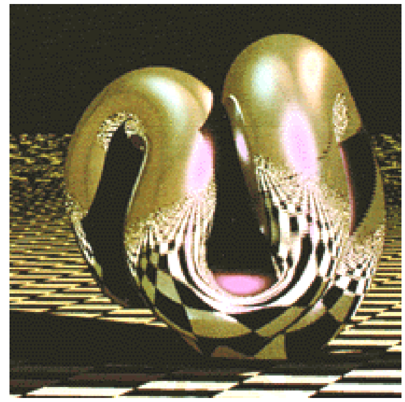
"Thinking Out Loud" by: David Pacchioli (*Research/Penn State*, Vol. 14, no. 3 (September, 1993))



(Photo: Clifford Pickover)

*What if we . . .*ran an undersea pipeline from the mouth of the Amazon to the northwest coast of Africa, carrying enough fresh water to quench the thirst of the northern Sahara? Such a tunnel, 4,300 kilometers long and 80 meters in diameter, would provide more than 1,000 times the amount of fresh water that desalination plants could muster using the same amount of energy. It could render a million square kilometers habitable. Its construction would employ the world's heavy industry for over a decade, offering a needed boost to the global economy.

What if we . . . could focus ultrasound waves to create a non- invasive device for stimulating selected areas of the human brain, enhancing thinking and alleviating pain?

What if . . . monkeys, our evolutionary forebears, invented mathematics?

These are the voyages of the 16-year-old international journal *Speculations in Science and Technology*.

Its new editor is an associate professor of engineering science and mechanics at Penn State, Akhlesh Lakhtakia, a bright- eyed man in his middle-thirties whose thoughts jump ahead of a playful smile. In his office in Hammond building, a stack of recent submissions scrawled with "Rejected" or "Sent to Press" in yellow marker fill a cardboard box. Return addresses read France, Venezuela, Egypt, the Czech Republic, Japan, India, California and Texas.

"What if Icarus had been a balloon pilot?"

"Why do multisexual living beings not exist?"

Lakhtakia shifts, puts one batch of papers down, picks up another. "Here's a good one," he reports. "By an earth scientist. Speculating on a north-south ridge on the floor of the Indian Ocean, why it happened." And another, by two medical doctors, on an evolutionary origin for cancer.

The next, marked "Rejected", has an angry follow-up letter attached, in which the author calls Lakhtakia "another of the popes of science." He sighs briefly. The following correspondent signs himself simply, "A citizen of the universe."

Lakhtakia shuffles the papers. He is trying to explain the journal's selection criteria.

"Is everything we publish true?" he asks, carefully settling another pile back into the box. Then answers: "No."

But everything is at least *plausible*. Flights of fancy are important, but we are not interested in the purely fanciful. This journal is devoted to new ways of thinking about what people have already observed."

He cites the famous comment on Kepler, the one about fruitful error being preferable to sterile truth.

"Every once in a while we write on wrong things," he adds. "I see that as no problem whatsoever."

Speculations in Science and Technology was the brainchild of an American in Australia. William M. Honig, an electrical engineer, had left New York and a career in industry in 1972 to join the faculty of the Western Australia Institute of Technology, in "the beautiful remote city of Perth." Honig had published numerous papers in his field. He was frustrated, though, by the lack of acceptance of some of his more speculative ideas in physics, and by what he called "the canonical policy of established journals." He had met a number of colleagues of like mind and, in 1977, he decided to do something about it. He assembled an editorial board of well-known scientists, including a Nobel Prize winner and a member of the Royal Society, and with some financing from his university and the rest from his savings, launched a journal of his own.

"Recognizing the value of frank speculation as preceding theoretical and experimental construction," announced the opening editorial, "and noting that the informal dissemination of ideas has been impeded by the huge growth and differentiation of all scientific fields . . . we welcome papers dealing with specialised, general, and interdisciplinary topics in the physical, mathematical, biological, medical, and engineering sciences. No topics related to ESP, UFO, etc., will be accepted."

Some 2,500 letters poured in over the first five months. (One early correspondent, writer Arthur C. Clarke, found *Speculations* "fascinating, but 90 percent over my head." Clarke couldn't resist offering up a few casual speculations of his own: "Is it possible to photograph, or make an objective record of, 'phosphenes,' — the fascinating and infinitely varied images seen when pressing on the closed eyes? This would be of great psychological and optical interest.") There were "favourable but cautionary" notices in *Science* and the *New York Times*, among other publications. By the end of the first year, Honig was able to strike a deal with the publisher Elsevier Sequoia, of Lausanne, Switzerland; despite changing hands and continents in the intervening 15 years, the journal has been appearing ever since.

The wealth of topics it has considered is boggling. The journal's pages have hosted lively debate on ball lightning and schizophrenic cognition, black holes and the prediction of heart attacks, body transplants and interstellar communication, as well as the perennial exchanges on the nature of subatomic particles.

There have been bumps along the way. Honig had expressly sought to create a forum for those outside the institutional mainstream, as well as for establishment scientists brave enough to air their speculative views. But papers from these "solitary workers," he reports, were often uninformed or unintelligible, their authors frequently hostile to criticism. Although part of his mission to outsiders, as Honig conceived it, was to school them in scientific conventions, and although the journal fostered an impressive degree of intellectual exchange — with published give-and-take between authors, reviewers, and referees — which many writers remarked was of value, Honig was forced to endure such an "unending stream of abuse" from other correspondents that, he wrote wryly, "I have come to realise the great usefulness that the social environment of established institutions provides."

Hobbyhorse riding was another frustration. In 1979 and '80, when, for the Einstein centennial, Honig announced that not one but three special issues of the journal would be devoted to alternatives to the Special Theory of Relativity, 400 papers flooded his office, many "from high-school students, college undergraduates, tradesmen, and businessmen. They were all deeply offended by the fact that modern physics . . . did not adhere to the general axiomatic tenets of Newtonian-type classical theories." A moratorium on Special Relativity had to be declared.

From the beginning there were questions about the nature — and value — of scientific speculation. To Honig, speculation meant first an idea "which may not be supported by a currently accepted body of experimental or theoretical work. . . . Its usefulness is that it may help to uncover ideas and procedures of ultimate utility and, in the contentious discussions of these ideas, clarify our understandings." To him, the "success" of such ideas is seen in their adoption — or rejection. "All that we ask is tolerance, which should be enough, because if our ideas are any good and if the forum is tolerated then such ideas will ultimately win out." Speculation, he adds, "is meta (to the side of) science and rightly so; only those ideas which survive the speculative arena would then enter science."

The substantive influence of the journal is not easy to gauge. But in the early '80s, *Speculations* was one of the first publications to take seriously the ramifications of chirality, or handedness, for the field of biomedicine. (Unawareness that the molecules in a chemical reaction could be left- or right- "handed" was the cause of the thalidomide birth-defects tragedy of the early 1960s.) Honig, who stepped down as editor in 1985, has speculated that other papers, on the mechanisms of cancer and artificial intelligence, and other topics, have planted seeds that flowered elsewhere. Many authors, he suspects, have used *Speculations* as a workshop for their ideas, but may be reluctant to cite a non-mainstream journal in subsequent, more buttoned- down, publications.

Two years ago, with Honig's successor, the British crystallographer Alan L. MacKay, approaching retirement, Clifford Pickover, a biologist serving on *Speculations*' editorial board, contacted his friend Lakhtakia at Penn State.

Lakhtakia had read the original announcement for *Speculations* back in 1978, as an undergraduate in electronics engineering at Banaras Hindu University in Varanasi, India. A nationally recognized scholar, he had from there embarked to graduate school in the United States, and on to a stunningly prolific early career in optics and electromagnetics, publishing 200 papers before he reached 35.

His credentials, as Pickover well knew, included a remarkably wide-ranging intellect and a sense of humor. Lakhtakia can talk at length on Darwin as well as on enantiospecificity, on the changing cultural myth of the scientist as well as on liquid crystals. His resume, before the pages of technical citations, notes his receipt, in 1990, of a Diploma in Children's Literature. He has published a paper exploring "Certain Quinary Aspects of the Hindu Civilization," in the journal *Symmetry*. His most requested reprint, from the *Journal of Recreational Mathematics*, confesses an epiphanic moment in his understanding of fractals that occurred while he was perusing Dr. Seuss's: *The Cat in the Hat Comes Back*. "My ideal is not an expert," Lakhtakia has said, "it is a Renaissance personality. A thinking mind."

At first he refused the chief editorship of *Speculations*, not eager to take on more to do. After getting his feet wet as American editor of the journal, however, he found the work to his liking, and when MacKay retired in January 1993, Lakhtakia accepted the title of editor in chief, stipulating that he be allowed to appoint two assistant editors to share the load. Thus Renata Engel and Eliot Fried, two of his contemporaries and colleagues in engineering science and mechanics at Penn State, were introduced to the journal. Their freshness, he felt, would be an asset. "We need that youthful vigor. Thinking in new ways occurs to younger people more easily."

Lakhtakia also added new faces to the editorial board, seeking to broaden its collective expertise, and took steps to revamp the journal's editorial policies. "Up to now, one editor ran it," he explains. "I think that's all right for subjects of a queen, but not for citizens of a democracy." Papers can now be submitted to (and accepted by) any of the 11 editorial-board members, as well as any of the staff. "This should dilute the effects of an editor's proclivities. The aim is to be a general science journal."

That said, Lakhtakia also expects that he and his Penn State colleagues will put their own particular stamp on *Speculations*. One factor is their common background in engineering, which, he says, inclines them more toward observations than the purely theoretical. Another quality they will consciously promote is social responsibility.

"The environment will definitely be an area of focus," Lakhtakia says. "I think that we can all worry about superstrings if we can first survive on the planet. Scientists of all stripes should be addressing this." In the United States, the journal has already begun a collaboration with the Science, Technology, and Society program, an interdisciplinary organization which stresses science's ethical context. At the group's national meeting in January, *Speculations* sponsored a symposium on rational speculation.

Sitting around a conference table in a quiet oasis in the busy dean's office in Hammond, Lakhtakia and his fellow editors struggle with the ongoing task of defining their composite vision of the journal's scope and purpose.

"Ideas need to be critiqued, they need to be worked out," says Engel. "In the science and engineering communities, things are geared to 'prove it, show how it works.' But ideas start someplace else. A lot of what is in *Speculations* is stuff that would be talked about around the coffee machine or at a conference, but wouldn't otherwise be in print. It's getting ideas out early on."

"To me," Fried adds, "*speculative* means to encompass different approaches than the traditional ones. This is my main orientation — taking a new tack on hot issues."

"We are not open to porcine-winged speculation," Lakhtakia says, with a smile. "There must be at least some observed facts — that's an important criterion for us." At the same time, he suggests, he believes in the need to challenge established paradigms. To take on the real popes of science. And just to think out loud. "When physicists are not even sure what an electron is, how can we be sure what is invalid speculation? The widest possible latitude must be given."

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"David Pacchioli" by: Matchsticks, Zig-Zags, S-shapes and Bedsprings (*Research/Penn State*, Vol. 17, no. 3 (September, 1996))

Liquid crystals, that curious phase of matter between solid and liquid, play tricks with light: they change its direction of vibration as it traverses them. Some liquid crystals split light into left and right-handed rays, whose vibrations describe opposing spirals as they pass through a crystal's layers. "One ray rotates clockwise, the other counterclockwise, at different velocities," explains Akhlesh Lakhtakia. "Or both rays may describe clockwise spirals, or counterclockwise, but still move at different velocities." One ray may bounce off the material, while another passes through it unscathed.

Liquid crystals, however, are not very stable: their properties change with temperature -- as witness the mood ring, or the more recent LCD-studded t-shirts, both of which respond not to emotional fluctuations but to body heat.

What if you could design a stable material with the same light-altering properties?

That's the question Akhlesh Lakhtakia asked himself a few years ago.

Lakhtakia, Penn State associate professor of engineering science and mechanics, considers himself a theoretical electromagneticist. It's his business, in other words, to ponder how light moves through materials. "Especially exotic materials."

His study of liquid crystals taught him that "a material's microstructure gravely influences wave propagation through it -- that shape controls properties."

This principle Lakhtakia was used to hearing from Russell Messier, who works across the hall. Messier, professor of engineering science and mechanics, is an expert on columnar thin films, another kind of in-between material, which possesses some of the qualities of bulk materials, some of the properties of molecules.

Columnar thin films are grown by painstakingly depositing gaseous atoms of metal, ceramic or other material onto a chosen substrate, or base material. If conditions are right, tiny clusters of particles can be directed to settle on top of one another, "grown" as tiny columns. Messier was one of the pioneers in explaining how such structure is achieved.

In recent years, Messier and other researchers have demonstrated that the shaping of a thin film can be extremely fine-tuned: they have successfully changed the direction of a column's growth within a space of three nanometers or less. (That's three millionths of a millimeter!)

If we can influence a thin film's structure at such a scale, Lakhtakia reasoned, why can't we engineer columns in the shapes we want -- as helices, say, replicating the spiraling of liquid crystals? If we could, presumably we'd have a stable material that exhibited liquid crystal properties.

He asked Messier, who said he thought the concept was sound. But Messier's lab was not set up to make such a material. "It would have required a major redesign of his equipment," says Lakhtakia.

Messier, however, knew of two researchers at the University of Alberta, Michael Brett and Kevin Robbie, who had previously published a paper depicting some two-dimensional zig-zag columns they had grown. Lakhtakia called these colleagues in Canada, who agreed to give the idea a try.

Lakhtakia picks up the story: "One day in March of last year I turned on my Mac and found the SEMs waiting. They had made the material, and had e-mailed me the micrographs."

The pictures show thick forests of spirals made of magnesium fluoride rising from a flat substrate. "Bedsprings," Lakhtakia calls them.

Now Lakhtakia, Messier, and their colleagues envision a whole class of such materials, which they call "sculptured thin films." Already, they have drawn up four basic shapes as building blocks: matchsticks, zigzags, and S-shapes, as well as bedsprings.

"If we can engineer at the scale of three nanometers," Lahtakia says, "we can build these shapes. They can be conformed to allow certain wavelengths of light to pass through, and to polarize or to focus light. And unlike liquid crystals, they should be able to withstand wide temperature changes and high pressures, because they will have no internal stresses to make them brittle."

These materials will be useful, he says, in many devices, from optical sensors to broad-range thermometers to ultra-thin photographic lenses -- even for biomedical applications. Sculptured thin films, Lakhtakia suggests, could be fashioned into tiny sieves for trapping viral particles, which run to about 50 nanometers in diameter -- too small for your ordinary microfilter.

"These films are highly porous," he explains. "They're up to 80 percent air. We could vary the shape in such a way that a virus passing through fits the microstructure like a key fits a lock.

"A directed microstructure," Lakhtakia concludes, "is something we can exploit in many ways. This is true nano-engineering."

Akhlesh Lakhtakia, Ph.D., is associate professor of engineering science and mechanics in the College of Engineering, 224C Hammond Building, University Park, PA 16801; 814-863-4319. Russell F. Messier, Ph.D., is professor of engineering science and mechanics. The results reported above appeared in the Nov/Dec 1995 issue of the Journal of Vacuum Science and Technology A.

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[2/27/1996] Solid Liquid-Crystals Created as Three-Dimensional Thin Films

University Park, PA (Feb. 27) – A material similar to the color-changing liquid in the mood rings might some day provide ultra thin photographic lenses, optical filters, gas sensors and broad-range temperature sensors, according to Penn State researchers.

These devices will be made of the solid equivalent of cholesteric liquid crystals realized as thin films. The new materials have been named helicoidal bianisotropic media.

"Normal liquid crystals are somewhere between a solid and a liquid," says **Dr. Akhlesh Lakhtakia**, associate professor of engineering science and mechanics. "A helicoidal bianisotropic medium has a rigid backbone sculptured by nano-engineering."

Cholesteric liquid crystals pose a problem for theoretical electromagneticists like Lakhtakia, because no general solution of the Maxwell equations for light propagation in them existed until very recently.

"Only one special exact solution to the Maxwell equations in cholesterics was known, so I decided early in 1994 to determine what optical properties the material would have if a general solution were possible."

The material that Lakhtakia theoretically designed was a helicoidal or twisted material with specific electromagnetic propagation properties. The twist of this material would affect the way light and electromagnetic fields propagate through it and could be tailored for specific electromagnetic propagation.

"I can only conceive of these materials, so I asked Russ Messier if they could actually be realized experimentally," says Lakhtakia.

"I thought that by modulating the density of the material and switching the sample orientation very fast, we could realize the theoretical material," says **Dr. Russell Messier**, professor of engineering science and mechanics.

While Messier thought that the materials could be made, his experimental set up was not configured in a way that could easily synthesize the product. However, **Kevin Robbie** and **Dr. Michael Brett**, department of electrical engineering, University of Alberta, Edmonton, had already made a herringbone-shaped thin film and agreed to try to make the theoretical material.

The Canadians succeeded in manufacturing the first thin films of a helicoidal bianisotropic medium from magnesium fluoride and calcium fluoride which they, along with Lakhtakia, reported in the November/December 1995 issue of the Journal of Vacuum Science Technology, Part A.

The films are highly porous and have a very strong backbone structure. Unlike liquid crystals, these non-engineered thin films are likely to withstand wide temperature changes and high pressure.

The researchers can control the form of the thin films to allow certain wavelengths of light to pass through, to polarize or focus light.

"The liquid crystal thermometers that currently exist can only cover a range of about 10 degrees," says Lakhtakia. "The new materials could make a true liquid crystal thermometer with a broad range because they are temperature stable."

Other possible uses would include single lens stereographic viewers, beam separators and camera lenses. These films could also be integrated with electronics to create opto-electronic devices. Lakhtakia and Messier are currently exploring their general idea of sculptured thin films for prosthetic and other biomedical applications.

"Experimentally, a one-micrometer thin film can be manufactured in about five minutes which is quite reasonable," say Messier.

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[10/18/2000] Lakhtakia Co-edits Book on Unconventional Materials and Structures

University Park, PA (Oct. 18, 2000)–**Akhlesh Lakhtakia**, professor of engineering science and mechanics, has co-edited a new book titled "Electromagnetic Fields in Unconventional Materials and Structures."

The 489-page book is part of the Wiley Series in Microwave and Optical Engineering and was co-edited with Onkar N. Singh of the Banaras Hindu University's Department of Applied Physics, in Varanasi, India.

Fourteen authors from six countries contributed their research and reviewed parallel developments on electromagnetic fields in unconventional materials and structures for the text.

Their aim is to engineer geometry at nanoscopic, microscopic, and/or macroscopic length scales in order to realize materials and structures with unusual and innovative performance characteristics in optical, infrared, and millimeter-wave regimes.

Lakhtakia contributed a chapter on isotropic materials with microstructural handedness, and co-wrote a chapter on sculptured thin films with **Vijay Venugopal**, a former graduate student.

The book is intended for researchers and doctoral students.

All royalties from the book are being donated by the publisher directly to UNICEF.

* * *

Editors: Dr. Lakhtakia can be contacted at (814) 863-4319 or by e-mail at axl4@psu.edu.

All inquiries regarding these news articles should be directed to Curtis Chan, Coordinator of College Relations.

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Penn State professor among top authors in optoelectronics

University Park, PA (Mar. 11, 2002)—**Akhlesh Lakhtakia**, professor of engineering science and mechanics, has been listed as one of the top twenty-five authors in optoelectronics by ISI, a company that provides access to high-value, essential information for researchers and scholars worldwide.

From 1991 to 1999, Lakhtakia authored 89 papers in the field, earning 7th place on the list. His papers were cited 488 times during the same period, for an average of 5.48 cites per paper.

For the complete list, check the Web at http://esi-topics.com/optoelectronics/index.html.

