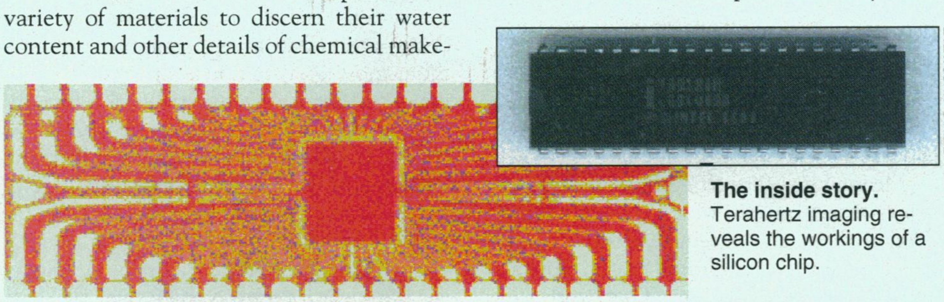
Scenes From a Marriage—Of Optics and Electronics

BALTIMORE—Exploring the common ground between optics and electronics, more than 6800 physicists, spectroscopists, and engineers gathered here from 21 to 26 May at the joint meetings of the Conference on Lasers and Electro-Optics and the Quantum Electronics and Laser Science conference. Participants unveiled new technologies that have sprung up on this common ground, such as an imaging technique that can gauge the chemical composition of materials. They also described ways to broaden that ground, such as a novel approach for integrating lasers and silicon chips—a challenge that has slowed progress toward a new generation of high-speed computers and communications.

Make Way for T-Rays

It may not rival Superman's X-ray vision, but T-ray imaging still has a pretty penetrating gaze. Unveiled at the meeting by a pair of researchers from AT&T Bell Labs in Holmdel, New Jersey, the new apparatus, unlike the Man of Steel, can't see through steel vaults or under rivers. But it can peer into a variety of materials to discern their water content and other details of chemical make-up—an ability that could be valuable for activities ranging from medical diagnosis to environmental monitoring.



MARTIN C. NUSS/AT&T

The inside story. Terahertz imaging reveals the workings of a silicon chip.

"It's very promising," says David Auston, a T-ray spectroscopy pioneer and provost at Rice University in Houston, Texas. "It involves a totally new region of the [electromagnetic] spectrum for imaging. So there's a good chance people will be able to get information using this technique not available from other imaging techniques."

The technique, formally known as terahertz imaging, probes materials with short pulses of electromagnetic waves at a frequency of 0.1 to 3 terahertz, or trillions of cycles per second. These T-rays span the range from high-frequency microwaves to low-frequency infrared, well below the wavelengths of visible light. They are good for imaging, says team leader Martin Nuss, because "each material changes the terahertz pulse in a very characteristic way." Liquid water, for example, strongly absorbs high-frequency T-rays and stretches the pulse over time, giving it a characteristic shape, says Nuss.

T-rays haven't been exploited for imaging until now because of limitations on signal strength and detector sensitivity; recording enough clear signals to assemble an image required days. But by boosting the power of the T-ray generators, the sensitivity of the detectors, and the speed of the signal processing and analysis, the Bell Labs researchers shortened the time needed to create an image to minutes.

To make the T-rays, the researchers fire ultrashort infrared laser pulses at a tiny semiconductor structure known as a dipole antenna. As the light hits the semiconductor, it generates an electric current that radiates T-rays from the antenna. A lens then focuses these T-rays to a fine point, which is then scanned over the material to be imaged. Another lens collects the rays as they emerge from the other side of the target and focuses them on a detector, which determines the shape of each T-ray pulse. Each pulse shape is digitized and fed into a computer that compares it to stored templates to identify the chemical composition of the material at each point, or pixel. As the scan progresses over a couple of minutes, tens of thousands of pixels are assembled into an overall image.

Because water is such a strong absorber of T-rays, the technique can image water-rich materials such as biological tissues only in slices a millimeter or less in thickness, says Nuss. That means T-ray imaging isn't likely to replace X-rays and other scanners for whole-body imaging. But Nuss says he and his colleagues plan to investigate whether it could serve as a laboratory diagnostic technique, distinguishing cell types based on water content.

