Shedding new light on controlling material properties in solid-layered perovskite

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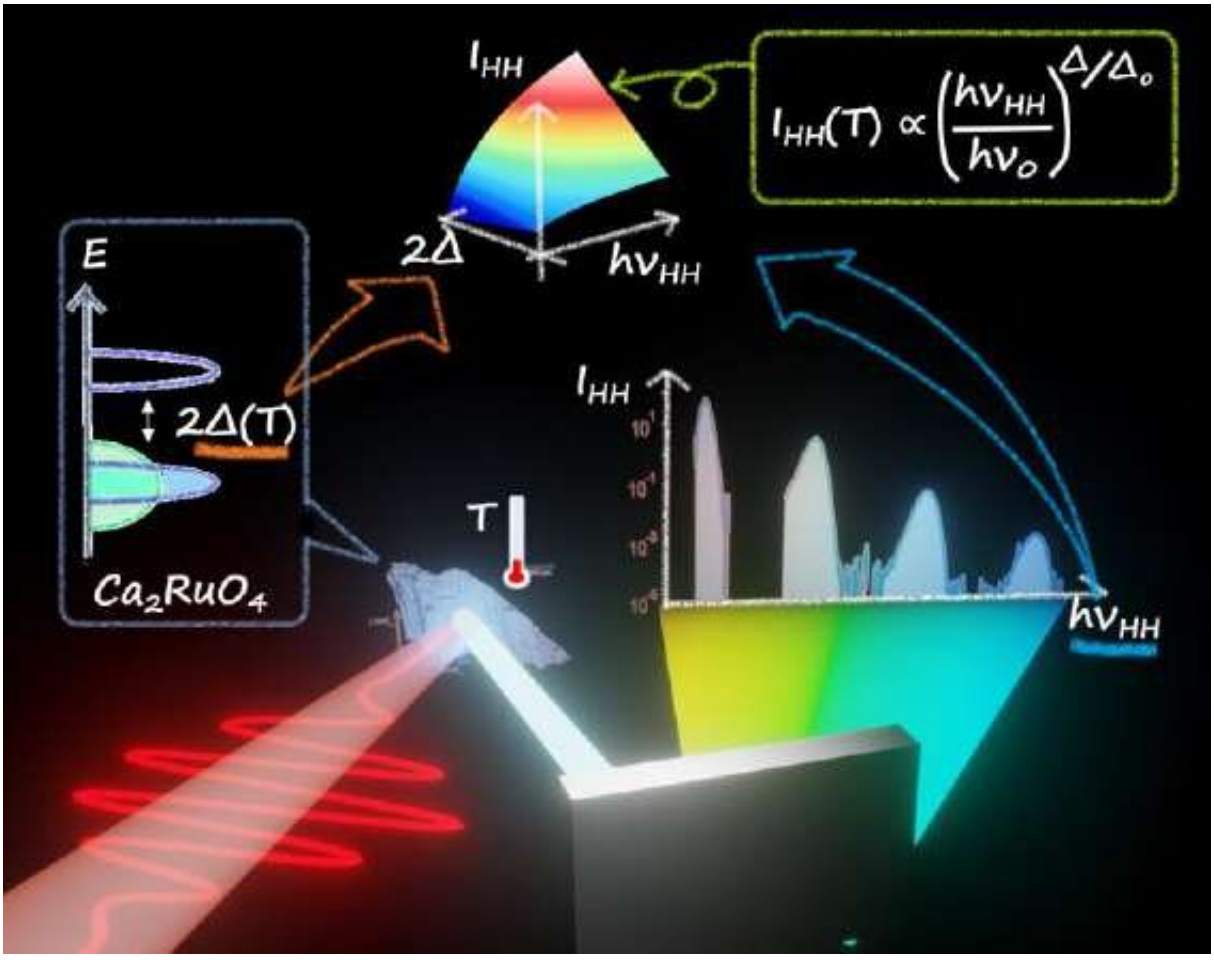

Scaling law in Mott-insulating Ca_2RuO_4. Credit: KyotoU/Kento Uchida

Materials scientists may soon be able to control material properties with

light.

A team consisting of researchers at Kyoto University and Kurume Institute of Technology have discovered a scaling law that determines high-order harmonic generation in the solid-layered perovskite material, Ca_2RuO_4.

High-order harmonic generation is a nonlinear optical phenomenon where extreme ultraviolet photons are emitted by a material as a result of interactions with high intensity light.

"The phenomenon, which was first observed in atomic gas systems, has since paved the way to attosecond science," says study author Kento Uchida. "But it is slightly more unpredictable in some strongly correlated solids, like Ca_2RuO_4."

Due to the strong interaction between electrons in these solids, the characteristics of high-order harmonic generation can only be established by understanding how these electrons move in the presence of light.

To tackle this question, which has never been confirmed experimentally, the team set out to observe the relationship between temperature and photon emission in Ca_2RuO_4. They used a mid-infrared pulse to measure and map out high harmonic generation intensity at temperatures from an extremely low 50 to a moderate 290 Kelvin.

At the low end, the team recorded high-order harmonic generation several hundred times more intense than at room temperature. Photon emissions continued to intensify with increasing gap energy—the energy required for electrons to conduct electricity—along with the drop in temperature.

The team found that such emissions occurred in the Mott-insulating phase of the material, where the strong repulsion between electrons and high gap energy transforms the metal from an electrical conductor to an insulator.

"We discovered that high-order harmonics in strongly correlated materials highly depend on the gap energy of the materials," explains Uchida.

This scaling law can direct theoretical studies towards more refined descriptions of non-equilibrium electron dynamics in strongly correlated materials: a central issue in condensed matter physics.

Uchida concludes that their "findings also provide a foundation for materials design to achieve more efficient nonlinear optical devices."

The research was published in *Physical Review Letters*.

More information: K. Uchida et al, High-Order Harmonic Generation and Its Unconventional Scaling Law in the Mott-Insulating Ca_2RuO_4, *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.128.127401

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