Manipulation of electrons and photons by controlling coherent lattice vibrations - Coherent phonon in solids and its applications -

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Under the irradiation of the femtosecond laser pulses, Raman active phonon modes in solids are excited through electronic excitation via real or virtual intermediate states, which are characterized by displacive and impulsive excitations of coherent phonons, respectively [1-3]. Recently, it has been revealed that the coherent phonon in solids can be optically controlled by the irradiation of the terahertz-rate pulse trains, whose time periods well match to the oscillation periods of the coherent phonon. This technique will open the new paradigm that one can manipulate material properties, such as crystal structure and carrier transport in solids, by the use of shaped femtosecond laser pulses. Here, I present recent developments on coherent phonon spectroscopy and control of coherent phonons in semiconductors and phase-change materials to examine manipulation of crystal structure and carrier transport, i.e., carrier mobility [4]. The laser used was a Ti:sapphire oscillator operating at 850 nm with 25 fs pulse duration. A fast scan technique, which enables us to accumulate the data more than 10,000 times, was utilized. In GaAs we observed plasmon-like coherent LO phonon-plasmon coupled (LOPC) mode, whose relaxation dynamics is dominated by the damping of plasmon and therefore it enables us to extract carrier mobility [5]. The mobility extracted by the use of coherent phonon spectroscopy matches to that obtained by Hall measurements [6]. In $Ge_2Sb_2Te_5$ (GST) thin film, which is a rewritable optical storage media, we observed strongly damped A_1-symmetry phonons in amorphous phase, while the decay time of the A_1 mode in the crystalline phase becomes longer. Investigation of the temperature dependence of the decay time of the A_1 mode in both phases indicates that the dephasing in amorphous phase is governed by phonon-defect scattering, while that in crystalline phase is due to anharmonic phonon-phonon coupling, in which the optical phonon decays into acoustic phonons under the conservation of energy and momentum [7]. Coherent control of coherent optical phonons in these materials by using the terahertz-rate pulse pairs generated through a Mach-Zehnder interferometer as well as a spatial light modulator (SLM) will be presented.
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References:

[1] J. D. Lee, J. Inoue, and M. Hase, Phys. Rev. Lett., **97**, 157405 (2006).
[2] M. Hase, J. Demsar, and M. Kitajima, Phys. Rev. B **74**, 212301(2006).
[3] R. Lu, M. Hase, M. Kitajima, S. Nakashima, and S. Sugai, Phys. Rev. B **75**, 012107(2007).
[4] J. D. Lee and M. Hase, Phys. Rev. Lett., **101**, 235501 (2008).
[5] M. Hase, Phys. Stat. Solidi (c) **5**, No.1, 364 (2008).
[6] M. Hase, Appl. Phys. Lett., in press (2009).
[7] M. Hase, Y. Miyamoto, and J. Tominaga, Phys. Rev. B, submitted (2009).

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