New Material Found to Store Digital Information

LASSP Scientists Join Others in Research Project

A new material for storing digital information at extremely high densities has been discovered by a collaborative research project involving scientists from Cornell, IBM, General Motors Research Laboratories, and Bell Laboratories. The experiments were performed at Cornell in the Laboratory of Atomic and Solid State Physics.

The new material is suitable for a novel data storage technique known as frequency domain optical storage. This technique, which would employ a laser to burn (write), read, or erase long-lived "spectral holes" in a storage medium, was originally invented at IBM in the late 1970s. Since then, a variety of researchers have been searching for the ultimate material that will allow practical application of the concept. The Cornell experiments represent an important step toward this goal.

Explaining the principle behind a frequency domain optical storage system, Cornell Professor of Atomic and Solid State Physics Albert J. Sievers notes that the crucial element is the phenomenon of persistent spectral hole burning. When molecules or other absorbing centers are placed inside a transparent, crystalline solid at low temperatures, a spread in absorption frequencies results because different molecules experience differing local environments. According to Professor Sievers, a narrow band laser producing radiation at a particular frequency causes only the molecules that are coincident with the light frequency to vibrate and change to a higher energy state.

"When we shined the light on these molecules, some of the ground states became empty," Sievers recalls, describing the work which began in 1980. "When we turned off the laser, they wouldn't refill. That was the big surprise, that we could actually — by turning on this light — change the state of a solid so that it no longer felt any absorption at this frequency. The molecules had absorbed the energy, changed to another state, and the system had a hole — a spectral hole — in the absorption line. The unusual thing is that the spectral hole remains after the laser is turned off, and that means we have a memory element. This is the phenomenon of persistent spectral hole burning."

The presence or absence of spectral holes at particular frequencies can be used to encode the digital "1"'s and "0"'s in a frequency domain optical memory. The holes could be read by rapidly sweeping the laser frequency across the absorption line while monitoring the light transmitted through the solid. Such a memory system is capable of extremely high density storage because many "bits" of information can be stored at one spatial location in the sample simply by varying the laser beam frequency.

Until the Cornell experiments, physicists believed that spectral holes could exist only in amorphous materials — those without order — or in photochemical systems excited by visible light.

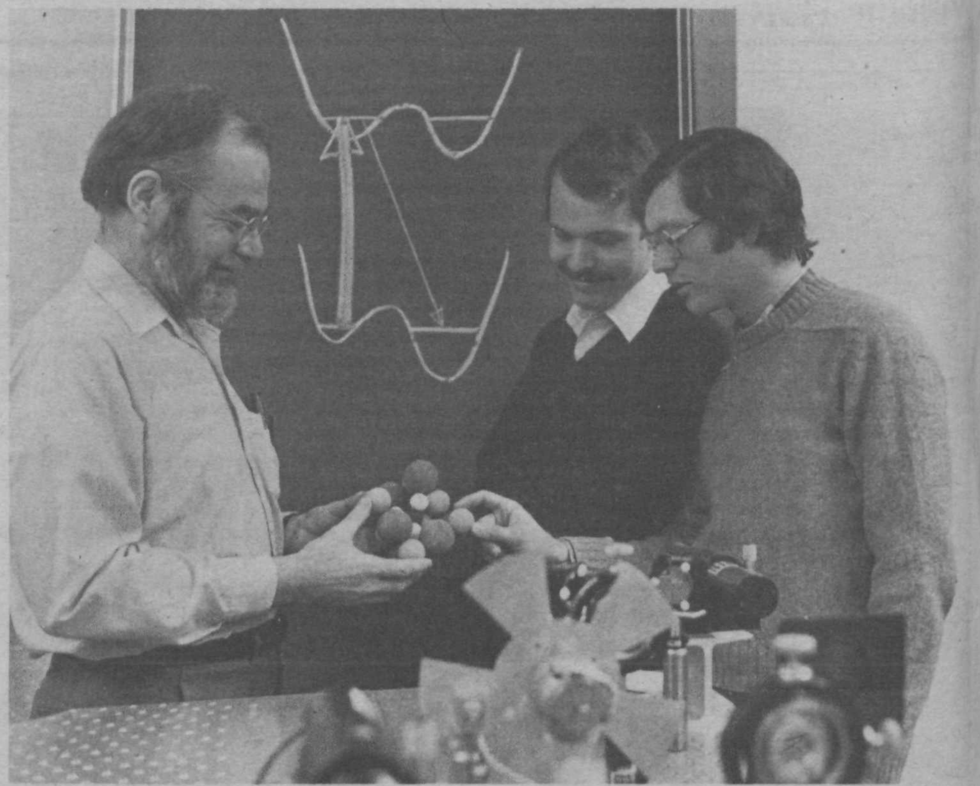
"We used low-frequency infrared light, which doesn't break up the molecules, and we demonstrated that spectral holes can be created in a different class of materials," according to the Cornell physicist. "The process of being able to build a memory into a system at low temperatures is much more general than people had thought." The Cornell experiments showed that persistent spectral holes can be formed in crystalline solids without the need for a photochemical reaction.

The spectral hole effect, like superconductivity, appears to work only at cryogenic temperatures and not at room temperatures. Additional research will be needed to determine whether that obstacle can be overcome or whether the increased speed and storage capacity of frequency domain memories are worth the inconvenience of having to cool the system.

