Harnessing chaos for optical communication

Police radio messages are vulnerable to interception. A wireless communication system based on the erratic, unpredictable output of an electronic circuit or a laser, however, offers the possibility of enhanced security. An eavesdropper would detect only static, even though an intelligible message rides atop the chaotic carrier.

Researchers have now shown that chaotic signals transmitted from one laser directly to another can be used to carry information. Such an optical scheme has the advantage of reducing the amount of power required and potentially increasing the number of signals that can be delivered along an optical fiber, says Henry D.I. Abarbanel of the University of California, San Diego.

Abarbanel and Matthew B. Kennel describe the principles underlying such a technique in a report scheduled for publication in PHYSICAL REVIEW LETTERS. Gregory D. VanWiggeren and Rajarshi Roy of the Georgia Institute of Technology in Atlanta report in the Feb. 20 SCIENCE the first experimental demonstration of chaotic communication using an optical system.

"What we've done is learned how to attach a message—it could be one voice, it could be hundreds of voices—to a carrier that is very irregular," Abarbanel says.

"In an ordinary digital signal, the message can immediately be seen," Roy adds. "In our system, digital information is encoded in the chaos, so the message would not be obvious to a person who may intercept it."

Using chaotic signals for communication requires synchronization of two highly unpredictable, virtually identical—but separate—systems. In 1990, Louis M. Pecora and Thomas L. Carroll of the Naval Research Laboratory in Washington, D.C., showed that it is possible under the right conditions to synchronize the wildly fluctuating voltages of a pair of properly matched chaotic electronic circuits (SN: 3/24/90, p. 191). Several years later, Kevin M. Cuomo and Alan V. Oppenheim of the Massachusetts Institute of Technology demonstrated that such synchronized circuits could be used for communication.

Abarbanel and Kennel focused on whether erbium-doped lasers, widely used in optical-fiber communication devices, could serve as the basis for transmitting information when such lasers are allowed to generate chaotic signals. They showed theoretically that the distant lasers can be synchronized by injecting light from one directly into the other via an optical fiber. Moreover, the sending and receiving lasers don't have to be perfectly matched for the system to work.

Roy and VanWiggeren developed an erbium-doped fiber ring laser to produce chaotic electromagnetic radiation with a wavelength of 1.53 micrometers. They combined that erratic signal with a message signal, consisting of a uniform string of pulses at a frequency of 10 megahertz, and sent the mixture through an optical fiber to the receiving laser system. In response, part of the receiving system began generating just the chaotic fluctuations to which it is synchronized. By subtracting that chaotic portion from the combined signal, the researchers recovered the message.

Compared to an electronic circuit like the one his group used, Oppenheim notes, lasers are more convenient and provide higher frequencies, which are needed to send information faster.

Using their chaotic lasers, Roy and his team have recently communicated random bits over optical fibers at rates of up to 150 megabits per second. "We'd like to go faster," Roy says. "We'd also like to be able to send multiple signals simultaneously."

The Department of Defense's Army Research Office is now funding an ambitious project to demonstrate the usefulness of chaotic signals in optical and wireless communication. —*I. Peterson*

Will petunias and poppies need sunscreen?

Plants can't slather protective lotion on their delicate parts, and that may pose a problem. A laboratory simulation of ozone-layer thinning that allows extra ultraviolet-B (UV-B) radiation to reach Earth has made pollen sluggish in more than half the species tested.

Pollen from 34 species got mock suntans in the broadest survey yet of UV-B effects on flowering plants. In these experiments, run by Javad Torabinejad and his colleagues at Utah State University in Logan, the low UV-B doses mimicked current losses in Earth's protective ozone layer and high doses simulated an extreme scenario of 15 percent less ozone.

Pollen from 19 of the tested species developed significantly more slowly than pollen that wasn't exposed to UV-B radiation, the group reports in the March AMERICAN JOURNAL OF BOTANY. If the irradiated pollen performs as feebly in fertilizing real flowers as it did in the tests, plants might set fewer seeds.

However, Torabinejad emphasizes that no one knows how the simulations translate into real-world effects. "I don't want to say this is going to be a devastation," he says.

The UV-B-sensitive pollen came from sweet corn, rye, pears, pistachios, Montmorency cherries, California poppies, the Ultra Pink petunia, and a range of other plants. Begonias and tobacco did not suffer significantly from the radiation.

Only a small fraction of previous research on UV-B effects has examined plant reproduction, notes study coauthor Stephan D. Flint. Some of Flint's work has shown that plant structures protect female reproductive systems—and even pollen at certain stages. However, pollen must face the elements as it hitchhikes between plants.

Pollen grains are exposed to sunlight when a bee or other pollinator brushes them up from their parent flower and sets off to forage. Pollen grains that finally reach other flowers often lie in the sun while germinating and sprouting the tube that penetrates the female tissue.

Pollen from California poppies and a range of other plants became sluggish when exposed to extra UV-B radiation.

In the test, exposure to UV-B radiation significantly reduced germination in only five species, yet it slowed tube growth in a wide variety of others.

For practical reasons, Torabinejad and his coworkers measured tube growth on artificial culture media instead of on flower tissue. Even so, the experiment was arduous, requiring more than 30,000 measurements under a microscope. "We hired people who quit within the first hour," Torabinejad remembers.

The results suggest that monocots, a large group of plants that includes grasses and lilies, tend to be more sensitive to UV-B radiation than other species. Torabinejad speculates that plants with slow-growing pollen cells that contain three nuclei, like the ornamental cargopteris, may also be particularly vulnerable.

Ecologist Jeffrey K. Conner of the Kellogg Biological Station at Michigan State University in East Lansing calls the wide range of plants in the new study "a real strength." His own studies of Brassicas found little cause for concern in the greenhouse but worrisome losses of seed quality and number in a field experiment. He hesitates to guess what the new study means for plants in the field, but he does say it presents "potential cause for concern." —*S. Milius*