Charles Shank at the Lawrence Berkeley National Laboratory (LBNL) in California reported producing x-ray pulses lasting just 300 femtoseconds (or 3/10 of a picosecond) by firing near-infrared laser light across an accelerated beam of electrons; the energetic electrons essentially give the infrared photons a kick, boosting them to x-rays (*Science*, 11 October 1996, p. 236). The LBNL team has yet to produce images with its ultrashort, but as yet relatively low-flux, pulses. But "ultimately, we want to be able to look at chemical reactions as they occur," says Shank.

No matter how short, x-ray pulses will still miss plenty of action, such as reactions in gases rather than in solids like protein crystals. That's because x-rays interact only weakly with atoms: Generally, researchers need huge numbers of atoms lined up in crystals to deflect enough x-rays to provide high-quality images, explains Ahmed Zewail, a physicist at the California Institute of Technology (Caltech) in Pasadena. So Zewail and other moviemakers interested in tracking chemical reactions in gases have turned to short pulses of electrons, which interact with atoms more readily than x-rays do.

While electron-diffraction experts have also been making movies for years—in this case of gas-phase chemical reactions—techniques here, too, have been advancing rapidly. In the 13 March issue of *Nature*, for example, Zewail and his Caltech colleagues reported making the fastest paced electron-diffraction movies to date by shortening their electron pulses about 1000-fold, from several nanoseconds to about 10 picoseconds, using a femtosecond light pulse to create short bursts of electrons that were then focused on their target.

The Caltech team shot movies of molecules as they are torn apart by laser light. To do so, the researchers first used a laser to fire a pulse of photons into a vacuum chamber filled with a methane derivative containing two iodine atoms. The photons began breaking apart some of the methane molecules—essentially starting a reaction stopwatch. A second pulse, fired a fraction of a second later, hit a metal-coated cathode ray tube, stripping away the electrons and creating an ultrashort electron pulse, which was channeled into the vacuum chamber to produce a diffraction image of the dissociating methanes. In this case, those images don't reveal the exact position of each atom, because molecules in a gas are oriented randomly and are not lined up like those in a crystal. Nevertheless, because all the molecules have the same constituent atoms, the diffraction images are able to reveal the precise distance between atomic neighbors within the molecules.

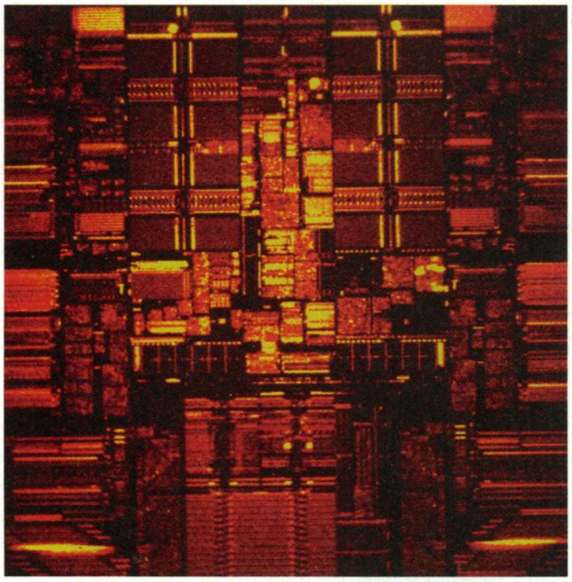
Buoyed by this success, the Caltech researchers hope to do even better. At this point, the movie only shows the methanes just before and after they break apart. To capture the bonds in the process of breaking will require shortening the pulses another 1000-fold, says Zewail's postdoc Jianming Cao. Nevertheless, says Carl Lineberger, a chemist at the University of Colorado, Boulder, "it's very exciting to see people taking steps toward seeing electron diffraction in real time." That excitement will undoubtedly grow if, as expected, the number of new movie releases begins to take off.

–Robert F. Service

MICROELECTRONICS

Catching Speeding Electrons in a Circuit City

Take a long-exposure aerial photograph of a city at night, and you will see traffic patterns traced in the bright streams and dense clusters of car headlights. The image (right), obtained by a team of researchers at the IBM Thomas J. Watson Research Center in Yorktown Heights, New York, is the equivalent shot of a functioning microprocessor, the 1997 S/390 used in the current generation of IBM mainframes. The "traffic" consists of electrons emitting light as they pass through the transistors, or crossroads, of this silicon city. By directly viewing such traffic patterns, circuit designers can look for weak spots and bottlenecks in the millions of components on a chip.



IBM

"Researchers have known since the 1980s that electrons emit light as they pass through the field-effect transistors [FETs] at the heart of most modern microchips," says Jeffrey Kash, of the IBM team that made the images. The light, which is in the near infrared and is extremely weak, can be detected only with cooled charge-coupled devices or special photomultiplier imaging tubes. Kash and his colleague James Tsang investigated this particular microprocessor because it consumed two orders of magnitude more current than it should have when it was not performing any operations. Kash and his colleagues obtained images of the chip in this "quiescent" state that showed a series of spots indicating that this excessive current was confined to a small portion of the chip. They couldn't tell which of the 7.8 million transistors were at fault, however, because they couldn't identify individual transistors in their images. "The issue was, how do you know where you are, how do you navigate," says Kash.

The team solved the navigation problem by spying on the individual FETs as they shuttled electrons around the chip when it was operating normally. "The only time a current is flowing is when you have a change of logic state," says Kash. The FETs produce picosecond light pulses as they switch on and off, so by photographing the chip in normal operation, Kash and his colleagues obtained a "road map" of the positions of the FETs. When the researchers superimposed this image on the photo showing the excess leak currents, they pinpointed exactly where the leaks occur.

The technique is useful for more than troubleshooting. "We can look at hundreds of thousands of FETs on a chip," says Kash, "and that is very helpful" in improving the design of subsequent chips. Indeed, Ingrid De Wolf of IMEC, Belgium's Interuniversity Microelectronics Center in Leuven, says optical-emission diagnosis of chips is beginning to spread throughout the microelectronics industry. Researchers are going beyond simple imaging, she adds: "We are now also trying to get more information from the spectrum of the emitted light, so we can measure the energy of the electrons."

–Alexander Hellemans

Alexander Hellemans is a science writer in Paris.