

SPEECH BY DR. THEODORE H. MAIMAN, HUGHES AIRCRAFT COMPANY,
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Thank you, and good morning, ladies and gentlemen.

We are here today to announce to you that man has succeeded in achieving a goal that scientists have sought for many years. For the first time in history a source of "coherent" light has been attained.

This is another way of saying that the long-sought "laser" is no longer an elusive dream but, is indeed, an established fact.

"Laser" is an acronym derived from the first letters of the principle words of the phrase, "Light Amplification by Stimulated Emission of Radiation." Many of you are, I am sure, at least generally familiar with the device called a "maser"-- from "Microwave Amplification by Stimulated Emission of Radiation"-- which operates in the microwave range of frequencies. The laser amplifies and generates coherent energy in the optical, or light, region of the spectrum; for the reason the laser is sometimes called an "optical maser."

I have here a laser which I have brought with me from the Hughes Aircraft Company's research laboratories in Southern California; it will be passed among you presently for closer inspection. As you can see it's size might be described as similar to that of a glass tumbler.

This laser is a new solid-state device. It is this device which is today being used to generate coherent light in our laboratories. Just what coherent light is and why it is so important I will try to explain briefly in a few moments.

But I think it is well to say here that achievement of the laser at Hughes marks the culmination by American industrial research of efforts by teams of

scientists in many of the world's leading laboratories. Some of these are privately and some publicly supported, some are working under defense contracts, some not. At Hughes the work was with the company's own funds.

One way of explaining the importance of the laser is to say that as a scientific advance it projects the radio spectrum into a range some ten thousand times higher than that which was previously attainable, and its success marks the opening of an entirely new era in electronics.

The radio spectrum in a broad sense of the term, is the range of electromagnetic frequencies starting with commercial radio at one million cycles per second and extending into the upper microwave region of fifty thousand million cycles per second. The laser jumps the gap from fifty thousand million cycles to five hundred thousand billion cycles per second, as such, it opens the way for a great many important applications:

For the first time in scientific history we have achieved true amplification of light waves.

We will have an important new scientific tool for investigating properties of matter and for performing basic experiments of physics.

We should be able to project light into very high-intensity beams for space communications.

We are shown the way to enormous increases in the present number of available communications channels.

The possibilities are very real for utilization of high light concentration for industrial, chemical and medical purposes.

Having arrived at this point, let us examine, in an elementary way just how and why we got here.

Light is electrical in nature--it is a form of electromagnetic energy. Like the alternating current from your wall socket it is a form of energy which oscillates back and forth in time analogously to the way a pendulum oscillates or swings to and fro. The number of times, or cycles, per second that the oscillations or alternations occur is referred to as its frequency. The frequency of ordinary house current is 60 cycles per second.

As we study the properties of electromagnetic energy at higher and higher frequencies, we find drastic changes, in the sense that the techniques of generating, amplifying, and detecting it depend essentially on this frequency.

To illustrate, your hi-fi set uses a microphone to convert sound into electrical energy, then amplifies it and converts it back into sound waves by use of a loud speaker. The frequency range that it covers is from about 30 cycles to 15,000 cycles per second. Higher in the electromagnetic spectrum is the commercial radio broadcast band where your AM receiver operates. Progressively higher frequencies are termed short wave; VHF (for very high frequency) containing the FM and TV bands; UHF (for ultra high frequency); microwaves, where most radars operate; infrared or heat waves; light; ultraviolet, X-rays, gamma rays and finally cosmic rays.

Throughout the entire radio spectrum it has been possible to generate energy which can be characterized or specified to be of almost one definite or single frequency. The band of frequencies or indefiniteness of specification can be quite small, sometimes a fraction of one cycle per second. This band of frequencies or portion of the electromagnetic spectrum over which any particular source generates energy is often referred to in terms of its "coherence"; the smaller the band in which energy is radiated, the more "coherent" the source. Previous

sources of light energy such as incandescent lamps, are "incoherent" sources since they simultaneously generate energy over a relatively large part of the electromagnetic spectrum. Radio frequency sources, on the other hand are very coherent. The advantages of a coherent source are many. It can be used, for example, for communications purposes because each one occupies only a small part of the spectrum. Thus we can tune in and obtain information from a desired source while filtering out all others. If your favorite radio station were to broadcast over a broad part of the spectrum (that is, if its transmitter were an incoherent source) you would experience interference from this station all over the band.

Scientists have recognized for years that if coherence at much higher frequencies could be achieved (that is, in the infrared and optical spectral regions) many worthwhile things could be accomplished.

However, progress in extending the available coherent spectrum has been slow. The most successful technique for generating coherent energy has been the use of properties of electrons in vacuum, i. e. various types of vacuum tubes. But electronic techniques are limited. The size of the elements of these tubes is roughly the same as the wavelength of the energy generated. In the upper microwave region, for example, we are dealing with dimensions in the order of one-eighth inch or so; imagine the problem in the optical region, where the wavelengths are only a few ten-millionths of an inch:

At WorldWar II's end the highest frequency that we could easily generate coherently was in the microwave area at about 10,000 million cycles per second. In the intervening 15 years we have been able to go up only by a factor of five to about 50,000 million cycles per second, chiefly by the very ingenious employment

of some equally ingenious vacuum tubes. But there for quite a long time we appeared to have bogged down.

