THz Pulse Induced Photoluminescence from GaAs Multiple Quantum Wells

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Carrier multiplication caused by impact ionization scattering plays an important role in the efficient working of photovoltaic nanomaterials, electroluminescent emitters, and highly sensitive photon detectors used in optical quantum information applications. Fundamentally, carrier-initiated impact ionization occurring in strong electric fields critically affects nonequilibrium quantum transport phenomena, but the elementary process of carrier scattering relevant to ballistic transport has not yet been clarified. Here we show that a 1-MVcm^{-1} terahertz pulse (1 THz = 10^{12} Hz), unlike a DC bias, can generate a substantial number of electron-hole pairs forming excitons that emit near-infrared luminescence. The bright luminescence associated with carrier multiplication suggests that the carriers coherently driven by a strong field can efficiently gain enough kinetic energy to induce a series of impact ionizations, which we demonstrate for the first time can increase the number of carriers by about three orders of magnitude on picosecond timescale (1 ps = 10^{-12} s). The carrier increase with an increase in the THz electric field was in agreement with phenomenological theory based on an impact ionization model including an electron motion in *k*-space with a pristine band structure. In the future, to reveal the microscopic origin of the observed carrier multiplication, a full quantum kinetic theory treatment of carrier dynamics in a band structure modified by an intense THz electric field should be performed and our results will spur such effort on. Also, our findings of efficient ultrafast carrier multiplication bode well for future applications in ultrahigh-speed devices such as high-quantum-efficiency THz-biased avalanche photodiodes that have femtosecond resolution and are sensitive to a single photon, and they may also be exploited in the development of efficient electroluminescent and photovoltaic nanoscale devices.