Supporting Information

Photoresponse of Graphene-gated Graphene-GaSe Heterojunction Devices

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1. Device I

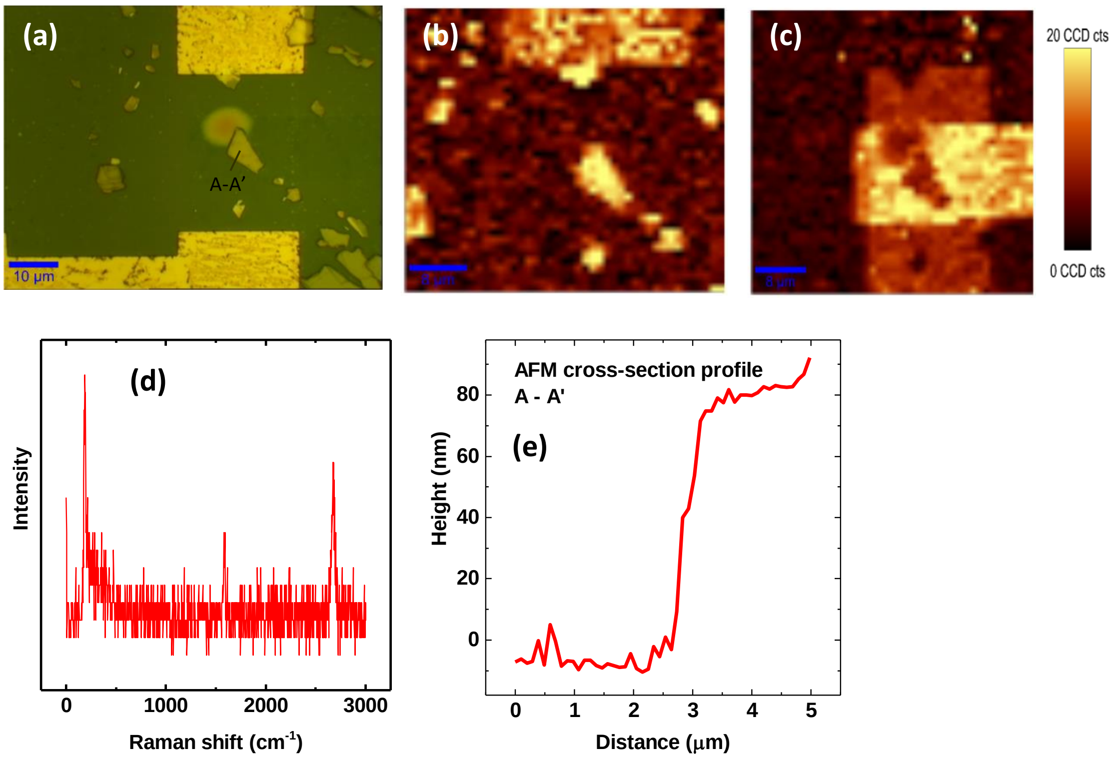
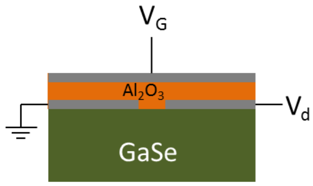
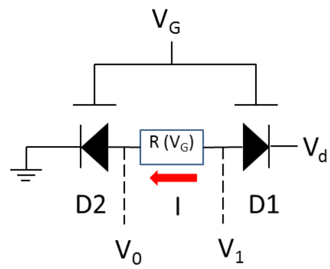


Figure S-1. Device I. (a) Optical image and Raman map for the peak of (b) GaSe appearing at ~212 cm^{-1} (E^1_{2g}) and of (c) the graphene at ~2680 cm^{-1} (2D). (d) Raman spectra corresponding to the point of the S/D area. (e) Height profile measured by AFM along the A-A' line in (a).





