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Time-resolved study of Higgs mode in superconductors[1]

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The behavior of superconductors far from equilibrium has been intensively studied over decades. Goals of these studies are the elucidation of bosonic fluctuations essential for the pairing mechanisms, the manifestation of competing orders or hidden phases, and the optical manipulation of superconductivity. The study of collective modes is crucially important for these perspectives as it provides the information on the dynamics of order parameters in non-equilibirium states. Generally, collective modes in ordered phases associated with spontaneous symmetry breaking are classified into 1) gapless phase modes and 2) gapped amplitude modes. In superconductors, the phase mode is eaten by gauge field, according to the Anderson-Higgs mechanism. The remaining amplitude mode is recently termed as Higgs mode from its analogy to the Higgs boson in particle physics. Despite its long history of investigation, unambiguous observation of Higgs mode has remained elusive. This is because the Higgs mode does not have a charge nor electric dipole and therefore it does not couple directly to the electromagnetic field. Here we report on our recent observation of Higgs mode in s-wave superconductors by using THz-pump and THz-probe spectroscopy technique. After nonadiabatic excitation near the superconducting gap energy with monocycle THz pulses, Higgs mode was observed as oscillations in the transmission of THz probe pulse. The resonant nonlinear coupling between the Higgs mode and coherent radiation field was also discovered, resulting in an efficient third order harmonic generation of the incident THz radiation. The extension of experiments to multiband superconductors and unconventional superconductors will be discussed.

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