Ultrafast dynamics in superconductor and Dirac semimetal with efficient terahertz harmonic generation

Ryusuke Matsunaga[1,2]

[1]*The Institute for Solid State Physics, The University of Tokyo, Japan*
[2]*PRESTO, Japan Science and Technology Agency, Japan*
matsunaga@issp.u-tokyo.ac.jp

Recent realization of intense terahertz (THz) pulse generation technique (~1 THz ~4 meV ~300 μm) on tabletop have opened a novel route to study the condensed matter physics out of equilibrium. In this talk we present our studies of ultrafast dynamics in superconductors by using THz pulse [1-5]. In superconductors where the symmetry for rotating phase of wavefunction is spontaneously broken, two kinds of collective excitation modes emerge as fluctuations of phase and amplitude of order parameter. The amplitude mode in superconductors is also called Higgs mode because of close analogy to the Higgs bosons in elementary particles. The Higgs mode in superconductors has evaded experimental detection for a long time except for a special case of $NbSe_2$ because electromagnetic wave cannot interact with the Higgs mode in linear response regime. By using an *s*-wave superconductor NbN and intense THz pulse, we revealed that the Higgs mode can be observed out of equilibrium as an oscillation of the response function in time domain in THz pump-THz probe spectroscopy [1].

We also show that superconductors irradiated with intense THz pulse with sub-gap frequency generate third harmonics very efficiently due to nonlinear resonance effect [2]. Such a nonlinear THz interaction in superconductors has played an important role to clarify the origin of THz third harmonics generation [3] and to observe the Higgs mode in *d*-wave cuprate superconductor $Bi_2Sr_2CaCu_2O_{8+x}$ [4]. We also revealed that the Higgs mode can be detected in linear response function under nonequilibrium static condition by applying strong supercurrent [5].

We also report our very recent observation of the extremely-efficient THz third harmonic generation in 3D Dirac semimetal Cd_3As_2 thin film [6]. While such an efficient THz nonlinearity has been also reported in graphene, we found that the conversion efficiency in Cd_3As_2 is even 100 times higher than graphene. By subcycle time-resolved detection of Dirac electron dynamics, we confirmed that the strong THz harmonics originate from coherent acceleration of Dirac electrons across the node as theoretically predicted. We also found that the high harmonic generation strongly occur in visible frequency range by mid-infrared excitation. The extremely efficient THz high harmonic generation in Dirac semimetal pave an avenue for realizing novel frequency convertor in a wide range of frequency based on Dirac semimetals

References:

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