Ultrafast Carrier Dynamics Studied by THz Emission

Toshiaki Hattori, Satoshi Arai, and Keiji Tukamoto

Institute of Applied Physics, University of Tsukuba,
1-1-1 Tennodai, Tsukuba 305-8573, Japan

E-mail: hattori@bk.tsukuba.ac, Phone: +81-29-853-5210, Fax: +81-29-853-5205

Terahertz (THz) radiation emitted from biased semiconductors pumped by ultrashort optical pulses is attracting attention because this provides a source of radiation of new frequency range, which can be used in many applications such as imaging and spectroscopy. It is of interest, however, that the emission process itself is influenced by the carrier dynamics in the emitter materials, and studies of the emitted THz radiation can provide rich information on the ultrafast processes in the semiconductors.

We have studied the carrier dynamics in GaAs and InP by measuring the THz field waveforms by changing the pump pulse photon energy. With positive excess energies with respect to the band gap, it was found that the THz waveforms are broadened with increased pump energy due to subpicosecond intraband relaxation of electrons in the conduction band (Fig. 1). On the other hand, wth negative excess energies, which correspond to the Urbach tail of the absorption spectrum, a tail was observed after the main peak in the THz waveforms. The decay times of the tail depended on the pump energy and were in the range of 1 to 2 ps. This shows that the photogenerated electrons have smaller mobility at their initial state and obtain larger steady-state mobility in a few picoseconds after excitation. This is attributed to the thermal excitation process of Urbach electrons to the conduction band. We believe this is the first observation of such a process. This was possible because of the high sensitivity of the THz emission method, which is sensitive to photogenerated electrons at densities of 10^{14} cm^{-3} level. The decay rate of the tails depended very much on the bias field (Fig. 2), and activation-type dependence was observed for GaAs. With InP, results similar to those of GaAs were observed.

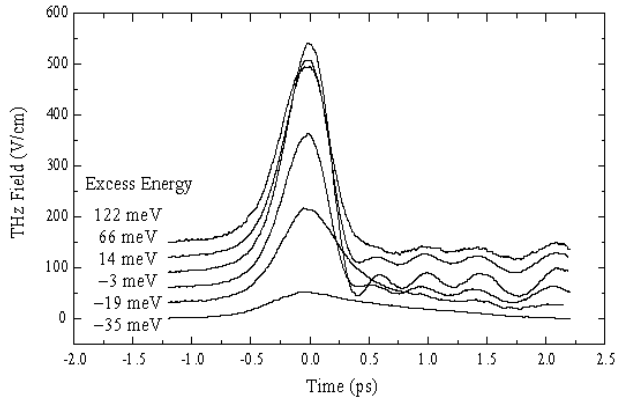

Fig. 1: The pump photon energy dependence of the THz waveforms emitted from a biased GaAs antenna. The excess energies are relative to the band gap energy of 1.428 eV. The oscillations at positive times are due to water vapor absorption.

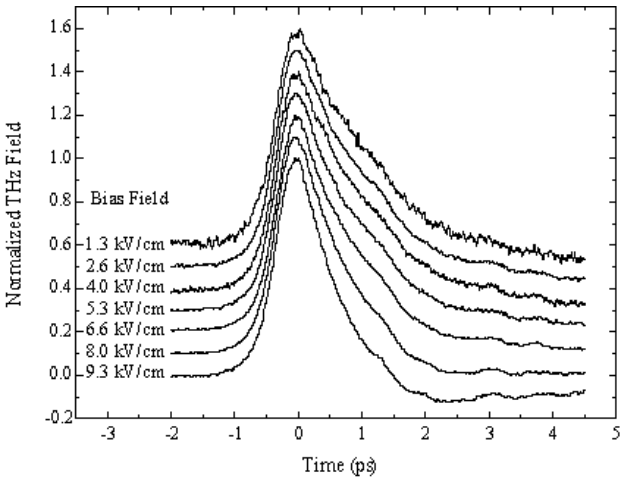

Fig. 2: The bias field dependence of the THz waveforms from GaAs at pump excess energy of –35 meV.