Electron Dynamics in GaAs Probed by Pump Wavelength Dependence of Terahertz Radiation

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Terahertz (THz) radiation generated by pumping semiconductor materials with femotosecond optical pulses has opened new field in spectroscopy and measurements. Widely used setup for THz pulse generation consists of a biased or unbiased semiconductor substrate and a femtosecond Ti-sapphire laser. For intense THz field generation, large-aperture biased GaAs antennas are commonly used. The waveform and amplitude of the emitted THz radiation reflects the electron dynamics in the emitter material. Since the band gap of GaAs (1.43 eV) is slightly lower than the photon energy (1.55 eV at 800 nm) of standard Ti:sapphire lasers, the initial excess energy of the photogenerated carriers is expected to play an important role in the electron dynamics. Change in the absorption coefficient in the vicinity of the gap energy is also expected to affect the emitted THz radiation. In this study, we have investigated the pump wavelength dependence of the amplitude and the waveform of the THz pulses generated from a large-aperture GaAs photoconductive antenna in the wavelength range around the band gap.

In the experiments, THz pulses were generated by pumping a biased GaAs wafer with a 30-mm intergap spacing by 180-fs optical pulses. The pumping pulses were generated by an optical parametric amplifier (OPA) at a repetition rate of 1 kHz. The emitted THz radiation was focused by an off-axis parabolic mirror, and the field waveform was measured using the electrooptic (EO) sampling method with a ZnTe crystal. For the wavelength dependence study, the center wavelength of the output of the OPA was tuned at 800 nm (1.55 eV), 830 nm (1.49 eV), 860 nm (1.44 eV), and 890 nm (1.39 eV).

The THz waveforms with a pump wavelength of 800, 830, and 860 nm obtained by the EO sampling measurements are shown in fig. 1. The THz pulses were gradually temporally narrowed by increasing the wavelength in this wavelength range. Increase in the peak field amplitude was observed at the same time in this wavelength range although quantative analysis of the result is to be done yet since the spectrum and the spatial beam profile of the OPA output depended on the wavelength. These results can be understood as follows. Photogenerated electrons with larger excess energy are scattered more frequently, which results in smaller mobility. The hot electrons are relaxed to the bottom of the conduction band in subpicosecond time scale, which results in the temporal increase in the electron mobility. Thus, the rise time of the photoinduced current on the surface of the emitter depends on the pump wavelength, which leads to the change in the temporal width and the amplitude of the emitted THz radiation.

With below-gap pumping at 890 nm, a 520-fs tail in the THz waveform was observed as shown in fig. 2. This can be attributed to the time required for the electrons initially photoexcited to below-gap states to be thermally excited to mobile states in the conduction band.

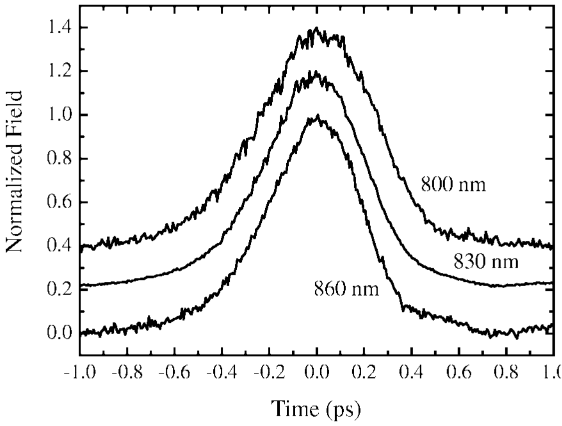

Fig. 1: The normalized waveforms of the THz radiation obtained by the EO measurements. The waveforms with pumping light wavelengths of 860, 830, and 800 nm are shown with a vertical shift of 0.2.

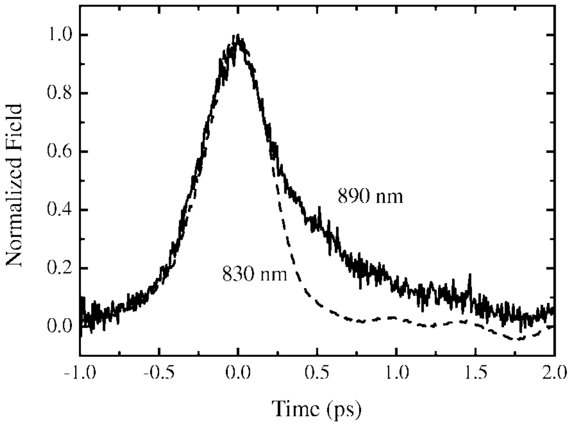

Fig. 2: The normalized THz waveforms with pump wavelengths of 830 and 890 nm.