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Engineering Penn State
The Magazine of the Penn State College of Engineering Summer 2002

Engineering the new economy

The Industrial Age and Information Age are melding to forge new, exciting possibilities

Today's factory floor is a far cry from the manufacturing plants of the past. Computer-controlled robots have propelled productivity. Networks have forged new avenues of communication between suppliers, manufacturers, and customers. Consumers can customize and order products through the Internet.

Penn State engineering students hone their skills in the Factory for Advanced Manufacturing Education (FAME) Laboratory, which boasts some of the most advanced technology in the country.

And that's just for starters.

The new economy is constantly evolving as engineers devise new ways of fusing information technology (IT) with manufacturing. In this emerging field, Penn State engineers are pioneering new territory in extended enterprise, customization, sensors, and survivability.

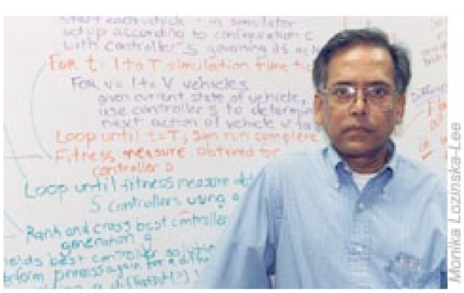
A more perfect union

In the old days, individual components were manufactured in several locations before being shipped to another locale for final assembly. Factories didn't communicate with each other regularly. Breakdowns or shortages in one area crippled an entire operation. But that is shifting as businesses utilize IT to make whole the sum of their parts.

"Next to e-business, enterprise integration is the biggest thing going on," says **Ravi Ravindran**, professor of industrial engineering. "It's happening big in companies now. The way things used to be, units operated independently with their own databases and such. There was no central way to access information."

Critical data wasn't shared in a timely manner between areas such as marketing, manufacturing, and accounting, Ravindran explains. Today's businesses face volatile demand, shorter production cycles, and information overload. By fostering interconnectivity between units, entrepreneurs can achieve quicker time to market, reduce inventory levels, raise quality, lower costs, and increase customer satisfaction, he says.

"In the digital world, the supply chain is called a value net, where the physical supply chain is connected to the information market infrastructure," says **Soundar Kumara**, professor of industrial engineering. "Everything is connected, so what happens on the factory floor also impacts the supplier two or three levels below."



According to Soundar Kumara, connectivity and customization share a "chicken-and-egg" relationship. The professor of industrial engineering says

Kumara is working with General Motors' Enterprise Systems Laboratory to develop an Order to Delivery (OTD) simulator system. As the name implies, the OTD allows users to tell the time it takes between order placement and delivery.

"We collected data on how long it takes to put a car out, how long it takes to get to a dealer, and when customers can get it," Kumara states. He and GM's Jeff Tew included factors such as machine utilization and the time taken to create specific car configurations.

greater connectivity fosters greater customization. Greater customization, in turn, demands more connectivity.

"We made the OTD system Web-based so that many people at GM could access it. Each decision maker needs a different type of data," Kumara says. For example, one person might need to know about machine use, another breakdown statistics.

He says the next phase involves optimizing the way cars are delivered. Kumara envisions that finished cars waiting for shipment might be equipped with electronic tags. The vehicles can then be more easily organized for transport.

"We want to maximize utilization of the trucks and trains used to get these cars to dealers while still satisfying the deadlines to get them there," he says.

Optimization is also the focus of research by **Vittal Prabhu**, assistant professor of industrial engineering. Prabhu is exploring methods to optimize the decision-making process for manufacturers by researching algorithms and hardware architectures to model man-made systems. His research is similar to the way meteorologists use mathematical equations and supercomputers to model weather patterns.

"There are so many options and combinations possible that supercomputing is absolutely necessary. If you buy the fastest supercomputer today, you can't harness the algorithms we've devised to take advantage. What we're researching is putting together the speed *and* the smarts," he says.

Buying a supercomputer also was not practical because of the size ("It's about the size of seventeen adult elephants—you couldn't put it on a factory floor," Prabhu states) or the cost (about $110 million, according to him). Instead, his team constructed their own supercomputer called PRIDE, or Parallel Reconfigurable Intelligent Decision Engine, to run the algorithms. "We built a prototype for about $30,000 or $40,000 in the lab using off-the-shelf components," smiles Prabhu.

Ideally, these computers could be networked to provide a constant stream of data. "It scales up from a shop floor to a plant to an entire chain. It'll propagate relevant information and let all decision makers adapt simultaneously," he says. "For example, as market conditions change, Ford or GM can decide the amount of supplies each tier needs to keep up with production and keep customers happy."

Irene Petrick, assistant professor of industrial engineering, and **Paul Cohen**, distinguished professor of industrial engineering, are developing what they call a 'digitized roadmap' that will aid manufacturers in new product development and process technology selection.

"Industry sectors and companies have been doing some form of roadmapping for years," Petrick states. "What new technologies are needed to create the next product family? What R&D projects should be mounted to support next generation products? We've been asking and answering these questions, often employing white boards or PowerPoint software to graphically represent the linkages between R&D, technology evolution, and product development."


Monika Lozinska-Lee

Irene Petrick, assistant professor of industrial engineering, and Paul Cohen, distinguished professor of industrial engineering, are working on a 'digital roadmap' to aid manufacturers in new product development and process technology selection.

The problem with the traditional roadmap is that it's a snapshot in time. Moreover, it's not in a format that is easily shared, reconfigured, searched, or updated. Petrick envisions the digitized roadmap as a dynamic document accessible to everyone, updated constantly to reflect the latest information. Once digitized, roadmaps can be evaluated across industry sectors or across companies.

"By capturing the elements (the technologies, the R&D projects, and the planned products) instead of just the linkages, the digital roadmap becomes the basis for company planning and for integrating R&D investments across the supply chain," she explains. "Now information can be used to plan forward and time developments of future products or plan backwards and invest in R&D to create new product opportunities."

The digital roadmap also would be an indispensable tool for displaying options on how to manufacture an item, otherwise known as process technology selection.

"For example, if I am an automobile manufacturer, and I want to build a tire rod with specialized features, the digital roadmap would tell me I can forge it, cast it, or use powdered metals. I can even look at technologies that are forecasted and plan for them," Petrick says. "Industry sector roadmaps will help companies identify processing technologies and sensors on the horizon, showing promising developments that can be incorporated into company manufacturing plans. They'll also identify the capabilities that aren't out there, thus guiding additional R&D planning."

Your way, right away

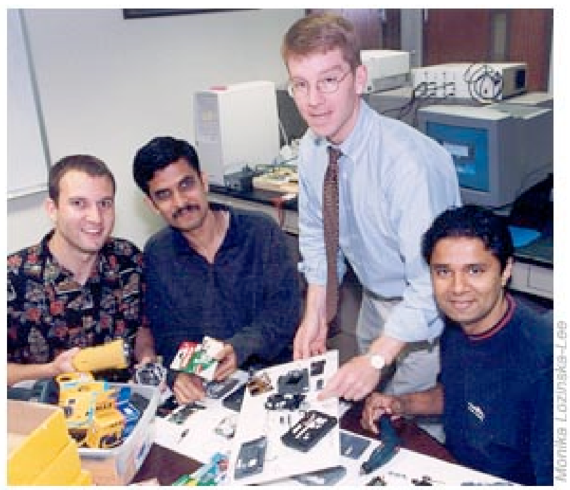
The marriage of IT and manufacturing is driving customization to new levels. Today's shoppers can not only choose the color of a shirt ordered online, they can monogram their own backpacks or design their own athletic shoes from scratch.

"There used to be no interaction between customers, designers, and manufacturers," Kumara states. "IT put into place the infrastructure for all these people to interact. Soon people will have a choice of customizing almost every product."

Ravindran agrees manufacturers will be offering higher levels of customization. "We may not be making thousands of units, but hundreds or maybe just even one."

A research team led by **Tim Simpson**, assistant professor of mechanical engineering and industrial engineering, is examining customization's impact on a manufacturer's underlying product realization processes.

As part of his design optimization research, Simpson studies how customers interact with Web sites to customize products, how that interaction impacts a product's underlying architecture, and how companies can optimize sets of products that can be quickly reconfigured by customers.



Tim Simpson, assistant professor of mechanical engineering and industrial engineering (standing), and his team of graduate students disassemble families of products to isolate common elements in customization. Pictured from left to right are students Gary Stump, Jyotirmaya Nanda, and Bryan D'Souza.

Simpson says, "The Internet is such a rich medium—you can get very detailed on what you want to customize, like the size of your hard drive or speed of the processor of your new computer. As a company, you don't want to overwhelm your customer with choices, but you want to provide enough options so that they can satisfy their individual needs."

Simpson's laboratory is filled with dissected products such as personal stereos, drills, coffee makers, and electronics. "We're trying to understand the complexity of the product itself and the manufacturing process involved," he explains. "For instance, we are asking the question, 'For this particular family of products being offered, what is the common platform from which all of these are derived?'"

For example, when a customer orders a computer, every machine might utilize the same motherboard and exterior case. Consumers can then customize these base machines by choosing more memory, a larger hard drive, or a faster graphics card.

By studying the variety of products that are available over the Web, Simpson hopes to develop a set of guidelines on how to tailor products and new software that will help companies design their product offerings for easy customization on the Web.

"These are design tools for engineers that won't be for just one industry," Simpson states. He has already received a National Science Foundation Career Award grant for his research and is working with three companies—Flowserve, Ivalo Lighting, and Durametal Corp.—to understand the nature of the products they customize and the corresponding manufacturing capability needed to produce those products.

Because of the work's strong commercial component, Simpson has also teamed with **Jennifer Chang-Coupland**, assistant professor of marketing, and **Arvind Rangaswamy**, Anchel Professor of Marketing, to study the role the Internet plays in product design and customization.

What's wrong with this picture?

Making sure things go smoothly throughout the manufacturing process will also become easier with IT. For years, Penn State engineers have been working on sensor technology with a multitude of applications. Work in machine vision, for example, could easily be applied to the factory floor.

Rangachar Kasturi, professor of computer science and engineering, believes machine vision is capable of capturing images and conducting analyses. He says machine vision can be used to find defects in manufacturing parts or ensure proper assembly.

Kasturi has already used his machine vision research for other applications, including automatic conversion of paper-based engineering drawings to electronic form for utilities such as telephone companies. With the help of **Rajeev Sharma**, associate professor of computer science and engineering, he developed a fuel gauge using computer sensors instead of wires to measure a tank's contents. He also teamed with **Octavia Camps**, associate professor of electrical engineering, to design a prototype obstacle avoidance system with NASA for airplane pilots.

Camps says many obstacles remain before an advanced form of computer vision will appear on factory floors, however. "When I first started, I tried to get the computer to recognize a stationary object," she recalls.

But as computers have grown faster and more powerful, Camps says her own research has moved on to getting machines to track moving objects in real-time. She envisions using not one sensor, but a network of sensors to track objects.

Camps is hard at work trying to get computers to understand how objects change shape as they move, as well as reconciling the data coming in from different sensors on a network.

"We humans are very good at seeing with our eyes and understanding. It's teaching the computers that's hard," she laughs.

Teaching the computer is a trick that Kumara is also trying to accomplish. In his case, he wants self-adapting machines to use sensor data for their own health monitoring.

"It's like our bodies—we sense things and the immune system takes action," Kumara says. "But how do you process these sensor signals?"

Kumara teamed up with **Akhlesh Lakhtakia**, professor of engineering science and mechanics, to tackle the problem of machine reliability. They devised what Lakhtakia calls a "boundary of acceptable limits" where a part or machine can no longer be considered stable enough for use.

Using Lakhtakia's expertise in fractals, the two engineers were able to analyze sensor signals to determine the dimensionality of a system.

"Instead of saying we need to replace a tool every 20 days, we already know when to replace it," Lakhtakia says.

Wireless technology may also be employed to help cope with equipment failure. "If a machine is going to fail, it can automatically send a signal to a part supplier for the replacement part or schedule maintenance—all in real time," Kumara states.

A more dangerous world

Even more vexing to engineers is how to maintain an IT infrastructure in the face of catastrophic failure. In the wake of last year's terrorist attacks, safeguarding this infrastructure has suddenly become a major priority.

"Looking at a value net, it's a big network with several nodes and links. All of these are networked together. Given what happened on 9/11, a lot of people are concerned about security," Kumara explains. "There can be physical attacks—people can bomb your plant—or information attacks—people can destroy your data. The question is, how survivable is your network?"

Through a project funded by the government's Defense Advanced Research Projects Agency, a team including Kumara, **Gautum Natarajan**, assistant professor of industrial engineering, and **C. R. Rao**, professor emeritus of statistics, is investigating the survivability of military supply chains using complexity theory and pattern recognition.

"We simulate a large network and see what happens under various conditions. We introduce corrupt data, change the available central processing unit, break off nodes, and see the changes of the agents on various networks," Kumara says. "By observing the resulting pattern of behavior, we are trying to predict the level of survivability of a network."

The team defines survivability as getting a particular response under threat. "Given the threats now," he continues, "how can we secure the network infrastructure and content? Conceptually, these are very simple problems. But from a theoretical and implementation view, this problem is a real nightmare."

The final piece of the puzzle

The most important component of all, the engineers say, remains the human decision makers. These tools, they say, merely facilitate better decision-making for manufacturers.

"We are in a knowledge economy where we need to learn more quickly and effectively," Petrick explains. "The link between data and action is knowledge."

—*Curtis Chan*

THE DIGITAL COLLEGIAN
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SCIENCE AND TECHNOLOGY

[Tuesday, Feb. 27, 2001]

Penn State undergraduate researcher strives to catch the sun

The student's research couples solar cells with reflectors and input variables to create efficient electricity.

By Drew Huang BIO
Collegian Staff Writer

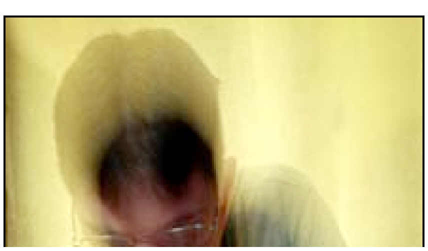
The mechanism might be difficult and complicated, but the end goal is simple: Catch the sun.

Toward that end, a Penn State undergraduate's research is helping make solar power more economical, possibly leading to the increased use of solar power for various applications in underdeveloped countries.

"The end goal is to make energy cheaper," Dave Denkenberger (senior-engineering science) said. "One of the most important things when you're doing a project for underprivileged countries is to make it cheap."

Denkenberger, who also is minoring in economics, began his research the summer after his sophomore year. As his research grew, it eventually became his senior thesis for Schreyer Honors College.

Since no Penn State professor is currently doing similar research, Denkenberger has been doing his work mostly solo, proving that "it is possible to do your own idea," he said.



Denkenberger's research began with solar cells, devices that turn sunlight into electricity. Solar cells are too costly for people to use currently, Denkenberger said.

PHOTO: Adam R. Harvey
Dave Denkenberger displays a solar cell used to convert solar energy into electricity.

"Right now, in most applications, the solar cells are so expensive that it doesn't pay back," he said.

In order to try to utilize less of the expensive solar cells while still producing a high-energy output, Denkenberger began experimenting with reflectors -- equipment that collects sunlight from a large area and reflects it toward solar cells. Thus, sunlight that does not land directly on a solar cell still can be received by a solar cell with the use of reflectors.

"What actually happened was that I figured out, on my own, the best shape of my reflector, and I was going to patent it, but then I figured out it was already patented in the early 1970s," Denkenberger said.

Nonetheless, "I independently found the equation," he said.

Reflectors are placed in a trough-like fashion on both sides of long and narrow strips of solar cells, Denkenberger said. The strips of solar cells themselves are on an inclined panel.

When viewed from the top, the parabola-shaped reflectors run along the same length of the solar cell strip and increase the effective sunlight-collecting area by about three times.

"These reflectors, it's not a simple question on how big to make them, because if you make them taller, then you catch more light in, but then it's more expensive," he said.

Additionally, while a flat bed of solar cells can accept sunlight from any angle, a strip of solar cells surrounded by reflectors can only accept sunlight from angles that do not bump into the outside of the reflectors. "Again, there's a tradeoff, because you're giving up some light, but when the sun is in the right spot, you're getting what we call a concentration factor," he said.

Denkenberger proceeded to write a computer program that would give the optimal angle of the panel and the optimal equation for the reflectors to produce a maximal amount of energy for a minimal price.

"There are a million and one variables involved," said Akhlesh Lakhtakia, professor of engineering science and mechanics and Denkenberger's research advisor, adding that, although other people had optimized reflectors with one variable before, Denkenberger's work was unique for its multivariable optimization.

"You want to expose solar cells to the most amount of energy," Lakhtakia said. "In reality, the thing is that the conditions that make the solar cells exposed change every minute, and they depend a lot on location."

Everything from climate, latitude, environment, reflectiveness of the reflector, cost of the reflectors and solar cells, time of year and other variables were factored into Denkenberger's optimization program.

"He's has taken the art of designing solar cell concentration to a new level," Lakhtakia said.

Thus, when the program finishes its calculations, it shows how to make solar energy cheaper.

"The power of my program is that it's not just for one size of solar cell or for one latitude," Denkenberger said. "I can actually enter in things that vary those parameters. If you're on the equator or if you're in State College, I can factor that in."

The program's optimization of the reflectors is the crux of Denkenberger's research. "The original part is optimizing, actually figuring out how to use these things," he said. "That's what this program does. ... It gives you real numbers."

Denkenberger's work did not stop with solar cells, however. He recently became involved with solar cookers and solar pasteurizers.

"Much of the world cooks with wood, and also this is the less-developed countries," he said, adding that people will deforest their living areas in order to find wood with which to cook.

"Most of the less-developed countries are near the equator, so they get more sun," he added.

Reflectors can be used to concentrate sunlight for use in cooking and heating water in order to kill dangerous microbes. Denkenberger said these cookers and pasteurizers, which work by sunlight instead of wood, could be an asset to the less-developed countries that have plenty of sunlight. "It makes a lot of sense to use solar," he said.

With a solar cooker, food is placed into an enclosed box with a clear cover. Parabolic reflectors are placed on all four sides on the top of the box. They collect and concentrate sunlight to heat and cook the food.

The use of reflectors is especially economical and useful in solar cookers, Denkenberger said.

A solar pasteurizer is similar to a solar cooker, in that reflectors are placed around the top of a box to heat up water inside the box. "We know we have to warm the water up to 150 degrees Fahrenheit," Denkenberger said. "Almost everything that causes disease in humans is killed at 150 F, not 212."

To make a solar pasteurizer, a tube curled into a rectangular spiral is placed inside the solar cooker. At one end of the tube comes the dirty water. The other end of the tube has a temperature-sensitive valve.

When the dirty water flows into the spiraled tube inside the box, it is stopped at the valve. The reflectors concentrate light into the box, which heats up the water. When the water has reached a high enough temperature, the valve opens up, allowing the clean, hot water to flow out and letting more, cold, dirty water to flow in until it reaches the valve, which then closes again.

The outgoing hot water and incoming cold water also go through what is called a heat exchange. "The heat exchange says that we have a bunch of clean water that's hot. We should be able to use some of that heat to warm the dirty water that's going to come in," Denkenberger said.

Thus, the hot water gives some heat to the cold water in the heat exchange, increasing the efficiency of the solar pasteurizer.

The autonomy of the solar pasteurizer makes it easier to use than simply putting a pot of water in a simple solar cooker and hoping that all the water will be heated enough to kill the microbes, Denkenberger said.

Denkenberger's research with the solar cookers and pasteurizers again utilizes a computer program. However, the curvature and height of the reflectors are no longer an output, but an input. "In this application, it's more of a calculator than it is an optimizer," he said.

Denkenberger also assumes that the solar cooker and pasteurizer will be frequently moved manually to point the reflectors more toward the sun, making the output of his computer program slightly different.

"What comes out is how much food you can cook or how much water you can pasteurize," Denkenberger said. "Also, the other thing it can do is tell you how much the reflector would cost."

