Switching to glass makes device ultrafast

Electrons are the best foot soldiers for doing computations, and photons are the speediest messengers for communications. Taking this technological tenet to heart, communications companies over the last few years have laid thousands of miles of optical fiber cables. These pathways for light promise to transmit unprecedented volumes of information — from telephone conversations to computer data and high-definition television signals—much faster and more efficiently than their conventional copper counterparts.

But as the optical fiber networks grow, companies will be faced with the increasingly difficult problem of policing all that photon traffic. And someday they will need devices that can almost instantaneously switch or route light signals between optical fibers.

While that day is not yet here, the first-generation ultrafast optical switch is — at least in its laboratory version. Scientists at Bell Communications Research in Red Bank, N.J., will soon unveil an all-optical, fused-quartz device that can repetitively shuttle a light beam into different optical fibers in less than a picosecond (10^{-12} second). That, says physicist Peter W. Smith, head of the group that designed the switch, is thousands of times faster than existing electro-optic switches, which use electrical signals to control the routing of light beams.

"This is really the first demonstration of such fast repetitive switching in any type of device," he notes. "It's the world's fastest switch."

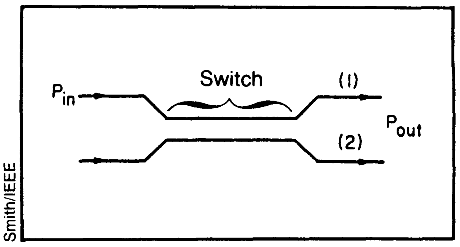
Behind this technological benchmark stands a new realization about the optical properties of glass and, in particular, their nonlinear qualities. Nonlinearity means that what goes in does not necessarily come out in the same manner; put another way, not all light signals passing through a nonlinear device are treated equally. The kind of nonlinearity that most interests Smith's group is the way a glass refracts a beam of light: The more intense a light beam is, the more it will change the glass's index of refraction, which is related to the light wave's velocity and, in this case, its ability to be routed into a switch's optical pathways.

Other scientists have been aware that they could exploit this nonlinearity to route beams of light by changing their intensities. But they had largely dismissed *glasses* as useful candidates for optical switches because their nonlinearities are very small — meaning that relatively large increases in intensity would be required to change the glass's refractive index. Instead, most research has focused on semiconductors and other materials that have much greater nonlinearities, and hence lower intensity requirements.

But the problem with these materials is that they absorb energy from the light beam. Not only can this degrade the light signal, but the resulting heating also changes the material's refractive index, causing the beam to act in undesired ways. "Although these semiconductor materials can switch fast once, they can't switch again for a very long time—that is, until they cool off," says Smith.

A switch made of optical glasses, on the other hand, is so transparent that it absorbs essentially no energy as the light passes through, thereby avoiding the heating effects that have plagued the development of optical switches, says Smith. In the Dec. 12 IEEE JOURNAL OF QUANTUM ELECTRONICS, he and Stephen R. Friberg defined a "figure of merit" that quantitatively balances a material's intrinsic nonlinearity against its adverse heating effects. After comparing the figures of merit for a number of different materials, the researchers concluded that optical glasses are the clear choice for optical switches. Smith plans to present the details of his work in April at the Conference on Lasers and Electro-Optics, to be held in Anaheim, Calif.

— S. Weisburd



Smith/IEEE

The switch's fast speed is due to the use of both a novel material and a novel geometry: It is a fused-quartz fiber that contains two closely spaced cores, (1) and (2). When the light intensity is low, the refractive index of both cores is equal and light traveling in (1) leaks into and gradually builds up in (2). Higher intensities change the refractive index of (1), altering the beam's speed in a way that prevents light from coupling to (2).

Trashes to ashes, all fall down

Two lawsuits filed last week by environmental groups may spur resolution of a longstanding dispute over the disposal of ash from municipal trash incinerators. The suits, filed by the Environmental Defense Fund (EDF) in Washington, D.C., and the Chicago-based Citizens for a Better Environment, claim that toxic ash from energy-producing municipal incinerators, or resource recovery plants, is not being disposed of in accordance with relevant hazardous waste regulations. At issue is a disputed interpretation of the federal Resource Conservation and Recovery Act (RCRA), which defines hazardous wastes and how they are to be disposed.

