SEARCH AND DISCOVERY

Lasers Offer Satellites Better Ways to Communicate

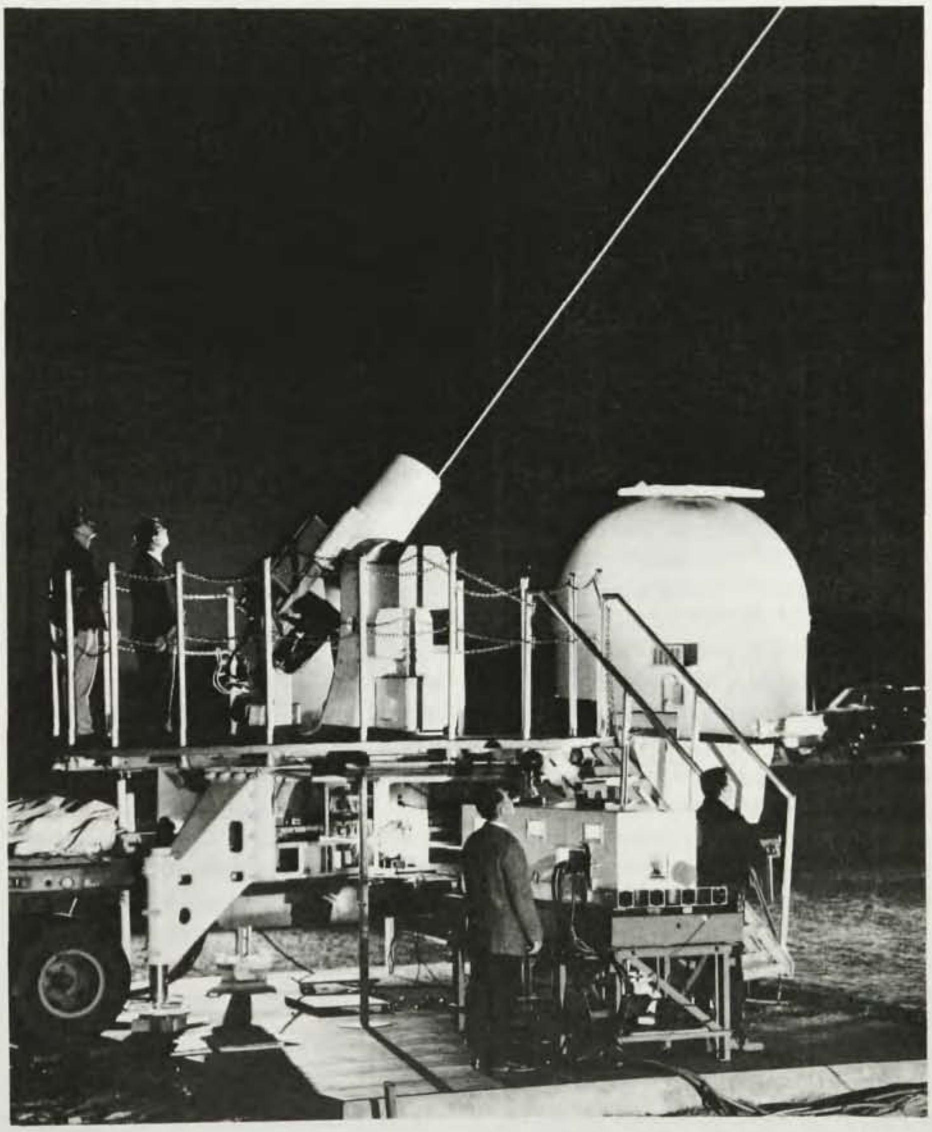
What happens to the wavefront of a beam of coherent light as it is propagated through the atmosphere? The question has become one of vital interest to space scientists, and is answerable now that we can study, for the first time, light sent out into space by lasers, as well as that originating from an external source such as a star. The answer will affect the development of optical space-communication systems (destined to supplement present microwave telemetry channels) and precision laser tracking for satellite-orbit determination, geodesy and lunar-motion studies.

