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Research sheds light on opto-electronics

By Jon Van

University of Illinois researchers in Urbana put rust on advanced optical computing chips to make them work significantly better.

In Chicago, University of Illinois faculty etch a multitude of tiny holes on the surface of silicon chips, making them emit light, a development that might have far-reaching commercial applications.

And in Evanston, Northwestern University scientists have for the first time built tiny lasers made from exotic materials onto a base of silicon, a difficult technical feat that could advance the marriage of optics and electronics.

These achievements and numerous others around the country this year herald impressive advances in technology that combines particles of light with electricity in making devices that process and communicate information in denser packages and at greater speeds.

But impressive as these fundamental scientific achievements may be, a nagging question lingers in the background: When will these advances make their impact in the marketplace?

At a time when policymakers in government and industry are taking a hard look at their traditional relationship with university-based scientists, assessing how it might change to improve American competitiveness, the opto-electronics research experience provides an instructive case study.

At least some scientists from industry believe their university colleagues spend too much time chasing "gee whiz" developments when it would be more helpful if they did some mundane, but fundamental, work in materials science and process engineering that would bring down costs and turn scientific knowledge into marketable technology.

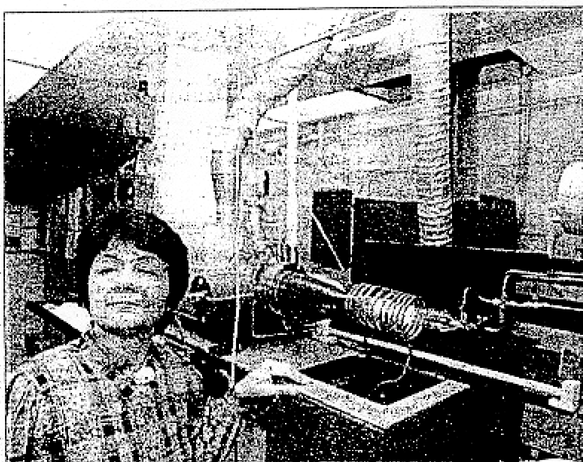
For their part, university scientists argue that they are pushing out the frontiers of knowledge and training the next generation of researchers with their work. Their breakthroughs point the way to new technology, but it is up to industry to do the research and development needed to take it to the market.

No one disputes that scientists have become very adept at using technology enabling them to build tiny materials almost one atom at a time, designing structures unknown in nature that have optical and electrical properties amenable to new applications.

Tiny lasers already make compact disc players and long-distance telecommunications commonplace.

New developments that promise to efficiently harness light particles for technological work are accumulating with dizzying regularity.

At Urbana, researchers in the University of Illinois laboratory headed by Nick Holonyak Jr. have found that by steaming chips of gallium arsenide, they can introduce oxides that provide a useful way of controlling the path of light particles called photons generated in gallium arsenide.



Tribune photo by Jim Robinson

"My objective is to attract American students to ... learn and transfer these techniques to industry," says Northwestern University's Manijeh Razeghi.

Gallium arsenide is the semiconductor material that is the leading candidate as the raw material for optical technology. It is readily combined with elements that make lasers and has very fast switching properties.

A similar strategy using oxides in silicon was essential to making that material the fundamental building block in electronics. So far, the discovery of how to make oxides in gallium arsenide has caused the university to file for three different patents, said Holonyak.

Dozens of companies are looking at the discovery and some have built prototype devices using this technology, he said.

In the University of Illinois microfabrications applications laboratory in Chicago, David Naylor and colleagues are exploring ways to make silicon an optical material as well as an electronic one.

By etching silicon with acid as it conducts electricity, researchers are able to create islands of silicon that emit light when they conduct electricity. Naylor said scientists don't yet agree what causes light emission, but several labs are busily trying to see how efficiently and reliably they can make silicon light emitters.

If someone discovers how to make silicon emit light in a reliable, controllable way, it would "revolutionize electronics as we know it," Naylor said.

Having a single medium to carry electronic and photonic traffic could radically boost efficiencies for electronic devices, he said. But research efforts in this field are only a few years old, and it will take a few more years to learn whether silicon has any chance as a viable light-emitting material, Naylor said.

At Northwestern University's center for quantum devices, Manijeh Razeghi and colleagues have managed to build a tiny laser made of indium phosphide on a silicon base. This is a difficult technical feat that also aims to better integrate optically active materials with silicon, the universal electronics material.

Razeghi said that the technology she uses to build the tiny lasers on silicon, a type of chemical vapor deposition, is widely used in industry. By teaching students how to use this tool to make lasers on silicon, she said, she is helping industry by providing a skilled work force.

"My objective isn't just to do something so I can publish a paper on it," said Razeghi. "My objective is to attract American students to come and learn and transfer these techniques to industry."

Using another technology that grows crystals almost one atom at a time, molecular beam epitaxy, David Nolte and colleagues at Purdue University, have produced optical chips that maximize efficiencies so they can operate with light intensities much lower than those commonly used today.

The Purdue work could advance research to produce optical computers that store information as holograms, Nolte said.

The fundamental technology needed to build opto-electronic devices atom by atom has been available for more than a decade, Nolte said. As scientists get more proficient using it and become more creative in their goals, new and exotic discoveries proliferate.

Another factor working to advance opto-electronics is federal funding. Several agencies recognize the usefulness of light technologies not only in defense research, but also for civilian applications ranging from surgery to industrial fabrication, said Lester Eastman, a Cornell University professor of electrical engineering.

"It used to be that electronics research dominated government support," said Eastman. "But now, there is a mix between optics and electronics. The funding people realize that this isn't a technology that is just limited to telecommunications."

Virtually everyone involved in advancing opto-electronics research talks about how this work will benefit industry. But at the world's premier industrial laboratory, where the laser itself was invented, there is some skepticism.

David Lang, director of the compound semiconductor device research lab at AT&T Bell Labs in Murray Hill, N.J., said he wishes some of his university colleagues would turn their attention to such questions as making optical materials like gallium arsenide as dependable and cheap as silicon.

"We've seen some very impressive advances in basic research, really leading-edge stuff that catches people's imagination," said Lang. "But the real progress in technology doesn't come from these breakthroughs so much as it comes from nitty-gritty work."

For the most part, Lang said, fundamental scientific knowledge of silicon hasn't changed much in 30 years, but silicon-based electronics has revolutionized the world in that time. Products from digital watches to hand calculators to the personal computer, all based on silicon, have had a profound effect on people's lives, he said.

At the same time, progress in optical sciences known broadly as photonics has been phenomenal, Lang said. But apart from specialized applications such as compact disc players and telephone transmission, photonics has yet to have a big impact on people's lives.

"We've had a very interesting first era, but now we've got to get the costs down," said Lang. "Only when optical devices become cost effective will they revolutionize our lives. We've got to do the mundane hard work. I say 'mundane' in the view of a physicist. These are really challenging materials and engineering problems.

"The challenge is to make simple things that are robust."

As chairman of the American Physical Society's committee on applications of physics, Lang has been telling his university colleagues that they need to devote more attention to materials-processing questions and packaging problems.

"This is basic research," Lang said, "but it's not the kind of 'gee whiz' stuff that gets attention. I'm afraid that too many people are just doing the fun stuff and not hitting the bull's eye where it's needed.

"At Bell Labs, we try to do about 80 percent relevant stuff, how to make systems work, and 20 percent gee whiz. I am really concerned that a lot of the exotic lasers people are making out there will never be reliable enough to be practical."