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Interface junction states and broadband polarization-sensitive photoresponse in inhomogeneous graphene

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Abstract. In graphene sheets, containing interface junctions [1], we have found electron states localized in the direction across junction. These interface junction states form a 1D transport channel along the junction. The discovered states have an enhanced polarization dependent dipole matrix element for interband excitation [2]. In graphene flakes with interface junctions connecting source and drain electrodes, the interface junctions contribute to an enhanced polarization sensitive photoelectric [3] broadband (THz-to-Visible) photoresponse in the way similar to that for a nanowire [2].

Suspended homogeneous and interface junction graphene devices

Device	Type of Junction	Antenna?	Junction Angle θ
1	Bernal bilayer graphene (BLG)/ABC-stacked trilayer (TLG)	Yes	-12$^{\upsilon}$
2	homogeneous ABA-stacked TLG	Yes	no junction
3	Bernal BLG/ABA-Stacked TLG	Yes	+71$^{\upsilon}$
4	ABA-TLG/4-layer	No	+8$^{\upsilon}$
5	Bernal BLG/ABC TLG	No	-6$^{\upsilon}$

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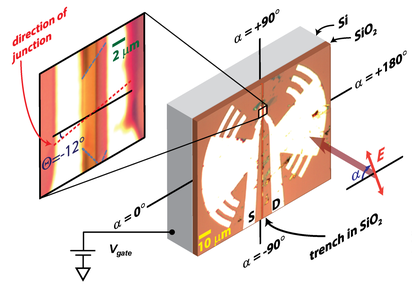
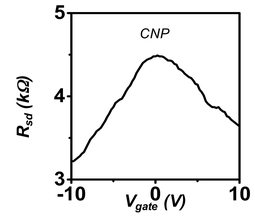
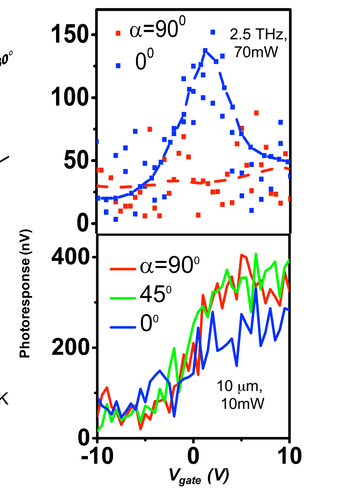
Design of devices





Role of antenna



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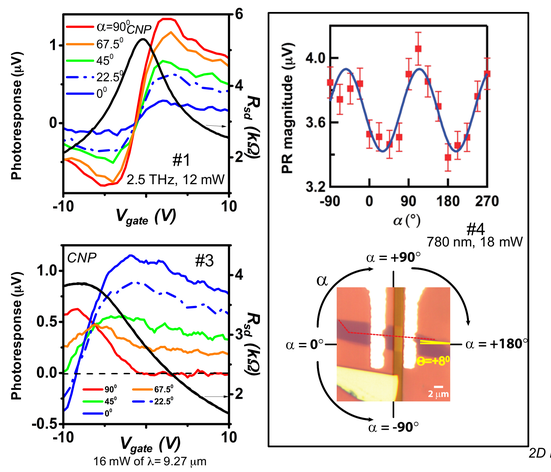
Photoresponse in interface junction devices



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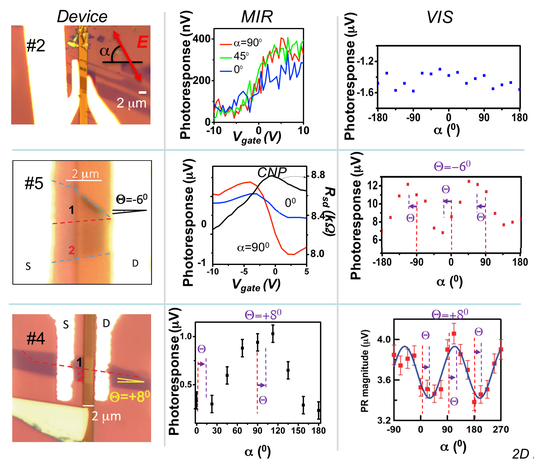
Polarization dependence of photoresponse