The significant increase in memory capacity that is possible by tuning lasers to different frequencies and burning many spectral holes at the same location in the solid can be understood by comparing a memory that uses persistent hole burning to conventional ablative optical memory. In the latter, a physical hole is burned through the material at the location of the laser spot. Hence only one bit can be stored at each laser spot position. Persistent spectral hole burning, on the other hand, allows as many as 1,000 bits to be stored in the frequency domain at one laser spot position. Due to limitations on the minimum achievable laser spot size, an ablative memory could store 10,000,000 bits per square centimeter, while a frequency domain optical memory could store 100,000,000,000 bits per square centimeter.

The Cornell researchers used salt crystals doped with an absorbing molecule, rhenium tetraoxide. Salt crystals would not be the preferred storage medium in a practical application of frequency domain optical memories, Sievers observes, if for no other reason than that the salt would melt in the rain. Nor is rhenium tetraoxide crucial as the dopant; it just happened to be the molecule coincident with the diode lasers and CO_2 lasers available at the time. The experimenters are now seeking persistent spectral holes in conventional semiconductor and other materials.

As sometimes happens in scientific research, the existence of persistent spectral holes in crystalline solids was discovered unexpectedly, when an experimenter blocked a laser beam with his hand. Indeed, spectral holes in crystalline solids might not have been discovered had it not been for a bit of good luck on the part of A.R. Chraplyvy, a former graduate student who is now a researcher at Bell Laboratories. "We were doing a different kind of experiment and weren't even looking for this effect," Sievers remembers. "We always assumed that when we turned the CO_2 laser off the hole would disappear immediately because that's what had always happened to everybody else. But when Chraplyvy blocked the beam we saw on the oscilloscope that the hole was still there. It was a complete fluke."



Former students A.R. Chraplyvy, center, now with Bell Laboratories, and W.E. Moerner, right, now with IBM, return to Cornell to discuss their chance discovery with Professor of Atomic and Solid State Physics Albert J. Sievers.

Six months of study followed by W. E. Moerner, a graduate student at the time and now a staff scientist at IBM, San Jose. "The researchers tried to learn how persistent spectral holes could exist in crystalline solids," says Sievers. He credits Robert H. Silsbee, professor of atomic and solid state physics, with making important theoretical contributions to the understanding of the effect.

Studies of spectral holes in solids continue at IBM, where a faster means of encoding information is being developed, as well as at Bell Laboratories and at Cornell, where General Motors researchers and lasers continue to be involved in the work. The researchers note that information storage is not the only possible use for spectral holes.

The variety of systems in which they have been seen suggests that the effect may also be useful as a way to study solids, and may lead to important industrial applications of physics.

The Cornell work was supported by the U.S. Army Research Office.

Cornell Chronicle

Editor, Randall E. Shew. Staff writers, H. Roger Segelken, Robert W. Smith, Barbara Jordan-Smith, Martin B. Stiles, Photographer, Sol Goldberg, Circulation Manager, Joanne Hanavan.
(USPS 456-650)
Published weekly during the academic year and once each in June and August. Distributed free of charge to Cornell University faculty, students and staff by the University News Bureau. Mail subscriptions, $13 per year. Make checks payable to Cornell Chronicle and send to Editorial Office, 110 Day Hall, Ithaca, N.Y. 14853.
Telephone (607) 256-4206.
Second-Class Postage Rates paid at Ithaca, N.Y.
POSTMASTER: Send address changes to the Cornell Chronicle (USPS 456-650), Cornell University, 110 Day Hall, Ithaca, N.Y. 14853.

Jobs

The following job openings are new this week. For information on vacant positions listed in previous issues of the Chronicle, contact Personnel Staffing Services, 130 Day Hall. Cornell is an affirmative action employer.

Administrative/Professional

Assistant Football Coach (Physical Education and Athletics)
Research Support Specialist II (Vegetable Crops)
Research Support Specialist (Biochemistry, Molecular and Cell Biology)
Custodial Supervisor (Buildings and Grounds Care)

Clerical

Office Assistant, GR19 (State Finance & Business Office)
Secretary, GR18 (University Health Services)
Secretary, GR18 (Veterinary Microbiology)
Secretary, GR18 (University Development)

General Services

Cook, SO18 (Residence Life)
Custodian, SO16 (Varied)

Technical

Technician, GR22 (Plant Pathology)
Technician, GR21 (Veterinary Microbiology)
Technician, GR21 (Biochemistry, Molecular and Cell Biology)
Technician, GR21 (Avian & Aquatic Animal Medicine)
Technician, GR18 (Vet Microbiology)

Part-time

Research Aide, GR18 (Government)

Academic

Assistant or Associate Professor in Human Service Studies (NYS College of Human Ecology)
Assistant Veterinary Medical Librarian (Veterinary Lib.)
Research Associate (Electrical Engineering)
Research Associate II (Poultry & Avian Sciences, Ag. and Life Sciences)
Assistant Professor of Crop Science (Agronomy, Ag. and Life Sciences)
Assistant Professor (Asian Studies, Arts and Sciences)
Lecturer, Human Service Studies (College of Human Ecology)

The Job Opportunities list is mailed to all Cornell departments. In addition, it is posted in the following places: Day Hall Information Desk, second floor lobby; at the Circulation and Reference Desks of all university libraries; in the Map and Newspaper Section, Olin Library; all college and technical libraries; Roberts Hall Post Office substation and in the Upper Activities corridor, Willard Straight Hall.