$T = 300$ K
$T_{ox} = 30$ nm
$\varepsilon_{ox} = 8.9$
$\varepsilon_{GaSe} = 7$
$N_a = 1e10\ cm^{-3}$
$N_v = 2.21e17\ cm^{-3}$
$W_g = 4.5$ eV
$E_{gap} = 2.1$ eV
$\chi_{GaSe} = 3.24$ eV

Diode equations

$I_2 = I_o\exp(-\phi_{b2}/kT)\exp(qV_0/\eta_2 kT)(1-\exp(-qV_0/kT))$
$I_1 = I_o\exp(-\phi_{b1}/kT)\exp(q(V_1-V_d)/\eta_1 kT)(1-\exp(-q(V_1-V_d)/kT))$

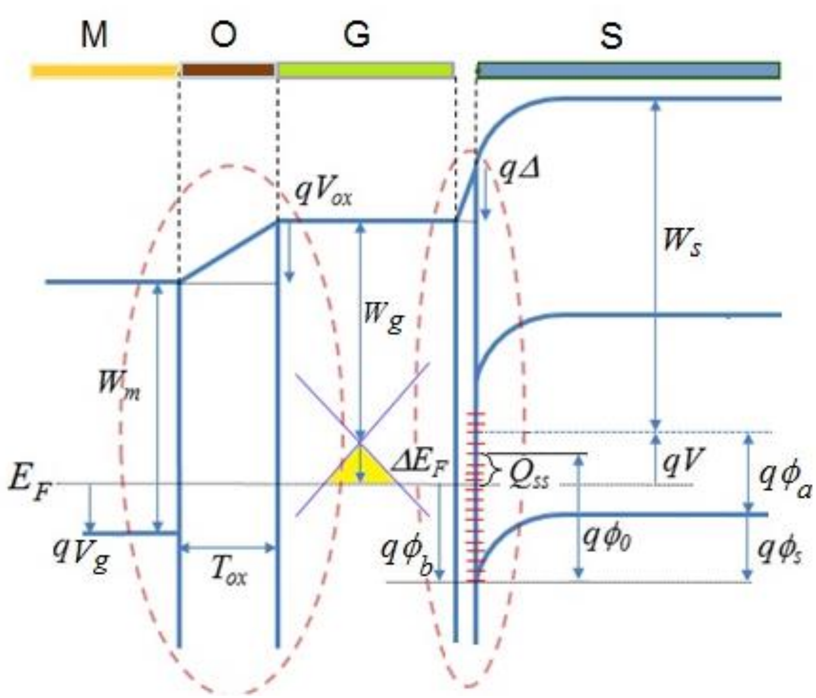
Circuit laws

$-I_1=I_2=I$
$V_1-V_0=IR$

Remark

ϕ_{b1} and ϕ_{b2} are determined following the procedure in Refs. (24) and (35) in the main text, taking into account possible Fermi level pinning.

