PHYSICS

World's Best Clock

High frequency microwaves have been obtained for the first time directly from molecules. These waves are used in the most accurate clock ever made.

➤ SCIENTISTS CAN, for the first time, generate microwaves of extremely high frequency by tapping directly the energy of molecules, Dr. Charles H. Townes of Columbia University's physics department reported in New York.

His device for doing so is known as the "maser," short for Microwave Amplification by Stimulated Emission of Radiation. Using a new fundamental principle, it permits amplification of high-frequency radio waves without use of vacuum tubes.

Besides serving as an amplifier, the maser can measure time with greater accuracy than has previously been possible. As an atomic clock, using the ammonia molecule, it produces microwaves with frequencies of 24,000,000,000 cycles per second, with a very small rate change. Other molecules can be used to generate either higher or lower frequencies.

Of Immediate Value

The maser, Dr. Townes said, is an excellent example of fundamental research that has proven to be of immediate practical value in such fields as radio communications, microwave transmission and reception, and navigation. Scientists will find it useful not only for accurately measuring time, but for determining the earth's rate of rotation and examining molecular and atomic structure with greater precision.

Work on the maser began three years ago in the Columbia Radiation Laboratory, which is jointly sponsored by the Army Signal Corps, the Office of Naval Research, the Air Research and Development Command and the University. Government agencies will have royalty-free use of any devices based on the maser, to which the Carbide and Carbon Chemicals Co. also contributed funds for development.

Dr. H. J. Zeiger, now working at Massachusetts Institute of Technology, Dr. J. P. Gordon, now at Bell Telephone Laboratories, and Dr. T. C. Wang of Columbia assisted Dr. Townes in development of the maser.

Not Only Atom Clock

The maser is not the only atomic clock, but it differs from previous atomic timing devices by using the molecular energy directly. Other atomic clocks use conventional oscillators and apply their output to a group of molecules. The molecules do not supply any of their own energy to the signal, as with the maser, but act as a kind of tuned filter. A conventional oscillator is tuned in frequency until its output agrees with that of the molecular filter.

It is primarily because the maser produces microwaves directly from the molecules that it is able to use their very precise resonant frequency with such success.

In the device, a stream of ammonia gas is forced under slight pressure into a sealed chamber from which the air has been removed by vacuum pump. The ammonia molecules are focused by an electrostatic field into two parts, one, molecules of low energy, which usually absorb energy, and the other those of high energy, which can radiate. The low-energy molecules are diverted from the beam, while the high-energy ones are directed into the main part of the device, a small copper cylinder open at one end and known as a "cavity."

Within its walls, some of the ammonia molecules undergo "transitions," giving up tiny amounts of energy in the process, and triggering other molecules to emit their energy, in a kind of molecular chain reaction that builds up a relatively large amount of energy quickly.

If there are sufficient molecules to start a self-sustaining chain reaction, then oscillation occurs inside the cavity and microwaves are emitted from it. If fewer molecules are present, the maser acts like an amplifier. Thus an operator can regulate its action by adjusting the flow of ammonia gas.

The maser can also be adjusted for frequency, using molecules of substance other than ammonia for large changes. Sodium chloride, common table salt, is one compound that will be tried, Dr. Townes said.

MISSING LINK—A primitive crustacean, so small that it can swim through the eye of a needle, is shown in a photograph taken of a microscope image. The tiny animal is believed to be a "missing link" between three of the five major groups of crustaceans now known to exist on earth. The creature was found in Long Island Sound by Howard L. Sanders, Yale graduate student working at the Bingham Oceanographic Laboratory.

Flows Like Liquid

The microwave output from the cavity, which is at most ten-billionths of a watt, flows out through a waveguide and is piped to its destination much like a liquid would be.

Two complete masers have been built so far, a necessity so that one could check the other, since the device is so accurate it cannot be adequately tested any other way.

The oscillation frequencies have been compared to an accuracy of one part in 100,000,000,000, which is probably the most accurate comparison or measurement of any two physical quantities that has yet been made.

Dr. Townes estimated that commercial maser units should sell, once development costs have been written off, for about $500. Masers with highest possible accuracy for scientific use would probably cost over $10,000.

Its First Job

First assignment outside the laboratory for the device is expected to be as a frequency standard, keeping radio and television transmitters precisely on frequency with greater accuracy than present-day vacuum tube oscillators and quartz crystals.

A maser system of navigation could also be developed by tuning in on two different radio stations and comparing that signal with one from the maser, which would tell a navigator the time the radio wave had been traveling to his plane or ship. The time difference can be converted into distance, since radio waves, like light, travel at about 186,000 miles per second.

The maser can also amplify signals too weak for vacuum tube amplifiers. It will probably also be used to check on the rate of the earth's rotation and to discover the exact frequency of oscillation of many kinds of molecules and atoms.

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Because of its nearness to the sun, *Mercury* is the least seen of all the planets visible to the naked eye.

The United States *mineral output* for 1954 is valued at an estimated $13,820,000,000, four percent below the 1953 figure.

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