AIR FORCE OFFICE of SCIENTIFIC RESEARCH [AFOSR]
Manager of the Basic Research Investment for the Air Force

Research HIGHLIGHTS

JAN FEB 02

Freezing Light in its Tracks

As laser beams change the properties of cooled sodium atoms, Dr. Lene Hau makes light stand still.

A researcher has achieved what would have surprised even Albert Einstein. Dr. Lene Hau and her colleagues have made light stand still.

"We slowed light to a complete stop and froze it in place for up to several 1,000ths of a second, an eternity to a light beam," said Hau in a *U.S. News & World Report,* March 2001 interview.

As of yet, no scientist has disproven the theory by Albert Einstein that a pulse of light cannot travel faster than 186,282 miles per second, but Einstein never said it couldn't go slower.

In a vacuum, nothing travels faster than light. However, all ordinary transparent media or materials slow down light. Water slows light to about 75% of its speed in a vacuum. A beam of light can be stopped with a non-transparent object like a brick wall, but in the process, it destroys the information that can be coded in the light beam.

In 1999, Hau slowed a light pulse down 20 million-fold to a leisurely 38 miles per hour. She and her team did this by first creating a small cigar-shaped cloud of sodium atoms trapped in a magnetic field and cooled to temperatures colder than those found in space. They illuminated the cloud with a carefully tuned laser beam that altered the optical properties of the cold atom cloud dramatically. The team subsequently sent another light pulse into the cloud and could then slow this pulse, while at the same time compress it spatially from a length of one mile in free space to only 0.002 inches within the cloud.

The key, Hau noted, was to chill the atoms to a temperature within a millionth to a billionth of a degree of minus 459.7 degrees Fahrenheit, referred to as "absolute zero." Absolute zero is the temperature at which atoms have the lowest amount of energy and any activity just about comes to a standstill. The sodium atoms are cooled by a combination of laser beams, magnetic fields and radio waves.

Using a similar technique to completely stop the pulses, a laser beam converts the frozen pulse back into a moving light pulse, but significantly with all of its original properties. This allows the researchers to control a light pulse by capturing and storing it, thus enabling them to release it at will.

To understand the conditions in which the light speed of a pulse can be reduced by factors of tens of millions and then be stopped completely is a result of quantum mechanics. "Quantum" refers to discrete changes in the energy or phase of atomic levels.

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One possible Air Force application for this breakthrough could be in a new generation of computers called quantum computers. Instead of the usual definite 1s and 0s used in binary coding, they are replaced with quantum superpositions of 1s and 0s called qubits. If such computers can be manufactured, they could solve problems completely inaccessible to today's computers.

An intriguing aspect of this research to quantum computer designers is that when light is stopped, all of its original characteristics are transferred to the cloud's atoms. When the light is unfrozen, the information is then transferred back to the light from the atoms. This is the link, photon-to-atom, that could become the quantum circuits of tomorrow's computers.

Another field of research to benefit by this breakthrough is nonlinear optics. Nonlinear optics has applications from telecommunications to imaging. Usually exceptionally powerful beams are needed to achieve optical effects, but using slow light techniques the same phenomena could be made with only a small amount of photons. This effect could be useful in designing ultra-sensitive optical switches.

Other practical uses for the Air Force for this light-stopping research could include new ways to communicate solely by light and coding methods. This would protect both military and personal information and control optical information storage.

Hau is Gordon McKay Professor of Applied Physics and professor of Physics at Harvard University in Cambridge, Mass. She has been funded by the Air Force Office of Scientific Research's Physics and Electronics Directorate since June 2000.

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Figure 1: Reference pulse (open circles) and a slowed and delayed pulse, delayed by 13 microseconds

