Astrophysicist Peter Wasilewski uses water frozen in petri dishes to study the optical properties of ice and to create striking photographs, such as the one shown on page 56.

Ice as Art

Peter Wasilewski is an astrophysicist who studies the magnetism of rocks, planets and meteorites for NASA. But it is ice that has made Wasilewski an artist.

His work has led him around the world, from Antarctica to the Himalaya Mountains. "And because I like to use a chain saw, I cut ice wherever I go," Wasilewski said. He has learned that the crystallographic and optical properties of ice make it a fascinating medium for artistic studies. Ice is transparent. Its low birefringence allows Wasilewski to study thick sections, which can provide a range of color displays.

Wasilewski works at the Goddard Space Flight Center in Greenbelt, Md. But his art—photographs of ice interacting with light—unfolds on his dining room table.

Wasilewski calls his work "frizions," or the fusion of "frozen" and "vision." He uses all kinds of water to create these frizions. He collects rainwater in buckets. He draws tap water from his faucet. He freezes the water and then tinkers with it to achieve various results, adding extra water to the forming ice to facilitate the process, for example. The ice samples are set in petri dishes, which are then sandwiched between polarizer sheets on a light table. As the ice forms and melts, he watches light interact with it and captures the images on a digital camera.

In nature, the components of ice produce very different colors and shapes. "White" ice, for example, is loaded with bubbles, scatters a great deal of light and produces fewer colors. Ice from waterfalls has finer grains than ice plucked from a lake, and therefore light interacts with it differently, Wasilewski said.

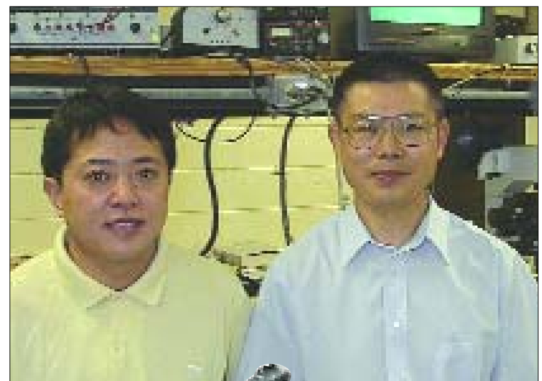
Even in Wasilewski's homemade ice, each piece has a different personality when it interacts with light. Wasilewski's grown son has taken on the job of naming each photograph: "Dreamcatcher," "Quest of the Apoidea" and "Newmorning Dragon," for example.

Wasilewski's images have been on display at the Goddard center and online, at www.frizion.com. He described his art form during a lecture at the National Museum of Natural History in Washington, D.C., in late June.

"I think it was a good presentation for a number of reasons," said Bevan French, a research collaborator with the Smithsonian Institution. "This is really kitchen table science, with very little technical material. Also, everybody knows about ice. It's a marvelous material, and you can go into all sorts of areas of science. And the exciting thing is that he's actually doing science and art at the same time." See one of Wasilewski's frizions by turning to the "After Image" on page 56.

Combining Tweezers and Spectroscopy

Single beam optical tweezers have been used to capture and manipulate beads and various other transparent particles. A new system uses a combination of tweezers and Raman spectroscopy to study the chemical composition of living particles, including cells, bacteria and chromosomes.



Yong-qing Li (*right*) and Changan Xie have been working on their optical tweezer/Raman spectroscopy system for three years.

"We have combined two technologies into one unit," said Yong-qing Li, a physics professor at East Carolina University, where the research was conducted. "It allows you to use one laser beam to capture moving biological particles. Spectroscopy allows you to identify what you've captured."

Li and Changan Xie reported their findings in June at the Conference on Lasers and Electro-Optics/Quantum Electronics and Laser Science. The tweezers, which use a near-infrared beam, could be employed at 690 nm or 785 nm to capture a particle and immobilize it for an hour. A laser beam is used by the spectroscopic part of the system to generate vibrational spectra of the particle.

"It allows for the rapid identification of microorganisms in the water, air, in biochemical weapons or toxic microorganisms," Li said. But the system also could be applied to highly refractive, absorptive and reflective non-biological particles, such as semiconductor powders or soot dust in the environment.

The team is working to make the system more compact; ideally, it could be used on a desktop, Li said.

"In general, the ability to simultaneously manipulate a biological system with optical tweezers and sense molecular composition with Raman spectroscopy is very exciting," said Mary-Ann Mycek, a professor in the department of biomedical engineering at the University of Michigan. "As their technology improves and data acquisition times shorten, opportunities for functional studies in living systems should arise."

DID YOU KNOW?

The number of first-year physics graduate students is on the rise at American universities, according to an American Institute of Physics study. The number of first-year physics/astronomy students in 2000 (2,697) was 5 percent higher than the recent low in 1997. Chinese students made up the largest single international component, at 25 percent. About 64 percent of the foreign students attending American schools were 24 or older when they began physics graduate programs, whereas among American students, only 41 percent were older than 24.

Ekmel Ozbay (*left*) and Ertugrul Cubukcu are part of a team working in negative refraction by photonic crystals.

New Possibilities Through Negative Refraction

Researchers at Bilkent University in Ankara, Turkey, have made what is thought to be the first demonstration of negative refraction of electromagnetic waves in a two-dimensional dielectric photonic crystal.

The team, which also included scientists from Iowa State University and the University of Crete, believes the work is a step toward the development of a "superlens" that could focus features smaller than the wavelength of light.

"There is no easy way to measure the field inside the crystal," said Bilkent's Ekmel Ozbay, who worked on the project. "You'd have to probe the material, which is impossible. Instead we looked at the field out of surface of the crystal."

The team's structure included a square array of alumina rods in air. To obtain negative refraction, the group needed equal-frequency surfaces for the crystal that were both convex and larger than those for air.

Researchers at the Massachusetts Institute of Technology predicted that the experiment could be done in three dimensions, and the Bilkent group is working on achieving this, Ozbay said.

The experiment could be scaled up to optical wavelengths, Ozbay said. The negative-refraction effect depends only on the refractive index of the dielectric material and on the geometric factors used in two-dimensional crystals, according to a *Nature* paper on this topic. "That's the beauty of our research. … The problem with conductors is that the absorption becomes a very big issue in optical wavelengths. Our material is completely non-conductive. We don't use any metals."

Still, "we don't have the microfabrication facility to show [this result]," he said. "Hopefully someone else will follow our research. There is no limitation."

The negative refraction work is significant for several reasons, said David Smith, a physics professor at the University of California, San Diego. "The first is that the structure is made only of dielectric material, and thus can be scaled to the optical. The second is that it is an experimental confirmation that effective refraction can be observed in a periodic structure, which usually displays diffractive-like behavior. … This work now opens the possibility that the interesting and compelling behavior predicted for negative refractive materials may be scaled to much shorter wavelengths—even optical."

Articles in "Scatterings" are written by Kim Douglass, assistant managing editor of *Optics & Photonics News*. Do you have a story idea? Write her at kdougl@osa.org.