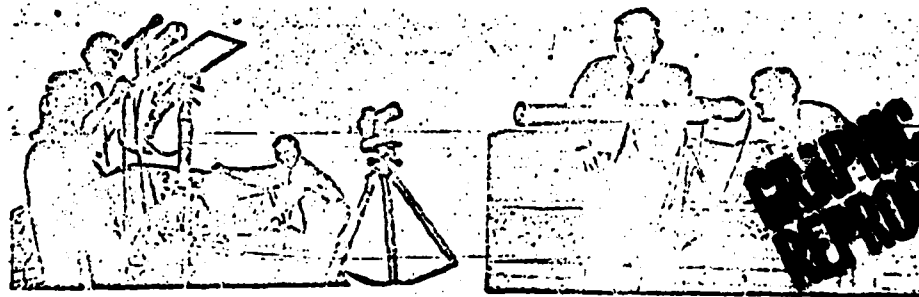


Fig. 4. Experiment using light waves in communications.

In order to prevent atmospheric interference on the ground, research has been directed toward placement of the communications system on man-made satellites, thus enhancing further the sensitivity and also the distance of transmission. For this purpose there is the problem of the high-power electrical source necessary for the optical pumps. Hence, investigations have been made on the use of solar energy to stimulate the laser. If this is realized,

then it is only necessary to add a solar energy collector to the space communications system to make the laser work, thereby simplifying the equipment greatly.

The use of lasers will not only make it possible for human beings on Earth to communicate with space vehicles or distant planets, but will also serve for communication between spaceships or between a spaceship and an interplanetary navigation station. This type of communication, besides the requirement of high sensitivity, calls for very little power. It usually requires only 1/100,000,000 of the power needed for microwave communication under identical conditions. Consequently, it will greatly simplify the design of space communications systems and very effectively raise working efficiency.

Not too long ago, it was suggested that laser beams could be used to scan other planets for the possibility of signals of a definite wavelength being sent by lasers on the planets to the earth. Using a large-aperture telescope with the addition of a laser and an ultrasensitive photoelectric detector, it would be possible to answer the riddle of life on other worlds.

COMMUNICATIONS ON THE GROUND

There are water vapor, dust and gas molecules in the atmospheric layer near the surface of the earth. The laser beam suffers loss of intensity to a certain degree in transmission. But we can use lasers whose output beams have a wavelength in the infrared region and thereby greatly reduce these atmospheric interferences. This is especially beneficial in communications in areas with dry climates.

In order to eliminate interference in the atmosphere entirely, it has been suggested that in ground communications, signals may be transmitted in sealed conduits. With the use of mirrors of high reflectivity, the light can be made to bend so that the signals finally arrive at the receiving station. This is the optical-waveguide system.

A characteristic of using the laser for ground communications is that it has the highest degree of security. For example, it is practically impossible for the enemy to intercept communications between combat ships, between shore and ship or the ground-to-ground communications, since the laser output beam has extremely good directivity and its cross section is very small. Especially in areas where radio communications is unsuitable and there is difficulty in setting up cables for telephone communications, the use of a laser communications system would far surpass the conventional infrared communications in possessing higher efficiency and longer range. At present, estimates of the communications distance for this type of system give at least 10 km. After making another forward step in overcoming atmospheric interferences, it will be easy to increase the distance to more than a hundred km.

OPTICAL RADAR

A laser used for radar purposes emits its beam through a

telescope to search for targets (Fig. 6). Simultaneously, a silvered mirror of definite reflectivity is used to reflect a small amount of the output light back to the photoelectric multiplier (1), which after amplifying this signal, transmits it to one of the circuits of a double beam scanning radar system. The original signal (figure) of the emission beam will then appear on the radar screen. When the transmitted beam has found a target, it will be reflected from the target and will be focused by the telescope onto the photoelectric multiplier (2). After amplification, the signal is sent to another circuit in the radar system. The result is that the figure of the returned signal appears on the radar screen. From the horizontal positions of the two figures on the screen and the emission direction of the beam, it is possible to determine the location, dimensions and distance of the target.

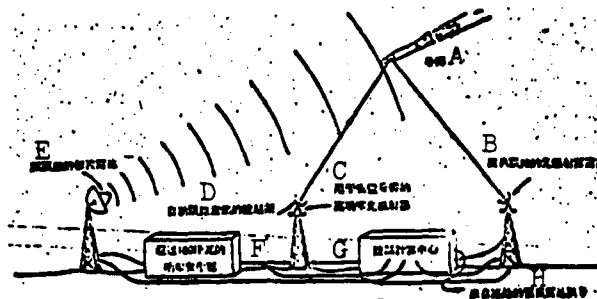


Fig. 5. Antimissile system. A) Guided missile; B) optical laser radar used in tracking; C) high-power optical laser used for destruction of the missile; D) and; E) [illegible]; F) power generator (over 100 kw); G) control computing center; H) signals from early warning radar.

The power required for this type of optical radar system is far below that of microwave radar. The energy output of an ordinary ruby laser already surpasses that of the most powerful modern radar; therefore the accessory equipment may be greatly simplified. Calculations show that a laser of 66-watt average output can scan the distance between two spaceships 16,000 km apart, with an accuracy reaching 1/100,000, which is far beyond the capability of the present-day microwave radar. An optical radar used for surveying on the earth's surface with a capability of estimating distance at 10 km weighs only around 10 kg. When atmospheric interference is overcome, this can be raised to several hundred kilometers.