Denkenberger hopes that his work with solar cookers and pasteurizers will eventually help less-developed countries stop major deforestation and provide them with clean water.

"Approximately half of the people in less-developed countries don't have safe drinking water," he said.

Lakhtakia was cautiously optimistic about Denkenberger's work. "The very best ideas can languish," Lakhtakia said. "Let's put it this way -- I think if his idea does catch on, then I think in the tropical areas, certainly it could have a major impact."

Lakhtakia did fully recognize the potential in Denkenberger's research, which so far has been mostly theoretical and done on a computer. "Ideas of this kind are certainly very significant," he said.

Denkenberger will have a poster of his work March 21-22 at the Undergraduate Exhibition in the HUB-Robeson Center's Alumni Hall. He is also traveling March 15-17 to Lexington, KY, where he will present his work at the National Conference on Undergraduate Research.

Most of all, Denkenberger is proud of the immediate applicability of his work.

"I really feel that this work can be used to help people in the real world," he said. "It means a lot to me because I think I can help people with it."

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Quick poll: Should Penn State stop scheduling Friday classes?

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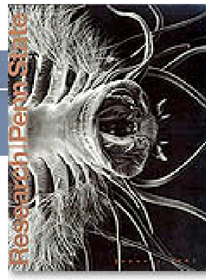

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encyclopedia

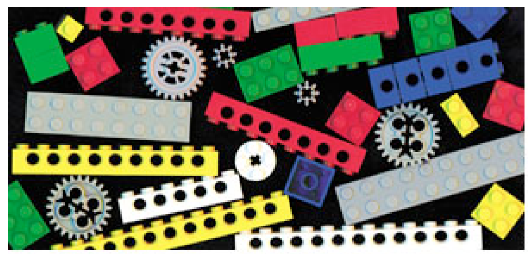
Building Bridges

By Evy Potochny

Scientific illiteracy abounds in America. One recent poll, funded by the National Science Foundation, found that fewer than half those interviewed knew that the Earth takes one year to orbit the Sun.

Unfortunately, grade-school teachers are not immune. And if teachers can't make sense of basic scientific concepts — if they can't "integrate them into their own understanding," as Vincent Lunetta, a Penn State professor of curriculum and instruction, puts it — then it is next to impossible for their pupils to do so.

Notes Akhlesh Lakhtakia, a professor of engineering science and mechanics, "The kind of students I often teach, although bright, don't know how to analyze, to break a job or task into several parts and figure out how it works." These skills, he adds, need to be taught in grade school. And by using concrete examples. "If we want to teach children analytical skills, we should not teach science through abstract notions. That does not inspire children."



James Collins

Building blocks of scientific literacy? Toys can be bridges to teaching science.

Two years ago, Lunetta and Lakhtakia got together to work on improving elementary science instruction. SciEd 497: The Fundamentals of Science, Technology, and Engineering Design was born.

The "fundamentals" include the stability of shapes, mechanisms of simple machines, and conservation of energy. Joe Taylor, the graduate student who teaches the class, typically uses his students' preconceptions of scientific principles — force, motion, and electricity — as the basis for customized instruction. Students about to study levers, for example, are asked to bring in household gadgets. These — bottle openers, scissors, staplers — are held up for discussion. Recognizing science in everyday objects, he says, is the first step to understanding it.

The students then morph into engineers in a hypothetical construction firm, working in groups of three or four. Their task is to design a bridge suited for car and pedestrian traffic across a waterway. Computer simulation software lets the students select parameters — length, height, and style of bridge — and test their designs. If an animated truck makes its way safely across the bridge, the design is sound. If not, the bridge collapses, sending the truck toppling into the water.

Once a design is agreed upon, the group goes to work with Lego and K'NEX blocks to build a scale model across a two-foot gorge between rows of desks. The finished bridges, says Taylor, can be remarkably different, helping students realize that a single problem can often have multiple solutions.

Each "firm" then prepares a presentation — including digital photos — and presents it to a "town council" made up of Lunetta, Lakhtakia, and other guests. Their goal is to convince the council that their bridge is both cost-effective and structurally sound.

Next, the same bridges must be substantially renovated, so that they can be raised or lowered for the passage of tall ships. Here, Taylor says, students learn about integrating basic machine systems — wheels and axles, pulleys and gears — and determine how the resulting complex machine can best perform the task. The last segment of the course introduces electrical circuits: the students add buzzers and lights to signal when the bridge is in use.

Fatih Tasar, a graduate student in science education, has studied how the students' initial scientific conceptions change over the course of the semester. Before a topic was covered in class, Tasar had students make word associations. For the concept of acceleration, he writes, one student chose "rate of change of velocity." Often, Tasar says, a student will memorize a scientific formula, i.e., *acceleration = rate of change of velocity*, without actually understanding it.

During the course, Tasar says, the students' understanding of abstract concepts evolved. One student, whose last physics class had been in seventh grade, initially understood acceleration as "whether or not a person is pushing harder" on an object. To get across the correct meaning, Tasar asked the student to think of a growing population. If the rate of increase from year to year drops from two percent to one percent, the rate of acceleration is decreasing. After that explanation, he says, "It began to make sense to her." Later in the semester, however, the same student again had difficulty explaining acceleration until prompted to remember the population analogy. Tasar concluded that while analogies can be helpful, long-held misconceptions are often hard to change.

Despite this resistance, Taylor adds, "What we've been hearing in end-of-semester interviews is a new confidence as science learners."

"I feel very comfortable with teaching science now," confirms one elementary-education student. "I feel as if I could handle almost any question my future students might ask about simple machines."

"My roommate is an engineering major," says another. "He couldn't believe that I was analyzing these complex truss bridges. At first, he just wanted to show me how he would do the problem. But by the time we were done talking, he asked me to show him my way. It really made me feel proud of what I had learned."

Joe Taylor is a Ph.D. student studying science education. M. Fatih Tasar completed his doctorate in science education in August 2000. Their advisers for this project were Vincent Lunetta, Ph.D., professor of education, College of Education, 166 Chambers Bldg., University Park, PA 16802; 814-865-2237; vnl@psu.edu; and Akhlesh Lakhtakia, Ph.D., professor of engineering science and mechanics, College of Engineering.
SCIED/ENGR 497f has been supported by the NSF-funded program ECSEL (Engineering Coalition of Schools for Excellence in Education and Leadership). In September, the Science Education Program received the Provost's Special Recognition Award from the University for this and other projects.

THE DIGITAL COLLEGIAN
PUBLISHED INDEPENDENTLY BY STUDENTS AT PENN STATE

NEWS

[Thursday, Feb. 15, 2001]

Engineering class uses toys as learning tools

Editor's Note: This is the first in a weekly series about innovative classes at Penn State.

By Ari Pinkus
Collegian Staff Writer

A box of Legos and K'NEX blocks can entertain children for hours on a rainy afternoon.

Using these same children's toys, students are busy assembling bridges in a college classroom. They select each piece with care because one more ounce may cause the bridge to collapse.

"I really understand a kid's frustration now," Brooke Cowles (sophomore- elementary education) said.

Engineering/Science Education 497F (Fundamentals of Science, Technology and Engineering Design), bridges the fields of engineering and education. By using Legos and K'NEX to build bridges, students learn how to think like engineers and teach science and engineering to children.

Although the class is geared toward students who are elementary education majors, other students may take it to fulfil their general science requirement in the general education core, said Akhlesh Lakhtakia, professor of engineering science and mechanics.

"Science education at the elementary school level in the United States is taught like in a primitive society — not the most industrialized nation in the world," he said. Children are curious but the people who are supposed to guide them are unprepared in science, he added.

To accomplish the primary goal of making future teachers comfortable and knowledgeable about science and engineering, the class is structured in a series of three modules or units.

"It involves solving problems in the physical sciences," said Vince Lunetta, professor of science education. After each unit, students are tested on the module's scientific concepts.

For the first module, small groups of students must design a bridge structure that is able to support a specified load for a specified distance. It must also be stable, relatively inexpensive and eye-catching. Using K'NEX to build the bridges helps future teachers feel at ease with science tools and can be used in the elementary school classroom.

"Teaching science is of the passive variety," Lakhtakia said. He cites taking students on a nature walk and being able to identify trees as an example of passive learning.

"It does not engage the student in hands-on activity," he said.

The active learning aspect of the class is exactly what intrigues students.

"So many classes are lectures. I like the class because it's hands-on," April Kearney (freshman-elementary education) said.

Although students are using Legos and K'NEX, two children's toys to build the bridge, the project involves scientific concepts.

"It's not like you are a 2-or 3-year-old playing with Legos. It's very challenging," Rich Schmidt (freshman-elementary education) said.

Six weeks into the semester, Schmidt has learned that using a triangular arrangement of blocks when building a bridge creates the most stable structure. Chris Johnson (freshman-secondary education) has learned how to make structures efficient and about compression and tension in bridges.

Michelle Hendershot (freshman-elementary education) said the use of computer software has been helpful in learning how to build a bridge.

The West Point Bridge Designer computer software aids students in constructing the bridges. They create a structure on the screen and work with virtual blocks before transferring their idea to a K'NEX structure.

"It is good introductory software," Erdat Cataloglu, a science education teaching assistant said.

The finished bridge must be 60 inches. After a group takes a digital photo of their construction, they must present their structure to the rest of the class and explain how their bridges are cost effective and structurally sound, Erdat said.

Learning how to think from a scientific prospective is a major aspect of this course. "I've found that students start to think like engineers about seven weeks into the course," Lakhtakia said.

Engineering is fundamental in an industrial society, he said. "Without engineering we might as well sit in caves and howl. Engineering makes us human," Lakhtakia added.

Lunetta and Lakhtakia were two of the faculty members in a team of people from the Colleges of Education and the College of Engineering who developed the class, Lunetta said. Throughout its three years, the class has been evolving, he said.

Although Lakhtakia said the class is taught in a language that students can understand, some students disagree.

"We don't know what's right and wrong. Our teacher doesn't give a complete answer. We're expected to know what engineering people do even through we're not engineers," Hendershot said.

Schmidt thinks there may be too much focus on independent learning.

"We're not being told why or how some of the principles we're using apply in the projects we're doing," he said.

Many in the class, however, would recommend it to other students.

"I would recommend it to people who really don't have a scientific mind," Nick Enciso (junior-theatrical production) said.

Johnson believes that elementary education majors would benefit most from the class.

"It's geared toward teaching younger kids," he said.

Despite its focus on education, students should expect the course to be rigorous. "They should be spending three if not four hours a week outside of class," Lakhtakia said.

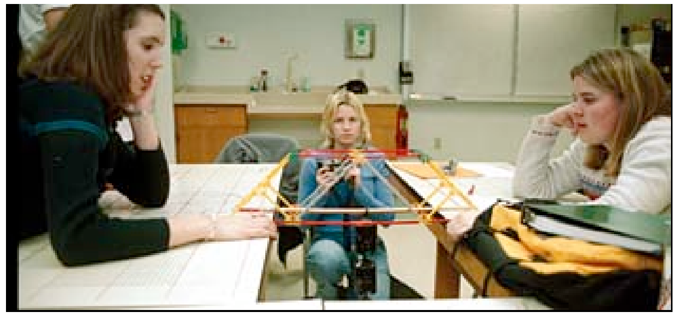


PHOTO: Adam R. Harvey

Engineering/Science Education 497F students study the properties of structure in class. The students used K'NEX blocks to build small bridges and then examined how it reacts to different weight loads.

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Engineering better teachers

New course inspires students about teaching engineering

x

Future elementary school teachers gain content knowledge and confidence in science and engineering through a special program designed in collaboration between the Colleges of Engineering and Education. Students apply engineering principles and practices and construct their own projects using materials they can use to teach elementary school children.

For **Akhlesh Lakhtakia**, the need for effective science and technical education in schools literally hit home while watching his daughter attend elementary school.

"When my daughter started going to school, I noticed she wasn't being challenged in science," says Lakhtakia, a professor of engineering science and mechanics. He says he became concerned his daughter would rule out a career in science and engineering at a very young age.

"When a child is eight or nine years old, that's when decisions take place," he says. "A child is ready to receive complicated ideas, so long as they feel involved."

Lakhtakia's concerns prompted him to collaborate with the College of Education, teaming up with **Tom Dana**, associate professor of science education, **Vince Lunetta**, professor of science education, **Mehmet Tasar**, doctoral candidate in science education, **Johanna Ramos**, graduate assistant in the College of Engineering, and **Joe Taylor**, a doctoral candidate in science education.

Together they developed a new course, ENGR/SCIED 497F, designed to teach education majors about engineering before they get to the classroom. According to Lakhtakia, the class is supposed help these students become comfortable with engineering principles and practices, give them confidence in teaching their own students, and allow them to cultivate children's curiosity of the natural world.

"It's a long-term investment," says Taylor. "We expect to make an impact with this course over the next 30 to 35 years. The future teachers who take this course will teach thousands of kids in that time."

The 497F course departs from the lecture-style of teaching and instead takes a project-oriented approach to teaching education students. Each module contains activities that culminate in a final project. For example, students learn about the strength of polygons in structures by building objects with Legos.

"I liked the hands-on activities," says **Wade Wooley**, a first-year education major from Mansfield, PA. "Those are things I remember learning in elementary school myself. We used Legos and K-NEX to build simple machines. I can incorporate this into my own lessons when I become a teacher, because we used practical materials.

I felt much more confident with all the tools. I'm more excited now that I understand it clearly. I won't be second-guessing myself on the material."

And that, Lakhtakia says, is the key to effective science education—getting the teachers excited through engineering about the science they're teaching and passing on that enthusiasm and curiosity to their own students.

"Engineering and science provide a way for us to make sense of our universe, our surroundings, and a way to make our lives better," he says.

Lunetta says, "Educating our citizenry is an important mission of universities—not just educating experts. We need to establish both a depth and a breadth of science experience in our society. This course is one of many things we should do to make our citizens well-informed, rational consumers, and to give those with interests in science the foundation that can take them, and us, to new frontiers."

Dr. Lakhtakia can be reached at (814) 863-4319 or by e-mail at axl4@psu.edu*. Special thanks to Jeff Deitrich at the College of Education for his contributions to this story.*

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[8/20/2002] Scholarship honors retiring head of engineering science McNitt

University Park, PA—In honor of retiring Engineering Science and Mechanics Head **Richard McNitt**, the department's faculty and staff have created the R. P. McNitt Scholarship in Engineering Science and Mechanics.

McNitt is retiring after 21 years of service to Penn State. He began his teaching career in 1959 as an instructor at Penn State, and then at Purdue University. In 1965, McNitt became an assistant professor at Virginia Polytechnic Institute and rose to the rank of full professor. At Virginia Tech he received several teaching awards and was a founding member of the Academy of Teaching Excellence.

In 1981, McNitt returned to Penn State as professor and head of the Department of Engineering Science and Mechanics. With the help of three deans and a dedicated faculty, McNitt expanded the department from 18 to 30 faculty members, oversaw significant increases in research expenditures, and cultivated two research laboratories into College-wide centers.

Over his 21 years at Penn State, he has created many new courses and won numerous awards for his teaching, including the Lawrence J. Perez Memorial Student Advocate Award in 1994 and the American Society of Engineering Education's Archie Higdon Teaching Award in 2001. Throughout his career he contributed to numerous publications, was active in several groups and societies, and taught every semester.

McNitt is a Fellow and past president of the Society of Engineering Sciences, past treasurer of the American Academy of Mechanics, past chair of the ASEE's Mechanics Division, and past chair of the National Science Foundation's Minority Fellowship Selection committee.

His research interests include continuum mechanics, environmental degradation, and vehicular safety.
He received his bachelor's in engineering science and master's in engineering mechanics from Penn State in 1957 and 1959, respectively, and his Ph.D. in engineering science from Purdue in 1965.

The McNitt scholarship will be given to undergraduate and graduate students in engineering science and mechanics who demonstrate superior academic achievement or who show promise of academic excellence.

The effort to form the scholarship was led by a group of faculty and staff including **Aklesh Lakhtakia**, professor of engineering science and mechanics; **Russell Messier**, professor of engineering science and mechanics; **Mirna Urquidi-Macdonald**, professor of engineering science and mechanics; and **Susan Croyle**, department administrative assistant.

All inquiries regarding these news articles should be directed to Curtis Chan, Coordinator of College Relations.

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The Magazine of the Penn State College of Engineering
Penn State
Fall 2002

Engineering science scholarship honors retiring head McNitt

In honor of retiring Engineering Science and Mechanics Head **Richard McNitt**, the department's faculty and staff have created the R.P. McNitt Scholarship in Engineering Science and Mechanics.

McNitt is retiring after 21 years of service to Penn State. He began his teaching career in 1959 as an instructor, first at Penn State and then at Purdue University. In 1965 McNitt became an assistant professor at Virginia Polytechnic Institute and rose to the rank of full professor. At Virginia Tech he received several teaching awards and was a founding member of the Academy of Teaching Excellence.

In 1981 McNitt returned to Penn State as professor and head of the Department of Engineering Science and Mechanics. With the help of three deans and a dedicated faculty, McNitt expanded the department from 18 to 30 faculty members, oversaw significant increases in research expenditures, and cultivated two research laboratories into Collegewide centers.

Throughout his 21 years at Penn State, he created many new courses and won numerous awards for his teaching, including the Lawrence J. Perez Memorial Student Advocate Award in 1994 and the American Society of Engineering Education's Archie Higdon Teaching Award in 2001. He contributed to numerous publications, was active in several groups and societies, and taught every semester.

McNitt is a Fellow and past president of the Society of Engineering Sciences, past treasurer of the American Academy of Mechanics, past chair of the ASEE's Mechanics Division, and past chair of the National Science Foundation's Minority Fellowship Selection Committee.

He received his bachelor's in engineering science and master's in engineering mechanics from Penn State in 1957 and 1959, respectively, and his Ph.D. in engineering science from Purdue in 1965.

The McNitt Scholarship will be given to undergraduate and graduate students in engineering science and mechanics who demonstrate superior academic achievement or show promise of academic excellence.

The effort to form the scholarship was led by a group of faculty and staff including **Aklesh Lakhtakia,** professor of engineering science and mechanics; **Russell Messier**, professor of engineering science and mechanics; **Mirna Urquidi-Macdonald**, professor of engineering science and mechanics; and **Susan Croyle**, department administrative assistant.

November 10, 2004

Nanotechnology: Issues and Obstacles- A Conversation with Akhlesh Lakhtakia

Akhlesh Lakhtakia, Distinguished Professor of Engineering Science and Mechanics, spoke to a lunchtime crowd at the final fall conversation of Research Unplugged on November 10.

"How small is nano?" Akhlesh Lakhtakia asked students, faculty, and community members during the final session of the fall season of Research Unplugged. "Divide an inch into 25 pieces," he said. "Then divide each piece into one *million* pieces. Each of those pieces is one nanometer."

According to Lakhtakia, distinguished professor of engineering science and mechanics, nanotechnology is defined as any technology with features of nanometer scale, such as thin films, carbon nanotubes, quantumdots, and fine particles. He said it is generally agreed that the nanometer scale is any width between 0.2 and 100 nanometer (nm).

What are the industrial prospects of technology at this scale? "As of today," Lakhtakia says, "absolutely zero. It is enormously expensive to manipulate matter precisely at the nano scale," he explained. "And in order to make a desirable product, you have to have reproducability. We don't have that yet." As a result, he said, "In a lab we can do all kinds of things; in a factory, no — as of now."

Lakhtakia also pointed out that nanotechnology has developed at a crucial stage of history. "We have the extraordinary convergence of three new technologies: biotechnology, information technology, and nanotechnology," he said. "They help one another, they feed one another, and the prospects they raise are either extremely pleasant to contemplate — anything is possible! — or too terrifying to contemplate." This convergence, he suggested, "will divide us — rich from poor, those who control these technologies from those who don't, those who benefit from those who don't. It is vital that the public consider the social implications of the enormous power that could be realized."

