Negative differential resistance induced bi-stability for single photon detection in moiré superlattices

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The sharp superconducting phase transition has enabled the development of sensitive bolometers and single photon detectors, revolutionizing the photodetector industry over the last 20 years. However, the excellent performance of these superconducting devices is severely compromised for mid-infrared and terahertz range, because of fundamental constraints imposed by the superconducting gap. In this work we introduce a novel photodetection mechanism utilizing a transition between Fermi velocity-limited electrons and the electron-hole plasma in moiré superlattices[1]. We demonstrate that the transition regime separating the two phases is extremely photosensitive to mid-infrared illumination. Furthermore, for certain doping levels in bilayer graphene/hBN superlattice (Fig. 1) we find that a negative differential resistance emerges within the transition regime, which we ascribe to the presence of a well-defined gapped state. Using the negative differential resistance, we engineer a bi-stable state, which serves as the probe for single photon absorption events. We measure a Poissonian distribution of photon counts, that always satisfies the relation 'variance equal to mean' with changing the laser power, which serves as a smoking gun signature of achieving the single photon detection operation. The detector can potentially work for mid-infrared wavelengths, addressing the current technological difficulties of photon counting in this part of the spectrum. Our device is broadband, tunable, CMOS-compatible and can operate at relatively high temperatures (>20 K), opening an avenue to surpass the current single photon detection technology for long-wavelength light.

References

[1] Berdyugin, A. I. et al. Out-of-equilibrium criticalities in graphene superlattices. Science (1979) 375, 430–433 (2022).

Figures

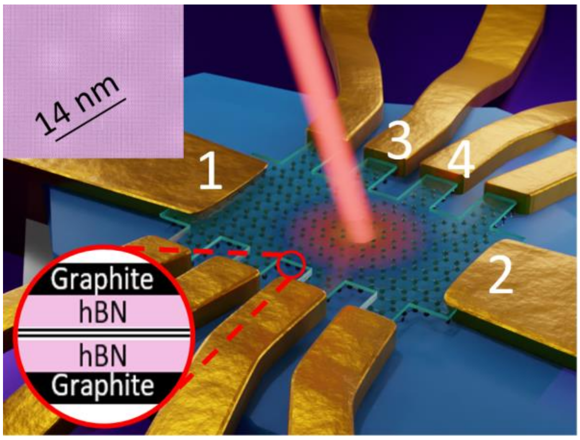

Figure 1: A cartoon of the BLG/hBN superlattice device