Temperature Dependent Ultrafast Edge Photocurrent and Carrier Dynamics in WTe_2 with On-chip THz Spectroscopy

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Illuminating a 2D semimetal while breaking its inversion symmetry can generate ultrafast photocurrents without requiring an externally applied voltage. This phenomenon is particularly intriguing for applications spanning energy harvesting, ultrafast optical communications, and advanced photodetectors. WTe_2, with its exceptional carrier mobility and anisotropic Fermi surface, has emerged as a prime candidate for investigating ultrafast photocurrent generation. Recent studies revealed that continuous-wave (CW) laser illumination on WTe_2 at zero bias induces a robust nonlinear edge photocurrent along its low-symmetry axes, which is absent along high-symmetry directions.[1] However, contrasting findings suggest that this photocurrent is predominantly governed by the photothermoelectric effect (PTE), as evidenced by photocurrent flow spectroscopy.[2] To resolve this uncertainty and gain deeper insights into photocurrent mechanisms and real-time carrier dynamics, a temperature-dependent ultrafast time-domain (TD) photocurrent study of WTe_2 is crucial.

Here, we followed the on-chip THz spectroscopy technique where a low-temperature grown (LT)-GaAs photoconductive (PC) switch was connected with WTe_2 via a Goubau-line waveguide [Fig. 1(a)].[3] WTe_2 was mechanically exfoliated directly on the sapphire substrate, and a PC switch was placed 440 μm away for detection of the TD photocurrent. A femtosecond pulsed laser with 517 nm wavelength light was used to excite and detect the photocurrent. The pump pulse was directed on WTe_2, while the probe pulse with a delay t was focused on the PC switch.

Fig. 1(b) shows the TD photocurrent at different temperatures. Pump laser was focused on the edge of the WTe_2 at lower symmetry axis [inset of Fig. 1(b)] to obtain the photocurrent signal. By increasing the temperature from 4K to 300K, the TD signal changes from Sine to Cosine-like shape. Interestingly, it is highlighting distinct cooling pathways arising from the contributions of multiple carrier pockets, influenced by the temperature variations. The disappearance of the peak at higher temperature can be explained by the shrinking of the hole pockets with increasing temperature.[4] This study reveals that photocurrent generation arises from the PTE induced by a temperature gradient. Our finding provides insights into energy relaxation, electron-phonon interactions, and their temperature dependence, paving the way for advanced applications in ultrafast photodetection, energy harvesting and communications.

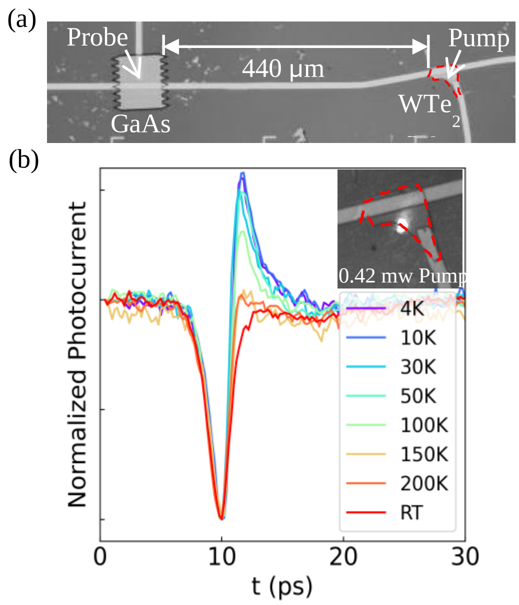

Fig. 1: (a) Optical image of the WTe_2 based on-chip photodetector device structure where low-temperature grown GaAs photoconductive switch is connected via a Goubau-line waveguide. (b) Temperature dependent TD photocurrent from 4K to 300K.

[1] Q. Wang et al. Nat. Comm. **10**, 5736 (2019).
[2] Y.X Wang et al. Nat. Phys. **19**, 507-514 (2023).
[3] K. Yoshioka et al. Nat. Photon. **16**, 718-723 (2022).
[4] Y. Wu et al. Phys. Rev. Let. **115,** 166602 (2015).
This work is supported by KAKENHI JP24H00828.

