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# Laser Sharp

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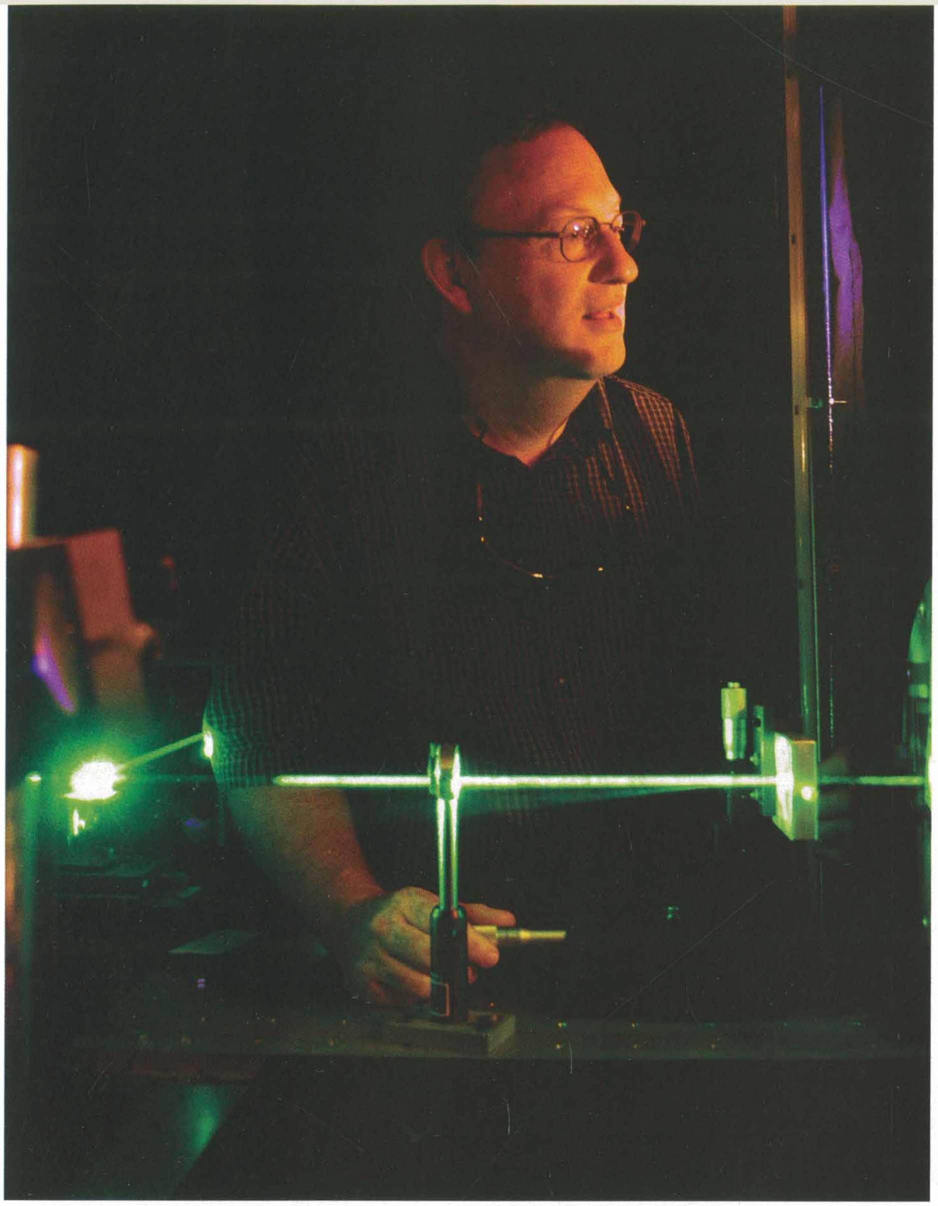


Mike Duncan '76 delivered the John Albert Southern Lecture in Chemistry this spring at Furman. Opposite: Duncan and University of Georgia graduate student Brian Ticknor, a 2001 Furman graduate, adjust the timing of a laser pulse. Photos by Carly Calhoun.

