spectral analysis of biophoton activity may herald new agricultural chemicals

Consecutive spectral analyses of ultraweak photon emission can allow researchers to chart the process of physiological transition in plants, leading to the eventual development of chemicals that work with plant physiology to fight infection, says Kimihiko Kato of the Shizuoka Agricultural Experiment Station (Shizuoka, Japan). “Many living organisms generate ultraweak photon emissions, which we call biophotons, generally as a response to external changes such as anaerobic treatment, growth hormone treatment, saline stress, temperature change, herbicide treatment, and attack by pathogens,” Kato says.

The existence of biophotons was postulated by Gurvitsch in 1923. “A determination of the sources of ultraweak luminescence is of fundamental importance for a further development of the field,” says Barbara Chwirot of the Institute of Biology and Protection of the Environment at Nicholas Copernicus University (Torun, Poland). “Such studies have already resulted in a qualitatively new approach to some features of cellular metabolic processes.” Indeed, Kato’s research team has used continuous spectral analyses to collect data confirming very strong intensity of biophotons associated with the defense response of sweet potatoes.

In the experiments, a multisample photon counting system (Hamamatsu Photonics K.K.; Hamamatsu, Japan) monitored the time-dependent intensity variations for the sample over several spectral regions. The

Subaru makes Uranus shine

A false-color, near-infrared (IR) image of Uranus taken by the Subaru Telescope combines images taken with three different filters to show the planet’s ring system and its satellites. Astronomers used the 8.2-m telescope’s coronagraphic imager with adaptive optics (CIAO) in conjunction with its adaptive optics system to capture the image. The blue color indicates the presence of methane, the dominant component of the planet’s atmosphere.

— Kristin Lewotsky
**closing the gap**

Optical integrated circuits, high-efficiency solid-state lighting, and materials that actually have a negative index of refraction are all possible thanks to advances in photonic bandgap crystals. “These systems essentially give us a new mechanism of controlling light,” says professor John Joannopoulos of the Massachusetts Institute of Technology (MIT; Cambridge, MA). At the recent American Association for the Advancement of Science meeting (AAAS; 14–19 February; Boston, MA), Joannopoulos brought together a number of photonic bandgap researchers in a nanophotonics session “to show all the neat stuff that can be done,” he says.

Photonic bandgap crystals use a periodic structure of components with high and low indexes of refraction to create a range of frequencies at which light is not allowed to propagate through the material (see *oemagazine*, October 2001, page 28). If the photonic bandgap structure within the material is then broken, the irregularity creates microcavities and waveguides through which light can travel. The setup allows engineers to manipulate light at scales on the order of half a wavelength, which lets them build highly dense optical devices. Researchers in the area are enthusiastic about the possibilities. “I believe that the optical world will slowly creep its way into the electronics world by replacing certain functionalities on a chip,” says Axel Scherer of the California Institute of Technology (Pasadena, CA).

For instance, engineers could build a series of closely spaced vertical-cavity surface-emitting lasers (VCSELs) on a chip and vary their lasing frequency based on the geometry of the bandgap structures. One laser could pump the laser next to it, or light at different frequencies could be channeled in different directions, leading to tunable chips. Light-emitting diodes (LEDs), which typically dissipate 80% of the light they produce, could be built with a periodic structure that would force out more light, making them much more efficient. In the AAAS session, Shanhui Fan of Stanford University (Stanford, CA) described his design of an optical add/drop filter that can be turned on and off by introducing partially reflecting elements into the waveguide. “As you switch the resonance frequency of the cavity a little bit, you can change the cavity from a complete...”
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treated with Fusarium oxysporum was 10 times greater than either of the other samples,” Kato says. “It is reasonable, we think, to assume that the ultraweak biophotonic activity of the sweet-potato samples treated with nonpathogenic Fusarium oxysporum matches the strong physiological changes that occur when defense-related substances are first introduced in plants.”

According to Kato, this noninvasive, real-time method can be used as a new parameter for identifying the physiological state of an organism. Kato’s organization is also working with agricultural chemical producers to develop a new kind of chemical. In the past, chemicals were developed to directly attack the origins of diseases in plants. With the new information Kato’s experiments provide, he and the corporate developers working with him believe that chemicals that stimulate defensive responses in plants can be effective against infection as well.

—Charles Whipple

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4Pi-confocal microscopy provides a three to seven-fold increase in axial resolution compared to pure confocal techniques. In the 4Pi approach, a sample is placed between a pair of lenses with a common focal point. Wavefronts from the two objective lenses interfere to form a pattern with a sharp maximum. By performing a linear deconvolution, the group suppresses interference side lobes to generate a high-resolution, 3-D image. The group has recently succeeded in speeding up the 4Pi-imaging by means of fast galvanometric scanning, which has allowed them to perform biophysical studies of the mitochondrial compartment of live yeast cells.

Moving a step further, the group has combined the STED and the 4Pi technique to image samples with axial resolutions as good as 30 nm, which corresponds to λ/23. The technique does have challenges, though, Hell notes. “If intensity of the stimulated light beam increases, resolution increases as well, up to the molecular scale, in principle. However, photobleaching occurs at high intensity levels, so that the highest possible resolution cannot be reached yet.”

The approach is powerful, but challenging, Tromberg says. “It’s a really hard experiment and there aren’t that many people in the world that can do it,” he says. “But that’s changing. Stefan is leading the way here, and there are substantial improvements in lasers and optics technology that are making it possible.”

The group is investigating methods for improving the minimum in the center of the stimulating light beam. Hell also believes that refinements will eventually eliminate the need for the linear deconvolution to remove sidelobes and expects the 30 nm axial resolution to be useful to study fundamental processes occurring at cell membranes.

“What’s really amazing is that the potential resolution for this is approaching near field methods. This whole approach has many of the advantages of near field methods but it’s very attractive to biologists and biomedical researchers because it still has all of the features of true optical microscopy,” Tromberg adds.

“Where Stefan is really pushing the limits is really hard to do, but I think [the technique] has the promise to be more widely useful. It’s also raised our consciousness about point spread function engineering as a reasonable approach in microscopy, which no one was seriously thinking about before.”

—Kristin Lewotsky