Lakhtakia has devoted his career to investigating research areas that no one else has pursued, or as he puts it, "operating at the edge of understanding." His work focuses on the interaction of electromagnetic fields with complex materials. In those interactions, he explains, "unusual things can happen."

Lakhtakia's many books include *Sculptured Thin Films: Nanoengineered Morphology and Optics* (forthcoming) with R. Messier, *Nanometer Structures: Theory, Modeling, and Simulation* (2004), and *Introduction to Complex Mediums for Optics and Electromagnetics* (2003).

Lakhtakia teaches several courses at Penn State, including Laser Optics Fundamentals (ESC 598G), Multidisciplinary Informal Engineering Education Seminar (ESC 597A), and Green Engineering (ESC 124).

— *Jeria Quesenberry*

Akhlesh Lakhtakia, Ph.D., is distinguished professor of Engineering Science and Mechanics in the College of Engineering, 212 Earth and Engineering Sciences Building, University Park, PA 16802; 814-863-4319;

axl4@psu.edu. Jeria Quesenberry, jquesenberry@ist.psu.edu, is a Ph.D. candidate in the school of Information Sciences and Technology. She is a member of the Research Unplugged committee.

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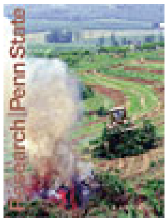

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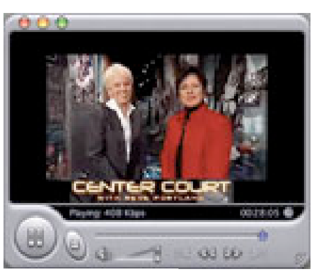

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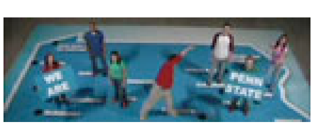


Recent Headlines

Twinkle, twinkle little star, how I wonder where you are
Thursday, August 5, 2004

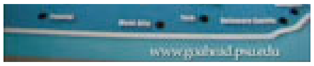
University Park, Pa. – Whether viewed dimly through the haze and lights of a city or in all their glory in a pristine wilderness, the stars that surround the Earth are magnificent, and one day Earthlings will travel to some of the new planets that astronomers are locating. However, the stars we see are not necessarily where we think they are, according to an international research team.

"We know that the light from distant stars takes a very long time to reach the Earth," said Akhlesh Lakhtakia, distinguished professor of engineering science and mechanics at Penn State. “But, taking into account the distance a star will have moved while that light travels, we still may not be able to accurately locate the star."

Negative phase velocity media or materials with negative refractive index may be responsible for this locational uncertainty. Recently, materials researchers at the University of California San Diego, working with micro- and nano-materials, developed a metamaterial that had a negative refractive index for microwaves, proving that negative phase materials could exist at least in the microwave part of the electromagnetic spectrum. Their requirements for this material were that both the relative permittivity, a measure of the charge separation in a material, and the relative permeability, a measure of how electrons loop in materials, of a substance must be less than zero.

While the implications for negative phase velocity media in the nano world are the creation of a perfect lens, a lens with no distortion with applications for optical transmission devices, CDs, DVDs, microwave systems, etc., in the universe at large, these media can disguise the location of a star, according to the researchers.

A material with negative index of refraction transmits light or other wave energy differently than one with positive index of refraction. In all natural materials, when an energy beam –– light, radar or



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microwave –- passes through water or glass or some other material, the beam is displaced in the same direction. The amount of displacement depends upon how much the material slows the speed of the beam. In negative phase velocity media, the displacement is in the opposite direction.

Lakhtakia and Tom. G. Mackay, lecturer in mathematics at the University of Edinburgh, decided to look at why the permittivity and permeability had to be less than zero. They found that one or both permeability and permittivity could be less than zero and negative phase velocity would occur. They then found that both could be greater than zero and a negative index of refraction would occur but only when special relativity came into play.

The researchers looked at transmission through space, where high velocities are common.

"First I did the derivations with the observer moving and the energy source stationary," said Lakhtakia. "Then Mackay did the derivations with the observer stationary and the light source moving."

What they found was that it depends on the state of the observer whether any particular media at any time has negative or positive index of refraction. The relative velocity of the observer changes the index of any material.

"Light coming off a stellar object passes through many different regions of space filled with different media and is affected by different gravitational fields," said Lakhtakia. "When we finally see it, we cannot really know where it originated."

While this may be of no consequence today, Lakhtakia believes it has important implications for when space travel is common. Because this is a direction-dependent effect, it will change the telemetry of objects and spacecraft.

"The business of space navigation and interpreting star maps could be a lot more complicated than we now think it is," said Lakhtakia. "Imagine mining of extrasolar asteroids. We might not want to send humans to do the mining, but robots would have to know where the asteroid is and where on its surface to mine when it left our solar system."

Calculations would need to be made from Earth on an asteroid that might not be where we visually see it. The effects of negative-phase velocity media would need to be taken into consideration.

Another problem would be navigating from somewhere far away from the Earth in a spaceship using information gathered from the Earth. Depending on the velocity of the spacecraft and the object aimed for, negative-phase velocity media between the spacecraft and the destination also would need to be considered.

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Star light, star bright

Engineers say today's methods can't precisely pinpoint stars' locations

Whether viewed dimly through the haze and lights of a city or in all their glory in a pristine wilderness, the stars that surround the Earth are magnificent, and one day Earthlings will travel to some of the new planets that astronomers are locating. However, the stars we see are not necessarily where we think they are, according to an international research team.

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—A’ndrea Messer

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Intercom bids farewell
Thursday, February 3, 2005


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"I WINKLE, TWINKLE LITTLE STAR"

After 34 years, Intercom is retiring and turning the job of informing the University community to Penn State Live.

A long-standing institution at Penn State is retiring. With the Feb. 3 issue, Intercom will bid farewell after more than three decades of service to the Penn State community.

For 34 years, Intercom has been the official source of news and information about Penn State to those who help keep the University ticking — its employees.

"It has become apparent to us that with more than a quarter of a million subscriptions to the Penn State Newswire system and the comprehensive Penn State Live news Web site that we now are reaching many times more people electronically than we have been reaching in print form," said Bill Mahon, assistant vice president for University Relations. "But we were spending a lot more of our budget printing week-old news and that does not make sense for a University as technologically advanced as Penn State."

"The reaction from readers to the Penn State Newswire and Penn State

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Live has surpassed anything we expected when we started down this road and now we can put more staff and resources into making them even better," Mahon said.

At its height, Intercom reached 22,200 subscribers 37 times a year. By comparison, the Faculty/Staff Newswire reaches up to 38,000 subscribers more than 90 times a year.

"Now that we no longer need to devote time to the production of Intercom, our staff will be able to work on making Penn State Live and the Newswires more robust and even more responsive to the needs of our subscribers," said Annemarie Mountz, former editor of Intercom, and manager of Penn State Live and the Faculty/Staff Newswire. "We're excited about the prospects of expanding what we do to serve our readers even better, and to interact with them more directly."

Penn State Live, the University's online news service at http://live.psu.edu/ is updated around the clock and features the latest news about Penn State along with photos, streaming video and audio streams of both WPSU-FM and ComRadio. Penn State Live also includes links to the close to three dozen Penn State Newswires, as well as WPSX-TV productions of "Weather World" and "Pennsylvania Inside Out" in streaming video.

The Faculty/Staff Newswire is published at University Park on Mondays, and University-wide on Thursdays. All full- and part-time faculty and staff automatically are subscribed to the Faculty/Staff Newswire, with the ability to opt out if they desire. Anyone who is not employed by Penn State but would like to receive the Faculty/Staff Newswire can subscribe by visiting http://www.psu.edu/INTERCOM/newswire/ on the Web. Anyone with questions can contact Annemarie Mountz at Live@psu.edu.

The Newswire family also includes close to three dozen general and specialized Newswires on topics including sports, diversity, science and technology, Greek life, alumni news and news from many of the University's campuses. To subscribe to any of these, go to http://newswires.psu.edu/

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Published online: 15 February 2005; | doi:10.1038/news050214-5

Black holes bend light the 'wrong' way

Jim Giles

Refraction effect may be distorting astronomers' results.

Astronomers could be misinterpreting their observations of distant stars, suggest mathematicians.

The galaxy Centaurus A has a supermassive black hole at its heart – but could its gravity be fooling astronomers?

© *NASA/JPL-Caltech*

Starlight may be bent in odd directions when it passes close to a rotating black hole, the researchers say, unexpectedly shifting its source's apparent position in the sky. The cause is a recently discovered phenomenon called negative refraction, which physicists are still struggling to understand.

Astronomers already adjust their observations to account for the fact that light is bent by massive objects such as black holes, an effect called gravitational lensing. But Akhlesh Lakhtakia, a mathematician at Pennsylvania State University in University Park, has studied what happens when a black hole rotates. In this case, light is bent in the direction opposite to that predicted by conventional theory.

"Astronomical measurements, particularly those relating to black holes and other massive stellar bodies, need careful reinterpretation," says Tom Mackay of the University of Edinburgh, UK, who worked with Lakhtakia on the analysis, published online in *Physics Letters A*[1].

Material fact

Negative refraction is new to astronomy, but has been causing a stir in materials science in recent years. When light crosses a boundary, it is bent in a characteristic way; this is why an oar dipped in water looks as though the submerged part is angled towards the surface.

But in 2001, US researchers showed that certain artificial materials bend light in the opposite direction[2]. If water had this property, the submerged oar would appear to angle away from the surface.

The revelation prompted a flurry of research, most of which has focused on understanding and developing negative refracting materials. "But this is exactly the same phenomena," Mackay points out.

Last year, Mackay and Lakhtakia demonstrated that negative refraction could occur in a vacuum, provided that the gravitational field in the region had the right properties. Now, they have identified something that meets these requirements: a rotating black hole. Very large rotating stars would have the same effect, adds Mackay.

Strong field

This might force astronomers to rethink some of their observations. "The deflection of light could be significant," says Mackay. In theory, starlight could even turn through a 90° angle, apparently putting the star in a completely different part of the sky. "And the further away the object is, the more likely it is that these effects are interfering with observations," adds Mackay.

However, some researchers question how much influence the effect will have in practice. Matthias Bartelmann, a theoretical astrophysicist at the University of Heidelberg in Germany, describes Mackay and Lakhtakia's paper as very interesting. "But I'm in doubt as to the astronomical relevance," he says. Bartelmann points out that the effect will be limited to small regions of space, as it can only occur in regions where the gravitational field is extremely strong.

The effect could find other uses, however. Theoretical astronomers are currently debating whether the cosmological constant, a key number in the equations that describe the evolution and growth of the universe, is positive or negative. Mackay says that negative refraction can only take place if the constant is positive, so experimental verification of such refraction could help to settle the debate.

Top

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1. Lakhtakia A., Mackay T. G. & Setiawan S. *Phys. Lett. A*, **336**. 89 - 96 (2005). | Article | ChemPort |
2. Shelby R. A., Smith D. R. & Schultz S. *Science*, **292**. 77 - 79 (2001). | Article | PubMed | ISI | ChemPort |

Fetal DNA Extracted From Mother's Blood

Rare genetic diseases could be detected without amniocentesis, nature.com reported.

A non-invasive blood test can now detect the gene for the fatal disease beta-thalassemia in a growing fetus. Its developers believe that the technique could be applied to a range of other diseases, overcoming the need for a more invasive procedure called amniocentesis.

Screening a mother's blood can already determine whether unborn children have certain hereditary diseases. But current screens can only detect large-scale irregularities in the baby's chromosomes, such as those found in Down syndrome, says Sinuhe Hahn, a molecular biologist from the University Women's Hospital in Basel, Switzerland.

Doctors use amniocentesis to spot single-gene mutations, such as the ones that cause beta-thalassemia. The test involves inserting a needle in the mother's abdomen to draw amniotic fluid out of the womb. But the invasive method can lead to damage or loss of the baby in up to 1% of cases.

Hahn and his colleagues have found that trace fragments of fetal DNA can be separated from the mother's genetic material in her blood. This allows them to pinpoint single mutations in the baby's DNA, which is normally swamped by the mother's own DNA.

Black Holes Bend Light the Wrong Way

Refraction effect may be distorting astronomers' results, nature.com reported. Astronomers could be misinterpreting their observations of distant stars, suggest mathematicians.

Starlight may be bent in odd directions when it passes close to a rotating black hole, the researchers say, unexpectedly shifting its source's apparent position in the sky. The cause is a recently discovered phenomenon called negative refraction, which physicists are still struggling to understand.

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The revelation prompted a flurry of research, most of which has focused on understanding and developing negative refracting materials. "But this is exactly the same phenomena," Mackay points out.

Hope to Cure Deafness

A pioneering form of gene therapy has cured deafness in guinea pigs.

It raises hopes that the same procedure might work in people, reports New Scientist.

"It's the first time anyone has biologically repaired the hearing of animals," says Yehoash Raphael, head of the US-Japanese team that developed the technique.

The therapy promotes the re-growth of crucial hair cells in the cochlea, the part of the inner ear which registers sound.

After treatment, the researchers used sensory electrodes around the animals' heads to show that the auditory nerves of treated - but not untreated - animals were now registering sound.

Raphael's team first gave the guinea pigs antibiotics which destroyed their inner-ear hair cells.

They then apparently repaired the damage by injecting them with genetically engineered adenoviruses.

"The recovery of hair cells brought the treated ears to between 50% and 80% of their original hearing thresholds," says Raphael.

Raphael warns that there are many obstacles to overcome before the procedure could be used in people.

Longer Lives for Organic LEDs

The performance of organic light-emitting diodes can be improved by doping them with carbon-60 according to scientists at Samsung in South Korea. The carbon-60 molecules can also extend the lifetime of the devices by a factor of two, PhysicsWeb.org said

Organic light-emitting diodes (LEDs) are potentially attractive for applications because they are easy to process and can emit over the full visible spectrum. Light emission from organic materials relies on electrons and "holes" combining to form excited states called "excitons" that subsequently emit photons when they decay.

A typical LED contains a thin light-emitting layer sandwiched between layers that transport the holes and the electrons. One way of improving the performance of organic LEDs is to increase the mobility of the holes in the hole-transport layer by adding a dopant. This should lead to more holes combining with electrons in the device.

Jun Yeob Lee and Jang Hyuk Kwon at Samsung's Corporate R&D Center in Yong-In City studied the effect of carbon-60 doping in phosphorescent devices that rely on an organic material called "TDAPB" as the hole-transport layer. Lee and Kwon varied the concentration of carbon-60 in the TDAPB from 0 to 3% while measuring the properties of the device with a spectrophotometer.

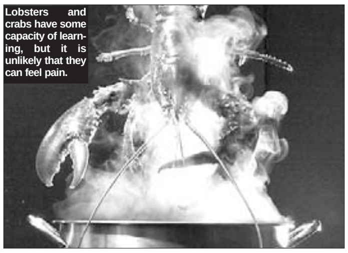
They found that the mobility of holes in devices doped with 3% carbon-60 was five times higher than that of pure TDAPB. The current density also increased by a factor of three, and there was a 30% increase in the luminance of the LED.

Doping with 3% carbon-60 also increased the lifetime from 700 hours for the undoped device to 1400 hours. Carbon-60 is an electron acceptor that protects the TDAPB from being "attacked" by excess electrons ejected from the light-emitting layer.

Lobsters Feel No Pain

Lobsters probably do not feel pain when they are dropped into a pot of boiling water, claims a new study. According to ananova.com, animal activists claim lobsters are in agony when being cooked, and that boiling them alive is torture.

But the study, by a scientist at Oslo University, suggests



Lobsters and crabs have some capacity of learning, but it is unlikely that they can feel pain.

lobsters and other invertebrates such as crabs, snails and worms probably don't suffer.

"Lobsters and crabs have some capacity of learning, but it is unlikely that they can feel pain," concluded the report.

Biologists maintain that the lobster['s primitive nervous system and underdeveloped brain are similar to that of an insect. "It's a semantic thing: No brain, no pain," said Mike Loughlin, a biologist at the Maine Atlantic Salmon Commission.

Οι μαύρες τρύπες κάμπτουν το φως με μη αναμενόμενο τρόπο

Πηγή: Nature, 16 Φεβρουαρίου 2005

Το φαινόμενο της διάθλασης μπορεί να διαταράξει τα αστρονομικά αποτελέσματα. Οι αστρονόμοι θα μπορούσαν να παρερμηνεύσουν τις παρατηρήσεις μακρινών άστρων, τονίζουν οι μαθηματικοί. Το φως των άστρων μπορεί να καμφθεί κατά αναπάντεχες κατευθύνσεις, όταν περνάει κοντά από μια περιστρεφόμενη μαύρη τρύπα, εξηγούν ερευνητές, κι έτσι να μετατοπίζει απροσδόκητα τη φαινομενική θέση του άστρου στον ουρανό.

Η αιτία είναι ένα φαινόμενο που ανακαλύφθηκε πρόσφατα, και λέγεται αρνητική διάθλαση, και το οποίο οι φυσικοί προσπαθούν ακόμα να το κατανοήσουν.

Ο γαλαξίας Κένταυρος Α έχει μια υπέρ-μεγέθη μαύρη τρύπα στην καρδιά του, αλλά θα μπορούσε άραγε η βαρύτητά της να ξεγελάσει τους αστρονόμους;

Οι αστρονόμοι ήδη λαμβάνουν υπ' όψιν κατά τις παρατηρήσεις τους την κάμψη του φωτός που προκαλείται από σώματα μεγάλης μάζας, όπως είναι οι μαύρες τρύπες. Το φαινόμενο αυτό λέγεται βαρυτική εστίαση και το βαρυτικό πεδίο ουράνιων σωμάτων με μεγάλη μάζα δρα σαν βαρυτικός φακός. Τώρα ο **Akhlesh Lakhtakia**, ένας μαθηματικός στο πολιτειακό πανεπιστήμιο της **Pennsylvania**, μελέτησε τι συμβαίνει όταν μια μαύρη τρύπα περιστρέφεται. Στην περίπτωση αυτή, το φως κάμπτεται σε κατεύθυνση αντίθετη από αυτή που προβλέπει η συμβατική θεωρία.

"Οι αστρονομικές μετρήσεις, ιδιαίτερα εκείνες που σχετίζονται με μαύρες τρύπες και άλλα ουράνια αντικείμενα μεγάλης μάζας, χρειάζονται προσεκτικές ερμηνείες," λέει ο **Tom Mackay** του πανεπιστημίου του **Edinburgh**, στη Βρετανία, ο οποίος δούλεψε μαζί με τον **Lakhtakia** στην εργασία που δημοσιεύθηκε στο περιοδικό **Physics Letters A.**

Η αρνητική διάθλαση είναι καινούργιο θέμα για την αστρονομία, έχει όμως προκαλέσει μια αναταραχή στην επιστήμη των υλικών κατά τα τελευταία χρόνια. Όταν το φως διασχίζει μια διαχωριστική επιφάνεια δύο μέσων, κάμπτεται κατά χαρακτηριστικό τρόπο. Έτσι εξηγείται γιατί το κουπί μιας βάρκας όταν είναι βυθισμένο στο νερό μοιάζει να έχει σπάσει και να έχει καμφθεί προς την επιφάνεια.

Το **2001** όμως, ερευνητές στις ΗΠΑ έδειξαν ότι ορισμένα τεχνητά υλικά κάμπτουν το φως κατά αντίθετη κατεύθυνση. Αν το νερό για παράδειγμα είχε αυτή την ιδιότητα, το μισοβυθισμένο κουπί θα έμοιαζε σπασμένο προς τον βυθό αντί για την επιφάνεια.

