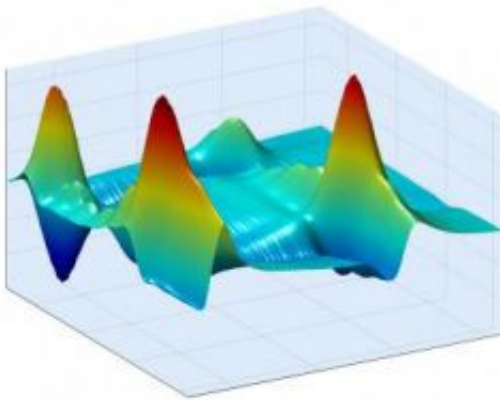


# Electronic 'crowd behavior' revealed in semiconductors

July 7 2007

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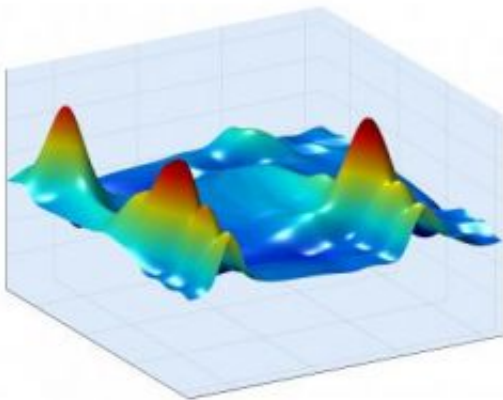


#1 - Experimental Data

Physicists at JILA have confirmed subtle "collective behavior" among electronic structures in semiconductors, research that may help improve the design of optoelectronic devices. In the first image (#1, showing new experimental data), matching large peaks in the foreground, showing energy intensity ranging from low in blue to high in red, indicate that pairs of large electronic particles called excitons are oscillating in concert as they absorb ultrafast laser light and emit energy at various frequencies. The data match new theoretical models accounting for all electronic properties of semiconductors (image #2) much better than older theoretical models. Credit: JILA and University of Marburg

Like crowds of people, microscopic particles can act in concert under the right conditions. By exposing crowd behavior at the atomic scale, scientists discover new states and properties of matter.

Now, ultrafast lasers have revealed a previously unseen type of collective electronic behavior in semiconductors, which may help in the design of optoelectronic devices. The work at JILA, a joint venture of the National Institute of Standards and Technology (NIST) and the University of Colorado at Boulder, is described in a new paper in the *Proceedings of the National Academy of Sciences*.



#2 - New Theory

Physicists at JILA have confirmed subtle "collective behavior" among electronic structures in semiconductors, research that may help improve the design of optoelectronic devices. Credit: JILA and University of Marburg

Design of optoelectronic devices, like the semiconductor diode lasers used in telecommunications, currently involves a lot of trial and error. A designer trying to use basic theory to calculate the characteristics of a new diode laser will be off by a significant amount because of subtle interactions in the semiconductor that could not be detected until recently.

To shed light on these interactions, the JILA team used a highly sensitive and increasingly popular method of manipulating laser light energy and

phase (the point in time when a single light wave begins) to reveal the collective behavior of electronic particles that shift the phase of any deflected light. Their work is an adaptation of a technique that was developed years ago by other researchers to probe correlations between spinning nuclei as an indicator of molecular structure (and led to a Nobel prize).

In the latest JILA experiments, a sample made of thin layers of gallium arsenide was hit with a continuous series of three near-infrared laser pulses lasting just 100 femtoseconds each. Trillions of electronic structures called excitons were formed. Excitons are large, fluffy particles consisting of excited electrons and the “holes” they left behind as they jumped to higher-energy vibration patterns.

By tinkering with the laser tuning—the frequency and orientation of the electric field—and analyzing how the semiconductor altered the intensity and phase of the light, the researchers identified a subtle coupling between pairs of excitons with different energy levels, or electron masses. The experimental data matched advanced theoretical calculations of the electronic properties of semiconductors, confirming the importance of the collective exciton behavior—and dramatically demonstrated the superiority of those calculations over simpler models of semiconductor behavior (see graphic).

Citation: T. Zhang, I. Kuznetsova, T. Meier, X. Li, R.P. Mirin, P. Thomas and S.T. Cundiff. Polarization-dependent optical two-dimensional Fourier transform spectroscopy of semiconductors. *Proceedings of the National Academy of Sciences*. Scheduled to be posted on-line July 6.

Source: National Institute of Standards and Technology

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