**It takes some time to find Michael Duncan's office in the chemistry building on the University of Georgia's South Campus.** The building seems at times like a maze of Legos, tucked in on the natural slope of a hill and wandering for hundreds of yards east and west along the ridge.

Once close, though, you can almost sense Duncan's place, because it reflects the personality of its occupant: laid-back, friendly, generous and intensely interested in work that has made him an internationally noted scientist. You will also know it is Duncan's office by the mildly hideous rattlesnake head — mouth open, fangs bared — sunk in a plasticine paperweight on a filing cabinet. An ironic gift from his brother, the snake is everything Duncan isn't.

Mike — it seems stuffy and pretentious to call someone this relaxed Dr. Duncan — sits in his chair among a cluster of papers, notes of phone calls to return, and hundreds of books that line his walls. He easily answers questions about his life, but when he starts talking about metals and lasers, he moves forward to the edge of his chair.

Not many scientists have a genuine "eureka" moment when they see a new field of study open before their eyes, but Mike did when he was a graduate student, working with legendary chemist Richard Smalley at Rice University. Although lasers had been around for a while by then, their use, which would become pervasive in society over the next two decades, was still largely unknown in the study of nanoparticles. Mike and a fellow graduate student were working on a molecular beam experiment when — oops — they accidentally misaligned the laser and vaporized part of the apparatus.

"We didn't even know what we'd done at first," Mike recalls with a laugh, "but then we looked at the mass spec and immediately knew something was weird."

Mass spectrometers are instruments that separate charged particles so that they can be studied when photographs and graphs are made of the distributed spectra of the resulting "masses." The signal Mike and his fellow student saw on the mass spec was clearly one for metallic compounds, so they knew they'd goofed and actually vaporized part of their equipment. The accident, happily, led to a new way to produce large, regular molecules called metal clusters,

# HARP

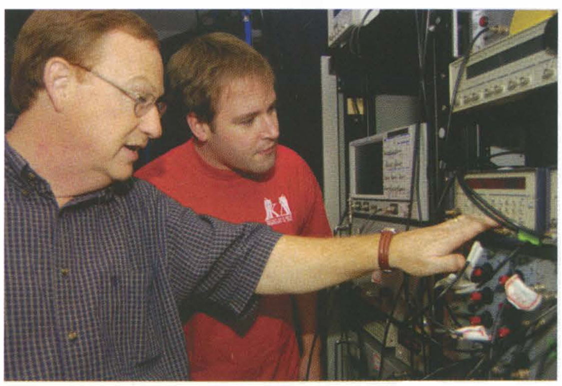
By Phil Williams

MIKE DUNC N IS EARNING INTERNATIONAL ATTENTION FOR HIS RESEARCH INTO GAS-PHASE METALS.

most of which exist only for milliseconds and are mind-bogglingly hard to study.

So what began as a lab accident led to an entirely new idea: shooting laser beams at metals and then studying the gaseous metal clusters that were blasted off. The Smalley group at Rice later used the same equipment and repeated the experiments on carbon and discovered a form of the element called carbon-60. Shaped in panels like the geodesic dome invented by architect Buckminster Fuller, the C60 forms were named "buckeyballs," and the team that discovered them was awarded the Nobel Prize for Chemistry in 1996.

**Since he came to the University of Georgia 20 years ago, Mike, a 1976 Furman graduate, has been on the cutting edge worldwide in the study of metal clusters.** For at least a decade his work on metal carbides has placed him among the most sought-after chemists of his generation for presentations and speeches, and his work has drawn interest and funding from an astonishing range of federal agencies, including the National Science Foundation, the Department of Energy and the U.S. Air Force.



Not too shabby for someone who didn't even own a chemistry set as a boy.

Growing up in Greenville, Mike had the usual preoccupations of a Southern boy: sports and the outdoors. He loved playing war games with bottle rockets with his brothers, and once he participated in a "court martial" that led to the brief hanging of a younger brother by his feet from a tree limb. (During World War II his father had, in fact, been a guard during the Nuremburg Trials.) Mike's greatest love, however, was baseball, which he played from boyhood through high school and, during his senior year, at Furman. He also pitched in a fast-pitch softball league while a postdoctoral fellow in Colorado.

