Researchers detect how light excites electrons in metal

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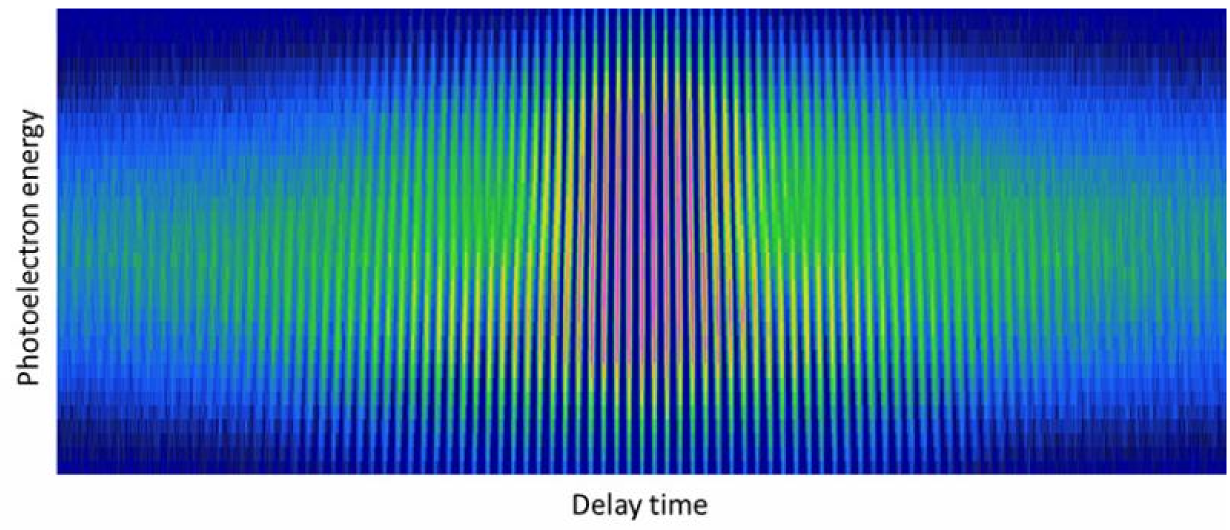

An interferogram showing the photoelectron energy vs. delay time between identical femtosecond pump and probe pulses, which excite coherent three-photon photoemission at a single crystal silver surface. The interferogram is taken from a movie of photoelectron energy vs. momentum with one frame corresponding to a 50-attosecond delay. The oscillations in the intensity of photoelectron signal for emission normal to the surface show how long light is trapped in the form of excitonic polarization during the coherent nonlinear interaction with the silver surface. Credit: Hrvoje Petek

Researchers have observed, in metals for the first time, transient excitons – the primary response of free electrons to light. Here, the researchers discovered that the surface electrons of silver crystals can maintain the excitonic state more than 100 times longer than for the bulk metal, enabling the excitons to be experimentally visualized by a newly developed multidimensional coherent spectroscopic technique.

Detecting excitons in metals could provide clues on how light is converted into electrical and chemical energy in solar cells and plants. This research may also provide ways to alter the function of metals in order to develop active elements for technologies such as optical communications by controlling how light is reflected from a metal.

The act of looking in a mirror is an everyday experience, but the quantum mechanical description behind this familiar phenomenon is still unknown. When light reflects from a mirror, the light "shakes" the metal's free electrons and the resulting acceleration of electrons creates a nearly perfect replica of the incident light – providing a reflection. Excitons, or particles of the light-matter interaction where light photons become temporarily entangled with electrons in molecules and semiconductors, are known to be important to this process and others such as photosynthesis and optical communications. Unfortunately, studying and proving how excitons function in metals is difficult because they are extremely short-lived, lasting for approximately 100 attoseconds, or less than a 0.1 quadrillionth of a second.

For the first time, researchers have observed excitons at metallic surfaces that maintain the excitonic state 100 times longer than in the bulk metal, enabling the excitons to be experimentally captured by a newly developed multidimensional multiphoton photoemission spectroscopic technique. This discovery sheds light on the primary excitonic response of solids which could allow quantum control of electrons in metals, semiconductors, and organic materials. It also potentially allows for the generation of intense femotosecond electron pulses that could increase resolution for time-resolved electron microscopes that follow the motion of individual atoms and molecules as they rearrange themselves during structural transitions or chemical reactions.

More information: "Transient excitons at metal surfaces." *Nature Physics* 10, 505-509 (2014). DOI: 10.1038/nphys2981

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