Band diagram of the MOGS heterostructure



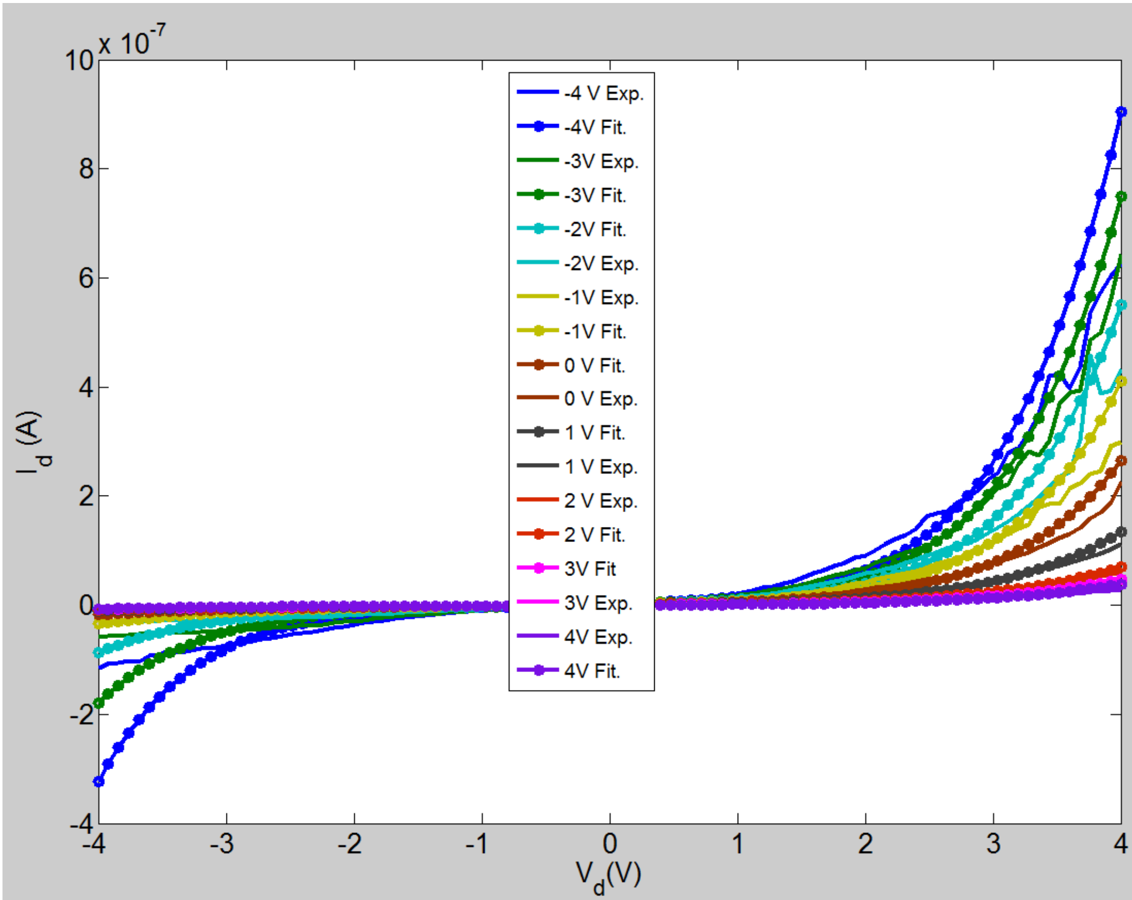


Figure S-2. Device I. Simulations for the output characteristics. (upper) Schematics of the device model and equivalent circuitries. (middle) Band diagram of the MOGS heterostructure indicating the Schottky Barrier Height ϕ_b. (lower) Simulated I-V characteristics with varied V_G in sweeping of V_D from -4 to 4 V, performed using the parameters and equations above.

2. Graphene gated metal-GaSe-metal FET

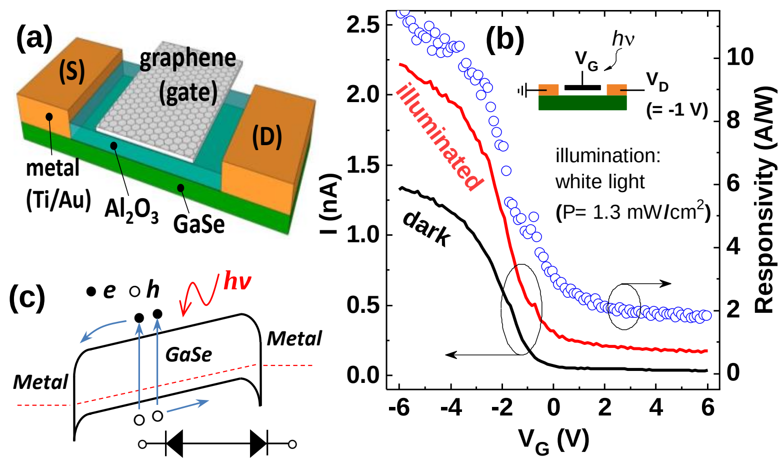


Figure S-3. (a) Schematic of graphene gated GaSe FET. (b) (left axis) Transfer characteristics of the device measured at V_D= -1 V. A black and red lines denote the currents measured in dark and under illumination (white light, P= 0.16 mW). (right axis) Corresponding photo-responsivity (= $I_{ph}/P_{channel}$) plotted with blue circles along V_G. The inset describes the cross-section view of device with electrical configuration. *h*ν is the incident light energy. (c) Band diagram describing the photocurrent generation process in hole transport when the device is biased, including equivalent circuitry (back-to-back diode configuration).