"Nobody in my family was involved with science at all," he says. His father was a salesman for a food brokerage company and his mother a homemaker. Mike is the oldest of five, with one sister and three brothers (including a pair of twins). "I guess I got interested because I just loved to read. I remember in the first grade I read everything in sight, and soon I was starting to read a great deal about astronomy and space, which fascinated me."

At J.L. Mann High School, an outstanding science teacher, Betty Reagan, kindled his interest in the lab — and, as it turned out, in Furman, where her husband, William Reagan, was a French professor. Mike discovered in his early physics and chemistry classes that these classic underpinnings of the physical world utterly fascinated him. An exceptional student, he was able to get a financial aid package, including a National Merit Scholarship, to attend Furman.

A self-described "typical nerd," Mike found tremendous satisfaction and challenge when he got to Furman. He was attracted to physical chemistry because he understood more than most how things are put together. He sometimes worked on cars and even, incredibly, designed and built a machine to evaporate metals while an undergraduate.

He met his future wife, Debra Moore '75, at Furman. Upon completion of his degree in 1976 — when, he says, he was "dead broke" — he took a year off to work before being accepted to graduate school at Rice. He was accepted at numerous universities, but Debbie, by then his wife, wanted to be near a school where she could pursue a master's degree in social work. The University of Houston, not far from Rice, had just such a program, so they packed everything and moved to Texas.

While Furman was excellent for Mike, Rice was even better, since Richard Smalley was already making a name for himself by finding novel uses for lasers. Mike quickly discovered that the Smalley lab was "heaven." He didn't work on metals right away, but after he accidentally vaporized part of the lab equipment, he knew the shape of his future. He also learned to build his own mass spectrometers, something he continues to this day.

Work in the Smalley lab was intense and days were numbingly long, typically lasting from 8:30 in the morning until midnight. After Mike finished his degree requirements at Rice, he and Debbie left Houston in 1981 so that he could accept a postdoctoral fellowship at the Joint Institute for Laboratory Astrophysics in Boulder, Colo. While there, he applied for open faculty positions back in his beloved Southeast and eventually accepted a job as an assistant professor of chemistry at Georgia in 1983.

Georgia turned out to be a perfect match. It was close to Greenville, and it offered an excellent start-up package and an unmatched instrument shop that proved perfect for Mike's increasingly complex needs.

During his years at Georgia, Mike has taken his interest in the gas phase of metal clusters to such a level that he's one of a handful of international authorities on the subject.

His research program synthesizes and characterizes novel atomic and molecular "aggregates" containing metals. These

"ONE OF THE BEAUTIES OF DOING FUNDAMENTAL SCIENCE IS THAT YOU NEVER QUITE KNOW WHERE IT MAY LEAD."

aggregates, which are called "clusters," may consist of only a few atoms of pure metal, mixtures of metals, or metal compounds such as carbides or oxides.

The goal of the research is to understand how these atoms bond chemically — something that remains unclear, in many cases, to science.

**In 2000, Mike was part of a startling discovery that is changing how science looks at the last evolutionary stages of low-mass stars.**