Η ανακάλυψη αυτή πυροδότησε πολλές έρευνες, οι περισσότερες εκ των οποίων επικεντρώθηκαν στην κατανόηση και ανάπτυξη υλικών με αρνητική διάθλαση. "Αλλά και στην αστρονομία έχουμε τα ίδια ακριβώς φαινόμενα" λέει ο **Mackay.**

Πέρυσι, οι **Mackay** και **Lakhtakia** έδειξαν ότι η αρνητική διάθλαση θα μπορούσε να συμβεί στο κενό, αρκεί το βαρυτικό πεδίο στην περιοχή εκείνη να είχε τις κατάλληλες ιδιότητες. Τώρα, οι ίδιοι πιστοποίησαν κάτι που ικανοποιεί αυτές τις απαιτήσεις: μια περιστρεφόμενη μαύρη τρύπα. Τα πολύ μεγάλα περιστρεφόμενα άστρα, θα έχουν επίσης το ίδιο αποτέλεσμα, λέει ο **Mackay.**

Η παρατήρηση αυτή θα μπορούσε να αναγκάσει τους αστρονόμους να ξανασκεφθούν μερικές από τις παρατηρήσεις τους. "Η απόκλιση του φωτός θα μπορούσε να είναι σημαντική" λέει ο **Mackay.** Θεωρητικά, το φως των άστρων θα μπορούσε να στραφεί μέχρι και **90** μοίρες, πράγμα το οποίο θα τοποθετούσε το άστρο σε τελείως διαφορετική περιοχή του ουρανού. "Και όσο πιο μακριά βρίσκεται το αντικείμενο, τόσο πιο πιθανό είναι τα φαινόμενα αυτά να επιδρούν στις παρατηρήσεις μας" προσθέτει ο **Mackay.**

Μερικοί ερευνητές όμως, αναρωτιούνται πόση επίδραση θα μπορούσε να έχει πρακτικά το φαινόμενο αυτό. Ο Matthias Bartelmann, ένας θεωρητικός αστροφυσικός στο πανεπιστήμιο της Heidelberg στη Γερμανία, περιγράφει την εργασία των Mackay και Lakhtakia, ως πολύ ενδιαφέρουσα. "Αλλά αμφιβάλλω για την αστρονομική της σημασία" λέει. Ο Bartelmann πιστεύει ότι το φαινόμενο αυτό θα περιορίζεται σε μικρές περιοχές του χώρου, επειδή μπορεί να συμβαίνει μόνο σε περιοχές που το βαρυτικό πεδίο είναι εξαιρετικά ισχυρό.

Το φαινόμενο όμως αυτό θα μπορούσε να βρει άλλες χρήσεις. Οι θεωρητικοί αστρονόμοι συζητάνε σήμερα αν η κοσμολογική σταθερά, ένα μέγεθος κλειδί στις εξισώσεις που περιγράφουν την εξέλιξη και ανάπτυξη του σύμπαντος, είναι θετική ή αρνητική. Ο Mackay λέει ότι η αρνητική διάθλαση μπορεί να συμβεί μόνο αν η σταθερά είναι θετική, κι έτσι η πειραματική πιστοποίηση μιας τέτοιας διάθλασης θα βοηθούσε να λυθεί το ζήτημα.

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Η συμπεριφορά του φωτός με την αρνητική διάθλαση

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Individuare le stelle

di: Donata Allegri

Sappiamo che occorre molto tempo prima che la luce dalle stelle distanti raggiunga la Terra. Se prendiamo in considerazione una stella molto lontana, quando la sua luce giunge a noi, lei si sarà spostata e quindi non è possibile determinare esattamente la sua posizione. Responsabili di questo possono essere gli strumenti usati che hanno indice di rifrazione negativo.

Un materiale con l'indice di rifrazione negativo trasmette diversamente la luce o altra energia che uno con l'indice di rifrazione positivo. Quando una luce attraversa un materiale naturale viene deviata e la quantità di spostamento dipende da quanto il materiale ritarda la velocità del fascio. Nei mezzi negativi con velocità di fase negativa, lo spostamento è nel senso opposto.

Dott. Akhlesh Lakhtakia

Recentemente scienziati dell'università di California San Diego, guidati dal Dott. Akhlesh Lakhtakia hanno trovato un metamateriale che presenta un indice di rifrazione negativa per le microonde, ed in questo modo hanno dimostrato che esistono materiali con fase negativa almeno per quanto riguarda la regione delle microonde dello spettro elettromagnetico. Dopo questi studi si potrà forse creare una lente senza distorsioni da usare in dispositivi di trasmissione ottici mentre nell'universo questi materiali possono impedire la localizzazione di una stella, dato che nello spazio la luce attraversa molti materiali differenti.

Lakhtakia e Tom. G. Mackay dell'università di Edinburgo hanno misurato la costante dielettrica e la permeabilità ed hanno visto che è sufficiente che una o l'altra siano inferiori a zero, perché la velocità di fase della luce sia negativa. Hanno anche dimostrato che anche se entrambi i parametri fossero più grandi di zero, l'indice di rifrazione potrebbe essere negativo, però accadrebbe soltanto quando entra in gioco la relatività speciale. Facendo esperimenti hanno visto che la velocità relativa dell'osservatore cambia l'indice di tutto il materiale. Questi studi potranno avere importanti implicazioni in un futuro in cui si diffonderà il volo spaziale.

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VERSIONE STAMPA INVIA QUESTA NOTIZIA AD UN AMICO

N.B.: gli eventuali indirizzi di recapito presenti nell'articolo possono cambiare senza che la redazione di ECplanet ne venga a conoscenza.

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Juodosios skylės šviesą galbūt iškreipia „ne į tą pusę“

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Skaityti komentarus (14)

Gali būti, kad astronomai klaidingai vertina tolimų žvaigždžių stebėjimo duomenis, tvirtina matematikai. Netoli besisukančios juodosios skylės praėjusi šviesa gali būti iškreipta neįprastomis kryptimis, tvirtina mokslininkai. Todėl kai kuriais atvejais matomo šviesos šaltinio tikrosios buvimo vietos negalima nustatyti tiksliai. Tokio neapibrėžtumo priežastis – neseniai atrastas reiškinys pavadintas „neigiama refrakcija“, kurią fizikai vis dar bando perprasti.

Astronomai savo stebėjimus jau patikslina atsižvelgdami į tai, kaip šviesą iškreipia masyvūs dangaus kūnai, pavyzdžiui, juodosios skylės. Šis reiškinys vadinamas gravitaciniu didinimu. Tačiau Pensilvanijos universiteto matematikas Akhleshas Lakhtakia tyrė, kas būna, jei juodoji skylė sukasi. Tuo atveju šviesa iškreipiama priešinga kryptimi nei teigia įprastinė teorija.

„Astronominiai matavimai, o ypač tie, kurie susiję su juodosiomis skylėmis ir kitais masyviais objektais, turi būti iš naujo įvertinti“, - sakė su A.Lakhtakia dirbęs Edinburgo universiteto (D.Britanija) mokslininkas Tomas Mackay. Mokslininkų darbo rezultatai publikuojami žurnale „Physics Letters A“.

Neigiama refrakcija astronomams
yra visiškai nauja sąvoka, tačiau medžiagų moksle ji jau figūruoja keletą pastarųjų metų. Spinduliui kertant dviejų paviršių sąlyčio ribą, jis lūžta tam tikru būdu. Dėl to atrodo, kad į vandenį įmerkta irklo dalis su paviršiumi sudaro mažesnį kampą nei neįmerkta.

Tačiau 2001 metais JAV mokslininkai įrodė, kad tam tikros dirbtinės medžiagos šviesą laužia priešinga kryptimi. Jei vanduo pasižymėtų šia savybe, tai atrodytų, kad į vandenį įmerkta irklo dalis su paviršiumi sudarytų didesnį kampą.

Po šio atradimo mokslininkai suskubo atlikinėti naujus tyrimus. Didžioji jų dalis buvo naujų neigiama refrakcija pasižyminčių medžiagų kūrimas. „Tačiau tai yra tas pats reiškinys“, - pažymi

Antraštės
- Lietuvio išrasti sprogmenys pripažinti ir pradėti naudoti
-

Praėjusiais metais abu mokslininkai pademonstravo, kad neigiama refrakcija gali pasireikšti vakuume, jei tos srities gravitacinis laukas pasižymi reikiamomis savybėmis. Dabar jie išsiaiškino, kas atitinka jų nusakytas sąlygas - besisukanti juodoji skylė. Be to, pasak T.Mackay, besisukančios didžiulės žvaigždės šviesą veiktų taip pat.

Tai gali priversti astronomus iš naujo įvertinti kai kuriuos stebėjimus. „Šviesos nuokrypis gali būti reikšmingas“, - sakė T.Mackay. Teoriškai šviesa netgi gali pasisukti 90° kampu, todėl stebima žvaigždė gali būti visiškai kitoje dangaus dalyje. „Kuo toliau yra stebimas objektas, tuo didesnė tikimybė, kad neigiama refrakcija turi įtakos stebėjimo duomenims“, - sakė T.Mackay.

Tačiau kai kurie mokslininkai abejoja neigiamos refrakcijos įtaka realiems matavimams. Teorinės astrofizikos specialistas Matthias Bartelmannas iš Heidelbergo universiteto (Vokietija) T.Mackay‘aus ir A.Lakhtakia darbą pavadino labai įdomiu. „Tačiau abejoju jo reikšme astronomijai“, - sakė M.Bartelmannas. Jo teigimu, neigiamos refrakcijos poveikis apsiribos nedideliais erdvės regionais, nes jis gali pasireikšti tik ten, kur gravitacinis laukas yra labai stiprus.

Visgi šis reiškinys gali būti panaudotas kitu būdu. Astronomai teoretikai dabar ginčijasi ar kosmologinė konstanta – vienas iš pagrindinių skaičių lygtyse, nusakančios visatos evoliuciją ir augimą – yra teigiamas ar neigiamas dydis. T.Mackay teigimu, neigiama refrakcija įmanoma tik tuo atveju, jei konstanta yra teigiama, todėl eksperimentinis neigiamos refrakcijos verifikavimas galėtų padėti išspręsti šį ginčą.

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Straipsnių komentarai

Vardas **El. paštas**

Straipsnio komentarų skaičius: **14**

Skaityti komentarus Pagalba

- Rasta pirmoji nematoma galaktika
- Mokslą išmanantys žmonės tyrimus vertina palankiau
- Japonai išrado dantų pastą, kuri "sutaiso" pradedančius gesti dantis
- Titane stebima geologinė veikla
- Marse aptikta didžiulė užšalusi jūra
- Alpių ledo žmogus atskleidžia akmens amžiaus paslaptis
- Mokslininkas nori „sunaikinti“ tamsiąją energiją
- Atjaunėti galima perpylus jauno kraujo
- Paukščių take užfiksuotas galingas kosminis sprogimas
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Verta aplankyti

Black Hole Belokkan Cahaya ke Arah ’Keliru’

Para astronom bisa jadi salah menginterprestasikan observasi mereka terhadap posisi bintang-bintang di kejauhan. Alasannya, black hole dan objek-objek raksasa di jagad raya ternyata membelokkan cahaya pada arah ’keliru’ sehingga sebuah bintang seolah berada di titik lain.

Menurut para matematikawan, cahaya bintang akan dibelokkan ke arah yang berbeda dari anggapan semula bila lewat di dekat sebuah black hole yang berputar. Ini akan mengakibatkan kesalahan interprestasi mengenai posisi sang bintang di langit. Penyebabnya adalah sebuah fenomena yang ditemukan baru-baru ini - disebut refraksi (pembiasan) negatif - suatu hal yang masih berusaha dipahami oleh para ilmuwan.

Sejauh ini para astronom masih melakukan observasi untuk meneliti bagaimana cahaya bisa dibelokkan oleh objek-objek raksasa seperti black hole. Efek pembelokan itu sendiri disebut gravitational lensing. Nah, seorang matematikawan dari Pennsylvania State University, Akhlesh Lakhtakia, menemukan sesuatu yang - bila benar - bakal mengubah banyak data perbintangan. Ia mengajukan pendapat bahwa cahaya akan dibelokkan ke arah kebalikan dari apa yang selama ini diduga dalam teori konvensional, bila mendekati sebuah black hole yang berputar.

"Artinya, pengukuran-pengukuran astronomis, terutama yang berkaitan dengan black hole dan objek-objek raksasa lain, mungkin keliru dan perlu diinterprestasikan ulang," ujar Tom Mackay dari University of Edinburgh, Inggris, yang bersama Lakhtakia mempublikasikan perhitungannya dalam Physics Letters.

Pembiasan negatif sendiri adalah hal baru dalam dunia astronomi, namun berakibat besar terhadap materi-materi ilmu pengetahuan. Untuk lebih memahami pembiasan, bayangkan hal ini: ketika cahaya melintasi suatu perbatasan, ia akan melengkung. Ini bisa terlihat pada tongkat lurus yang dimasukkan dalam air, bagian yang tercelup akan terlihat patah dan membelok. Ini adalah pembiasan positif.

Nah, pada tahun 2001, peneliti-peneliti AS menunjukkan bahwa beberapa material membelokkan cahaya pada arah berlawanan, alias terjadi pembiasan negatif. Dan fenomena inilah yang ditengarai terjadi pada black hole dan bintang-bintang besar yang berputar. Dalam kasus ini arah cahaya yang dibelokkan tidak seperti yang diduga para astronom.

Ini bakal memaksa para astronom meninjau kembali beberapa observasi mereka. "Pembiasan yang berbeda arah pastilah akan mengubah kedudukan bintang-bintang menjadi tidak seperti apa yang selama ini kita sangka," kata Mackay. Secara teori pembelokan cahaya bintang ini bisa mencapai sudut 90 derajat, sehingga kedudukan sebenarnya berada di bagian lain langit. "Dan semakin jauh objek, makin mungkin efek ini mempengaruhi pengamatan," ujarnya. **(newscientist.com/wsn)**

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In the Stars: Beholding the monster

By Phil Berardelli
Science & Technology Editor

Washington, DC, Mar. 10 (UPI) -- Black holes are the stepchildren of the Big Bang. The products of extremely intense gravitational attraction caused by gigantic agglomerations of matter, they are universal consumers, gobbling up everything from gas and dust to planets and stars -- even their own kind.

The biggest black holes sit at the centers of galaxies like celestial monarchs, squashing out the space within their molecules and atoms and permitting nothing, not even light, to escape their mighty grasp. Time and space are bent by their sheer massiveness.

Since their existence was first proposed -- in 1969, by American physicist John Wheeler -- and even when the first one

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was indirectly observed in 1971, black holes have remained among the most mysterious structures in the universe, represented more by analogy than measurement.

Two factors have perpetuated this mystery: (1) all known black holes are too far away from Earth to observe clearly and (2) even if the distance could be closed, they are much too dangerous to approach with present-day technology.

Yet black holes compel investigation because they approximate certain characteristics of the universe at the earliest moments of its existence.

That is where a new computer simulation can help. Developed by a team at Johns Hopkins University and the University of Virginia, the model apparently is helping to answer questions about black holes and even challenging some of the popular assumptions about them.

"Only recently have members of the research team ... created a computer program powerful enough to track all the elements of accretion onto black holes, from turbulence and magnetic fields to relativistic gravity," said Julian Krolik, a physics professor at Hopkins and co-leader of the team.

The new program is "opening a new window on the complicated story of how matter falls into black holes," he added, "revealing for the first time how tangled magnetic fields and Einsteinian gravity combine to squeeze out a last burst of energy from matter doomed to infinite imprisonment."

One of the counterintuitive aspects of these monsters is they seem to hurl out tremendous amounts of matter and energy in the process of sucking things in.

This differs from the first theories about black holes, in which scientists thought matter passing through the zone called the event horizon did so like it was moving along the ultimate one-way street -- directly into the darkness, never to return.

Observations and theoretical calculations quickly put an end to that concept, however. In the process of pulling in a huge amount of matter, scientists found, black holes expel an enormous amount of energy, in the form of X-rays, gamma radiation and vast gas jets moving at millions of miles an hour or more.

The Hopkins-Virginia computer model has helped to refine that violent picture even more. It reveals that the inward plunge of matter toward a black hole amplifies its random motions intensely, like a powerful stream of water creates violent turbulence.

It turns out this process actually might be visible.

"Just like any fluid that has been stirred into turbulence, matter immediately outside the edge of the black hole is heated. This extra heat makes additional light that astronomers on Earth can see," said the University of Virginia's John Hawley.

Scientists have known for some time the powerful but erratic magnetic forces generated by the turbulence surrounding black holes cause variable radiation. The new computer model shows how this same process is responsible for expelling jets of particles moving close to the speed of light and results in a peculiar effect on the black hole's central mass.

The magnetic forces connect with matter orbiting far away from the event horizon. When the matter is drawn inward, the magnetic field accelerates some of the particles and spews them back out, usually in directions perpendicular to the black hole's spin.

"If a black hole is born spinning extremely rapidly, its 'drive train' can be so powerful that its capture of additional mass causes its rotation to slow down," Krolik explained. "Accretion of mass would then act as a 'governor,' enforcing a cosmic speed limit on black hole spins."

In other words, Krolik said, the mass-accretion governor could be connected to some of the major properties of black holes. It is widely thought, for example, the strength of a black hole's jet is related to its spin, so a sort of spin speed limit might determine the strength and size of the jets, he said.

Other black-hole effects are downright bizarre. New calculations by scientists at Penn State University and the University of Edinburgh, Scotland, suggest that objects as massive as black holes might bend passing light and radiation so much that their true direction of origin might be impossible to determine.

The phenomenon is called negative refraction and it involves a severe warping of space -- and consequently objects moving within space -- by massive gravitational fields such as those generated by black holes.

"We should not be disappointed if we cannot discover the origin of the universe," said Akhlesh Lakhtakia, a professor of engineering science and mechanics at Penn State. "The gravitational effect probably makes it so that we do not really know where we are looking."

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In the Stars is a weekly series examining new discoveries about the cosmos. E-mail: sciencemail@upi.com

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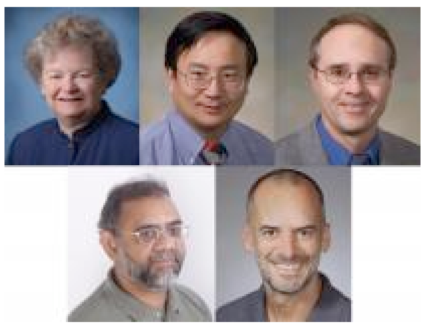

(top row, from left) Maureen Carr, Hong Ma and James F. Kasting; (bottom row, from left) Akhlesh Lakhtakia and Frank R. Baumgartner

University Park, Pa. -- Five Penn State professors will receive 2004-2005 Faculty Scholar Medals for Outstanding Achievement. Maureen Carr, professor of music, will receive the Arts and Humanities Medal; Hong Ma, professor of biology, will receive the Life and Health Science Medal; James F. Kasting, distinguished professor of geosciences, will receive the Physical Sciences Medal; Akhlesh Lakhtakia, distinguished professor of engineering science and mechanics will receive the Engineering Medal, and Frank R. Baumgartner, distinguished professor of political science, will receive the Social and Behavioral Sciences Medal.

Established in 1980, the award recognizes scholarly or creative excellence represented by a single contribution or a series of contributions around a coherent theme. A committee of faculty peers reviews nominations and selects candidates.

Carr receives her award for her books, "Multiple Masks: Neoclassicism in Stravinsky's Dramatic works on Greek Subjects" and "Stravinsky's Historie du soldat," which position her as an authority on Stravinsky's musical sketches and one of the leading scholars on the music of Stravinsky. Her research not only expands the knowledge of Stravinsky's compositional process, but also provides new insights into

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the cultural context for the works that she has studied. Her research has been conducted primarily in Switzerland at the Paul Sacher Stiftung in Basel. In addition, she has worked at archives in Winterthur, Lausanne, London and Paris. She received grants from the Penn State Institute for the Arts and Humanities, the College of Arts and Architecture, the American Association of American Women and Pro Helvetia.