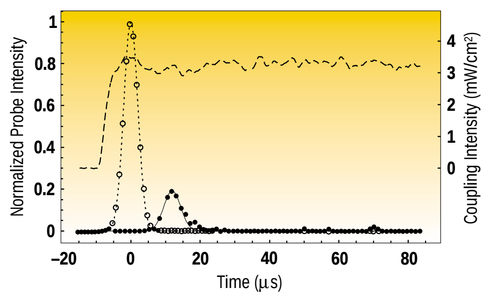


Figure 2: Stopped and revived light pulse, stopped for 40 microseconds

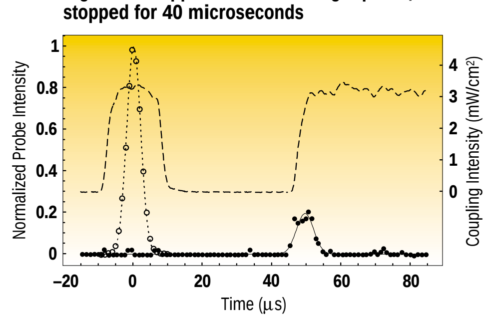


Figure 3: Pulse stopped for almost a millisecond and released

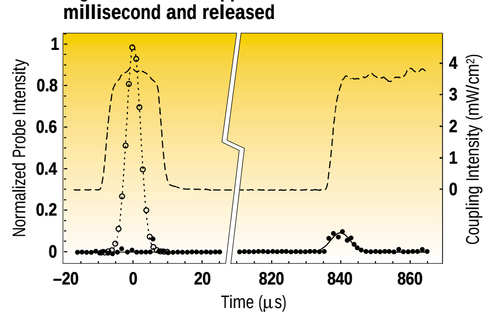
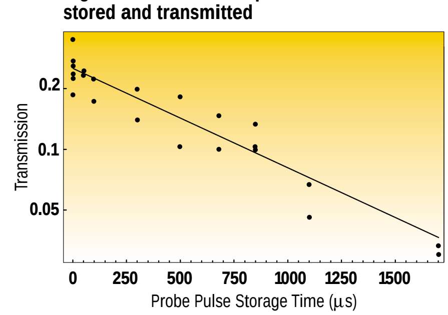
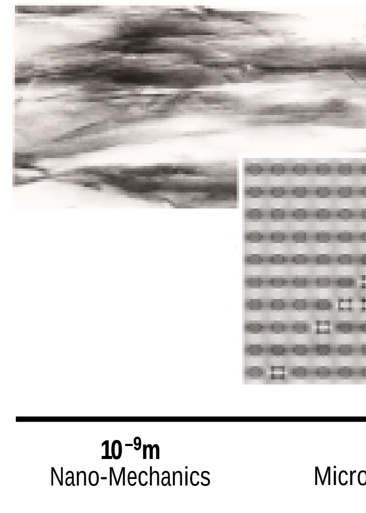


Figure 4: Amount of impulse that has been stored and transmitted



New Multi-Scale Comput

Advanced Air Force weapon systems could not exist without the use of light, strong, and corrosion-resistant composite materials. Helping to introduce the next generation of composite materials, a team of scientists is developing new design tools based on multi-scale computational modeling, replacing or reducing costly testing procedures.



A team of researchers from the Materials and Manufacturing Directorate of the Air Force Research Laboratory, as well as a number of universities, is focusing on multi-scale computational methods to minimize the required testing for new composite systems. The same predictive methods can be used to enhance the current structural integrity and prolong lifetimes of existing systems, resulting in lower life-cycle costs for the Air Force and improved performance.

The team is developing efficient computational models that can be used to design composite materials across three different length scales: macro, meso and micro. At the macro-scale, composite laminates are treated as homogeneous (same) media, as in conventional materials. The existence of constituent plies or layers characterizes the meso-scale. The micro-scale is the smallest continuum scale, where reinforcing fibers can be seen.

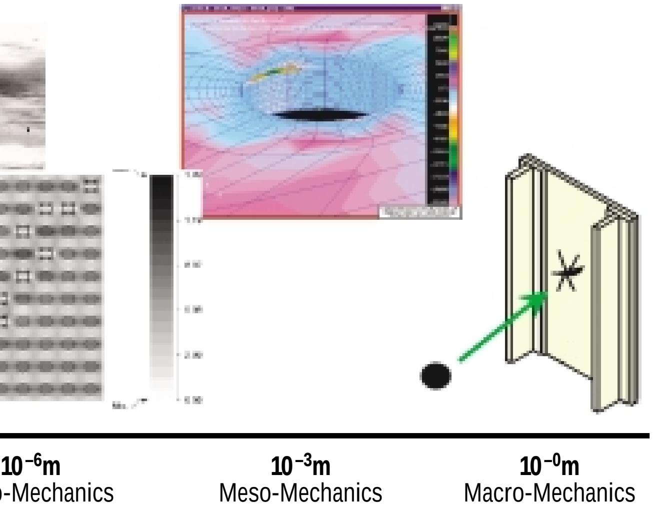
When examined with a microscope, a composite laminate reveals a number of plies. Each ply has continuous fibers embedded in a matrix material. In uni-directional plies, these fibers are all aligned in the same direction to provide maximum performance in the fiber direction.

