or from some compound created by the etching process.

To find out whether silicon itself can luminesce, researchers need a supply of pure silicon clusters. At the conference, Brus and his colleague Karl Littau described a technique for making them from a gaseous compound of hydrogen and silicon: Heat the gas until it decomposes to form a haze of pure silicon clusters. Heath, in contrast, forms his clusters in solution. He heats a solution of silicon-chlorine compounds to high temperatures, then adds sodium metal to the reaction vessel. The sodium snares the chlorine, forming table salt and leaving behind silicon atoms that gather into clusters.

The verdict on luminescence: Brus' pure silicon clusters, at least, do sparkle, suggesting that the glow of his silicon really is a quantum effect in the element itself. Brus is confident only of his own samples, not necessarily of the porous silicon tested by others. But silicon's star seems to be on the rise.

–Anne Simon Moffat

TECHNOLOGY

An Everyman's Free-Electron Laser?

Some lasers generate their light in a crystal, others in glass, gas, or semiconductors. Still others, so-called free-electron lasers, generate light from a beam of electrons, usually by snaking it through a gauntlet of magnets. Now recent research suggests that still another kind of laser may be on the horizon: a free-electron laser (FEL) in which far-infrared light would be coaxed from a washboard-shaped metal surface by a beam of electrons zooming just above it.

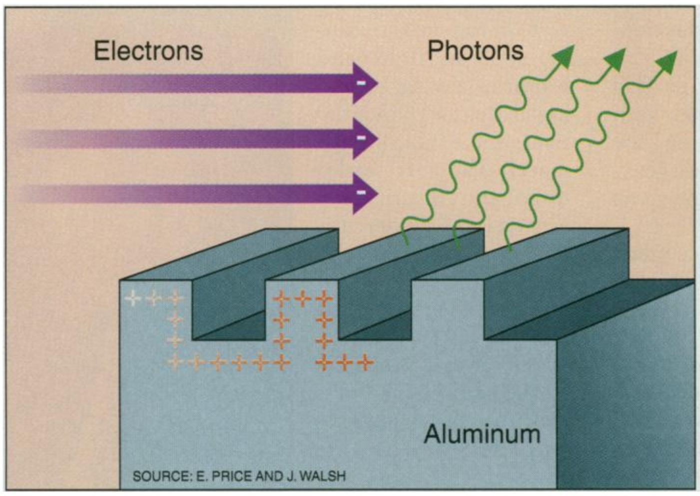
The researchers—Dartmouth College physicist John Walsh and his colleagues at the Universities of Oxford and Essex—have so far succeeded only in generating the infrared light, not in amplifying it into a laser beam. But if they can transform their basic research, reported in the 21 September *Physical Review Letters*, into a working laser, they will have equipped researchers in many fields with a powerful new tool. Since most kinds of lasers can't generate coherent, intense beams of far-infrared light, the promise of this spectral region for such areas of science and technology as chemical analysis and surgery has remained largely untested. Only FELs can open the blinds on this region, but they have been off limits to most researchers because of their size and cost.

Walsh and his colleagues speculated that a phenomenon first observed 40 years ago, known as Smith-Purcell radiation, might bring FELs within reach. In conventional free-electron lasers, an intense beam of electrons from an accelerator passes through a periodic magnetic field, or a wiggler. As the electrons wiggle through the field, they emit radiation at wavelengths that depend on their velocities, enabling researchers—in principle, at least—to tune the laser to virtually any region of the spectrum, including the far infrared. But that advantage has been offset by the size and complexity of an FEL's accelerator and wiggler.

Smith-Purcell radiation could pave the way to an everyman's FEL, Walsh says, because it eliminates the wiggler. The principle is straightforward. Electrons speeding above a metal grating induce an oscillating charge in the grating, which, in turn, emits radiation, much as a stick dragged over a washboard generates a rat-a-tat sound. And like the radiation generated by a conventional FEL, Smith-Purcell radiation can be tuned—in this case by adjusting the period of the grating or the velocity of the electrons passing over it.

Previous experiments by other workers had produced Smith-Purcell radiation at visible wavelengths—but at intensities far too low for a laser. Walsh, John Mulvey of Oxford, and their colleagues reasoned, however, that they could generate more intense far-infrared radiation by increasing the energy of the electron beam. When they commandeered an obsolete Van de Graaff electron accelerator at Oxford and used it to fire electrons over an aluminum grating at nearly the speed of light, they observed a broad range of far-infrared Smith-Purcell radiation. The intensity, they say, was satisfyingly high—roughly one-tenth the far-infrared intensity generated by synchrotrons, massive accelerators in which electrons emit radiation as they speed around a ring.

Turning that success into a far-infrared FEL, Walsh admits, will require several advances. For one, since the grating emitted radiation at many different wavelengths, each going off at a different angle, it was not behaving like a laser, which gives off radiation at only one or a small ensemble of wavelengths. The solution: Flank the grating with mirrors that would capture a specific wavelength and send it back and forth over the grating. Theoretically, Walsh says, this arrangement should, in laserly fashion, stimulate the grating to emit more radiation at exactly the same wavelength, thereby amplifying it. A tiny hole in one of the mirrors would allow the amplified coherent radiation to stream out as a laser beam for research or technical jobs.



C. FABER SMITH

Ripple effect. As electrons speed over a corrugated metal surface, they induce "image" charges, which oscillate and emit radiation.

Another must is to miniaturize the apparatus. Even though the setup did away with the bulky magnets of a conventional FEL, it did include an accelerator that towers several stories—not exactly standard lab bench equipment. But calculations suggest to Walsh and his colleagues that a compact linear accelerator (linac) a few meters long could elicit far more intense far-infrared radiation from a grating than the Oxford accelerator was able to generate. Walsh says he is already arranging with Robert Palmer, director of the Center for Accelerator Physics at Brookhaven National Laboratory, to test those calculations with a real linac.

If all of this effort ever yields a no-frills benchtop FEL, says Harvard University chemist William Klemperer, it could give chemists a better means of probing weak and experimentally elusive intermolecular interactions such as the hydrogen bonding between water molecules. Such a laser might also serve military or medical roles—as a means of sizzling sensitive electronic components on missiles, say, or as a laser bone saw—adds Phillip Sprangle, head of the beam physics branch of the Naval Research Laboratory in Washington, D.C., who is also trying to develop compact FELs. Physicist Frank Delucia of Ohio State University speculates that a powerful beam of far-infrared radiation could even serve for remote sensing and air traffic control, since such radiation is little affected by clouds and haze. If a small, inexpensive FEL were available, concludes Klemperer, "I would buy one."

–Ivan Amato