# Electrons may shed light for X-ray lasers

Invoking a well-known effect in quantum mechanics to answer a nagging question about electron behavior, physicists believe they may have found a recipe for making the first small X-ray lasers.

X-ray lasers, invented in 1984, can serve as powerful weapons or as scientific tools to probe the details of viruses and other molecules, but current models require hundreds of feet of laboratory space.

The new research clarifies a phenomenon noted in the 1940s: Electrons of a certain energy beamed at a metal diffraction grating produce unusually intense radiation. In the decades since, researchers have reasoned that the electrons emit the light as they pass near the diffraction grating and induce currents on its surface. Other scientists have theorized that the "braking radiation," or bremsstrahlung, emitted by electrons as they slam into a solid object could account for the intense light.

But experiments conducted over the past year by I-Fu Shih and his co-workers at the Hughes Aircraft Co. in Long Beach, Calif., show that the electron-generated light is 10,000 times more intense than induced surface currents can explain and 100 times more intense than predicted by the bremsstrahlung theory. "We wondered, 'What in the world is happening here?' " recalls David B. Chang, who collaborated with Shih on the yet-unpublished work.

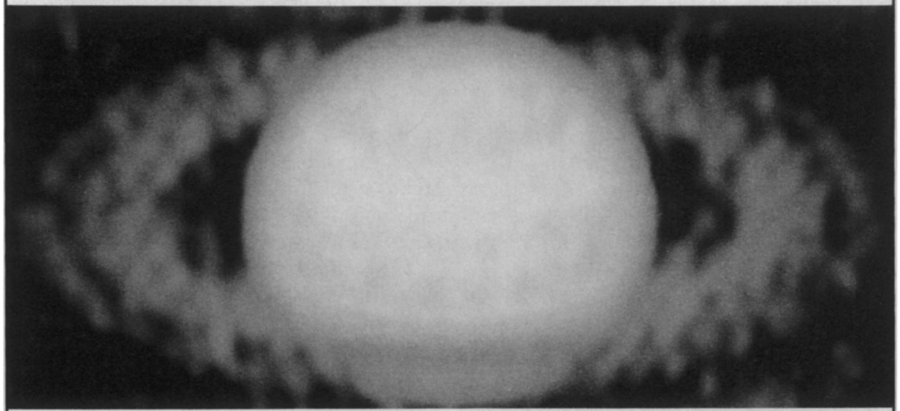
The answer may lie in a fundamental effect of quantum mechanics, suggest Chang and James C. McDaniel in the Sept. 4 Physical Review Letters. According to quantum theory, all particles, including electrons, have a wave-like nature. Thus, when an electron travels through a wall with two slits, its wave passes not just through one slit or the other but through both. The wave-like electron emerges from both slits and interferes with itself, creating a pattern of bands of high and low electron density. This scenario reflects in miniature what happens when electrons impinge on the hundreds or thousands of slits in a diffraction grating, Chang says. A single electron then generates an interference pattern from all the slits simultaneously, greatly amplifying the two-slit interference effect. Chang and McDaniel propose that this phenomenon accounts for the intense radiation observed.

They note that Shih's group exploited the radiation to produce a tiny laser, known as a free electron laser, using a low-energy electron beam and a 3-centimeter grating. Chang and McDaniel calculate that with a smaller-spaced diffraction grating or a more energetic electron beam, scientists could use the same phenomenon to make a compact X-ray laser.

The interference effect relates to one of two steps necessary for electrons to produce a free electron laser, they explain. In the first step, electrons striking the grating produce bremsstrahlung radiation. But because of the grating's multislit structure, this radiation peaks at a particular frequency and travels mostly in one direction — two properties that help produce laser light. Next, the bremsstrahlung interacts with electron wave functions above the grating surface, their spatial pattern determined by their interference with the grating slits. That interference-induced pattern enables the bremsstrahlung to stimulate the electrons to produce even more radiation with the same frequency and direction. "You have one photon that causes several more to be produced," Chang says. Such a coherent cascade of optical photons creates a free electron laser.

John M. Madey, who in 1977 invented the first free electron laser, says he remains unconvinced that the grating concept can yield an X-ray laser. The electron velocity and density distributions Chang uses may not be possible in the laboratory, argues Madey, a physicist at Duke University in Durham, N.C. But regardless of X-ray potential, he says, using a diffraction grating to produce laser light "is a damn clever idea." — *R. Cowen*

# Mapping deeper within Saturn's clouds



Grossman et al.

The world knows the spectacular whorls, streaks and stripes that bedeck the atmospheres of Jupiter, Saturn and Neptune from the photos taken by the Voyager and Pioneer spacecraft. But are those complexions only skin deep, overlying smoother features farther down in the atmosphere? Three space scientists report signs that, in the case of Saturn at least, not all the atmospheric action is on top.

The researchers, from the California Institute of Technology in Pasadena, recorded the planet's microwave radio emissions at wavelengths of 2 and 6 centimeters in 1986. They used the National Radio Astronomy Observatory's Very Large Array near Socorro, N.M., a complex of 27 separate dish-shaped radio antennas. Other scientists have studied Saturn's microwave emissions in the past, but the newly reported data represent what the Caltech scientists call "the ultimate in resolution and sensitivity obtainable from Earth-based radio telescopes."

The emissions come from ammonia in Saturn's atmosphere, most of it near the top. The new results, however, indicate that the atmosphere below the clouds has a region depleted in ammonia, revealing an area of warmer temperatures across the planet, says Arie W. Grossman, who reports the findings with Duane O. Muhleman and Glenn L. Berge in the Sept. 15 Science.

The band is well known at visible wavelengths from Voyager photographs, Grossman points out, but the new data "suggest that the bands which you see in the visible aren't just variations in the clouds." The authors maintain that the dark band detected in the radio data, centered at about 35° latitude in the northern hemisphere, represents "a region of ammonia clearing, which allows us to see to deeper, hotter temperatures."

"Actually," Grossman says, "we were quite surprised to observe this. Until these observations, the general notion was that these features were all cloud-top features." During much of the three years since the observations, the researchers have labored to reduce the "noise" in their data, due in part to the equipment and in part to scintillations in Earth's atmosphere. Berge says this is "the first radio map of Saturn that shows detailed latitude variations. Previous observations had indicated only a slight north-polar warming."

Grossman, Muhleman and others say they hope Congress funds a proposed spacecraft called Cassini, to be launched in 1996 and to arrive in orbit around Saturn with a microwave radiometer in 2002. — *J. Eberhart*