Team generates frequency comb with more than 100 terahertz bandwidth

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Many of the communication tools of today rely on the function of light or, more specifically, on applying information to a light wave. Up until now, studies on electronic and optical devices with materials that are the foundations of modern electronics—such as radio, TV, and computers—have generally relied on nonlinear optical effects, producing devices whose bandwidth has been limited to the gigahertz (GHz) frequency region. Thanks to research performed at the University of Pittsburgh, a physical basis for terahertz bandwidth (THz)—the portion of the electromagnetic spectrum between infrared and microwave light—has now been demonstrated.

In a paper published March 4 in *Nature Photonics,* Hrvoje Petek, a professor of physics and chemistry in Pitt's Kenneth P. Dietrich School of Arts and Sciences, and his colleague Muneaki Hase, a professor of applied physics at the University of Tsukuba in Japan and a visiting scientist in Petek's lab, detail their success in generating a frequency comb—dividing a single color of light into a series of evenly spaced spectral lines for a variety of uses—that spans a more than 100 terahertz bandwidth by exciting a coherent collective of atomic motions in a semiconductor silicon crystal.

"The ability to modulate light with such a bandwidth could increase the amount of information carried by more than 1,000 times when compared to the volume carried with today's technologies," says Petek. "Needless to say, this has been a long-awaited discovery in the field."

To investigate the optical properties of a silicon crystal, Petek and his team investigated the change in reflectivity after excitation with an intense laser pulse. Following the excitation, the team observed that the amount of reflected light oscillates at 15.6 THz, the highest mechanical frequency of atoms within a silicon lattice. This oscillation caused additional change in the absorption and reflection of light, multiplying the fundamental oscillation frequency by up to seven times to generate the comb of frequencies extending beyond 100 THz. Petek and his team were able to observe the production of such a comb of frequencies from a crystalline solid for the first time.

"Although we expected to see the oscillation at 15.6 THz, we did not realize that its excitation could change the properties of silicon in such dramatic fashion," says Petek. "The discovery was both the result of developing unique instrumentation and incisive analysis by the team members."

Petek notes the team's achievements are the result of developing experimental and theoretical tools to better understand how electrons and atoms interact in solids under intense optical excitation and of the invested interest by Pitt's Dietrich School in advanced instrumentation and laboratory infrastructure.

The team is currently investigating the coherent oscillation of electrons, which could further extend the ability of harnessing light-matter interactions from the terahertz- to the petahertz-frequency range. Petahertz is a unit of measure for very fast frequencies (1 quadrillion hertz).

More information: For more information on Petek's research, visit www.ultrafast.phyast.pitt.edu/Home.html

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