Intense terahertz pulse induced phenomena in low dimensional electron systems: carbon nanotubes and organic conductors

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With increasing laser field strength, the interaction between light and matter changes from multi-photon transition regime to laser field-induced tunnel-ionization regime. The crossover of these two regimes is described by a parameter $\gamma=(I_p/2U_p)^{1/2}$, introduced by Keldysh in his seminal paper[1], where $U_p=e^2E^2/4m_e\omega^2$ is the ponderomotive energy describing the quiver energy of electron during one cycle period of light, and I_p is the ionization potential for bound electrons[1]. The parameter γ, termed as Keldysh parameter, can be recognized as the ratio of laser frequency to tunneling frequency, and thus $\gamma<1$ gives the criterion for the laser field to cause the electron escape from the bound state by tunneling. As seen in its expression, the ponderomotive energy is inversely proportional to ω^2. Compared to the visible wavelength region($h\nu\sim$ 1.5 to 3 eV), the terahertz photon energy($h\nu\sim$ 4 meV for 1 THz) is about three orders of magnitude smaller so that significantly large ponderomotive energy may be achieved if one can obtain intense THz pulses. For example, the field amplitude of 1 MV/cm at 1 THz results in U_p ~12 eV for free electrons, which would make it possible to enter into a highly nonlinear regime $\gamma<<1$ with valence electrons in solids. With such intense THz pulses, various terahertz nonlinear effects are expected in a wide range of materials.

Aiming at such extreme nonlinear THz optics, we have developed a highly intense THz pulse light source. To generate the THz pulses, we used the optical rectification with a $LiNbO_3$ crystal adopting the pulse-front tilted phase-matching scheme [2]. By carefully designing the excitation laser beam profile to obtain nearly Gaussian beam of THz wave after the $LiNbO_3$ crystal, and also by introducing a parabolic mirror with short focal length, we could tightly focus the generated THz beam into a diffraction limited spot size. As a result, we have achieved the peak amplitude of THz electric field as large as 0.87 MV/cm[3], under the irradiation of 90 fs and 800 nm laser pulse with the pulse energy of less than 1 mJ.

In this talk, I will report on our recent results on the intense THz excitation phenomena in low dimensional electron systems investigated by using this intense THz light source; 1) intense THz field induced electroabsorption in carbon nanotubes[3-5], and 2) Intense THz pulse excitation effect in the charge ordered phase of quasi-2D organic conductor, θ-(BEDT-TTF)$_2$CsZn(SCN)$_4$, and in the spin density wave phase in quasi-1D organic conductor (TMTSF)$_2$PF$_6$[6-8], which both exhibit gap structures in the THz range in their ordered phases. The possibility of THz field-induced phase transition will be discussed.

References

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