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Auger-assisted hot carrier energy harvesting with monolayer semiconductors

Strong electron-hole interactions in 2D semiconductors [2] result in the efficient exciton–exciton annihilation (EEA), a four-body interaction involving the energy and momentum transfer between two holes and two electrons. The resulting high-energy charge carriers are effectively at the surface and therefore can be transferred to the adjacent van der Waals layer at an ultrafast rate [2]. While the EEA effect has been identified experimentally in ultrafast transient absorption measurements its manifestation in the photocurrent has never been demonstrated. Here we report unconventional photoresponse in van der Waals heterostructure devices due to hot carriers derived from EEA in monolayer transition metal dichalcogenide (TMD) [3]. We show that the photocurrent results from ultrafast transfer of Auger-induced high energy holes from monolayer TMD to the valence band of hexagonal boron nitride (hBN). Simultaneous measurements of photoluminescence quantum yield and photocurrent external quantum efficiency reveal that EEA play an important role above the generation rate of 10^{19} $cm^{-2}s^{-1}$.

References

[1] Mouri et al. “Nonlinear photoluminescence in atomically thin layered WSe_2 arising from diffusion-assisted exciton-exciton annihilation” Phys. Rev. B 90, 155449 (2014)
[2] Hong et al. “Ultrafast charge transfer in atomically thin MoS_2/WS_2 heterostructures” Nature Nanotech. 9, 682 (2014).
[3] Linardy et al. Manuscript in preparation.

Figures

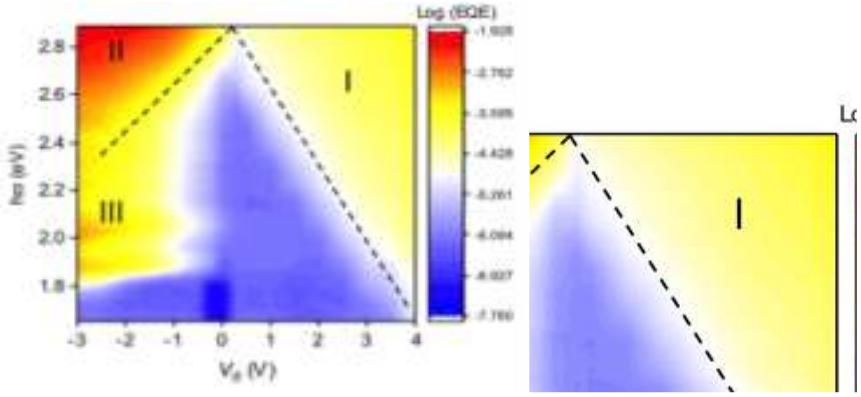

Figure 1 External quantum efficiency (EQE) of photocurrent in metal-insulator-semiconductor (MIS) heterostructure (left), and illustration of its origin (right).