To find out what is being done to answer this question, PHYSICS TODAY visited the most active center for laser tracking experiments—Goddard Space Flight Center in Greenbelt, Maryland. Here, at this sprawling campus-like complex dotted with brick buildings, Henry Plotkin, head of the Optical Systems Branch, is carrying out a number of interesting space experiments with ruby, argon and carbon-dioxide lasers. The principal one at the time of our visit was an experiment in which the intensity and fluctuations of light reaching a satellite from a ground-based argon laser were being measured.

On the ground, the continuous 488-nm light was modulated at a 13-kHz rate as it left the transmitter, and projected through a tracking optical system (see photograph). It was then detected at the GEOS-II (Explorer 36) satellite, as far as 1500 kilometers away, by a photomultiplier peering down at the earth through a color filter and wide-angle optics. On several nights previous to our visit, Plotkin and his colleagues had conducted successful tests in which the satellite detected the argon laser radiation and radioed back to Goddard a detailed record of the variations in the incident light. These are the first data of their type available for comparison with theories of atmospheric propagation (see, for example, the paper by D. L. Fried in *J. Opt. Soc. Am.* 57, 980, 1967.)

The argon-laser experiments are part of a program that started in 1964, when pulsed ruby-laser radiation was reflected from the Beacon Explorer satellites. These satellites were fitted by Goddard with arrays of cube-corner retroreflectors so that they could be tracked accurately by laser radar for geodetic studies and orbit determination. This technique has been so successful (with lasers, the satellite distance can be measured with an accuracy of 1 meter) that there are now six such retroreflecting satellites in orbit and experimental laser stations around the world. Goddard is preparing to reflect the argon laser from these same satellites to determine satellite velocity from the Doppler effect.

The Goddard team has given much attention to pointing the very narrow laser beams used for space experiments. For instance, the GEOS-II argon-laser experiment is being conducted from a mobile station located several miles from the center. The mobile units are packed with a computer, control equipment and television apparatus to help in hitting the target, as well as power supplies, detectors, radio receivers, and recorders



ARGON LASER at Goddard Space Flight Center tracks the GEOS-II satellite. Beam is modulated at 13 kHz and transmitted to the satellite, where it is detected by photomultiplier. Return radio signal carries the same modulation.

to carry out the experiment. The same station is also being used for pulsed-ruby, satellite-ranging measurements.

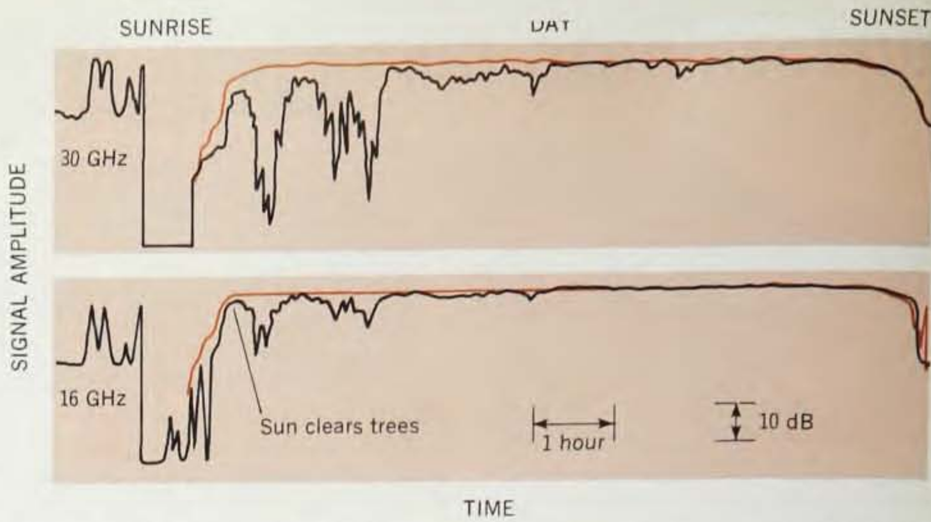
Future projects of this group include development of high-data-rate-capacity space-communication systems using carbon-dioxide laser radiation at 10.6 microns. These will require active optical transmitting and receiving terminals on the spacecraft; so a good deal of further development may be needed. —HEB

