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Exploration of new frequency frontiers

An international team of physicists under the leadership of Prof. Matthias Kling at the Max-Planck-Institute for Quantum Optics and the Ludwig-Maximilians-Universität has extended a measurement method for the observation of light-induced processes in solids.

When matter is irradiated by ultrashort laser pulses, excited electrons scatter on femtosecond timescales. A femtosecond is a millionth of a billionth of a second. Information about the scattering and other fast processes in the material can be extracted from the wave characteristics of transmitted or reflected light fields, in so-called field-resolved spectroscopy. Some of this information, however, was not accessible. Field-resolved experiments had covered only frequencies below 50 terahertz (a terahertz is a trillion vibrations per second). An international team around Prof. Matthias Kling at the Ludwig-Maximilians-Universität Munich (LMU) and the Max-Planck-Institute for Quantum Optics (MPQ) in Germany has now extended the method to a range of 50-100 terahertz. With the doubling of the maximum frequency the researchers gained new insight into light-induced processes in solids.

If physicists want to learn more about the dynamics of electrons in solids, they probe them with electromagnetic fields. A particularly powerful method is transient field-resolved spectroscopy. When a laser pulse excites electrons in a solid, its transmission or reflectivity changes. Transient field-resolved spectroscopy permits to monitor these changes after the excitation in the waveform of a sampling light field. Experiments so far, however, concentrated on frequency ranges below 50 terahertz.

An international team led by Prof. Matthias Kling has now extended transient field-resolved reflectometry to frequency ranges of up to 100 terahertz, doubling the maximum frequency. The physicists could furthermore achieve repetition rates in the megahertz region in the measurements. They excited semiconductors with near-infrared laser pulses (at 800 nanometer wavelength), which lasted only for a few cycles in the femtosecond range. “The advantage of measurements in this extended frequency range is that it is free of other resonances. This permits to accurately monitor the response of free electrons in the materials”, explains Marcel Neuhaus, first author of the study. This way, the technique provided a time resolution of electron dynamics in solids below 10 femtoseconds.

By the extended frequency range the physicists studied dynamics of free charges in the semi-conductors germanium and gallium arsenide in a resonance-free range and could among other things observe, how electrons scatter between the different energy minima in the conduction band, the so called valleys. This allowed them to draw conclusions how the electrons influence each over in their scattering dynamics.

“The demonstrated field-resolved transient reflectometry at frequencies of 50-100 terahertz paves the way to studies of a broad range of intramolecular dynamics, including in molecular/organic electronics”, Prof. Kling explains. He adds: ”In the future, the new frequency range might enable measurements with high sensitivity to molecular vibrations in organic and novel 2D materials.”

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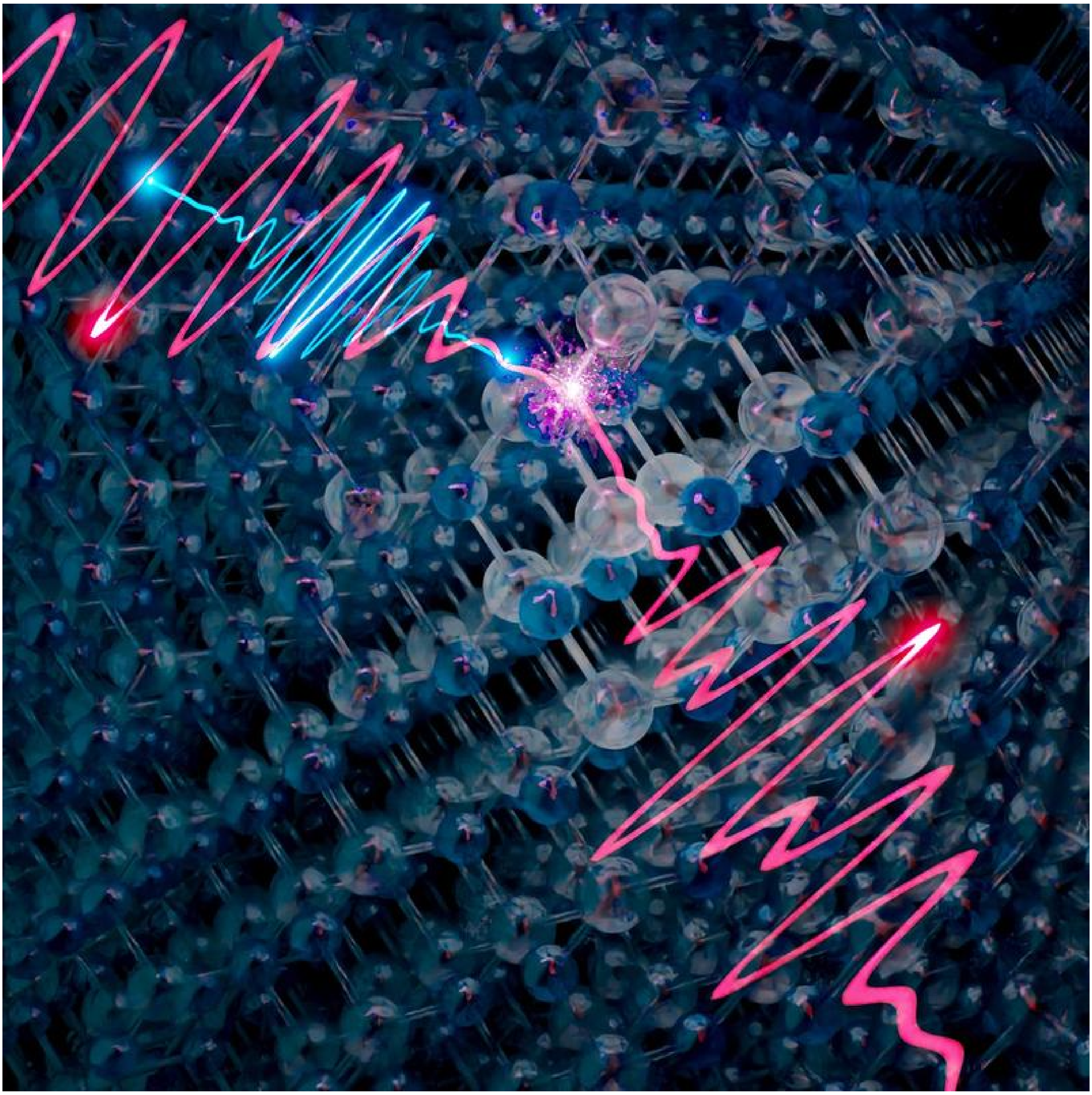

A near-infrared pulse (blue) excites a semiconductor. The unfolding ultrafast dynamics is interrogated by field-sampling spectroscopy, where changes to the waveform of a reflected mid-infrared light field (red) are recorded.
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