It had been clear for some time that a fresh approach to the problem was needed. In 1955 Professor C. H. Townes of Columbia University invented a device for which he coined the acronym "maser". The basic principle of the maser is to use the natural properties of atoms or molecules in interacting with electromagnetic radiation. Properly designed masers are able to take advantage of these properties and amplify or generate electromagnetic energy. Although the Townes' maser operated in the microwave region it was clear from the start that this basic principle could be used to generate and amplify energy at much higher frequencies perhaps up into the optical region. This was further elucidated by Dr. A. L. Schawlow of Bell Telephone Laboratories and Professor Townes in a paper published in the latter part of 1958. They gave particular emphasis to a proposed scheme in the infrared spectral region. The laser, or the optical maser, here represents the result of a research program in the optical spectral region at the Hughes Research Laboratories. Instead of jumping a gap in the spectrum by five as has been done in the last 15 years, the laser represents a jump by a factor of ten thousand from previously attainable coherent sources.

We have described the laser as an "atomic radio-light" because it uses atomic methods to generate the light and because its coherent properties are similar to those of radio waves.

A paper describing this laser in detail has been submitted to the U. S. "Journal of Applied Physics" and also to "Nature", a British scientific journal.

I would be glad to discuss these technical details with those of you who are interested in this information during the question-and-answer period following these remarks or, at greater length, after lunch.

But very briefly, the essential steps in the operation of the laser are these:

A light source, in the form of a powerful flash tube lamp, irradiates a synthetic ruby crystal which absorbs energy over a broad band of frequencies.

This optical energy excites the atoms to a higher energy state from which the energy is reradiated in a very narrow band of frequencies.

The excited atoms are coupled to an optical resonator and stimulated to emit the radiation together; hence the acronym laser. This is in contrast to ordinary light sources where the atoms radiate individually at random and is responsible for the incoherence of these latter sources.

As a direct consequence of its coherence the laser is a source of very high "effective" or equivalent temperature higher than at the center of the sun or stars even at their hottest centers. By this term we mean the temperature to which an ordinary light source would need to be heated to generate a signal as bright as the laser's at the laser's color. A Hollywood klieg light theoretically would have to reach a temperature of several billions of degrees (to vie with the laser on this score) - a purely hypothetical example since the lamp's materials would disintegrate if such heat could be achieved. The laser is not hot but is a "cool" source in the ordinary sense of the word and therefore does not burn up.

The color of light is a manifestation of its frequency, and the purity of a color is determined by the width of the emitted spectrum. Because light waves,

in principle could be produced a million times more monochromatic, or single hued, as those from a mercury or neon lamp, lasers could generate the purest colors known. This is one more way to describe the coherence of the laser.

Another important property of a laser, indirectly a consequence of its coherence, is that it radiates an almost perfectly parallel beam. It could in principle, generate a beam less than a hundredth of a degree of arc wide which when reaching the moon, for example, nearly a quarter million miles away would illuminate a lunar area less than 10 miles wide. By contrast if an ordinary searchlight could reach the moon, its beam would spread over 25,000 miles and its brightness would of course be correspondingly reduced. This follows from the fact that the searchlight is a finite-sized incoherent source. As another example, the laser beam if sent from Los Angeles to San Francisco would only spread 100 feet, while the searchlight beam would spread 50 miles.

The laser's use in radar and communications for space work is obvious, since there is no atmosphere in space to absorb or scatter the beams. It could be used in effect as a light radar. The small beam spreading would give rise to extremely high resolution and would enable one to take detailed pictures of a super-clarity never before attainable. A beam directed at the earth from a satellite 1000 miles up would be concentrated into an area about 200 feet wide.

The minimum spot size that a coherent energy beam can be focussed into is approximately equal to the wave length of the radiant energy. The laser emits energy in the extremely high frequencies of optics where the wave lengths, (that is, the distance between crests of the waves) is between 15 to 30 millionths of an inch. In the middle microwave region the wave length is about an inch, for commercial broadcast radio waves this length is some 300 yards (60 cycle

current has a wave length of 3000 miles).

Therefore laser beams, in principle, could be concentrated to the pinpoint size of a few ten millionths of an inch in diameter.

The word pinpoint is apt because the head of a pin is some two million times larger in cross-sectional area than that of a focussed laser beam.

When energy is concentrated in such small areas, as it could be using a laser, its intensity is very great and it therefore could generate intense local heat.

This suggests the possibility of many uses such as sterilizing surfaces with the focussed beam. Perhaps individual parts of bacteria, small plants and particles could be vaporized. Surface areas might be modified and chemical or metallurgical changes induced, and thus the laser could be useful in biology, medicine and industry.

In closing, I would like to say to you, ladies and gentlemen, that in the near future, you most assuredly will be reading--and no doubt writing--about coherent light and lasers or optical masers, because there are many laboratories doing important work on such devices. I hope that in our meeting here today we have been able to shed a little light on this important subject and have been of service to you in announcing and discussing the first working optical maser, in a way which will be helpful as further news along this line develops.

Thank you