Laser spotlights molecular choreography

Molecules pack more dancing action into 1 second than the cast of "A Chorus Line" could muster in a century's worth of performances. In less time than it takes to say "off-off-Broadway," a two-atom molecule such as iodine can perform about 10 billion rotations. Moreover, during each high-speed somersault, the atomic partners oscillate toward and away from each other about 1,000 times.

But even these dance steps aren't too fast for the scientific eyes of three physical chemists of the California Institute of Technology in Pasadena. Using some of the world's fastest laser pulses as though they were flash bulbs for freeze-framing molecular motions, Ahmed H. Zewail, Marcos Dantus and Robert M. Bowman have captured in detail the individual rotations and vibrations of iodine molecules. The studies provide basic experimental data to check the accuracy of theoretical pictures of molecular motions, which rely on quantum mechanical calculations.

The laser observations work like photography, notes chemist Ian W.M. Smith of the University of Birmingham in England, whose commentary accompanies the researchers' latest report in the Feb. 22 NATURE. Just as a photographer has to use a shutter speed of one-thousandth of a second or less to snap clear pictures of a sprinter moving at 10 meters per second, chemists seeking clear "pictures" of fleeting molecular rotations and oscillations must use light pulses that are shorter than the time required for the motions, Smith explains.

Zewail's group uses laser pulses that last about 10 femtoseconds, or 10 quadrillionths of a second. A femtosecond is to a second as a second is to roughly 32 million years.

Since 1987, Zewail has used femtosecond laser observations to observe simple reactions in which a chemical bond breaks (SN: 9/24/88, p.203). The new work represents the first observations of atomic motions in bound systems like iodine molecules. Since so much of the natural arena involves dancing molecules, "to be able to see molecular motions as they happen is as fundamental as it gets," Zewail told SCIENCE NEWS. Practical applications aren't even on a back burner.

"It's the first time we've ever been able to see that kind of thing," adds chemist James L. Kinsey of Rice University in Houston. "I think it will influence the way people think about these processes for a long time."

To observe and monitor molecular vibrations, the Caltech researchers first use a "pump pulse" to inject energy into the molecules. Then these primed pairs of atoms in vibrating molecules can absorb a second pulse, called a probe pulse, lasting several femtoseconds. After soaking up this extra energy, they fluoresce (emit photons) as they relax to lower energy states. By monitoring the laser-induced fluorescence over picoseconds of time (trillionths of seconds), the researchers can assemble a detailed picture of the molecules' simple or complicated vibrations.

Even though molecular rotations are a thousand times slower than the vibrations, observing them requires more finesse. To get fluorescence signals clean enough for reliable interpretation, the first laser pulse must both excite the molecules and align their spins in a common spatial plane. To do this, the researchers use polarized laser pulses, which energize only those molecules whose axes happen to coincide with the angle of polarization. Jolting the molecules with the second laser pulse yields a fluorescence pattern that reveals, among other things, the number of distinct rotational speeds present in the population of aligned spinning molecules.

Zewail predicts the development of even speedier laser pulses in the future, and notes that sub-femtosecond observations may reveal yet another realm of molecular behavior. Nonetheless, he says, touring chemical reactions and molecular motions with femtosecond pulses should prove a fruitful pastime for many years to come. *– I. Amato*

Hints of El Niño surface in Pacific Ocean

Changing climate conditions in the central Pacific, where an El Niño warming appears to be brewing, could cause abnormal weather in many regions of the world during the next year and may bring some eventual relief to drought-plagued southern Florida, more than 6,000 miles away from that portion of the Pacific.

"We're seeing signs that [an El Niño] could be getting started. Whether or not these features will persist for a sufficient amount of time so that it will develop into an El Niño – that is still a point in question," says Vernon Kousky of the National Weather Service's Climate Analysis Center (CAC) in Washington, D.C., which released an El Niño/Southern Oscillation advisory on Feb. 16.

El Niños, which are related to an atmospheric pressure phenomenon known as the Southern Oscillation, bring abnormally warm water to the central and eastern equatorial Pacific – a condition that wreaks widespread changes in the world's weather. During the century's strongest El Niño in 1982-83, India and Australia suffered droughts while heavy rains pounded the west coast of South America. Mike Halpert of the CAC says that in the United States, El Niño events typically increase rainfall over Florida and the Gulf Coast, so southern Florida's dwindling freshwater reserves could benefit if an El Niño materialized over the next year.

El Niño oceanic warmings typically last 12 to 15 months and recur on average about four to seven years apart. After the last El Niño, which ran from mid-1986 through late 1987, the central Pacific turned abnormally cold as part of a climate pattern recently dubbed La Niña, whose weather effects generally contrast with those of an El Niño. When the La Niña started dying out in late 1988, ocean temperatures in the central Pacific began to rise toward normal.

The CAC advisory notes that several developments in recent months could herald the start of another warm phase. Sea-surface temperatures have risen significantly, and the equatorial trade winds, which travel east to west, have weakened. Under normal conditions the trade winds push warm surface water toward the western Pacific and keep the central and eastern portions cooler than the west. But a significant reservoir of warm water is now building in the central Pacific and may spread eastward if the trades remain weak, Kousky says.

Most climate researchers agree it is too early to tell whether a full-blown El Niño will develop. "The next two or three months are going to be a crucial time," says Maurice Blackmon of the National Oceanic and Atmospheric Administration's Environmental Research Laboratory in Boulder, Colo.

An El Niño this year would contradict several computer models that had shown promise in forecasting previous warmings. For instance, three models in the United States predicted the last El Niño three to nine months before the warming began, yet the same models currently predict that near-normal conditions will persist in the tropical Pacific for at least the next few months. One of these, a "dynamical" model at Columbia University's Lamont-Doherty Geological Observatory in Palisades, N.Y., is "predicting more or less normal conditions for the next year," says Mark Cane of Lamont-Doherty. However, a statistical model at the Max Planck Institute for Meteorology in Hamburg, West Germany, does forecast a warming for this year, Blackmon says.

If an El Niño does develop soon, it could signal some flaws in the design of the three U.S. models. Alternatively, Blackmon says, the unsuccessful predictions may stem from a lack of sufficient input on wind speeds in the remote ocean, which are measured by ships, island stations, buoys and other sources scattered sparsely over the region.

– R. Monastersky