Counting photons: Squeezing a quantum limit

Even the best lasers aren't perfect enough for applications requiring extremely precise control of light. The problem lies in the quantum nature of light, which allows for a tiny amount of randomness that limits how much the noise, or fluctuations, in any signal can be lowered.

To overcome this problem, researchers have focused on reducing the uncertainty in one particular characteristic of a light wave at the expense of another, which would become more random. The light wave resulting from such a tradeoff is said to be in a "squeezed" state. By using the more predictable, or less noisy, component of this squeezed light, researchers can partly circumvent the system's inherent quantum fluctuations, permitting them to make more precise measurements.

One group has now devised a new way to squeeze light, using pulsed light from an ordinary laser to generate and then detect strings of photons to an unusually high precision. "These results take us into a new regime of quantum optics," says Prem Kumar of Northwestern University in Evanston, Ill., who led the effort. The technique may eventually prove useful in optical communications systems by permitting light pulses to carry information more efficiently.

An ideal laser would produce light of a single wavelength in which every wave present is exactly in step with every other wave. Kumar and his colleagues, however, use a less coherent laser in which the waves are generally out of step. By shining pulses of green light from that laser into a crystal of potassium titanyl phosphate, they generate two separate beams of infrared light pulses.

In other words, the crystal in effect splits each green photon in the light pulses into a pair of infrared photons. "We know the two photons are generated simultaneously at the same location," Kumar says.

Measuring the number or location of photons in one beam necessarily modifies or destroys the photons in that beam but leaves photons in the other, duplicate beam unscathed. Because the beams are correlated, the measurement provides crucial information about the unaffected beam, which can then be used for some application.

"It gets around the problem of the random emission of photons in an ordinary laser where we don't know where the photons are," Kumar says. "If we looked at either of the two beams, there would still be a lot of randomness in it. The point is that we have essentially duplicated the beam, so we can dispense with one to learn about the other."

The results show that a well-defined, coherent light source isn't essential for generating squeezed light. "It certainly broadens the range of optics where you might run into quantum light effects," says Richart E. Slusher of AT&T Bell Laboratories in Murray Hill, N.J.

Kumar and his colleagues describe their preliminary experiments in the Feb. 26 PHYSICAL REVIEW LETTERS and in a forthcoming issue of OPTICS LETTERS. They are now combining several of their ideas for producing and detecting pulses of squeezed light to achieve even better results.

"So far, they haven't generated much usable squeezing," says Northwestern's Horace P. Yuen, who in 1976 first proposed the possibility of squeezing light. "But Kumar's group is now building a system that has the potential of generating much larger squeezing."

"We're very excited about the next generation of experiments that we're doing," Kumar says. "We should get some new results within the next six months or so."

But the gap between laboratory results and practical applications, especially in optical communications, remains wide. "It takes time for people to invent all sorts of different ways to adapt the technique to a fiber-optic environment," Yuen says.

Some researchers are already trying to use techniques for squeezing light to make precision measurements. For example, Slusher is working with a group building a squeezed-light microscope that could detect the minuscule increase in thickness of a nerve membrane when a nerve is activated. *– I. Peterson*

Young researchers earn top science awards


Headrick


Liu


Shull

Photos: Westinghouse

Emerging from a field of 1,431 entrants, 17-year-old Matthew Peter Headrick captured the first-place $20,000 college scholarship in the 49th annual Science Talent Search this week. For his research project, Headrick isolated a gene necessary for nitrogen fixation in a type of blue-green algae. A senior at the University of Chicago Laboratory Schools H.S., Headrick believes his work will aid understanding of cellular differentiation – which determines how the myriad different cells in the human body develop from a single fertilized cell.

David Ruchien Liu, a 16-year-old senior at Poly H.S. in Riverside, Calif., placed second in the competition, which is sponsored by the Westinghouse Electric Corp. and administered by Science Service, Inc. Liu, who received a $15,000 scholarship, developed two neural networks on a computer that simulate how human brains process visual information.

A $15,000 scholarship also went to third-place winner David Michael Shull, a 17-year-old from Henry Foss H.S. in Tacoma, Wash. Shull introduced DNA into fragile human white blood cells by using electric shocks to temporarily open the cell membranes. He says the engineered cells may help in the study of Type I (insulin-dependent) diabetes.

The winners were picked from 40 finalists who visited Washington, D.C., for the last stage of the competition. During interviews with eight scientists, the students were judged on their creativity and scientific potential. The students also met with scientific researchers in the area, Vice President Quayle and members of Congress.

Scholarships of $10,000 each went to fourth-place winner Soojin Ryu of the Bronx H.S. of Science, who studied HLA Class I molecules that play a role in activating the human immune system; fifth-place winner, Joshua Bailey Fischman of Montgomery Blair H.S. in Silver Spring, Md., who examined mathematical expressions called p-adic continued fractions; and sixth-place winner, Royce Yung-Tze Peng of Rolling Hills H.S. in Rolling Hills, Calif., who explored the mathematical properties of two joined planar surfaces.

The committee also awarded scholarships of $7,500 to seventh-place winner Laura Andrea Ascenzi of the Bronx H.S. of Science, who completed a project on values and relations among family members and peers; eighth-place winner Andrew Matthew Lines of Yorktown H.S. in Arlington, Va., who programmed a computer to solve the minimal surface problem; ninth-place winner Mina Kim Yu of Thomas Jefferson H.S. for Science and Technology in Alexandria, Va., who determined the structure of complex chemicals using iodide reagents; and tenth-place winner, Bianca Denise Santomasso of Stuyvesant H.S. in New York City, who studied the spread of cancer cells. The remaining 30 finalists each won a $1,000 scholarship. *– R. Monastersky*