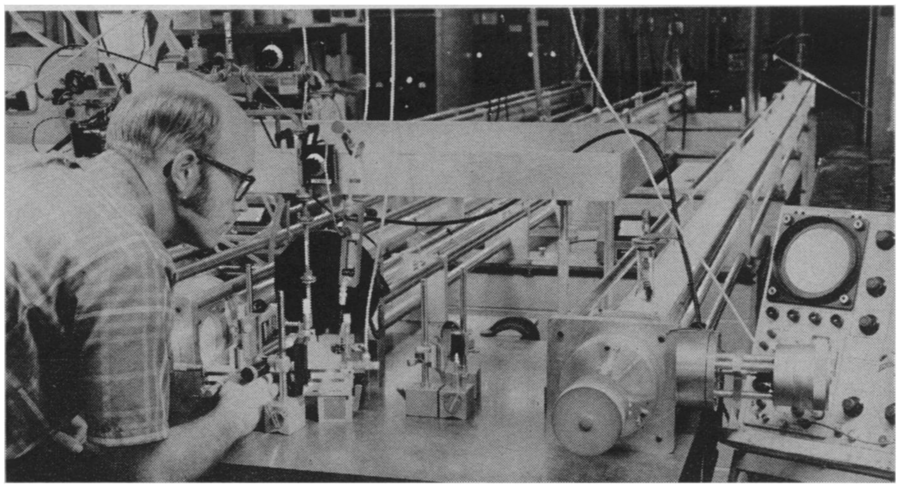
Taking the measure of light

Highest frequency measurement could lead to a single standard of length and time



NBS

Evenson with helium-neon laser: Improved light-velocity figure is next goal.

As every first-year physics student learns, the frequency of an electromagnetic wave multiplied by the length of the wave is equal to the speed of light. It is a neat and elegant relationship. Because the speed of light in a vacuum is constant (in fact it is a fundamental constant of nature), it naturally follows that the higher the frequency of any particular form of electromagnetic radiation, the shorter the wavelength; the lower the frequency, the longer the wavelength.

Another consequence, of course, is that if one knows the values for any two of the factors in the equation, he can, simply by plugging in the numbers, easily calculate the third. In fact, the most accurate speed-of-light measurement was calculated this way—by measuring the wavelength and frequency of radio waves. But the waves were necessarily of relatively low frequency, because the direct measurement of high frequencies is an extremely difficult task. This use of low frequencies in turn introduces uncertainties into the calculation because the measurement of wavelength at such frequencies is limited to an accuracy of 300 parts per billion. But at high infrared frequencies, the measurement of wavelength should be limited only by the accuracy of the length standard itself (about 10 parts per billion). So physicists interested in obtaining a more accurate figure for the speed of light have naturally relished the thought of obtaining direct measurements of the frequency of a high-frequency electromagnetic beam.

This is one reason there is so much excitement about the report this week of the highest absolute frequency measurement ever made. Four scientists at the National Bureau of Standards' Boulder, Colo., laboratories found the absolute frequency of an emission from a helium-neon laser to be 88.376245 terahertz (trillion cycles per second). The four are K. M. Evenson, G. W. Day, J. S. Wells and L. O. Mullen.

Their measurement represents a 100-fold increase in the span of frequency measurements over the last four years and surpasses the previous high-frequency measurement (58.024341 terahertz) reported in September 1970 by a group of scientists from the Massachusetts Institute of Technology, D. R. Sokoloff, A. Sanchez, R. M. Osgood and Ali Javan. Prior to the NBS team's measurement, frequencies that high had to be calculated by dividing the speed of light by the measured wavelength. Frequency-measuring techniques, however, are more than 10,000 times more accurate than wavelength-measuring techniques.

With the new frequency-measuring ability, a 30-fold more accurate determination of the speed of light should be possible, says NBS Director Lewis M. Branscomb. The measurement of the helium-neon frequency has so far been made to an accuracy of 6 parts in 10 million. By plugging in the known value for the laser's wavelength (3.39 micrometers) this is good enough to obtain a value for the speed of light roughly comparable in accuracy to the presently accepted figure of 2.9979267×10^8 meters per second, but it is not good enough to exceed it. But Evenson told SCIENCE NEWS this week that he and his colleagues hope to have a 100-fold improvement in the accuracy of the frequency measurement within six months. That should allow an improved calculation of the speed of light.

To obtain that objective Evenson's group now has to stabilize all the lasers used and remeasure their frequencies. (In the experiment, a hydrogen cyanide laser, water vapor laser and carbon dioxide laser form a chain of lasers linking the NBS frequency standard to the helium-neon laser whose frequency was measured. Each laser in the chain was tuned to its maximum output power, but for better accuracy the frequencies of each now have to be accurately measured and "locked.")

As the NBS points out, a more accurate value for the speed of light will be of great value not only to the space scientist in tracking satellites and space vehicles and the astronomer in measuring interplanetary distances, but also to all physicists who must use the figure in their calculations.

Other groups might benefit indirectly. "Manufacturers should achieve finer accuracy in instrument manufacture and other precision equipment," said Branscomb. "Environmental scientists will find that improved control of precisely tuned lasers will permit new progress in the study of minute quantities of pollutants." Development and accurate measurement of super-stable laser oscillators at frequencies approaching those of visible light—about a million times higher than those used in FM radio and television—opens the possibility of a whole new frequency range for telecommunications.

But there is also another possibility, long dear to the hearts of basic scientists. It is the possibility of having a single international standard for both length and time. "Ever since Albert Einstein showed that time can be considered the fourth dimension of the space in which we live," said Branscomb, "scientists have looked forward to the possibility of using one gauge—one 'yardstick' so to speak—not only for the three dimensions of space but for the fourth dimension of time as well. To interchange clocks and rules scientists must know the speed with which light travels. . . . With this demonstration that both the space (wavelength) and time (frequency) dimensions of a single light source can be measured with prodigious accuracy, this goal is now within our grasp." Adoption of such a single standard, however, would be years, perhaps decades, away.

Further details of the measurement are reported in the Feb. 1 APPLIED PHYSICS LETTERS. □