In multi-directional types of plies, fibers can take different forms of architecture, such as woven, knitted, braided, etc. These arrangements sacrifice the properties in the fiber direction, but provide better performance in other directions. One of the challenges in the design of composite structures is to find optimum fiber architectures for given functional requirements.

Although standard finite element methods are available, they become impractical when the design has to be done across different length scales, which is why the team is also developing a number of computationally-efficient models to facilitate multi-scale modeling. Some of these include:

- spline variational elastic laminate theory (SVELT) to design ply stacking sequence;

tational Modeling



- finite element model to predict properties of textile composites with cracks;
- Voronoi cell finite element model (VCFEM) to determine stresses around multiple fibers;
- effective field model to determine stresses around a single fiber; and
- computational model to predict properties of carbon foams

A parallel effort is underway to provide experimental validation to these models. This effort has led to the development of new experimental techniques, such as the cruciform test to measure fiber/matrix interfacial strength and a Moiré technique to measure interlaminar stresses on curved surfaces.

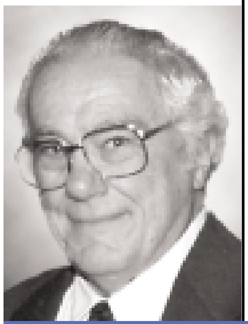
When multi-scale computational models are fully established, they will enable designers to translate structural requirements into material requirements and minimize the need for redundant testing.

With the above goal achieved, the next challenge will be to design new constituent materials that can meet more stringent property requirements of future Air Force systems. The control of material properties requires the understanding of nano-mechanics, where continuum modeling meets molecular modeling. The current research effort has been expanded into the area of nano-mechanics in collaboration with other materials science programs at the Air Force Office of Scientific Research.

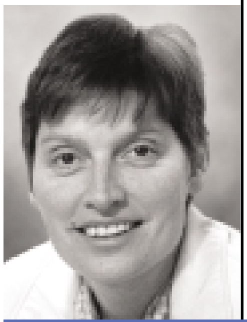
This area of research is supported by the Aerospace and Materials Sciences Directorate of the Air Force Office of Scientific Research.

Dr. B. Les Lee, AFOSR/NA, (703) 696-8483

AWARDS


Dr. Edmond Dewan

Dr. Edmond Dewan, a scientist from the Air Force Research Laboratory's Space Vehicles Directorate at Hanscom AFB, Mass., has recently received the ***Guenther Loeser Memorial Award.*** Dewan was recognized for his unusually wide array of research in such scientific fields as special relativity, satellite scintillation effects, ball lightning, cybernetics and atmospheric physics. He has spent most of his career focusing on atmospheric physics, specializing in the area of waves and turbulence. Dewan credits much of his success in atmospheric waves to AFOSR's many years of sustained funding. The award, considered the highest award a scientist can receive at Hanscom, was named for Loeser in 1955, after he lost his life conducting meteorological research for the Air Force. Dewan is funded by AFOSR's Physics and Electronics Directorate.


Dr. Lene Hau

Dr. Lene Hau, Gordon McKay Professor of Applied Physics and physics professor in the Faculty of Arts and Sciences at Harvard University in Cambridge, Mass., won a $500,000 ***MacArthur Fellowship*** for her work in freezing light. The AFOSR-supported research is in the field of nonlinear optics and may lead to a new computer system based on quantum computing and innovative ways to communicate solely by light. Among 22 recipients, she will receive $100,000 a year for the next five years. She is funded by AFOSR's Physics and Electronics Directorate.


Dr. Olvi Mangasarian

Dr. Olvi Mangasarian, professor of computer science at the University Wisconsin-Madison in Madison, Wis., received the ***Lanchester Prize from the Institute for Operations Research and the Management Sciences*** for his work on computer pattern recognition and data mining. Awarded since 1954, the Lanchester Prize recognizes the most influential contributions to computer science in the prior three years before selection. Mangasarian's pioneering work introduces the use of Operations Research techniques in the field of data mining, resulting in applications used currently in hospitals to diagnose breast cancer. He is supported by AFOSR's Mathematics and Space Sciences Directorate.