The researchers also believe T-rays could analyze gases in industrial smokestacks and perform other environmental monitoring tasks. "Many gases are strong absorbers in this range," says Nuss, which should make it easy for T-rays to pick out trace amounts of many gases at the same time. That feat is beyond existing analytical techniques, so an imaging system that could accomplish it would be heroic indeed.

Paint-On Lasers

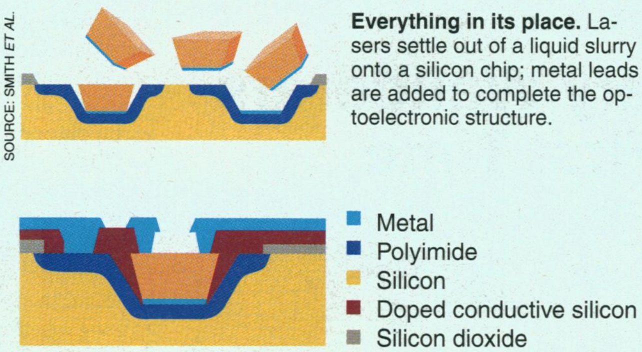
Many a technophobe knows the frustration of trying to hook up mismatched electronic components—and old-fashioned TV and a VCR, say. Optoelectronics researchers don't fear technology, but they do experience a similar frustration. They are developing tiny lasers and detectors that should speed the flow of electronic information between computer chips by converting it into light pulses and transmitting it optically. But because the optical components and silicon microchips are made of different materials, it can be difficult and expensive to integrate them into a single structure.

At the Baltimore meeting a team led by electrical engineer John S. Smith of the University of California, Berkeley, and his graduate student Jay Tu reported a finding that may ease the frustration. It's a faster, simpler way to hook up microscopic lasers to silicon devices: Just douse the silicon with a liquid carrying the lasers and allow them to settle into place on the device's surface. "It's an intriguing process," says Kent Choquette, a lasermaker at Sandia National Laboratory in Albuquerque, New Mexico. "It looks like it's scaleable to making thousands of wafers [at the same time]."

The frustration arises because semiconductor alloys such as gallium arsenide, which are the stuff of optical components, have a crystal structure that differs from that of the silicon in ordinary chips. This atomic-scale incompatibility makes it extremely difficult to grow the optical devices on the silicon chips as part of the same manufacturing process. The alternative—making the optical and electronic components separately and assembling the pieces one by one—is slow and expensive.

The new technique, called fluidic self-assembly, gets around this problem with a solution reminiscent of the childhood game in which a player tries to steer a series of ball bearings into matching holes on a palm-top game board. In this case, the ball bearings are grain-sized semiconductor lasers that resemble tiny pyramids with their tops lopped off; the holes are divots with a matching shape, carved in a silicon wafer.

To place these lasers in their slots, the researchers simply mix them with ethanol to make a slurry and swish it over the silicon wafer for a few minutes. Bit by bit, the lasers drop into the holes. "When the lasers go in properly, they stay," says Smith. If they land on their sides or upside down, they don't sit flush and can be swept out again by the moving fluid. Once the lasers are in place, the wafers are heated, melting metal layers on the floor of the divots and the base of the lasers to bond the lasers in place. Conventional semiconductor processing techniques then add metal leads to carry electrical impulses from the chip to the lasers.



SOURCE: SMITH *ET AL.*

Everything in its place. Lasers settle out of a liquid slurry onto a silicon chip; metal leads are added to complete the optoelectronic structure.

Still, says Choquette, the Berkeley group faces some hurdles, among them showing they "can get all the [lasers] in the little holes and get them to work." In past experiments with dummy blocks instead of real lasers, the researchers filled more than 99% of the holes with the help of a pump designed to move the ethanol-block slurry across the openings. That device worked well when there was a lot of slurry and many openings for the blocks to drop into. But it couldn't be used in the current experiment, because the expense of making the lasers limited the researchers to using a smaller number of them—and therefore less slurry. At the same time, the chip contained fewer holes, to give it a closer resemblance to potential optoelectronic chips. The result was a much lower success rate: 10%.

To improve their hole-filling rate, the researchers are developing a new pump and ultrasonic agitators to shake the fluid, says Smith—the same technique that improves the odds with ball bearings. If the group succeeds, integrating optics and electronics may soon become child's play.