She has a B.A. from Marywood College, an M.F.A. from Rutgers University and a Ph.D. from University of Wisconsin-Madison. She has served on several national and regional committees related to the field of music theory. She has presented papers at national meetings as well as at international conferences in Belgium and England. In 1995, she received the Penn State College of Arts and Architecture Outstanding Teaching Award, was named a Distinguished Alumna by the University of Wisconsin-Madison School of Music in 1998, and in 2004 she received a Marywood University Professional Achievement Award.

Ma receives his medal for his research on the molecular basis of plant reproduction, which helps us understand one of the most important and basic of biological processes: the production of eggs and sperm. Using a variety of approaches, including molecular genetics of flower development and genome-based studies of flower evolution, Ma's research is at the forefront of both disciplines and is widely applicable to plants and animals that reproduce sexually, including humans.

Ma received his B.A. from Temple University in 1983 and his Ph.D. from the Massachusetts Institute of Technology in 1988. He was a postdoc at the California Institute of Technology from 1988 to 1990. He joined Penn State in 1998. He received the American Cancer Society Junior Faculty Research Award for1994-1997 and a Guggenheim Fellowship for 2004-2005.

Kasting's medal is for his deep and broad contributions to our understanding of planetary habitability and evolution. His work has covered such problems as the "Faint Young Sun Paradox," carbon dioxide levels in early Earth's atmosphere, the origins of oxygen in Earth's atmosphere, the effects of glaciation, global warming and asteroid impacts. He is one of the foremost experts on the atmosphere of Mars and on planetary habitable zones.

He received his A.B. in chemistry and physics from Harvard University in 1975, an M.S. in physics and an M.S. in atmospheric science in 1978 and his Ph.D. in atmospheric science in 1979 from the University of Michigan. From 1979 to 1981, he was in the Advanced Study Program at the National Center for Atmospheric Research, and then from 1981 to 1983, he was a post-doctoral fellow at NASA Ames Research Center. From 1983 to 1988, he was a research scientist at NASA Ames and joined Penn State in 1988 as an associate professor. He became distinguished professor in 2003. Kasting is a Fellow of the American Geophysical Union, the American Association for the Advancement of Science and the International Society for the Study of the Origin of Life.

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- **Penn State fights phishing scams**
- **Annual Faculty/Staff Awards honor 30 across University system**
- **Deans' gift to trustee matching scholarship program aids Commonwealth College students**

Lakhtakia receives his award primarily for the theoretical and experimental development of sculptured thin films and also for a theoretical treatment of the negative-phase-velocity propagation of light in gravitationally-affected vacuum. His theoretical foundations, modeling and simulation of nanometer structures led to the fabrication of nanoengineered sculptured thin films. These films have been developed as optical filters and now are being developed for applications in tissue and bone growth and sensors for toxic and bacterial agents. His recent paper on negative wave refraction in space has major implication for locating distant stars, determining distances in space and deep-space travel.

He received his B.Tech in electronics engineering from Institute of Technology, Banaras Hindu University and his M.S. and Ph.D. in electrical engineering from the University of Utah. He joined Penn State in 1983. He is a Fellow of the Optical Society of America, SPIE – International Society for Optical Engineering and Institute of Physics (United Kingdom). He is a visiting professor of physics at Imperial College, UK.

Baumgartner is a leading scholar in our understanding of public policy formation. He receives his medal for explanations of why policy change in the U.S. government is incremental most of the time but is prone to occasional dramatic disruptions. His groundbreaking studies of interest groups, public advocacy and public agenda setting led to an understanding of what triggers incrementalism and punctuations in policy formation.

He received his B.A. in 1980, his M.A. in 1983 and his Ph.D. in 1986 in political science from the University of Michigan. From 1987 to 1998, he was assistant, associate and professor at Texas A & M University. He joined Penn State in 1998, became head of the Political Science Department in 2000, and was named distinguished professor in 2005. He currently is a visiting professor at Centre d'Etudes de la Vie Politique Francaise/L'Institut d'Etudes Politique, Paris. In 2001, he received the Aaron Wildavsky Award from the American Political Science Association for his book "Agendas and Instability in American Politics."

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THE DIGITAL COLLEGIAN | PUBLISHED INDEPENDENTLY BY STUDENTS AT PENN STATE

SCI-HEALTH

[Tuesday, April 5, 2005]

Black holes may reveal much about universe

By Greg Prince EMAIL
Collegian Staff Writer

Black holes are known to gobble up everything around them, but the knowledge they share is changing research in fields besides astronomy.

Several Penn State programs, like the Chandra X-ray Observatory and the Swift Gamma-Ray Burst Explorer satellite, already study the physical aspects of black holes, which remain largely a mystery to astronomers. Researchers are also interested, however, in the theoretical and practical uses of studying these phenomena.

"Are black holes exactly what we think they are?" said Akhlesh Lakhtakia, professor of engineering science and mechanics. "An understanding of black holes could bring about a better understanding of current physics or a completely new physics."

The gravity around a rotating black hole acts in a way that is similar to material that has a negative phase velocity (NPV), he said.

This material, or a strong gravitational field in a vacuum, causes a beam of light to be refracted differently than if the beam were passing through a material with a positive index of refraction, like water, Lakhtakia said.

When a beam of light hits water, it bends downward slightly. However, when a beam passed through the NPV material, it will bend down but also in the opposite direction, he added.

Black holes allow researchers to study this concept, called negative refraction. This could bring about a new design of optical lenses that are virtually distortion-free, Lakhtakia said.

However, this idea of negative refraction adds uncertainty to our understanding of the night sky, he said.

Penn State's Institute for Gravitational Physics and Geometry (IGPG) works on projects in three different fields involving black holes, one of which is fundamental physics.

In this area, the IGPG works outside of EinsteinÃRs constraints and makes theoretical challenges that could extend or even change what is known about physics, said Abhay Ashtekar, professor of physics and director of the IGPG.

The theories posed by researchers that are based on known physics are then passed on to astrophysicists and astronomers to better guide their observations, Ashtekar said.

For example, the information-loss paradox questions whether things that enter a black hole can be recovered. Currently, the general belief is that the information is lost, Ashtekar said, but a few researchers believe it can be recovered.

The IGPG is also involved with gravitational wave research, with black holes as the source. Gravitational waves are disturbances in spacetime caused by the motion of matter.

To study these huge waves, the Laser Interferometer Gravitational-Wave Observatory uses three satellites to detect the waves, which have incredibly long wavelengths, Ashtekar said.

Other satellites Penn State is involved with are focusing on studying black holes at much shorter wavelengths. The Chandra X-ray Observatory records detailed images of X-rays given off by the accretion disk around a black hole, said Niel Brandt, professor of astronomy.

The observatory is able to study these emissions from distant galaxies because X-rays are very penetrating and are able to travel through the dust, allowing researchers to view images that would otherwise be obscured, Brandt said.

Observers therefore are able to learn how black holes develop, he said.

A black hole has still not been directly viewed, so researchers can't be exactly sure what they are, Lakhtakia said.

"It's disconcerting to realize that our understanding of the universe could be mucked up," he said.

Quick poll: Do you think performance-enhancing drugs in sports is a problem Congress should deal with?

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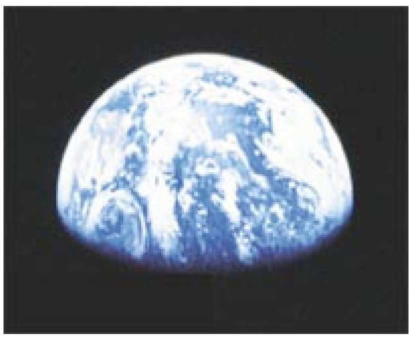
Black holes influence knowledge of the universe



Black holes have a reputation for voraciously eating everything in their immediate neighborhood, but these large gravity wells also affect electromagnetic radiation and may hinder our ability to locate the center of the universe.

“Any attempt to discover what was happening a long time ago at the beginning of our universe must take into account what gravitationally assisted negative refraction does to the radiation being viewed,” says **Akhlesh Lakhtakia**, distinguished professor of engineering science and mechanics.

Electromagnetic radiation is affected by the material through which it travels. A material with a negative index of refraction transmits light or other wave energy differently than one with a positive index of refraction. Natural materials have a positive index of refraction. When an energy beam—light, radar, microwaves—passes through water or glass or some other natural material, the material displaces the beam in the same direction. The amount of displacement, due to a material with negative index of refraction, is in the opposite direction.

Previously, Lakhtakia and **Tom Mackay**, mathematics lecturer at the University of Edinburgh, used Albert Einstein’s Special Theory of Relativity to examine refraction by moving materials. They calculated that negative refraction can be concluded to have occurred by an observer moving at a very high relative velocity in certain directions.

Later they showed that no material is needed for negative refraction in outer space. Instead, when a beam passes through the gravitational field of a massive object, such as a rotating black hole, negative refraction theoretically is possible.

When it comes to the influence of gravity caused by rotating black holes or other massive objects, it really depends on where one stands. A local observer can see only a very small piece of the universal picture of how large gravitational forces influence electromagnetic radiation. To the local observer, gravity is uniform and does not cause negative refraction.

However, Lakhtakia and Mackay, assisted by **Sandi Setiawan**, a postdoctoral researcher at the University of Edinburgh, decided to look at a global observer—one who stands in space-time as described by Einstein in his General Theory of Relativity. A global observer sees a region around rotating black holes, called the ergosphere, as possibly bending electromagnetic radiation according to a negative refractive index.

These new derivations indicate that not only do the effects of the minute stuff of the universe have to be considered when mapping the universe, but the existence of large gravity wells also must be considered. The three researchers have extended their theory of negative refraction to even more general scenarios. As we reach out into extrasolar space, for example via Pioneer 10, scientists are getting more interested in the actual existence of such scenarios.

When researchers hunt for the universe's origin, multiple black holes and other massive objects can make the light beams bend in unexpected and unpredictable ways.

"We should not be disappointed if we cannot discover the origin of the universe," says Lakhtakia. "The gravitational effect probably makes it so that we do not really know where we are looking."

Nevertheless, Lakhtakia and his collaborators are optimistic that scientists eventually will overcome many of the obstacles put forward by negative refraction in outer space.

—A'ndrea Elyse Messer

Dr. Lakhtakia can be reached at akhlesh@psu.edu or at 814-863-4319.

Vendelinus Astronomy Newsletter

March 2005

Erwin Verwichte
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Contents

1 Solar System

1.1 Envisat enables first global check of regional methane emissions

Source: ESA Press Release, March 18th, 2005 [1]

The SCIAMACHY sensor aboard Envisat has performed the first space-based measurements of the global distribution of near-surface methane, one of the most important greenhouse gases. As reported in Thursday's issue of Science Express, the results show larger than expected emissions across tropical land regions. The report concerns work carried out by the Institute of Environmental Physics (IUP) at the University of Heidelberg in cooperation with the Royal Netherlands Meteorological Institute (KMNI), based on interpretation of methane observations made by the SCanning Imaging Absorption SpectroMeter for Atmospheric ChartographY (SCIAMACHY) instrument, one of ten sensors aboard ESA's Envisat environmental satellite.

A comparison was made between space-based methane observations and model simulations for atmospheric methane for the time period August to November 2003.

"In general the observations agree very well with the model," explains Christian Frankenberg of IUP. "For example, the measurements confirm the occurrence of enhanced methane concentrations over the Ganges plains in India as well as parts of China caused by emissions from rice paddies and domestic ruminants such as cattle.

"However in large parts of the tropics there is a considerable difference. It cannot yet be concluded which source category or combination of source categories is responsible for the discrepancy. Potential candidates include wetlands, biomass burning, termites, ruminants or a hitherto unknown source."

These results are of more than just academic interest, since methane is the second most important 'anthropogenic' or man-made greenhouse gas after carbon dioxide. Methane is among the six greenhouse gases addressed by the Kyoto Protocol that went into operation last month.

In fact, the model produced deviations from a purely radial expansion that were three to seven times higher than astronomers had actually observed, Governato said.

"The observed motion was small, and we could not duplicate it without the presence of dark energy," he said. "When we added the dark energy, we got a perfect match."

Governato is one of three authors of a paper describing the work, scheduled for publication in the Monthly Notices of the Royal Astronomical Society, an astronomy journal in the United Kingdom. Co-authors are Andrea Maccio of the University of Zurich in Switzerland and Cathy Horellou of Chalmers University of Technology in Sweden. The work was supported by grants from the National Science Foundation and Vetenskapsrdet, the Swedish Research Council.

The authors, part of an international research collaboration called the N-Body Shop that originated at the UW, ran simulations of universe expansion on powerful supercomputers in Italy and Alaska. Their findings provide supporting evidence for a sea of dark energy surrounding galaxies.

"We studied the properties of galaxies close to the Milky Way instead of looking billions of light years away," Governato said. "It's like traveling from Seattle to Portland, Ore., rather than from Seattle to New York, to measure the Earth's curvature."

2.18 Black Holes Influence Knowledge of the Universe

Source: Penn State University Press Release, March 8th, 2005 [34]

Black holes have a reputation for voraciously eating everything in their immediate neighborhood, but these large gravity wells also affect electromagnetic radiation and may hinder our ability to ever locate the center of the universe, according to an international research team.

"Any attempt to discover what was happening a long time ago at the beginning of our universe must take into account what gravitationally assisted negative refraction does to the radiation being viewed," says Dr. Akhlesh Lakhtakia, distinguished professor of engineering science and mechanics, Penn State.

Electromagnetic radiation is affected by the material through which it travels. A material with a negative index of refraction transmits light or other wave energy differently than one with a positive index of refraction. Natural materials have positive index of refraction. When an energy beam light, radar, microwaves passes through water or glass or some other natural material, the material displaces the beam in the same direction. The amount of displacement depends upon how different the material is from air or vacuum. The displacement, due to a material with negative index of refraction, is in the opposite direction.

Previously, Lakhtakia and Tom G. Mackay, lecturer in mathematics, University of Edinburgh, used Albert Einstein's Special Theory of Relativity to examine refraction by moving materials. They calculated that negative refraction can be concluded to have occurred by an observer moving at a very high relative velocity in certain directions.

Later they showed that no material is needed for negative refraction in outer space. Instead, when a beam passes through the gravitational field of a massive object such as a rotating black hole, negative refraction is theoretically possible.

When it comes to the influence of gravity caused by rotating black holes or other massive objects, it really depends on where one stands. A local observer can only see a very small piece of the universal picture of how large gravitational forces influence electromagnetic radiation. To the local observer, gravity is uniform and does not cause negative refraction.

However, Lakhtakia and Mackay, assisted by Sandi Setiawan, a postdoctoral researcher at the University of Edinburgh, decided to look at a global observer – one who stands in space-time as described by Einstein in his General Theory of Relativity. A global observer sees a region around rotating black holes, called the ergosphere, as possibly bending electromagnetic radiation according to a negative refractive index.

These new derivations, reported in the March 7 issue of Physics Letters A, indicate that not only do the effects of the minute stuff of the universe have to be considered when mapping the universe, but the existence of large gravity wells must also be considered.

"When we are tracking light, we must take into account gravitational forces," says Lakhtakia. "Although the effect is only significant very close to rotating black holes."

The three researchers have extended their theory of negative refraction to even more general scenarios, in a paper published today (March 8) in the New Journal of Physics, an electronic journal. As we reach out in extrasolar space, for example via Pioneer 10, scientists are getting more interested in the actual existences of such scenarios.

Normal light bending by a gravity source such as our sun is known as gravitational lensing. It has been suggested since Einstein's time and was experimentally shown by a British team of scientists in 1919. This gravitational lensing sometimes causes multiple images to be seen. The effect is taken into account in global positioning systems. However, this light bending is positively refracted.

But, when we search for the origin of our universe, multiple black holes and other massive objects can make the light beams bend in unexpected and unpredictable ways.

”We should not be disappointed if we cannot discover the origin of the universe,” says Lakhtakia. ”The gravitational effect probably makes it so that we do not really know where we are looking.”

Nevertheless, Lakhtakia and his collaborators are optimistic that scientists will eventually overcome many of the obstacles put forward by negative refraction in outer space.

2.19 Galaxies in the Early Universe Came in Every Flavour

Source: Universe Today, March 9th, 2005 [35]

It appears that galaxies in the early Universe didn’t evolve at similar speeds or in the same ways. Almost right from the beginning, the Universe was filled with galaxies large and small, dusty and clear, active with star formation and relatively sedate. Researchers from the US used Infrared Array Camera (IRAC) aboard NASA’s Spitzer Space Telescope to study galaxies 10-12 billion light-years away. Instead of finding a similar set of galaxies, they turned up tremendous varieties, as much as we see in the night sky today.

What did the universe look like when it was only 2 to 3 billion years old? Astronomers used to think it was a pretty simple place containing relatively small, young star-forming galaxies. Researchers now are realizing that the truth is not that simple. Even the early universe was a wildly complex place. Studying the universe at this early stage is important in understanding how the galaxies near us were assembled over time.

Jiasheng Huang (Harvard-Smithsonian Center for Astrophysics) said, ”It looks like vegetable soup! We’re detecting galaxies we never expected to find, having a wide range of properties we never expected to see.”

”It’s becoming more and more clear that the young universe was a big zoo with animals of all sorts,” said Ivo Labb (Observatories of the Carnegie Institution of Washington), lead author on the study announcing this result.

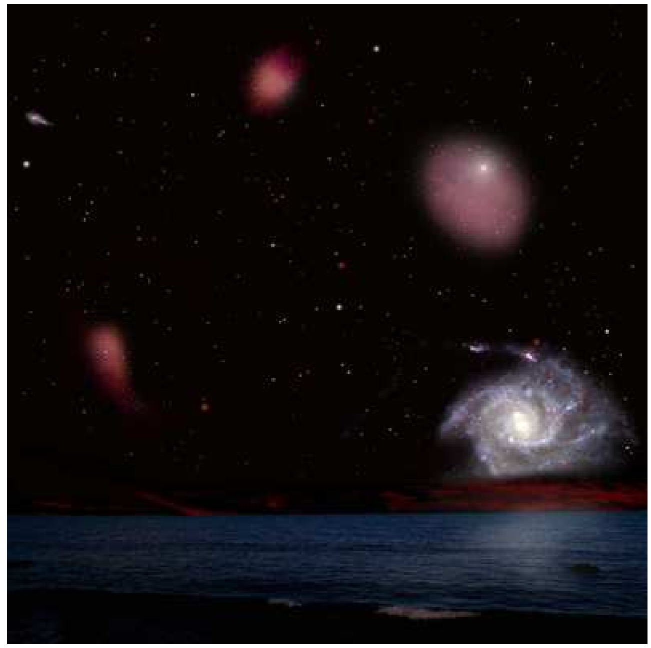

Figure 24:

Using the Infrared Array Camera (IRAC) aboard NASA’s Spitzer Space Telescope, the astronomers searched for distant, red galaxies in the Hubble Deep Field South-a region of the southern sky previously observed by the Hubble Space Telescope.

Their search was successful. The IRAC images displayed about a dozen very red galaxies lurking at distances of 10 to 12 billion light-years. Those galaxies existed when the universe was only about 1/5 of its present age of 14 billion years. Analysis showed that the galaxies exhibit a large range of properties.

”Overall, we’re seeing young galaxies with lots of dust, young galaxies with no dust, old galaxies with lots of dust, and old galaxies with no dust. There’s as much variety in the early universe as we see around us today,” said Labb.

The team was particularly surprised to find a curious breed of galaxy never seen before at such an early stage in the universe–old, red galaxies that had stopped forming new stars altogether. Those galaxies had rapidly formed large numbers of stars much earlier in the universe’s history, raising the question of what caused them to ”die” so soon.

The unpredicted existence of such ”red and dead” galaxies so early in time challenges theorists who model galaxy formation.

”We’re trying to understand how galaxies like the Milky Way assembled and how they got to look the way they ap-

WEEKLY | NEWS IDEAS INNOVATION | THE BEST JOBS IN SCIENCE

NewScientist

4 June 2005

What's kicking the stars out of place?