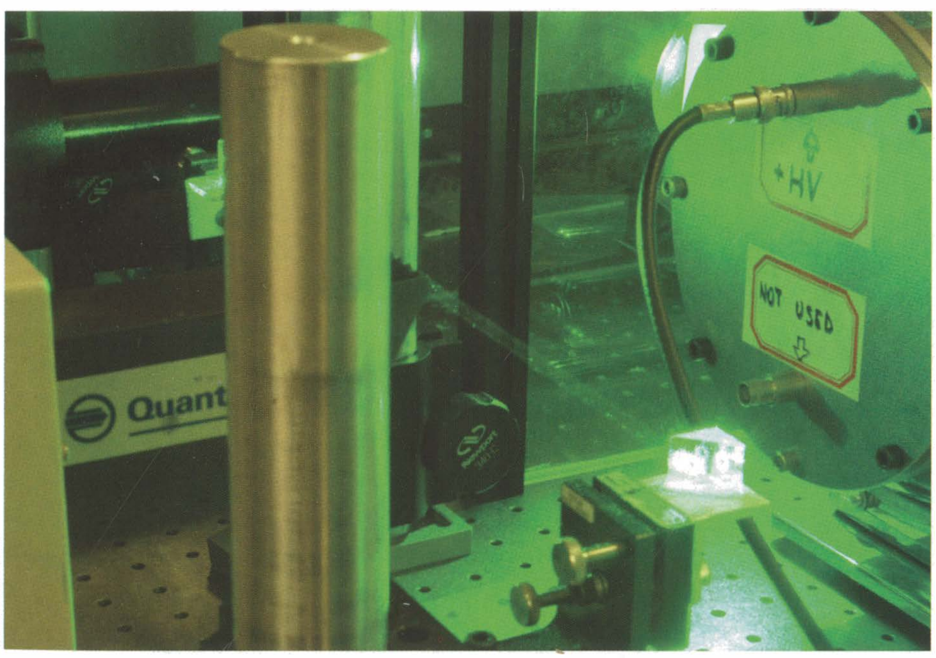
Scientists had thought that when low-mass stars — called red supergiants — die, they fade away on a "wimpy" wind. Mike's research, co-authored with scientists from the University of Nijmegen in the Netherlands and published in the journal *Science*, suggested the opposite may be true. These stars may die with a bang and not a whimper. The study may lead researchers to a new understanding of red supergiants, which are studied to resolve issues in nucleosynthesis, stellar structure and the evolution of stars.

"This discovery was really a gigantic surprise," says Mike. "One of the beauties of doing fundamental science is that you never quite know where it may lead."

During their death throes, low mass stars turn into red supergiants, which are more properly called asymptotic giant branch stars, or AGBs. Actually a stage of development rather than a specific kind of star, the AGB phase is a relatively short stage during which low-mass stars become their brightest but experience heavy mass loss that leads them rapidly to the planetary-nebula phase and a final cooling to white dwarfs. White dwarfs are extremely hot, Earth-sized objects that fade and cool for billions of years until they become black, cold cinders. Scientists have been studying AGB stars for a long time, but research has been accelerated in the past few years thanks to the Hubble Space Telescope and the European Space Agency's Infrared Space Satellite.

Mike's involvement in the discovery was the kind of scientific serendipity that often leads to unexpected breakthroughs. His work took a huge step forward through his collaboration with Dr. Gerard Meijer, whom he met at a scientific meeting at Ohio State University in 1998, and Meijer's colleagues in the Netherlands.

"He was talking about the free-electron laser called FELIX [Free-Electron Laser for Infrared Experiments] that had been built at his institute, and I happened to ask him if it had ever been used to study gas-phase metal clusters," says Mike. "From that, our collaboration was born."




CHARLIE REGISTER

**There are probably no more than 20 free-electron lasers in the world, and only five in the United States.** (Priority for use of the U.S. machines is largely for medical science or industrial applications.) FELIX is the only one optimized for measuring infrared signals, or "spectra," of chemicals, and seemed a perfect match for the metal-cluster experiments.

After meeting Meijer, Mike realized that his own team had a free-electron laser and that he had both the pulsed molecular beam machine and experience working with metal clusters. All his team needed was to find a way to make them work together.

Luckily, Meijer received a large grant from the Dutch government, and so the team in the Netherlands was able to construct a copy of the molecular beam machine that Duncan had been using to study metallic clusters and mate it with the free-electron laser.

The result was a machine that could detect the infrared spectra of gas-phase metals and thus give important clues to how they are structured. The new apparatus worked beautifully, and when Mike visited the lab in the summer

MIKE DUNCAN

of 1998, the team achieved the first direct infrared spectra of these clusters.

These spectra, in themselves, will likely open a new era in the study of how gas-phase metals are structured. But a chance meeting with other Dutch scientists initiated a startling discovery that led the research from the lab to the stars.