Dr. Lee Semiatin

Dr. Lee Semiatin, a scientist from the Air Force Research Laboratory's Materials Directorate at Wright-Patterson AFB, Ohio, received a ***Lifetime Achievement Award*** from the Thermec Conference. One of six recipients, he was cited for his "outstanding contributions in advancing the understanding of the thermomechanical processing of titanium and titanium aluminide alloys." Held every three years, the Thermec Conference provides an avenue for the latest developments in the science and technology of thermomechanical processing of metals and emerging manufacturing techniques. Semiatin called the Air Force Office of Scientific Research's efforts in processing fundamental laboratory tasks critical in the basic research of aerospace metals. He has been funded by AFOSR's Aerospace and Materials Directorate continuously since 1978.

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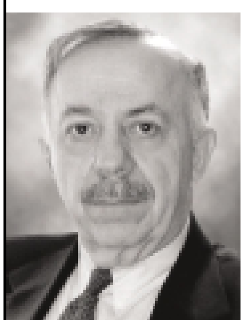
Dr. Michael Berman

Dr. James Fillerup



Dr. Alex Glass

Maj. Tim Lawrence

Dr. Michael Berman, Program Manager, Air Force Office of Scientific Research's Chemistry and Life Sciences Directorate, was elected to receive the rank of ***Fellow of the American Association for the Advancement of Science (AAAS).*** Berman was honored for his "outstanding leadership, advocacy, and support of chemical physics research and for contributions to applications of laser methods to chemical kinetics and spectroscopy." Election as a fellow within AAAS is bestowed upon a member by their peers and is based on "efforts for the advancement of science and engineering, which are scientifically or socially distinguished." Berman will be honored at a reception in Boston, Mass. in February.

Dr. James Fillerup, Program Manager, Air Force Research Laboratory's International Office in Arlington, Va., received the ***Air Force Materiel Command International Award*** for Armaments Cooperation. Fillerup provided the leadership needed to the Aerospace Science and Technology Committee, or COCITAE, to foster coordination and cooperation among 18 member countries throughout the American continents. Fillerup's committee conducted joint studies and disseminated unclassified materials and ideas for improving aerospace education and technology. The committee's achievements include researching, compiling, and sharing unclassified information on ozone-related studies conducted by the USAF, tools for Air Force modernization, and space weather and meteorological remote sensors.

Dr. Alex Glass, Program Manager, Air Force Office of Scientific Research's European Office of Aerospace Research and Development, was selected as a ***Life Fellow of the Institute of Electrical and Electronics Engineers (IEEE)*** in recognition of the many years of loyal membership and support of the activities of the institute. In 1998, Glass was named as a Fellow of the IEEE for "contributions to quantum electronics and to the design of glass lasers for fusion research." IEEE helps promote the engineering process of creating, developing, integrating, sharing and applying knowledge about electrical and informational technologies. In his current position at EOARD, Glass is responsible for the Lasers, Photonics and Optical Materials through an Intergovernmental Personnel Act (IPA) assignment. Glass was a member of the Air Force Scientific Advisory Board from 1993 to 1997 and contributed to its *New World Vistas* report, published in 1995.

Maj. Timothy Lawrence, a former European Office of Aerospace Research and Development Program Manager, was selected by the Junior Chamber International (JCI) as one of ***The Outstanding Young Persons of the World 2001*** for his contributions to scientific and technological development. The award recognizes individuals between the ages of 18 and 40, who embody the finest characteristics of the world's young people. JCI contributes to the advancement of the global community by providing the opportunity for young people to develop the leadership skills, social responsibility, entrepreneurship, and fellowship necessary to create positive change. As one of 10 recipients, Lawrence is known as an international expert in the field of Astronautics. His work led directly to the first-ever spacecraft to fly in space with nitrous oxide resistojet thrusters. Lawrence also participated on several international technical committees on propulsion and small satellites for the European Space Agency, German Aerospace Center, International Astronautics Federation and the International Space University. Lawrence is now stationed at the U.S. Air Force Academy as an assistant professor in the Department of Astronautics.

Research Highlights

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Research Highlights is published every two months by the Air Force Office of Scientific Research. This newsletter provides brief descriptions of AFOSR basic research activities including topics such as research accomplishments, examples of technology transitions and technology transfer, notable peer recognition awards and honors, and other research program achievements. The purpose is to provide Air Force, DoD, government, industry and university communities with brief accounts to illustrate AFOSR support of the Air Force mission. *Research Highlights* is available on-line at:

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