The suits are significant because municipalities are becoming increasingly reliant upon resource recovery incinerators for trash disposal. Such facilities generate moderate amounts of electricity by burning household garbage. Since the advent of new technologies for minimizing air pollution, more than 100 such incinerators have gone on line in U.S. cities, and thousands more are on the drawing boards. If the court rules that the ash from these plants must be disposed of as a hazardous waste, the cost of operating the incineration facilities will increase substantially.

"In our haste to adopt incineration as a panacea for the serious health threats that have resulted from landfilling trash, we can't afford to repeat the same mistakes by improperly managing the ash, which must also be landfilled," says Richard A. Denison of the EDF. Test data compiled by the EDF show that landfilled ash from municipal incinerators typically contains toxic metals such as lead and cadmium in concentrations considered hazardous by the EPA. The lawsuits single out resource recovery plants in Chicago and Peekskill, N.Y.

According to Wheelabrator Environmental Systems, the nation's largest municipal incinerator company and owner of the Peekskill plant, the management and disposal of its ash residues "are in strict compliance with applicable state and federal requirements." The Hampton, N.H.-based company contends that toxic ash from municipal waste incinerators is exempt from RCRA disposal regulations. The EDF says this is "wishful thinking."

In fact, both Congress and the Environmental Protection Agency (EPA) have been struggling to clarify how RCRA should apply to municipal facilities. The issue is complicated because it involves both statutory and regulatory provisions that use slightly different language. Moreover, according to Robin Woods, a spokesperson for the EPA, the agency is considering changing its hazardous disposal regulations. But for now, she says, "We do have a policy in effect that says if the ash tests hazardous . . . then it must go to a hazardous waste facility."

Also at issue is the reliability of the test commonly used to determine the toxicity of incinerator ash. The so-called Elution Procedure Toxicity Test, currently accepted by the EPA, is meant to mimic landfill conditions to determine the rates at which metals and pesticides leach into groundwater. Industry representatives claim the test overestimates leach rates. Environmentalists say the test is too conservative, noting that it doesn't even attempt to measure many of the toxic organic solvents that have in recent years been found in drinking water (SN:1/16/88, p.39).

In related news, the EPA last week said it would stop work on its design of guidelines for the incineration of toxic wastes at sea. The announcement was considered a major victory for environmentalists and members of Congress who had opposed the EPA's proposed plan to burn hazardous wastes on giant incinerator ships off U.S. coasts. — *R. Weiss*

Is dark matter causing a glow?

Cosmologists have believed for a long time that the universe has to contain a large amount of dark matter, which cannot be made of ordinary neutrons and protons, but must be some less ordinary subatomic particle. On the supposition that the dark matter consists of an astronomically large number (110 per cubic centimeter) of neutrinos that decay radioactively, three scientists now suggest that the decay of the neutrinos sets aglow large clouds of hydrogen that have recently been observed around the universe. If the neutrino-decay mechanism they propose is correct, it will prompt important changes in particle physics and solve a couple of seemingly unconnected astrophysical puzzles.

As Adrian L. Melott, Douglas W. McKay and John P. Ralston, of the University of Kansas at Lawrence, point out in the Jan. 15 ASTROPHYSICAL JOURNAL LETTERS, a number of observations in recent years have found large amounts of ionized, glowing hydrogen in different parts of the universe. The ionization requires the presence of a background flux of ultraviolet light. As Melott told SCIENCE NEWS, "It's something people have been puzzled about. No one can figure where it comes from. Quasars can't do it."

What can do it, suggest Melott, McKay and Ralston, is decay of neutrinos in the dark matter. There are three known kinds of neutrinos, and here one kind would decay into another, emitting ultraviolet as it did so. If this mechanism is correct, particle physicists would have what they call a generation-changing interaction, which would be very important to the unification of their discipline.