THE "SEA-BOTTOM" LASER AND ANTISUBMARINE WARFARE

The technique used at present for exploration of the bottom of the sea usually involves sound-wave or ultrasonic methods. Since sea water has the highest transparency (degree of transmission) for light-blue light, if light-blue laser could be made, it could be used to explore the bottom of the sea or to establish communications between submarines. Owing to the small cross-sectional area of its output beam and its high energy, the degree of

precision in its measurements could be very much better than what is attainable with sonic devices. At the same time, these underwater communications again would have very good security. It has been suggested that an airborne laser searchlight could be used in the battle against submarines, illuminating part of the target in certain time segments. For the receiver one could use a flying spot scanning device and photoelectric multiplier synchronized with the searchlight. Thus the scattering caused by reflection of the light from the target may be greatly reduced and the location of the submarine can be accurately determined.

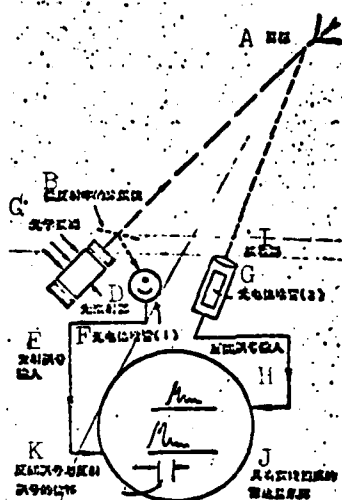


Fig. 6. Schematic diagram of an optical radar. A) Target; B) [illegible]; C) optical pump; D) laser; E) emission signal input; F, G) photomultiplier; H) return signal input; I) [illegible]; J) [illegible]; K) shift of return signal and reflected signal.

The laser working under the sea can also avoid completely the interference caused by the noises by marine animals which are often mistaken for targets when acoustic or ultrasonic waves are used in the measurements. At the same time, certain types of mines used in submarine warfare may explode automatically when exposed to sound waves, and these explosions can also be avoided by using lasers for deep-sea scanning. Consequently, it may be predicted that once the underwater laser is perfected, it will be of tremendous significance to exploration of the bottom of the sea and in submarine warfares.

THE DEATH RAY AND ANTIMISSILE WARFARE

After a laser beam of concentrated high energy is focused by lenses, its light energy can be concentrated onto a small spot whose area is reckoned in microns. The luminous flux density may reach 1 million watts per cm^2 to 1 billion watts per cm^2 . By it to illuminate a lump of coal, it is possible to raise the temperature of the spot being illuminated to 8000°C in less than $5/10,000$ of a second. This temperature is high enough to burn through steel

plate or any other material.

After further development to increase the power output of the laser, a military weapon of tremendous destructive power may be manufactured - namely the death ray. It may even be used to destroy guided missiles, airplanes and tanks. Many countries are at present engaged in research in this direction.

Figure 5 shows an antimissile (or antiaircraft) system. It is composed of early warning radar systems, microwave tracking radar and optical radar using a laser. The first two provide information on the rough position of the guided missile (or airplane), and then the laser optical radar is used to track the guided missile accurately, and through it the precise position of the target is obtained. This intelligence is sent along to the control center which controls another target-destroying optical laser, instructing it to track the target automatically at the same time. The principal portion of the target is zeroed in upon and kept on it for a sufficiently long time to burn it. This then will guarantee the destruction of the guided missile.

SPRAY GUN

A new type of weapon may be made with liquid lasers - the spray gun. This gun contains two small chambers in which two different chemicals are stored. When the trigger is pulled, it starts a small pump which pumps the first chemical solution into the second one. The two react and produce a negative temperature system that has an amplifying effect. The beams that are emitted at the end may be focused by a lens system to hit the target with sufficient power to destroy it. This type of weapon could be made to be carried by hand.

PROSPECTS OF OTHER APPLICATIONS

After further research and development, it will not only be possible to use the laser in the above applications, but also in other areas. For example, in computers, glass fibers may be used as conducting wires, using this type of light beam to send information without the use of electricity and thus raising the speed of computer operation; using lasers to track and guide man-made satellites; using light beams of extremely good monochromaticity to stimulate selected molecules and thereby achieving control of chemical reactions; carrying out welding or cutting in very small areas; drawing or photographing extremely fine and detailed figures or pictures; making measurements of distances in space or on earth (Fig. 1); carrying out spectral analyses (Fig. 2); conducting research on changes in the structure of materials under the illumination of this type of extremely intense beam and thereby discovering new characteristics of materials, etc., etc.

Besides all these, it has also been proposed in other countries that by focusing the lasers available at present it is possible to create a light pressure of 1000 atmospheres per square centimeter. Combining it with the piezoelectric effect of certain crystals one may create an electric field with intensity reaching 100 million volts per centimeter. When this type of crystal is

erfected still further, it will be possible to revise the above figures upward by another 10,000 times. A source of such superhigh pressure and ultrastrong electric field could open up radically new avenues of technical applications. It has also been suggested that it may be used for electron accelerators. According to its capability at this date, it has the ability to accelerate electrons to 100 million electron volts (in the February issue of this journal we shall continue to introduce the applications of the laser in the fields of metalworking, medicine and biology).