3. Device II

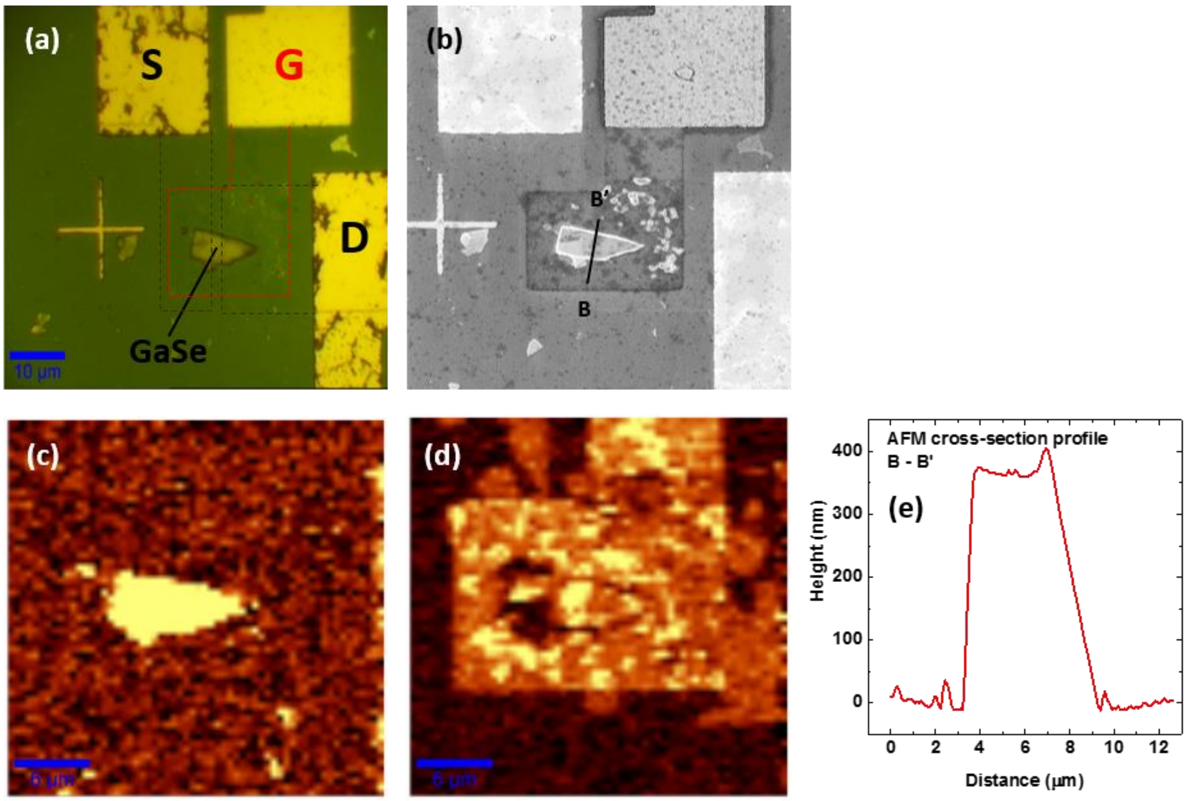


Figure S-4. Device II. (a-b) Optical and SEM image of the device. Dashed lines in black and red denote a graphene contact and a topgate, respectively. (c-d) Raman map for the peak of (c) GaSe appearing at ~212 cm^{-1} (E^1_{2g}) and (d) of the graphene at ~2680 cm^{-1} (2D). (e) Height profile measured by AFM along the B-B' line in (b).

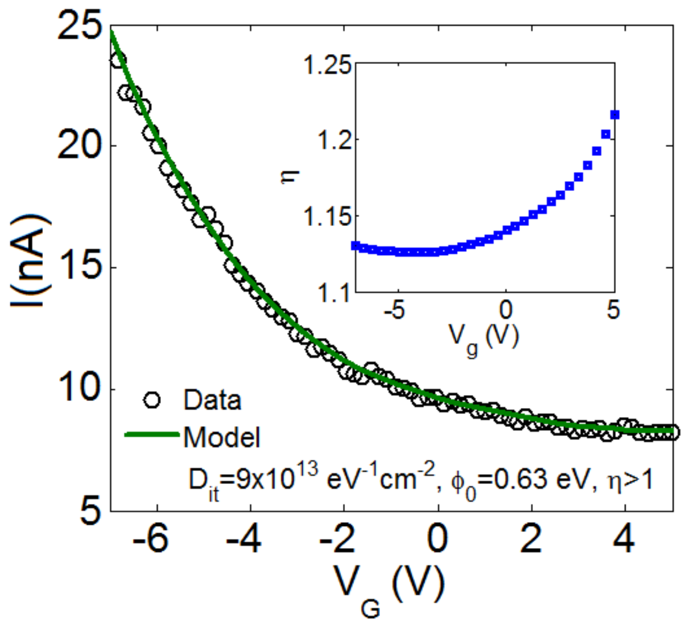


Figure S-5. Device II. Simulated transfer characteristics. The best fit to the measurements is reached when D_{it} ~10^{14} $eV^{-1}cm^{-2}$ and ϕ_0 ~ $E_g/3$ are assumed. To gain consistency with the experiment we have considered an ideality factor that depends on the gate bias, as shown in the inset.