As Ralston told SCIENCE NEWS, the particles of physics can be divided into three separate generations, exemplified by the electron and the electron neutrino, the muon and the muon neutrino, and the tau particle and the tau neutrino. The generations seem to parallel each other without any connection between them or any reason for there being more than one. Physicists have searched for an interaction that would cross from one generation to another and point a way to unifying them. This decay of one neutrino to another is such a generational link. The link goes by way of a new particle, a resonance that Ralston calls eta.

Eta makes only a virtual appearance in the neutrino decay; it is really only part of the quantum mechanical calculation, Ralston says. However, it makes a real appearance in the mechanism he suggests to explain the strange radiation coming from the X-ray pulsar Cygnus X-3. A detector deep in a mine in northern Minnesota has shown evidence for highly energetic particles coming straight to us from Cyg X-3 (SN: 4/11/87, p.228). Ralston suggests that these mystery particles are neutrinos.

In known processes all neutrinos are emitted as left-handed — that is, they spin to the left in the direction they are going, like left-handed screws. However, neutrinos have a small magnetic moment. They are like little magnets, and a magnetic field could flip them over and make them right-handed. It happens that this model of neutrinos gives them a much larger magnetic moment than the standard one, so it is plausible that on the way from Cyg X-3 some of them are flipped over by the galactic magnetic field. When these now right-handed neutrinos enter the earth, they interact with electrons and produce the eta particle. (Left-handed neutrinos can't make eta particles.) The eta decays, and its decay products are the muons the detector sees.

This high magnetic moment also makes possible a mechanism to solve the solar neutrino puzzle put forward by the Russian physicists M. Voloshin, M. Visotsky and L. Okun. Detectors looking for neutrinos from the sun find far fewer than scientists think they should, and lately they have noted that the flux is lower when the number of sunspots is high and vice versa. These things could be explained if solar magnetic fields were flipping left-handed neutrinos to right-handed ones on the way out of the sun. The detectors are not equipped to record right-handed ones.

Ralston sees two possible ways of seeking evidence for the eta particle, which is the key point in checking the theory. Certain aspects of a much-studied decay, that of a muon into an electron and a neutrino, might give some evidence. Or, direct evidence of the eta — which is expected to have a mass between 30 billion and 60 billion electron-volts — could show up in machines like the Japanese KEK accelerator.

— *D.E. Thomsen*

Lightning pattern found in storms

Atmospheric scientists have discovered that in many thunderstorms, the most dangerous lightning develops on only one side of the storm instead of striking randomly throughout the entire area. This observation will aid those who are studying the development of thunderstorms, and may provide a warning system for locating potentially damaging parts of a storm.

Using a large network of instruments that monitor individual lightning flashes, researchers from the State University of New York at Albany found that many storms, especially during the fall and winter, display an unexpected organization. At the downwind end of the storm, most lightning flashes are positive, meaning that they transfer positive charge from the cloud to the ground. Meanwhile, 100 kilometers away at the rear of the storm, most flashes lower negative charge to ground.

Richard E. Orville and his colleagues discovered this so-called bipolar pattern when they linked several small lightning-detection networks. "The pattern has been there, but we've never had a lightning network large enough to observe it," Orville told SCIENCE NEWS. Orville, Ronald W. Henderson and Lance F. Bosart report their findings in the February GEOPHYSICAL RESEARCH LETTERS.

Scientists have measured electrical currents in positive lightning that are sometimes twice as strong as those found in negative lightning. If scientists can predict where positive lightning is likely to occur, they can forecast which areas of a thunderstorm will be the most hazardous.

The Albany scientists speculate that horizontal winds may help cause the bipolar arrangement in storms. Individual thunderclouds normally have a vertical organization with positively charged tops and negatively charged bottoms. But observations have shown that when horizontal winds develop at the level of the cloud top, the cloud begins to tilt, with the positive charge drifting downwind.

Over time, suggest the researchers, this drift would build a center of positive charge at the downwind end of the storm, leading to positively charged lightning in that area.

Such a theory, however, does not explain the entire phenomenon. Horizontal winds are normally too slow to carry enough charge to the storm front. The researchers believe that another mechanism may help generate the positive-charge center. In future studies they will address this issue by combining satellite and radar data with records from the lightning network. — *R. Monastersky*