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Could the familiar night sky be a giant optical illusion, where nothing is quite as it seems? It would explain a lot, says **Michael Brooks**

Starry, starry fright

ASTRONOMERS like to think they know where the stars are. They can point to them in the night sky: there's Polaris, there's Vega, there's Adhara... We've had the night sky mapped for millennia now. But how do we know the maps are right? After all, no one has been out to check that the stars really are where we think they are.

Our celestial maps are based on the assumption that photons of light almost always travel from the stars to our telescopes on Earth in a straight line. Is that a fair assumption? Maybe not. "The universe is roughly 13 billion years old: a lot of things could have happened to photon trajectories in that time," says Akhlesh Lakhtakia.

It is an unusual claim from someone in his job. Lakhtakia is not an astronomer, but an electrical engineer based at Penn State University in University Park, Pennsylvania. Nonetheless, working with Tom Mackay, a mathematician at the University of Edinburgh in the UK, he has now published a string of peer-reviewed papers showing that some of our astronomical observations really could be wrong. They have demonstrated that our cherished night sky could be replete with optical illusions created by the gravitational fields of black holes.

The significance of their work remains controversial, but it could be revolutionary. Understanding these illusions could lay bare the composition of the universe, the existence of wormholes and extra dimensions – even the very nature of space and time.

The story began three years ago when Mackay and Lakhtakia started working together on a phenomenon called negative refraction. Light travelling through air bends, or refracts, when it passes into other materials such as water or glass. This is because light travels at different speeds in water and air, and the amount of refraction depends on this speed difference. Every known material slows light relative to its speed in a vacuum, and it always bends in the same direction.

But in 1967, a Russian physicist called Victor Veselago came up with the idea of a material that bends light the other way. Veselago modified Maxwell's equations, which describe how electromagnetic waves travel through materials, and showed it should be possible to create a material that would bend light in the opposite direction.

Veselago's material remained a flight of fancy for over three decades. Then, in 2000, physicists announced that they had at last created a composite material that produced negative refraction. It was an array of wires and copper crescents, and worked at microwave frequencies. Signals flowing through this strange composite behaved as though they were speeded up, not slowed down, and bent the opposite way to normal.

This innovation has huge potential. Adapting it to work at visible wavelengths could lead to "perfect" lenses capable of focusing on details hundreds of times smaller than conventional lenses can. Such lenses would be a huge boon to computer chip manufacturers, who are desperate to squeeze ever more components onto ever smaller circuits. No wonder armies of electrical engineers have been trying to create more of these negative refraction materials, piecing together ever-smaller arrays in the hope that they will eventually work at wavelengths small enough to bend visible light the wrong way (*New Scientist*, 14 April 2001, p 35).

But Lakhtakia and Mackay decided not to follow the crowd. "Everyone was trying to do it

"The universe is roughly 13 billion years old: a lot could have happened to photon trajectories in that time"

on smaller and smaller things, creating nanostructures with negative refraction properties," he says. "But I knew it should also be found on large length scales – so we decided to go the other way." Since the laws of electromagnetism are the same at all scales, Lakhtakia thought the best test of negative refraction might be to see whether space itself could produce the effect.

To test their idea, the pair had to get to grips with general relativity, Einstein's description of the way gravity affects light's path through the cosmos. This theory tells us that space can affect the path of light, because mass and energy distort space and time, creating warps and dents that we call gravity. This is the basis of gravitational lensing, in which light from distant galaxies can be deflected on its way to Earth by the gravitational field of some massive object that lies in the way. Because of this we see the galaxy distorted into an arc or halo, or even multiple separate images.

But could gravity's distortion ever create negative refraction? Not wanting to reinvent the wheel, Lakhtakia and Mackay began to search through the literature, and found that Igor Tamm, a Russian physicist who shared the Nobel prize in 1958 for the discovery of Cherenkov radiation, had already suggested that curved space-time might create curious conditions for electromagnetism.

In the late 1920s Tamm found a way to simplify the description of how electromagnetic waves move through a space-time warped by the myriad dimples made by stars and galaxies. According to Tamm, it is exactly equivalent to moving through a non-warped space-time – but in a very strange, imaginary "bi-anisotropic" material. That material affects the electric and magnetic components of an electromagnetic wave in different ways, and its effect also depends on the direction in which the wave is moving through the material.

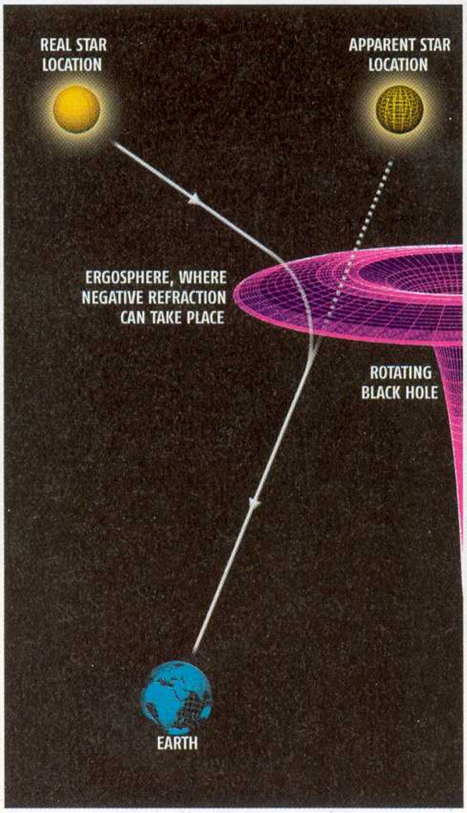
The way that bi-anisotropic materials handle electromagnetic waves gives scope for negative refraction effects. So Mackay and Lakhtakia worked out the conditions in which the material would create negative refraction (*Journal of Physics A*, vol 37, p 5697), and set about finding where in the universe these conditions might occur.

They began by searching through the cosmology literature for examples of relativistic equations and solutions that matched the results they had derived, trying to pin down what the equations were saying in terms of astrophysical phenomena – an arduous task for people who normally read engineering journals. But by August ▶

> **"Negative refraction might have a bearing on the existence of hidden extra dimensions"**

COSMIC MIRAGE

Negative refraction around rotating black holes can change the apparent location of stars as viewed from Earth



last year Mackay and Lakhtakia were convinced they had found what they were looking for.

They discovered that the equations describing the region near a rotating black hole bear a striking similarity to those for materials that produce negative refraction. Of course gravity is so strong inside a black hole that nothing, not even light, escapes. But just outside this horizon of no return lies a zone called the ergosphere, where energy and matter can still escape being sucked into the black hole. So the extreme distortion that a spinning black hole creates in Einstein's space-time seems to provide the right conditions to bend light in the opposite way to that which you would normally expect.

Mackay and Lakhtakia are quick to point out that there is not yet any evidence that negative refraction actually occurs in space. But that doesn't mean it is not happening; after all, there are a million black holes in our galaxy alone, and almost all of them are thought to be rotating.

Other astronomical objects may also create a similar effect. "I would think black holes aren't the only objects that could cause this phenomenon," Lakhtakia says. So far the only other type of space-time distortion they have looked at is that caused by an inflating universe – and they found it also creates conditions for negative refraction. Massive stars might create similar conditions, and the researchers are investigating other possibilities too. "We are looking at charged black holes now and I think we will see the same thing there," he says. "The phenomenon is not likely to be uncommon."

Lakhtakia thinks negative refraction might be observed in the same way as gravitational lensing, although perhaps not for a while – he simply doesn't know where to start. "There are no candidates that I know of," he says. "But I don't know enough. I'm not an astrophysicist." Not that astrophysicists would necessarily know where to start, either: their observations of the universe already present them with puzzling phenomena. And negative refraction could confuse the picture even more.

Dark matter, for example, is a serious headache. When astronomers measure the mass and spin rate of rotating galaxies, they find that the gravitational attraction between all the matter in the galaxies is not strong enough to hold them together; the centrifugal force should tear them apart.

Researchers have come up with two ways to explain this. By far the most popular solution is to suggest that the galaxies are shrouded in invisible "dark matter" that provides the required gravitational top-up. The other answer is that we haven't understood gravity properly, and some modification to its laws at galactic scales would explain the anomaly.

Skewed stars

Mackay and Lakhtakia now offer two more options. First, that the stuff we see in the galaxies may not be where we think it is: rotating black holes in our line of sight may be causing negative refraction and skewing all our measurements of stellar positions (see Diagram). Reinterpret the distribution of the matter within the galaxies through the prism of negative refraction and maybe the dark matter problem will go away, they suggest.

The second option is that the dark matter itself could cause negative refraction. "If light is observed to undergo negative refraction in a region of apparently empty space-time, then we may infer that there is dark matter acting. We may also be able to infer something about the nature of the dark matter," Mackay says.

These are speculative and controversial ideas, but the dark matter problem is far from resolved, and the distortion of starlight is certainly at the centre of the controversy.

A BRIEF HISTORY OF NEGATIVE REFRACTION

Late 10th century
Ibn Sahl, Arab mathematician and astronomer, discovers law of refraction during investigation of lenses

1601
Thomas Harriot, English mathematician and astronomer, discovers law of refraction during his study of optics. Harriot did not publish his result

1621
Willebrord van Roijen Snell, a Dutch lawyer and mathematician, discovers law of refraction. His work on refraction was not published until 1703 (by Christiaan Huygens), 77 years after Snell's death

1637
René Descartes, French philosopher, publishes the law of refraction in his *Discourse on Method*. In France, the law is known as Descartes's Law

1873
Scottish physicist James Clerk Maxwell publishes *A Treatise on Electricity and Magnetism*, which includes his equations describing the properties of electromagnetic waves

1968
Russian physicist Victor Veselago adapts Maxwell's equations to show that it is possible for "left-handed" materials with a negative refractive index to exist

1996
Theoretical physicist John Pendry of Imperial College London begins to design left-handed materials

Some gravitational lensing observations, for example, suggest that either we have underestimated the age of the universe by 6 billion years, or we have to accept that we have completely misunderstood dark matter and how it is distributed in galaxies (*New Scientist*, 13 November 2004, p 42). Another set of lensing surveys have produced conflicting results about the very nature of dark matter (*New Scientist*, 16 April, p 10).

Negative refraction might also have a bearing on another area of cosmology: the existence — or otherwise — of dark energy and hidden extra dimensions of space. Lakhtakia and Mackay have shown that the phenomenon of negative refraction is linked to something called the cosmological constant (*The European Physical Journal C*, DOI: 10.1140/epjcd/s2005-01-001-9). Einstein first included this constant in his description of space-time because he believed the universe was meant to be static – neither expanding nor contracting. Only by putting a positive constant into his equations could he make them describe a static universe. Without it, the universe's expansion would slow down, stop and eventually reverse.

Einstein later referred to this fudge factor as his "biggest blunder", after observations made by Edwin Hubble revealed that the universe is not static, but is expanding. What's more, recent observations of distant supernovae indicate that something is accelerating that expansion. Cosmologists suggest this expansion is caused by a "dark energy" that permeates the universe, corresponding to a small, positive value for the cosmological constant.

According to the supernova results, the dark energy causing the acceleration accounts for 73 per cent of all the energy in the universe. But this stretches the credulity of some physicists, who argue that we can't be sure that the universe's expansion is really accelerating. The evidence is scant, they say, and the cosmological constant could still be zero, or even negative. That latter possibility is borne out by "brane-world" models of the universe, where the three dimensions of space we experience are just part of a multidimensional reality. In these models the cosmological constant can be either positive or negative.

Lakhtakia and Mackay might have found a way to help. Based on a description of space-time developed in the 1970s by Stephen Hawking and Gary Gibbons at the University of Cambridge, they have shown that negative refraction is only consistent with a universe that has a positive cosmological constant. So seeing a star in the wrong place might do more than shed some light on dark energy: if astronomers find evidence of negative refraction away from the vicinity of a rotating black hole, it will confirm that the universe's expansion is indeed accelerating. It might also rule out some of the brane-world models. Not bad for an idea born from electrical engineering.

Of course, all this hinges on someone finding a concrete example of a star that appears out of place because of negative refraction. Lakhtakia and Mackay are now appealing to astrophysicists to have another look at their observations, to see if there are any clues worth following up.

On the surface, it looks promising. "The ergosphere of a black hole is a very peculiar place where many physical phenomena go against our intuition," says Serguei Komissarov, a cosmologist based at the University of Leeds in the UK. "The idea that some electromagnetic waves can suffer negative refraction within the ergosphere is not that crazy." But, he adds, he would need to study the issue in detail to know whether there were really interesting astrophysical implications.

Christopher Kochanek, an astronomer based at Ohio State University in Columbus, doesn't think it would be worth the effort; ▶

A wild ride through space and time

YOU don't need special materials to see the effects of negative refraction – all you need to do is move very fast. And in space, where enormous relative velocities are commonplace, that might have very important implications.

That's because the velocity of an electromagnetic wave has two important components: the velocity with which the wave's energy moves through space, and the velocity of the phase of the wave through space. Negative refraction can occur when the properties of space cause the wave's energy to travel in the opposite direction to the phase.

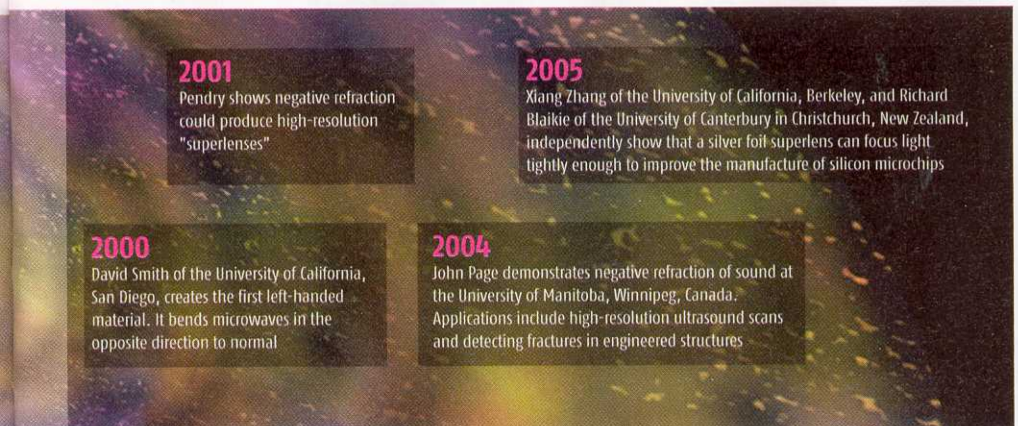
Tom Mackay of the University of Edinburgh, UK, and Akhlesh Lakhtakia of Penn State University in Pennsylvania have found that a material can seem perfectly normal when you are standing next to it, but if it is moving towards or away from you at high speed, the apparent phase and energy velocities of light passing through it are affected differently, producing a negative refraction effect (*Journal of Physics A*, vol 37, p 5697). "I would say the effect is noticeable at 10, maybe 20 per cent of the speed of light," Lakhtakia says.

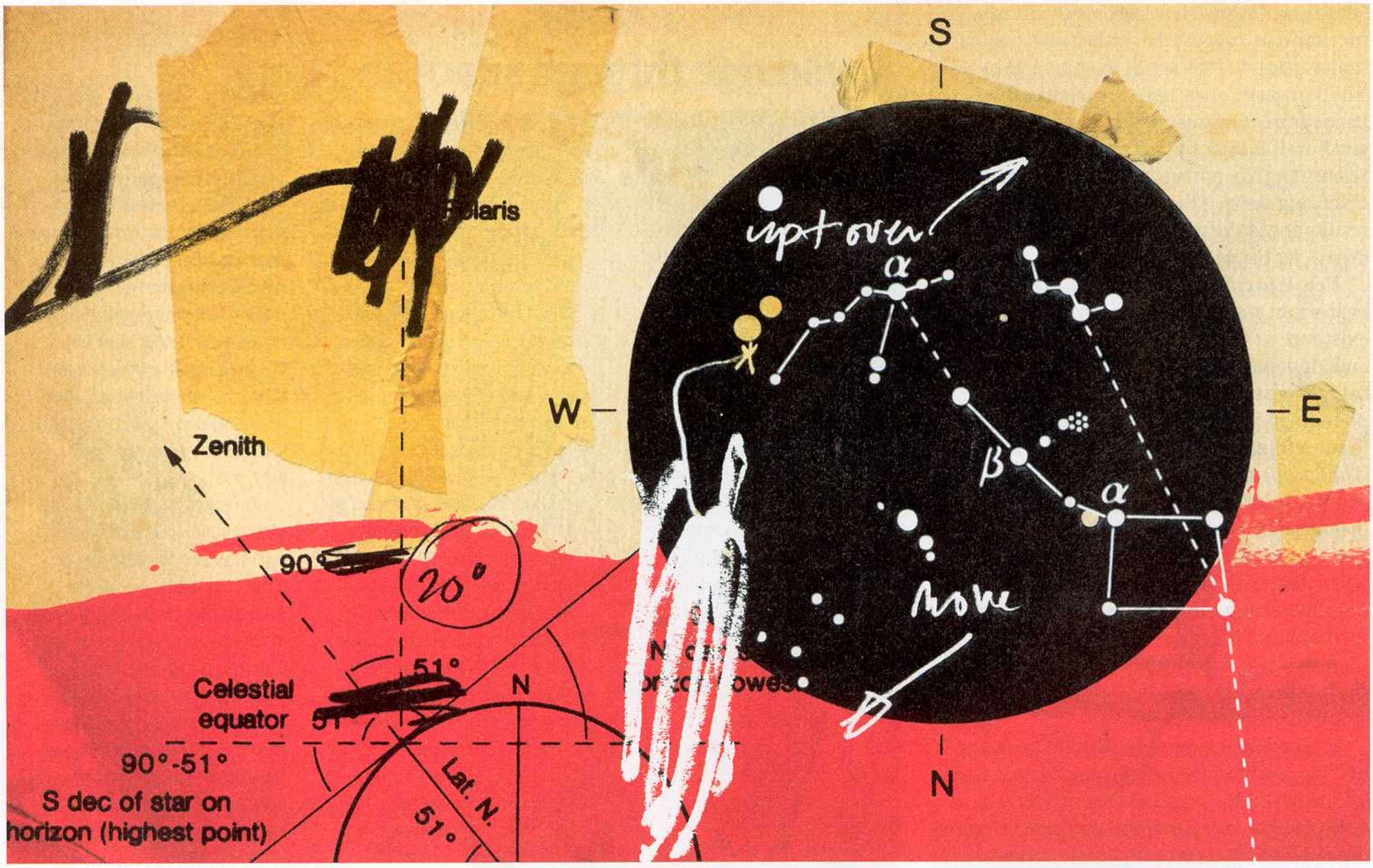
This raises the possibility that the light reaching us from distant astronomical objects might have been negatively refracted en route. If it passed through interstellar dust clouds that are moving fast relative to Earth, for example, we could see the objects in a different part of the sky to where they actually are (*Current Science*, vol 86, p 1593).

Negative refraction might also explain the anomalous trajectory of the Pioneer 10 spacecraft, which was launched in the 1970s and is now way beyond the orbit of Pluto. No one has been able to explain the mysterious acceleration that seems to have nudged the craft some 400,000 kilometres off track. But maybe there is no acceleration: maybe the electromagnetic signals from the craft have simply been negatively refracted somehow.

Negative refraction also supports the idea that space-time near black holes can contain regions of negative energy density. If there is negative refraction going on around rotating black holes, electromagnetic waves passing through these regions will have an energy density with a negative value (*New Journal of Physics*, vol 7, p 75).

This opens up the possibility of wormholes connecting widely separated regions of space and time – physicists and science fiction writers have long dreamed of time travel or rapid long-distance space travel using wormholes, but they need a source of negative energy to keep the mouths of the wormholes open. Perhaps with a little help from negative refraction, building a time machine is possible after all.





