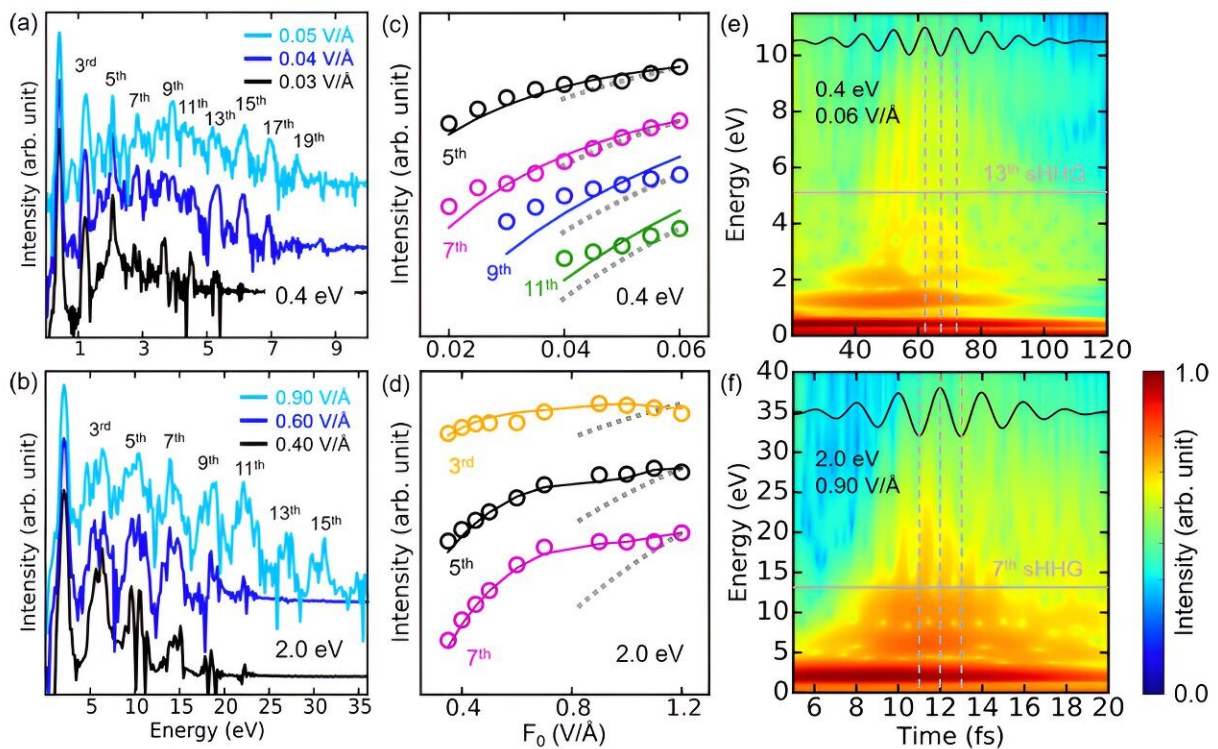


# High harmonic spectroscopy retrieves electronic structure of high-pressure superconductors

February 2 2024, by Zhang Nannan



The HHG spectra in high-pressure superconductor  $H_3S$ . Credit: Institute of Physics

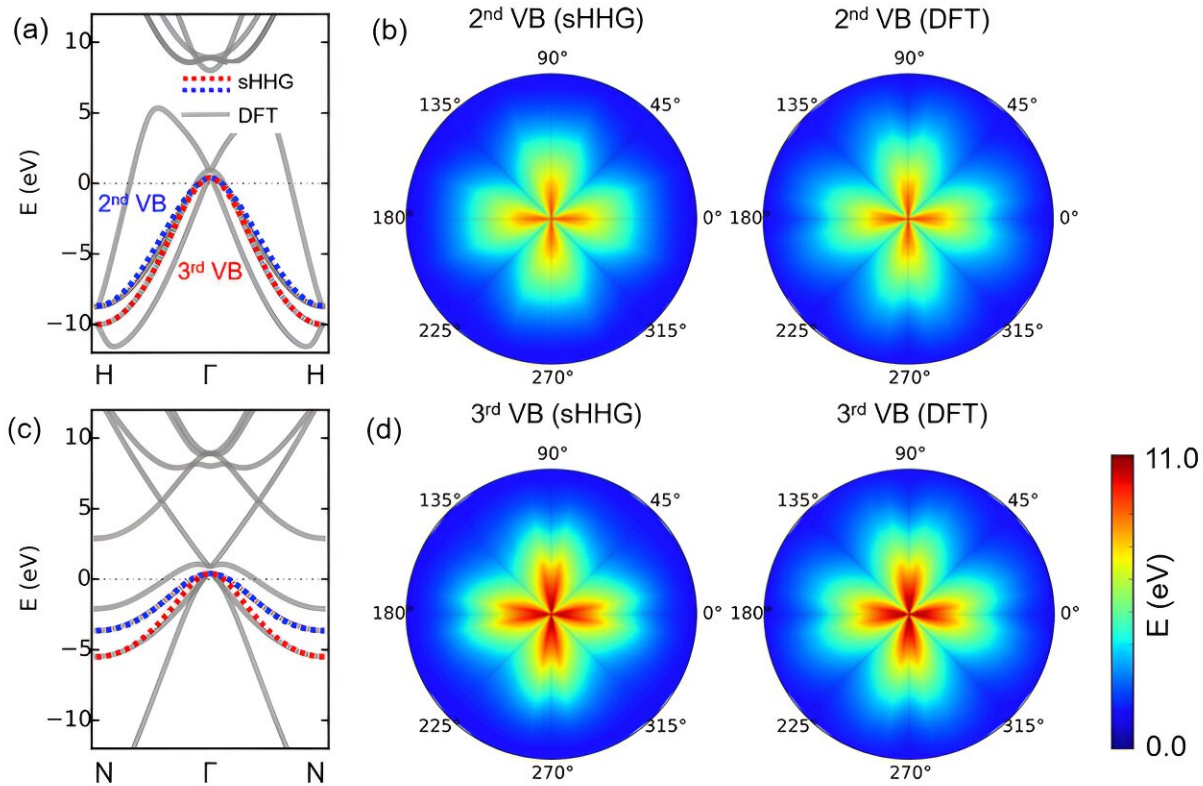
High pressure has revealed surprising physics and created novel states in condensed matter. Exciting examples include near room temperature

superconductivity ( $T_c > 200$  K) in high-pressure hydrides such as  $H_3S$  and  $LaH_{10}$ .