NMR Spectra Yield Data On Protein Structure

High-resolution nuclear-magnetic-resonance spectroscopy may be able to correlate biochemical reactions and electronic structure in protein molecules. K. Wüthrich and Robert Shulman (Bell Labs, Murray Hill) and J. Peisach (Yeshiva University) have examined the NMR spectrum of cyanometmyoglobin from the sperm whale; this compound, molecular weight 17 816, contains one iron atom. Its biological function is to store oxygen in muscular tissue.

The NMR spectra of proteins contain many overlapping resonances that cannot be separated by current techniques, but Wüthrich, Shulman and Peisach noticed that, with cyanometmyoglobin and some other proteins, well resolved proton resonances appeared outside the usual range, at both higher and lower fields. Certain of these resolved resonances are interpreted as resulting from hyperfine interactions of the unpaired spin of the iron ion Fe^{3+} with a relatively small part of the molecule— the protoporphyrin IX group. This group, with the iron ion, represents that part of the protein molecule that combines with oxygen. Studies of the resonances as a function of temperature allow these hyperfine interactions to be distinguished from other effects caused by interactions with ring currents in the molecule.

Further identification of these resonances will give information about the distribution of the unpaired spin, which in turn determines the wave function of the iron–porphyrin group within the protein. This information should ultimately lead, says Shulman, to a correlation of the electronic structure of the molecule with its biological function.



EFFECT OF RAIN ON RADIO SIGNALS. Clear (colored line) and rainy weather (black line) signals are compared at frequencies of 30 and 16 GHz. Rain attenuates the 30-GHz signal more than it does that at the lower frequency.

Rain Showers Dampen Solar Centimetric Radio Waves

Robert W. Wilson of Bell Labs, Holmdel, is making measurements to see whether the useful radio spectrum for satellite and space-probe communications can be extended to frequencies up to 30 GHz; the aim is to determine the effect of weather (particularly rain) on these high-frequency signals. The sun is a convenient extraterrestrial radio source for these experiments; so Wilson has made a sun tracker that records solar emission at 16 and 30 GHz.

A polar heliostat, consisting of a 1.5 × 2.75-meter metal reflector rotating about a polar axis and a stationary horn antenna, follows the sun automatically each day; rotation of the reflector about a declination axis corrects for seasonal variations in the solar position through the year. Detection is by a microwave radiometer; background noise is monitored by a 1-Hz oscillation of the heliostat away from the sun.

Absorption and scattering in raindrops cause attenuation, greater in the 30-GHz signal than in that at 16 GHz (see figure). Data taken for a year or more should show whether satellite communication at frequencies greater than 12 GHz (wavelengths less than 2.5 cm) would be seriously hampered by wet-weather losses; perhaps a network of several ground stations could be set up sufficiently far apart that at least one of them would be able to receive strong signals when heavy rain was affecting the signals at others.

Radio Satellite Monitors Low-Frequency Space Signals

A US satellite successfully extended four of its five antennas to 139 meters in late July and has been monitoring low-frequency radio signals from space since then. Space-agency officials were to decide in August whether to attempt deploying the booms to their full 229 meters.

From its vantage point in a circular orbit 5820 kilometers above the earth, the satellite will provide radio astronomers with their first low-frequency (below 10 MHz) map of our galaxy.

The four antennas form two vee shapes above and below the satellite (with respect to the earth). Those above monitor the Milky Way, Jupiter, the sun and other sources of radio emission. Slow-scan television cameras tell ground crews how the antennas are positioned at any time.

The array below the spacecraft measures low-frequency radio emissions that come from the earth's environment and, because the force of gravity is slightly greater on it, provides the satellite with gravity-gradient stabilization.

A separate 36.6-meter dipole antenna measures bursts of radio signals from Jupiter, the sun and other sources. The sixth and final boom is a 165-meter libration damper.

The radio receivers on board are designed to monitor strong, sporadic