Ultrafast Semiconductor Electron Dynamics Observed by Terahertz Radiation Emission

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We studied the subpicosecond to picosecond dynamics of photoexcited carriers in GaAs and InP by observing the waveforms of the THz radiation emitted by these semiconductors under an electric bias. This study has revealed ultrafast carrier transport dynamics, or mobility dynamics, in these materials, which cannot be obtained by conventional optical time-resolved spectroscopic techniques. Dynamics of carriers excited by light with photon energy below the band gap (the energy region corresponding to the Urbach tail) has also been observed for the first time using this technique.

For the THz emission experiments, large-aperture biased photoconductive antennas were constructed using semi-insulating GaAs and InP wafers with an electric bias up to 9.3 kV/cm. The antennas were excited by 150-fs optical pulses obtained from an optical parametric amplifier. The excitation pulses were tuned across the band gap energy (E_g) of these materials with spectral width of about 15 meV. The emitted THz radiation was focused onto an electro-optic (ZnTe) crystal for EO sampling measurements of the waveforms. The THz waveforms correspond to the time derivative of the time dependent current density induced by the photogeneration of carriers.

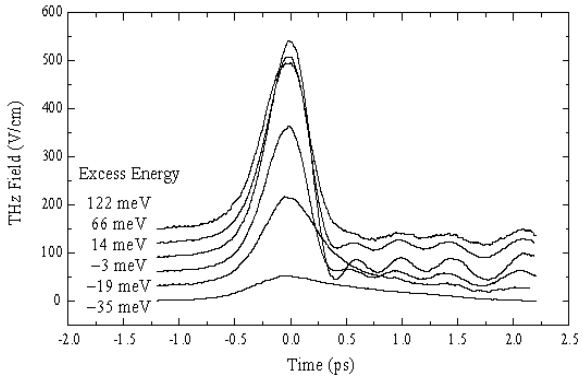

Fig. 1 The THz temporal waveforms emitted from biased GaAs for several values of the pump excess energy with respect to the band gap.

The THz waveforms obtained from GaAs are shown in Fig. 1 with excess energies (the excitation photon energy minus E_g) from 122 meV down to −35 meV. With positive excess energies, subpicosecond mobility rises corresponding to intraband carrier relaxation were observed. Highest peak THz field and shortest pulse duration were obtained with an excess energy of 14 meV, which corresponds to the photogeneration of carriers at the bottom of the conduction band. With negative excess energy, slower THz decays, which correspond to slower rises in carrier mobility, were observed. The decay time constant obtained at −35 meV was 1.4 ps. This corresponds to the dynamics of the thermalization of the Urbach-tail carriers. The decay rates were also found to depend on the bias field, as shown in Fig. 2, which suggests bias-field-induced activation processes. With InP, almost the same features were observed.

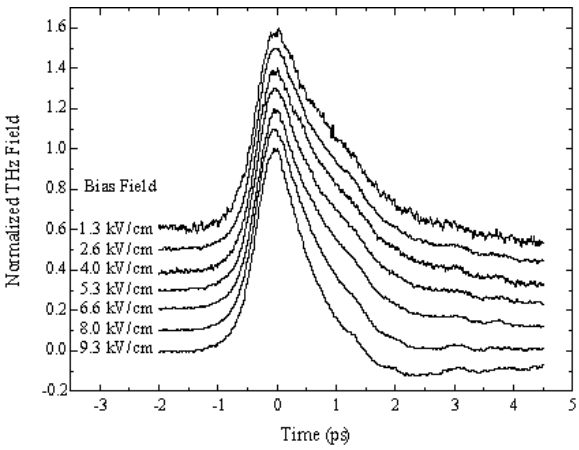

Fig. 2 The THz temporal waveforms emitted from GaAs for several values of the bias field for excess energy of –35 meV.