MICHELLE THOMPSON

researchers already take these issues into account, he says. He points out that cosmologists routinely use the equations of general relativity to compute photon trajectories through the universe – including the regions around rotating black holes. "Remember that in all of this there is no change in how electromagnetism works or how you calculate photon trajectories," Kochanek says. "It may be interesting to phrase some of the astrophysical stuff in terms of a negative refraction, but it doesn't actually change how you compute anything."

"Things get even more interesting if dark matter is composed of black holes"

Lakhtakia thinks he's seen this kind of scepticism before, however. "Technically the astrophysicists are right: they take ergospheres into account," he says. But he worries that astrophysicists may be throwing away important information. For example, until five years ago, researchers using Maxwell's equations to calculate the path of light through materials routinely discarded results that lead to a negative refraction. "After all, who had ever heard of negative refraction?" Lakhtakia says. "Astrophysicists are building in all sorts of assumptions based on the current state of knowledge. People discard results that do not fit into their experience."

But Alexei Starobinsky, a cosmologist based at the Landau Institute for Theoretical Physics in Moscow, has a more fundamental objection. He points out that black holes capable of producing these kinds of effects constitute a negligible part of the whole sky. Mackay agrees, but he says that doesn't mean their contribution must be negligible. "Their effects are definitely considered as spectacular. Even tiny effects are amplified by astronomical distances." There is also the negative refraction that could be caused by the inflating universe to consider. And things get even more interesting if dark matter is composed of black holes, as some cosmologists suspect. "If this is the case then the negative refraction effect contributed by these black holes may be substantial," Mackay says.

Mackay, Lakhtakia and Sandi Setiawan, a mathematician who has begun working with Mackay in Edinburgh, are aware they are treading on toes, but they also think the astronomers are assuming too much. "We are neither astronomers nor astrophysicists," Mackay says. "However, those two groups of scientists have not 'seen' or 'explained' everything. We know the human race is largely ignorant of what happens in outer space."

Until astronomers re-examine the solutions to Einstein's equations that they have hitherto ignored, we cannot be sure that we haven't misunderstood what the stars are telling us, Lakhtakia says. "The situation with negative refraction in space is extraordinarily complicated, and our best inputs are going to come from people who will keep an open mind. These are speculations on our part, but then much of astrophysics is speculation." ●

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News Releases for 7/19/2005

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[7/19/2005] Sculptured thin film technology earns recognition

University Park, PA—Sculptured thin film technology developed by **Akhlesh Lakhtakia**, distinguished professor of engineering science and mechanics, has been named a winner in *Nanotech Briefs* magazine's first annual Nano 50.

The Nano 50 recognizes the top fifty technologies, products, and innovators that have significantly impacted, or are expected to impact, the state of the art in nanotechnology.

Sculptured thin films are a class of nanoengineered materials with properties that can be designed and realized in a controllable manner using physical vapor deposition.

* * *

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-- Sculptured thin film technology developed by **Akhlesh Lakhtakia,** distinguished professor of engineering science and mechanics, has been named a winner in Nanotech Briefs magazine's first annual Nano 50. The Nano 50 recognizes the top 50 technologies, products and innovators that have significantly impacted, or are expected to impact, the state of the art in nanotechnology. Sculptured thin films are a class of nanoengineered materials with properties that can be designed and realized in a controllable manner using physical vapor deposition.

Michael Modest, professor of mechanical engineering, has been named the recipient of the 2005 Heat Transfer Memorial Award by the American Society of Mechanical Engineers. The award is given to individuals who have made outstanding contributions to the field of heat transfer through teaching, research, practice and design, or a combination of such activities. Modest will receive his award at this year's International Mechanical Engineering Congress and Exposition in Orlando, Fla.

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PENN STATE BRIEFS

PSU commencement set for Aug. 13

UNIVERSITY PARK -- Penn State's summer commencement ceremonies will take place Aug. 13.

About 2,100 students will graduate. President Graham Spanier will preside over the ceremonies. The associate and baccalaureate ceremony will start at 10 a.m., and the graduate school ceremony will start at 2:30 p.m., both in the Bryce Jordan Center.

Spanier will speak at the undergraduate ceremony. Harry R. Allcock, Evan Pugh professor of chemistry at Penn State, will speak at the graduate ceremony. A schedule of ceremonies and activities is online at http://commencement.psu.edu.

The Schreyer Honors College will hold its medals ceremony at 5 p.m. Aug. 12 in Presidents Hall at The Penn Stater Conference Center Hotel. Penn State trustee emeritus Lloyd Huck will speak at the ceremony.

Professor's work wins Nano 50 recognition

UNIVERSITY PARK -- Nanotech Briefs magazine's first annual Nano 50 has recognized sculptured thin film technology that PSU professor Akhlesh Lakhtakia developed.

Lakhtakia is a distinguished professor of engineering science and mechanics in the College of Engineering. The Nano 50 recognizes the top 50 technologies, products and innovators that have had an impact or are expected to significantly affect nanotechnology.

According to the college, sculptured thin films are a class of nanoengineered materials with properties that can be designed and realized in a controllable manner using physical vapor deposition.

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Bookshelf

Lakhtakia, Messier pen new text

Akhlesh Lakhtakia, distinguished professor of engineering science and mechanics, and **Russell Messier**, professor of engineering science and mechanics, have authored *Sculptured Thin Films: Nanoengineered Morphology and Optics.*

The text pairs the author's knowledge of thin-film morphology with the response characteristics of optical sculptured thin film (STF) devices, enabling scientists and technologists to design STF materials and devices for optical applications.

A CD containing Mathematica™ programs designed by the two is included. Suitable for graduate students and professionals in optics, the work can be purchased online at bookstore.spie.org.

Cimbala coauthors new book

John Cimbala, professor of mechanical engineering, has coauthored an undergraduate textbook on fluid mechanics.

Published by McGraw-Hill, *Fluid Mechanics: Fundamentals and Applications* by Yunus Cengel and Cimbala presents the basic principles and equations of fluid mechanics through numerous and diverse real-world examples. Focus areas in the text include the visual nature of fiuid dynamics, current research, computational fiuid dynamics, and precise definitions of key terms. In addition, the book helps students develop an intuitive understanding of fiuid dynamics by emphasizing underlying physical mechanisms.

The book can be purchased online at www.mhhe.com.

Wagener coauthors text

Thorsten Wagener, assistant professor of civil and environmental engineering, has coauthored a new text, *Rainfall-Runoff Modelling in Gauged and Ungauged Catchments*. The other authors are Howard Wheater and Hoshin Gupta.

The work is based on the results of a study on the identification of conceptual lumped rainfall-runoff models for gauged and ungauged catchments. The theory underlying the application of rainfall-runoff models for predictions in ungauged catchments is discussed, problems are highlighted, and ways to move forward are investigated. Modelling frameworks for gauged and ungauged cases are presented.

Suitable for graduate students, hydrological researchers, and consultants, the book is published by World Scientific Publishing and can be purchased online at www.wspc.com.

Awards honor outstanding staff, faculty

The College celebrated achievements in teaching, research, service, and advising with its annual Penn State Engineering Society (PSES) Faculty Staff Awards in March.

The PSES Outstanding Staff Award recognizes dedicated individuals who place extra effort in and show initiative and loyalty to the College beyond their job descriptions. The award recipients are **Michelle Alterio**, mechanical and nuclear engineering staff assistant; **Cheryl George**, electrical engineering staff assistant; and **Teresa Reed**, Office of Graduate Studies, Research, and Outreach staff assistant.

Three faculty members won the Outstanding Advising Award for their dedication in advising students or student groups. The recipients are **William Haering**, assistant professor at Penn State DuBois; **Akhlesh Lakhtakia**, distinguished professor of engineering science and mechanics; and **Daniel Linzell**, assistant professor of civil engineering.

The PSES Distinguished Service Award, which recognizes dedicated individuals who willingly donate their time, expertise, and energies to the College, was given to **Lee Coraor**, associate professor of computer science and engineering.

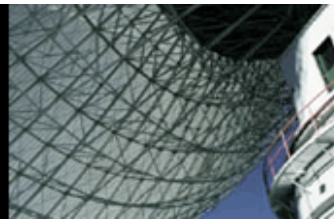
The PSES Outstanding Teaching Award recognizes individuals who show a special talent and commitment to teaching. In addition, recipients of the award are innovators and experimentalists in the classroom and laboratory who have at least three years of experience at Penn State. The winners are **Ivan Esparragoza**, assistant professor at Penn State Delaware, and **Lawrence Hochreiter**, professor of mechanical and nuclear engineering.

The PSES Premier Teaching Award is given to faculty members who have been previously recognized for outstanding teaching and have continued to excel in the classroom. The award recipient is **Timothy Simpson**, associate professor of mechanical engineering and industrial engineering.

The PSES Outstanding Research Award, which recognizes notable contributions to research, was given to **Mary Frecker**, associate professor of mechanical engineering.

The PSES Premier Research Award, which honors faculty who have previously been recognized for outstanding research and are considered preeminent in their field, was presented to **Vigor Yang**, distinguished professor of mechanical engineering.

PSES award recipients are nominated by their respective departments in which the individual is employed or from which the candidate earned a degree and are selected by a panel of peers and PSES representatives. All awardees are selected through secret ballot by committees composed of faculty, staff, alumni, and former award recipients.



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Making Optical Lenses Better and Cheaper

September 19, 2005

One of the biggest challenges facing companies in the optical telecommunications industry is how to produce near-perfect lenses cheaply. Such a capability could dramatically drive down the cost of fiber optical networks and make such systems less expensive to build and deploy.

A new study, recently issued by the University of Edinburgh and Pennsylvania State University, suggests a smart solution to the problem of making lenses that are both cheap and nearly perfect. To reach these goals, the researchers have devised a simple method of producing materials that bend light the "wrong" way. The technology enables lenses with minimal distortion to be constructed from flat slabs of negatively-refracting materials. In technological fields where lenses are key components, such as telecom, microwave engineering and optical engineering, negatively-refracting materials could have a revolutionary impact on lens development cost, says the study.

Although scientists have sought to minimize lens distortion for centuries, it is only within the past five years that the production of near-perfect lenses has become a realistic possibility. Progress has been made possible with the recent creation of negatively-refracting materials that enable rays of light, passing from one material to another, to bend in the opposite direction to that described in conventional physics textbooks.

However, these negatively-refracting materials are difficult and costly to produce, since they involve complex assemblies of intricately-shaped conducting components embossed on non-conducting platforms. A study by Tom Mackay, a researcher at the University of Edinburgh, and Akhlesh Lakhtakia, a Penn State professor, suggests a much simpler method of construction.

The new study, recently reported in the Microwave and Optical Technology Letter, shows that rather than creating complex and costly microelectronic devices, negatively-refracting materials can instead be produced by simply blending two granular substances together. Neither of the two granular substances can refract negatively by itself. Yet the study predicts that a homogeneous mixture of these two substances can refract negatively, provided the relative properties and proportions of the

substances are chosen appropriately.

"Through its simplicity, this method represents an exciting breakthrough for inexpensive exploitation of negative refraction technologies," says Mackay, who conducts his research for the University of Edinburgh's School of Mathematics. "The prospects for near-perfect lenses, and beyond, brings dreams a step closer to reality."

The researchers don't say how long it will take for their technology to become commercially feasible, but note that the method's simplicity offers hope that its adoption will be fairly rapid.

 The preceding article was written by John Edwards, a freelance technology writer based in Gilbert, Arizona. He can be reached by phone at +1-480-854-0011.

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EE Times: Latest News

Optics theory may yield low-cost, near-perfect lenses

Chappell Brown
EE Times
(09/26/2005 9:00 AM EDT)

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Peterborough, N.H. - If two theorists turn out to be correct, making optical components with a negative index of refraction could become as cheap and easy as the processes used in conventional optics.

While conventional optical components, like glass, naturally have a positive index of refraction, in the 1960s theorists predicted that it would be possible to do much more with optical components that had a negative refractive index, even though such materials do not exist in nature. And although progress has been made recently in building artificial materials with these properties, the industry is still far from having a practical negative-index-of-refraction material to work with.

That might change with a new study of the problem by Tom MacKay at the University of Edinburgh (Scotland) and Akhlesh Lakhtakia at Pennsylvania State University. They predict that it is possible to mix two positively refracting materials homogeneously to create a composite with a negative index of refraction.

About five years ago, researchers working in the microwave range were able to demonstrate that negative refraction could take place physically, but only if they built complex geometric configurations of conductors and insulators. Since microwaves have longer wavelengths than light, it was easier to build these structures.

"The interest in negatively refracting materials stems from the fact that these can be used to make near-perfect lenses capable of extremely high-resolution imaging," said MacKay. "The negatively refracting metamaterials that have been produced so far have highly complex architectures. Typically, they are made up of arrays of complex-shaped inclusions, such as double rings and oriented ring-post couples."

But building similar structures at visible wavelengths has proved very difficult.

Negatively refracting composite
If the theory advanced by Mackay and Lakhtakia proves to be correct, experimental physicists would have a wide-open field in which to work.

"The two positively refracting materials used as ingredients in our approach belong to the general category of dielectric-magnetic materials. This category contains an enormous range of naturally

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occurring materials," said MacKay. "In our paper, we show that it is theoretically possible to combine two such positively refracting materials to produce a negatively refracting composite material. We also present one specific, representative, example. But the example we present is not the only possible example.

"The parameter space of dielectric-magnetic materials now needs to be explored to identify the full range of possible materials that can be combined, in the way we describe in our paper, to give a negatively refracting composite material," MacKay explained.

The latest findings are the fallout from a long-term study of composite optical materials. "A general theme of our work has been how to combine two or more relatively simple materials to produce a complex composite material. The basic approach was to take a known property of a material and find some way to extend its properties by finding complementary materials with which it could be blended. In the process, the theorists began to realize that it would be possible to create materials that had fundamentally new properties not shared by either material.

"The combination of two positively refracting materials to produce a negatively refracting composite material is a classic example of this," said MacKay.

To achieve negative refraction from a combination of two positively refracting materials, the individual granules of each component must be at least 10 times smaller than the wavelength of light. In that case, the light waves experience a uniformly transparent medium that has the right composite properties for negative refraction. "The positively refracting ingredients can be crystalline or amorphous-it doesn't matter which, because the structure of the ingredient granules is not 'seen' in the negatively refracting composite," he said.

Once the properties of such composites are proved out in experiments, it will be a simple matter to produce them in bulk using existing manufacturing processes, MacKay said.

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Laser Focus World

Dust mix could negatively refract light

Dust mix could negatively refract light

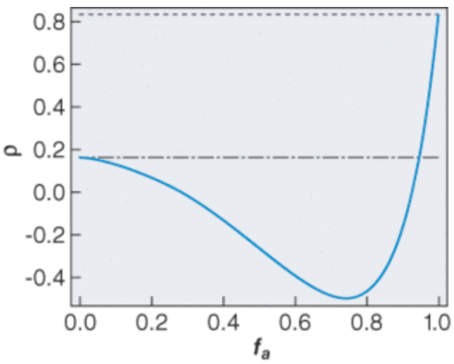
Fabricating a negative-refractive-index lens that works well at visible wavelengths and is of reasonable size would be a coup for any photonics researcher. Such a lens, made of a flat slab of metamaterial-a properly designed array of subwavelength resonant structures-would focus light without aberrations. But metamaterials are complex structures, containing arrangements of wires, conducting arcs, and so on; they benefit if they have array spacing much smaller (ten times or so) than the wavelength of the light they are to focus. Creating a practical metamaterial for visible light is a tall order indeed.

But what if periodic arrays were not required? Then one could fabricate millions of subwavelength structures and dispense them into a mold like sand to make a lens. And what if the nanostructures themselves were almost as simple as grains of sand?

That's what Akhlesh Lahktakia

of Pennsylvania State University (University Park, PA) and Tom Mackay of the University of Edinburgh (Edinburgh, Scotland) asked themselves. They modeled homogeneous mixtures of two hypothetical isotropic dielectric-magnetic materials, each pulverized to 1/10-wavelength-size (or smaller) grains, then the two intermingled homogeneously.[1]

For the composite, however, the researchers found that a certain parameter ρ (the sum of the inverse dielectric loss factor and the inverse magnetic loss factor) can dip below zero for certain volume fractions of the two components. A negative ρ signifies that a substance supports negative phase velocity and can negatively refract.



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When the negative-phase-velocity parameter ρ for a material is negative, the material can negatively refract light. A hypothetical substance consisting of well-mixed nanoparticles of two properly chosen (also hypothetical) dielectrics has a ρ that dips below zero for volume fractions (fa) ranging between 0.28 and 0.92. The two dashed lines represent ρ for each of the two constituent materials.

The refractive indices of the hypothetical substances allowed for an "imaginary" component, which in practical terms means that the substances could attenuate light as well as refract it. For this reason, a lens made of a homogeneous composite may have to be very thin-a fraction of the wavelength if the attenuation is not sufficiently small, says Lahktakia.

The challenge is to translate this hypothetical material into something real. The researchers, who are theorists, not materials scientists, have no specific materials in mind for the components. "The knowledge base of materials (either in part or completely) extends to a few million materials," notes Lahktakia. "Now that we have mathematically shown the possibility, experimentalists can be inspired to realize this architecture for negatively refracting materials." He notes that geometry could also play a part-for example, instead of spherical grains, a composite could contain spheroidal and ellipsoidal grains, or even grains with a distribution of shapes.

"The first exemplar, indicated in our paper, is not going to be the only one," he says. "Other regions of the materials-property-parameter space need to be looked into, now that it is known that such a route is possible."

John Wallace

REFERENCE

1. arXiv:physics/0505005 v1 (April 30, 2005).

Laser Focus World November, 2005
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News Analysis

Long Shot

By: **Justin Mullins**

Could Simple Mixed Materials Make Flat Lenses Cheap?

It sounds too good to be true: high-quality flat lenses that focus light and can be made in sheets and cut to size. That's the promise of a new class of materials with a negative refractive index that bend light in the opposite direction from conventional materials [see diagram].

There's a problem, however. These materials are hard to make. The first ones were made in 1999, and the only ones created to date operate in the microwave region and consist of a complex assembly of copper rings and wires that must be painstakingly assembled by hand into a periodic structure [see "Left-Handed Material Reacts to 3-D Light," *IEEE Spectrum*, October 2002]. Such materials are not mass-producible using known techniques.

That could be about to change. According to Tom Mackay, a mathematician at the University of Edinburgh, and Akhlesh Lakhtakia, a mechanical engineer at Pennsylvania State University, in University Park, another way to make them is to take a handful of one material and mix it with another. Their breakthrough is the discovery that blended materials can have properties that were not present in the originals.

The possibility of negative refraction was first raised in the late 1960s by the Russian physicist Victor Veselago of the General Physics Institute of the Russian Academy of Sciences in Moscow. Veselago based his ideas on the discovery by James Clerk Maxwell that light's behavior in a material could be described in terms of two constants: for the magnetic field, the material's permeability, and for the electric field, its permittivity.

The permittivity and permeability of all natural materials have positive values. Veselago asked what would happen if he switched the sign of these constants from positive to negative, and found that the material would bend light in the opposite direction it normally is refracted.

Taking Veselago's thought experiments a step further, Mackay and Lakhtakia asked whether ordinary materials could ever combine in a way that produces negative permittivity and permeability. To their surprise, the equations showed that this is possible using easily available materials. "One material needs to be metallic in character while the other must be magnetic," says Mackay. "It was really a very unexpected result."

There are a couple of other conditions. The materials must be formed as spheres that are about the same size as the wavelength of light they are designed to bend. And the materials must be mixed in certain proportions. Mackay says that the technique should make it possible to bend visible light the wrong way for the first time.

"Nanoparticles of the size needed to manipulate visible light are now common," he says. "There is nothing to prevent this from working in the optical regime." Until now, however, the technique has worked only with microwave.

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