Umklapp-Assisted Electron-Phonon Coupling Enables Ultrafast Cooling in Magic Angle Twisted Bilayer Graphene

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In rotated van der Waals heterostructures, the twist angle controls the moiré lattice constant, which in turn modifies the electron momentum and the phonon spectra. Theoretical studies predict that the moiré potential also strongly affects electron-phonon coupling. [1-4] However direct measurements of moiré-enhanced electron-phonon coupling, and a clear understanding of its origin, are lacking.
Here we reveal the occurrence of electron-phonon Umklapp scattering in twisted bilayer graphene near the magic angle. [5] Using time-resolved photovoltage measurements and a direct analysis based on Boltzmann theory, we show that it provides the main relaxation mechanism for hot carriers across a broad temperature range. By comparing twisted and non-twisted bilayer graphene, we find that a twist angle of 1° speeds up cooling by several orders of magnitude.
Our work demonstrates the ability to engineer electron-phonon coupling and the resulting cooling power in twistronic systems. These results are relevant for transport measurements, while the short carrier lifetime will enable the development of ultrafast photodetectors based on moiré materials.

References
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Figures

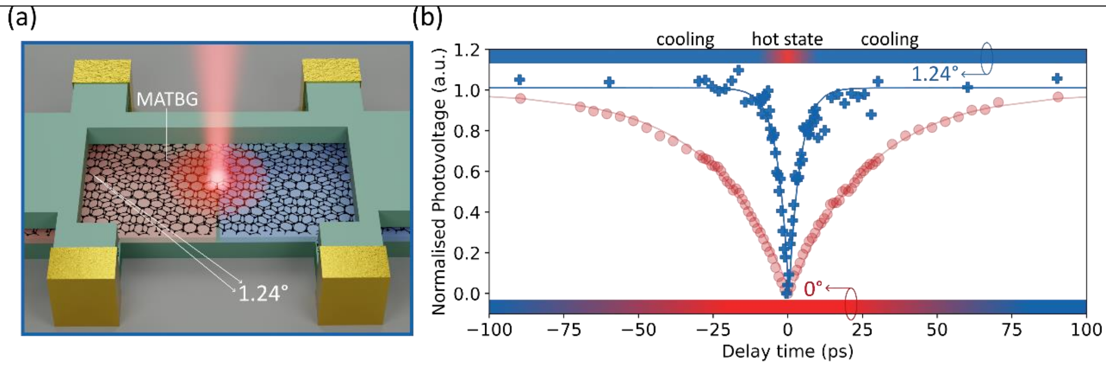

Figure 1: (a) Illustration of the hBN-encapsulated MATBG device. We generate a photovoltage by illuminating the pn-junction (red/blue regions). (b) Controlling the time delay between two ultrafast pulses reveals the hot carrier cooling dynamics. At low temperatures, these are significantly faster in the case of MATBG (1.24°) than non-twisted BLG (0°).