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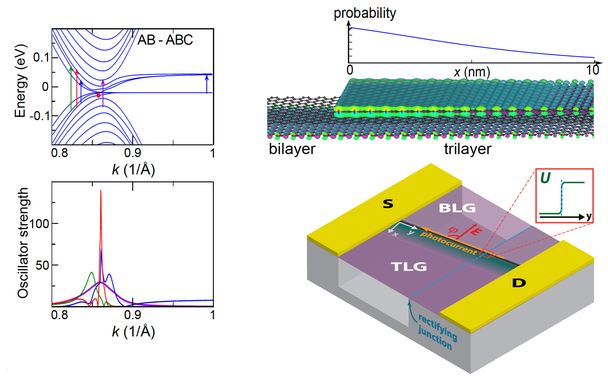
Interface junction electron states



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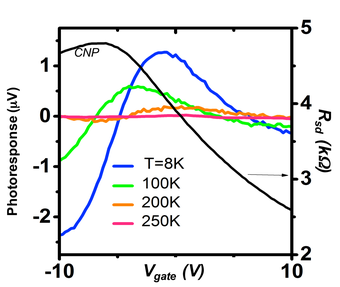
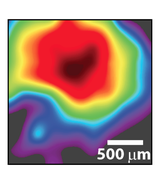
Temperature dependence of photoresponse

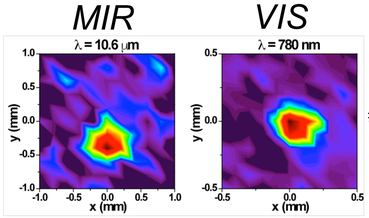


4.25 THz, 11 mW, #3

Beam profile imaging



THz
2.5THz, #3, 10K



#2, 10K

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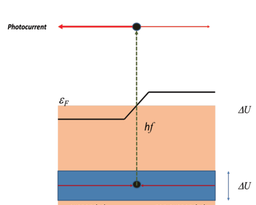
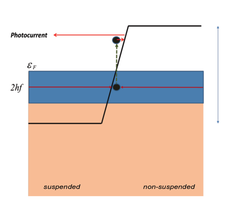
Polarization and gate voltage dependence of photoresponse

$$\hat{H} = \hat{\sigma}_z \varepsilon\left(\vec{k}\right) + \Delta_R \hat{\sigma}_x \cos(\omega t) + U(y)$$

$$\Delta_R \propto \sin(\varphi)$$





$$\Delta U = \frac{2\pi\hbar^2\varepsilon_0(\varepsilon-1)}{emD} V_{gate}$$

$$P \approx \Delta_R^2 d \,/\, |\Delta U|$$

$$\Delta U \le hf \quad I_{ph} \approx P\delta E(p_L - p_R) \approx d\Delta_R^2 (hf)^{1/2}\left[\frac{\Delta U}{hf}\right] \qquad |\Delta U| \ge hf \quad I_{ph} \approx d\Delta_R^2 \left(|\Delta U|\right)^{1/2}\left(\frac{hf}{\Delta U}\right)$$

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Summary. We discuss a previously unobserved type of electronic state with a relatively strong photoresponse tied to the interface junction between graphene sheets with different number of layers on each side of the junction. We have characterized the optical properties of these interface states both experimentally and from first principles calculations. The revealed interface states are localized and have an enhanced dipole matrix element for interband excitation. Optically excited electrons generate photocurrent and photovoltage at the rectifying junction between suspended and non-suspended parts of graphene flakes. Because of 1D geometry, the interface junction states support a polarization dependent photocurrent which is aligned along the junction in inhomogeneous graphene samples.

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