"These astronomers were visiting the FELIX lab and hearing about work on polyaromatic hydrocarbons, which are important in the composition of interstellar space," says Mike. "It just so happened that our work on gas-phase metals was on a machine nearby, and they asked what it was. Meijer and another scientist on the project, Gert von Helden, showed them the machine and the spectra we had. That's when their jaws dropped."

The astronomers, led by Alexander Tielens of the University of Groningen, realized immediately that the infrared spectra that the group had elicited from their study of titanium carbide nanocrystals corresponded almost exactly to spectra of unknown origin seen again and again in AGB stars. The discovery created a problem, however.

Meteorites containing micrometer-sized graphite grains with embedded titanium carbide (TiC) grains have been discovered on Earth. Isotopic analysis has identified AGB stars as the birthplace of these grains, although no direct link has been discovered. Astronomers believe that as AGB stars begin to die, newly synthesized elements such as TiC are mixed to the surface where they spread over the galaxy in a wind, most often in the form of stardust.

The problem: the amount of titanium in low-mass stars is so low that "high densities are required just to get high enough collision gains to grow to the sizes observed in graphite stardust." For some 20 years, scientists have thought that a so-called "superwind" phase takes place when these stars exhibit a dramatic loss of mass. But the superwind phase, despite its name, has been considered a relatively modest event in which the star's remaining stellar envelope is blown away.

The identification of the infrared spectra around AGB stars as gas-phase titanium carbide, however, changes that picture. Because of the low amounts of titanium in the stars and the apparent large amount in the ejecta, the event creating them must be caused by something that releases tremendous energy over a relatively short period of time. Or, as the authors wrote, "The TiC identification suggests that rather than with a wimpy wind, low-mass stars end their lives with (almost) a bang."

The study of metal clusters in the Duncan lab, of course, goes far beyond this notable discovery, and his colleagues across the country and internationally know his work quite well.

"Professor Duncan is a distinguished scientist, nationally and internationally renowned for his work on clusters," says Kit Bowen, a professor at Johns Hopkins University in Baltimore. "Specifically, he is the leader in studies involving the photodissociation of cluster cations, and his work on clusters has also had a substantial impact in the quest to discover cluster-assembled materials. Also, his infrared spectroscopic work at the free-electron laser in Holland definitively characterized 'Metcars', and his work there on other metal carbide systems is of fundamental astrophysical interest. Personally, he is well known for his helpfulness, often sharing his data and techniques with his colleagues around the world. He is an excellent colleague."

**The Duncan lab buzzes with activity, but it's not based on a type A personality — which Mike wouldn't know if it bit him — but on his sheer drive and joy in discovery.**

Mike studied neutral clusters first, and in the 1990s, he and his colleagues began to study cation particles, which are significant because researchers can "size-select" the particles, making them easier to study.

By the mid-1990s, all of this activity came together in a rush of national and international publicity. His work on so-called "nanocrystals" has drawn interest from a wide variety of groups and government agencies. The lab is also combining and studying metal ions and water molecules in work that has earned increasing plaudits worldwide.

Mike speaks of his work with great passion, but he resolutely refuses to take himself too seriously. He laughs easily and enjoys playing tennis with Debbie, who is a social worker in Athens, and their daughters, Katherine (a rising senior at Georgia) and Allison (who will enroll at Appalachian State this fall). While finding time for golf and gardening, he has also maintained a lifelong love of music that took off when he was a member of the Furman Singers. He is now a tenor in his church choir. He often plays sports with graduate students, and he and his research group take occasional hikes together in the mountains.

Mike Duncan has been a highly sought teacher and mentor in the Georgia chemistry department and has acquired a dazzling list of honors, including being named a Fellow in the American Physical Society in 2001. His research has earned several million dollars in grants, and he is a senior editor of the *Journal of Physical Chemistry*.

All of this might go to the head of someone else, but Mike remains at heart a country boy from South Carolina, whose fascination with how things work has led him from the fields and woods to the stars.

*This story is reprinted with permission from the Fall 2003 issue of* The Franklin Chronicle, *the magazine of the Franklin College of Arts & Sciences at the University of Georgia.*