–Robert F. Service

ASTRONOMY

Radio Galaxies: Born in Cosmic Crackups?

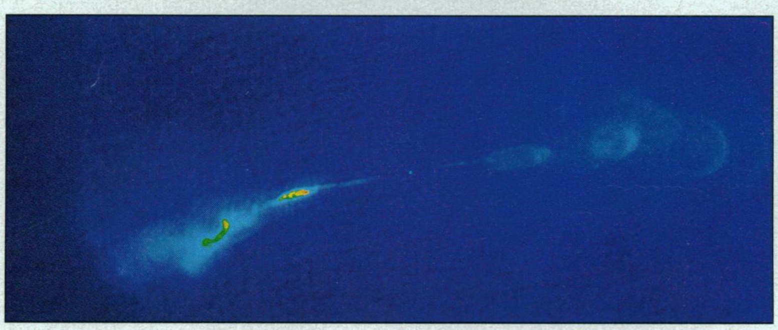
For decades, astronomers have been tuning in to some of the most powerful radio beacons in the universe without fully understanding their message. The broadcasts come from objects called active galactic nuclei (AGNs), which nestle at the centers of galaxies and pour out far more than their fair share of visible and ultraviolet light and x-rays.

In some instances, these strange objects—the brightest of which are known as quasars—emit intense radio waves as well. But not all; some AGNs are silent at radio wavelengths. The neat division between radio-loud and radio-quiet is a puzzle that "hits you in the face," says Caltech astronomer Roger Blandford, and it deepens the mystery of what turns on the cosmic radio stations. Now Andrew Wilson and Edward Colbert of the University of Maryland, College Park, have come up with a dramatic answer.

Last week at the American Astronomical Society meeting in Pittsburgh, the two astronomers proposed that radio-emitting AGNs, or radio galaxies, are the progeny of colossal cosmic accidents. The researchers propose that the radio broadcasts begin after two radio-quiet AGNs collide and giant black holes at their centers, each millions of times as massive as the sun, whirl around each other and coalesce into a single fast-spinning black hole. That scenario, they say, explains why radio-loud AGNs are comparatively rare and why they are found almost exclusively in elliptical galaxies, thought to be the product of collisions, and never in spirals. "What attracts me to [the theory]," says Blandford, "is that it makes rather strong contact with the observations."

Wilson and Colbert build on earlier explanations of a key feature of radio galaxies: spectacular jets of ionized gas that spurt millions of light-years from their centers and act as giant radio transmitters. The jets, say Blandford and some other theorists, are one expression of the black holes that are widely believed to power AGNs and quasars. In all AGNs, theory says, the black hole draws material from the surrounding galaxy into a disk. From there, the gas gets sucked gradually into the black hole, generating brilliant light and other radiation. If the black hole is spinning, according to Blandford and others, it can interact with magnetic fields generated by the disk to fire huge jets of plasma into space along the spin axis, transforming the AGN into the radio-loud variety.

DAVID MALIN



NRAO/AUI/PHOTO RESEARCHERS

A big turn-on. Radio galaxies like Hercules A, whose vast jets of plasma are visible in an image *(above)* from the Very Large Array in New Mexico, may be the offspring of colliding galaxies like the Antennae galaxies at top.

That picture left open the question of where the spin came from. Wilson and Colbert's new theory tries to fill that gap by attributing the spin to an earlier collision between two AGNs. Wilson and Colbert realized that black holes at the centers of colliding spiral galaxies could be "spun up" by the angular momentum created as the black holes circled each other before merging. The larger black hole resulting from the merger would then inherit the spin.

The picture would explain why radio-loud AGNs are "never, never, never, never, never [found] in a spiral galaxy," says Wilson, as collisions inevitably convert spirals to ellipticals. At the same time, it can explain why not all ellipticals are radio-loud: Only when the parent black holes have about equal masses will they produce a spinning "daughter," says Wilson, because "if a little black hole falls into a big black hole, it doesn't give the big one much angular momentum."

Still, Blandford says, there are plenty of alternative theories—such as the idea that concentrations of normal stars simply block the jets in some AGNs and not others. Only further observations of the stars and gases in galactic centers will settle the issue, says Blandford. Until then, astronomers will be tuning in without quite catching on.

–James Glanz