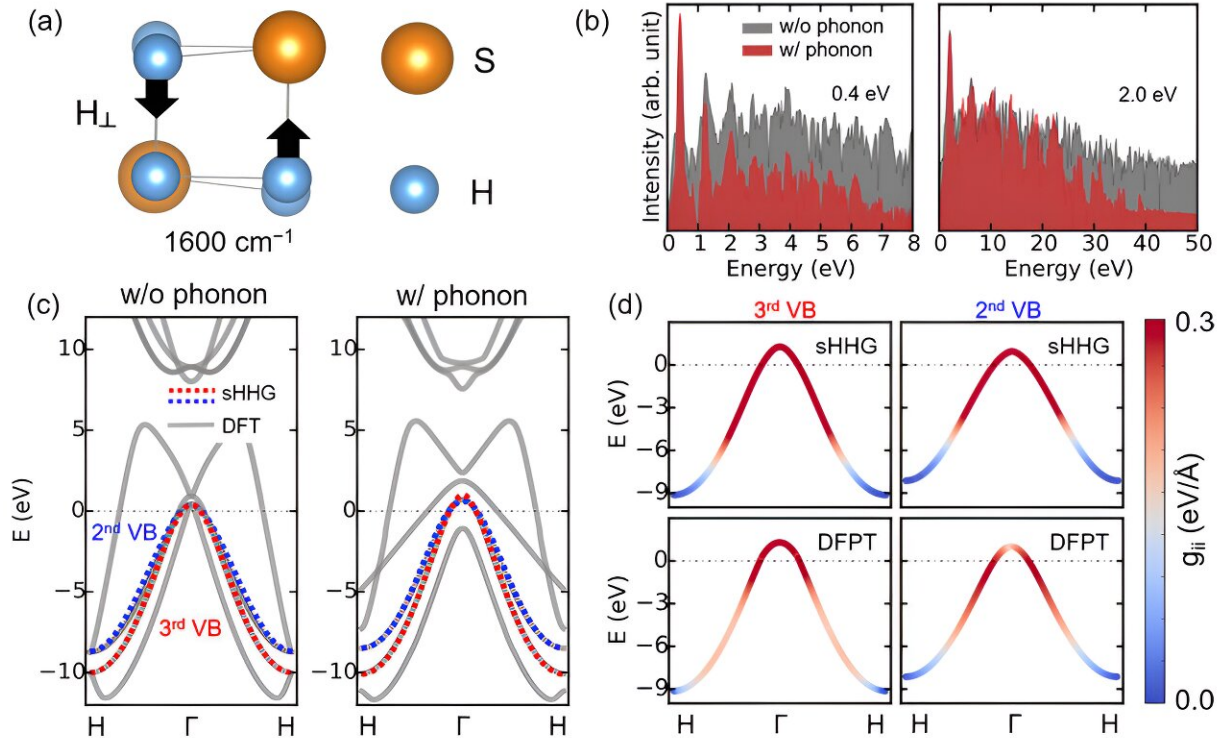
Although the superconducting transition temperature of high-pressure superconductors is constantly increasing, the mechanism of superconductivity at such high pressures remains an open question. Knowledge of the properties and ultrafast dynamics of electrons and quasiparticles in high-pressure quantum states is lacking.

High harmonic generation (HHG) is the up-conversion of laser light to radiation carried at multiples of the laser frequency. HHG in solids originates from the nonlinear driving of electrons within and between electronic bands by strong field light-matter interactions. Therefore, HHG spectroscopy naturally contains fingerprints of intrinsic atomic and electronic properties of materials. There is a great deal of excitement in learning about material properties through this nonlinear, non-perturbative laser-matter interaction.

Using state-of-the-art first-principles time-dependent density-functional theory simulations, Prof. Meng Sheng's group from the Institute of Physics of the Chinese Academy of Sciences has studied the ultrafast HHG dynamics in the high-pressure superconductor  $H_3S$ .



Band structure reconstruction via HHG spectra. Credit: Institute of Physics



Electron-phonon coupling reconstruction via HHG spectra. Credit: Institute of Physics

The researchers found that HHG in high-pressure superconductors is strongly dependent on the electronic structures and [electron-phonon coupling](#) (EPC). The study, titled "[Solid-state high harmonic spectroscopy for all-optical band structure probing of high-pressure quantum states](#)," is published in *PNAS*.

Using HHG spectroscopy, they retrieved the band dispersion and EPC, and revealed the significant influence of the many-body EPC on the electron behavior near the Fermi level.

Their results support the phonon-mediated mechanism based on the EPC of high-pressure superconductivity, providing an all-optical approach to

probe the band dispersion and EPC of high-pressure quantum states.

**More information:** Shi-Qi Hu et al, Solid-state high harmonic spectroscopy for all-optical band structure probing of high-pressure quantum states, *Proceedings of the National Academy of Sciences* (2024).

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