

Ultra-fast laser spectroscopy lights way to understanding new materials

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Scientists at the U.S. Department of Energy's Ames Laboratory are revealing the mysteries of new materials using ultra-fast laser spectroscopy, similar to high-speed photography where many quick images reveal subtle movements and changes inside the materials. Seeing these dynamics is one emerging strategy to better understanding how new materials work, so that we can use them to enable new energy technologies.

Physicist Jigang Wang and his colleagues recently used ultra-fast [laser spectroscopy](#) to examine and explain the mysterious electronic properties of iron-based superconductors. Results appeared in *Nature Communications* this month.

Superconductors are materials that, when cooled below a certain temperature, display zero electrical resistance, a property that could someday make possible lossless electrical distribution. Superconductors start in a "normal" often magnetic state and then transition to a superconducting state when they are cooled to a certain temperature.

What is still a mystery is what goes on in materials as they transform from normal to superconducting. And this "messy middle" area of [superconducting materials](#)' behavior holds richer information about the why and how of superconductivity than do the stable areas.

"The stable states of materials aren't quite as interesting as the crossover region when comes to understanding materials' mechanisms because

everything is settled and there's not a lot of action. But, in this crossover region to superconductivity, we can study the dynamics, see what goes where and when, and this information will tell us a lot about the interplay between [superconductivity](#) and magnetism," said Wang, who is also an associate professor of physics and astronomy at Iowa State University.

But the challenges is that in the crossover region, all the different sets of materials properties that scientists examine, like its magnetic order and electronic order, are all coupled. In other words, when there's a change to one set of properties, it changes all the others. So, it's really difficult to trace what individual changes and properties are dominant.

The complexity of this coupled state has been studied by groundbreaking work by research groups at Ames Laboratory over the past five years. Paul Canfield, an Ames Laboratory scientist and expert in designing and developing iron-based superconductor materials, created and characterized a very high quality single crystal used in this investigation. These high-quality single crystals had been exceptionally well characterized by other techniques and were essentially "waiting for their close up" under Wang's ultra-fast spot-light.

Wang and the team used ultra-fast laser spectroscopy to "see" the tiny actions in materials. In ultra-fast laser spectroscopy, scientists apply a pulsed laser to a materials sample to excite particles within the sample. Some of the laser light is absorbed by the material, but the light that passes through the material can be used to take super-fast "snapshots" of what is going on in the material following the laser pulse and then replayed afterward like a stop-action movie.

The technique is especially well suited to understanding the crossover region of iron-arsenide based superconductors materials because the laser excitation alters the material so that different properties of the material are distinguishable from each other in time, even the most

subtle evolutions in the materials' properties.

"Ultra-fast laser spectroscopy is a new experimental tool to study dynamic, emergent behavior in complex materials such as these iron-based superconductors," said Wang. Specifically, we answered the pressing question of whether an electronically-driven nematic order exists as an independent phase in [iron-based superconductors](#), as these materials go from a magnetic normal state to superconducting state. The answer is yes. This is important to our overall understanding of how [superconductors](#) emerge in this type of materials."

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Provided by Ames Laboratory

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