A Need for Speed

NSF Awards Grant to MU Researchers for Ultrafast Laser System

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A University of Missouri team of researchers has been awarded a Major Research Instrumentation award from the National Science Foundation (NSF) that will allow the team to purchase an ultrafast amplified laser system that will facilitate research in condensed-matter physics, material science and engineering, chemistry, chemical engineering, biology, bioengineering, and medicine. Principal investigator Suchi Guha, a professor of physics, says probing materials with ultrafast short laser pulses allows researchers to capture some of the most fundamental physical processes that occur at extremely short timescales.

“Electrons are not stationary—they move very fast, so how do we capture that?” Guha asks. “One of the examples I give my students is, ‘If you have a ceiling fan and it is going very fast, and you cannot switch it off to figure out how many blades there are, what do you do? If you blink you can determine the number of blades, so you need some kind of pulsed technique to figure out the dynamics.”

Guha says another example is photosynthesis, in which light changes to chemical energy.

“Chlorophyll absorbs the light, and then the electrons are transferred to an acceptor, and that’s a very fast process—about one picosecond (one trillionth of a second),” she says. “In materials science, the same process occurs in donor-acceptor solar cells. So how do you study these

processes that have to do with dynamics and transfer of charges? These things happen very fast, so a tool like this ultrafast laser helps us."

In fact, Guha says improved solar cells could be one application of this new technology. Current solar cells are silicon based, but her team has been conducting research into organic or plastic solar cells that are flexible and bendable and could, in theory, be printed onto fabrics or flexible windows. Right now, Guha says plastic solar cells have shorter lifetimes and are less efficient, but by understanding processes like photosynthesis and charge transfer processes, they may overcome the limitations of the new technology.

In applying for the NSF award, MU physics professors Suchi Guha (top) and Ping Yu said the transdisciplinary breadth of available expertise is unmatched in the region, "empowering STEM students to obtain a competitive edge by hands-on experiences, and preparing them for employment in nanotechnology, biotechnology, materials science and engineering, and semiconductor-based academic research or industry."

Unimaginably Fast

The NSF award will allow the team to acquire a femtosecond laser system that is capable of multi-dimensional spectroscopy. A femtosecond is one quadrillionth of a second. The system includes a femtosecond oscillator (laser), a femtosecond amplifier, and a nonlinear optical parametric amplifier that can be used to change the wavelengths of the amplified femtosecond laser pulses into a wide range of wavelengths, allowing scientists to study different materials for different research projects.

For example, Guha says another team member, Assistant Professor of Physics Guang Bian is conducting research into quantum materials, two-dimensional materials, and nonlinear optical phenomena. Guha says the new system also will allow researchers like Bian to study the symmetry of materials and symmetry-breaking phenomena, which she says is at the heart of condensed-matter physics.

Physics Professor Ping Yu, also a co-principal investigator, says the short pulsed laser system can be used for diagnosing disease as well as for some laser surgeries. He says the system also can be used for high-resolution bio-imaging, producing three-dimensional images of a patient.

"I'm working on this project now—the imaging of the human eye and 3-D images of the retina and of skin cancer and those kinds of applications," Yu says. He says other applications include looking at carrier dynamics—the heart of electronics—to create exceedingly fast switches, which would be needed for quantum computing. Another co-principal investigator, Associate Professor of Biological Engineering Heather Hunt, is interested in fabricating micro- and nano-structures using the ultrafast laser system. Rainer Glaser, formerly with the MU Department of Chemistry, who now chairs the Department of Chemistry at Missouri University of Science and Technology in Rolla, synthesizes molecules with non-linear optical phenomena and will utilize the new laser system for his research. It is this collaboration across different disciplines and different educational institutions that most excites the members of the team, as well as a proposed center for nonlinear optics.

Center for Nonlinear Optics

“All of the parts are there. It’s just a question of putting people together,” Guha says. ”We’ve already formed a group that includes condensed matter theorists at MU and other collaborators at Lincoln University and at Missouri State University.”

Yu says the NSF grant has an educational component for undergraduate and graduate students. Some of the students who will be trained to use this new system will come from Lincoln University.

“The physics chair was a postdoc of mine, and he’s an expert on ultrafast lasers,” Yu says. “Not only will students be exposed to this sort of knowledge, but also they will be trained to learn how to solve problems in a way that uses this system.”

In applying for the NSF award, the team said the transdisciplinary breadth of available expertise is unmatched in the region, “empowering STEM students to obtain a competitive edge by hands-on experiences, and preparing them for employment in nanotechnology, biotechnology, materials science and engineering, and semiconductor-based academic research or industry.”

Guha says, “There may be several unchartered areas that we still have not thought of, but the new instrumentation award could lead us in that direction.”

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