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Supplementary Materials for

The ultrafast dynamics and conductivity of photoexcited graphene at different Fermi energies

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SUPPLEMENTARY MATERIALS

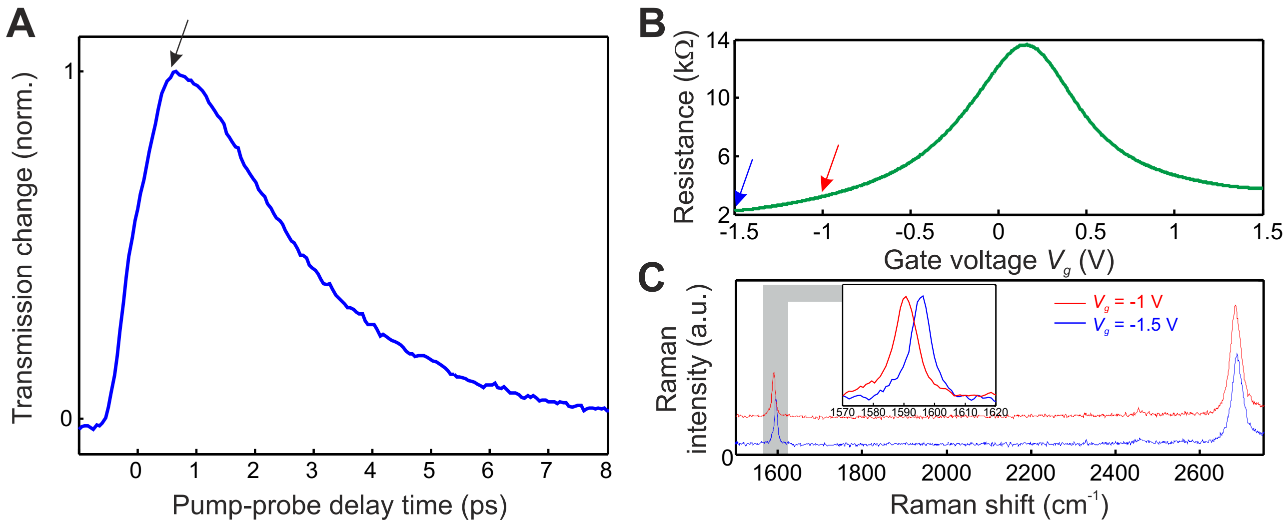

fig. S1. Sample characterization. A) Normalized change in THz transmission as a function of pump-probe delay time for the gate-tunable device. The 800 nm pump pulse coincides with the peak of the THz pulse at time zero. The black arrow indicates the time delay where we typically examine the THz photoconductivity. **B)** Transport measurements of the device with resistance as a function of gate voltage. The Dirac point lies at slightly positive voltage, whereas changing the gate voltage clearly leads to bipolar doping behavior. The blue and red arrows indicate the gate voltages where Raman spectra are taken. **C)** Raman spectra of the device at $V_g = -1.5$ V ($V_g = -1$ V) in blue (red), with more detail of the carrier-density sensitive G peak in the inset. We extract a carrier density of $8{\cdot}10^{12}/\mathrm{cm}^2$ ($5{\cdot}10^{12}/\mathrm{cm}^2$) following Ref. [61]. We use these extracted carrier densities together with the measured conductivities from transport in panel **B** (corrected for an estimated contact resistance of 1.5 kΩ) to obtain a mobility of $\sim$1000 $\mathrm{cm}^2/\mathrm{Vs}$. The width of the 2D peak is $\sim$25–30 cm^{-1}.

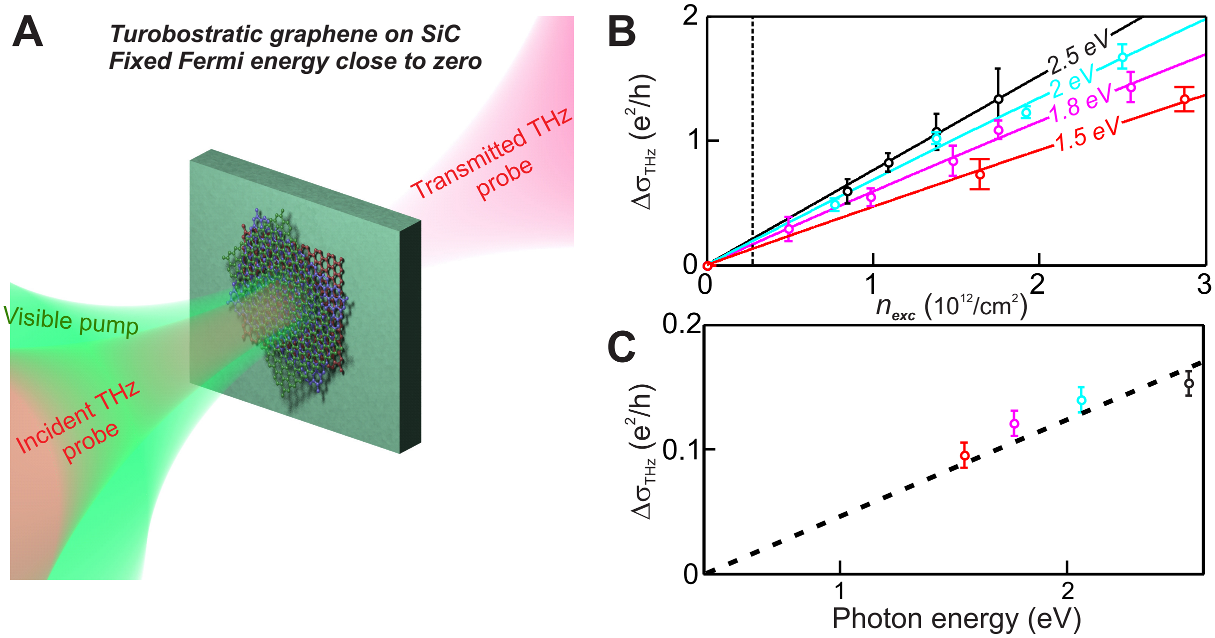

fig. S2. Intrinsically undoped graphene. A) Illustration of the optical pump – THz probe measurement technique applied to turbostratic graphene supported by SiC substrate. This device consists of multiple graphene monolayers with random relative orientation and very low doping [62]. The graphene thickness was estimated to be about 8 layers via Raman spectroscopy [63, 64]. Through these optical pump – THz probe measurements, we further examine graphene close to the charge neutrality point, as in Fig. 4 for the gate-tunable sample. **B)** The THz photoconductivity $\Delta\sigma_{\rm THz}$ as a function of the pump pulse fluence, parametrized by the photoexcited carrier density $n_{\rm exc}$, for several values of the pump photon energy $E_{\rm ph} = 1.5$, 1.8, 2.0, and 2.5 eV (empty circles). The turbostratic graphene samples are characterized by a very low doping, so this panel should be compared to Fig. 4A. The solid lines are linear fits to the data. **C)** The THz photoconductivity at $n_{\rm exc} = 0.2 \times 10^{12}/{\rm cm}^2$ [vertical dashed line in **B)**], as a function of the pump photon energy. The dashed line is a linear fit to the data. Consistently with the THz photoconductivity measured on gated samples, we observe larger THz photoconductivity for larger photon energy, as discussed in Fig. 4. This trend indicates that efficient interband heating takes place in the, intrinsically undoped, turbostratic graphene samples.