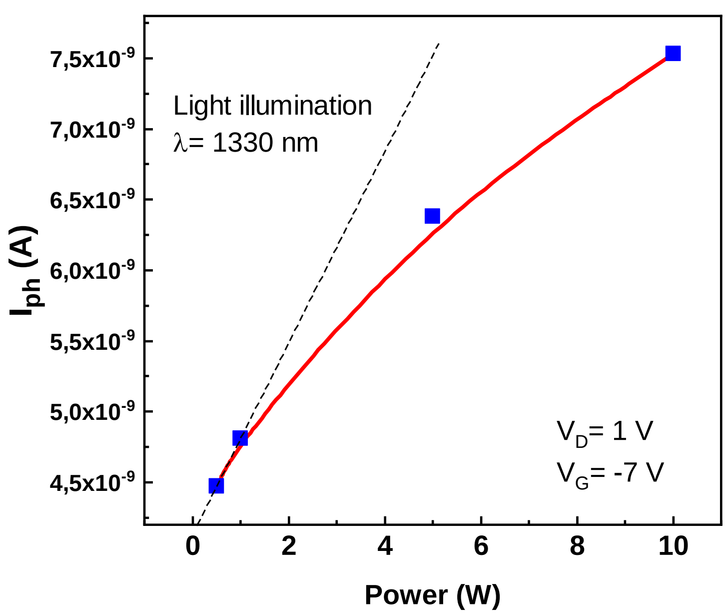


Figure S-6. Device II. Photogenerated current versus illuminated power at 1330 nm. The red line is a curve fitted to data obtained with the power (P)= 0.5, 1, 5, 10 mW. The trend of linear curve-fit to points for P= 0.5 and 1 mW is shown with a dotted line.

4. Device III

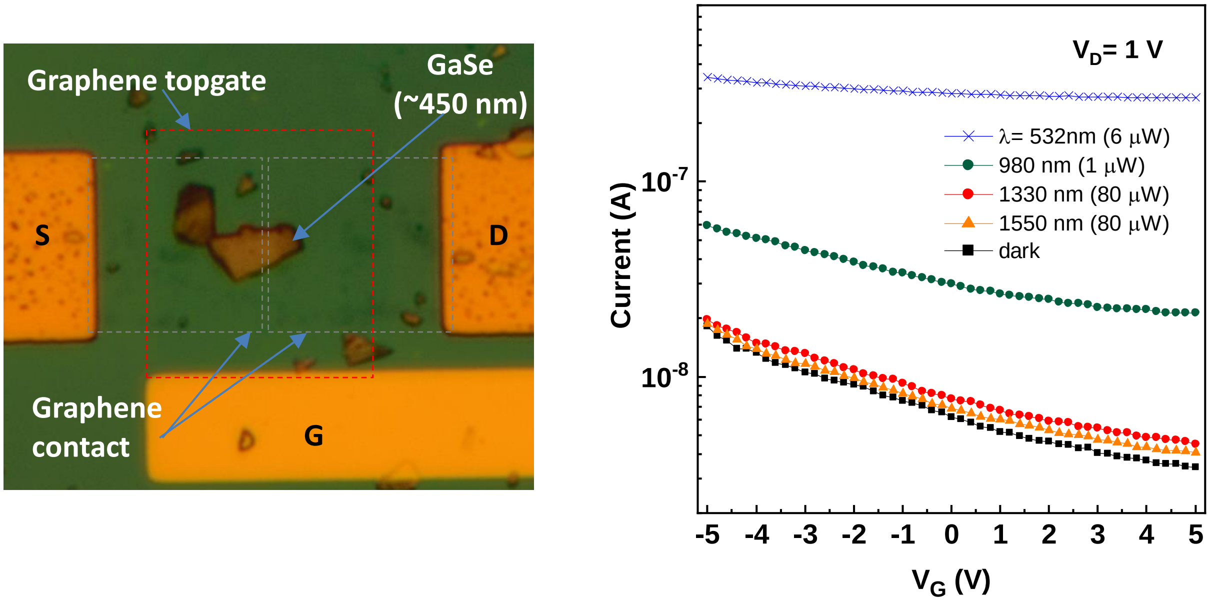


Figure S-7. Device III. (left) optical image of graphene-gated graphene-GaSe heterojuction structure. The channel size (width x length) of GaSe is 6 × 1 μm^2. (right) Transfer characteristics of the device under illumination.

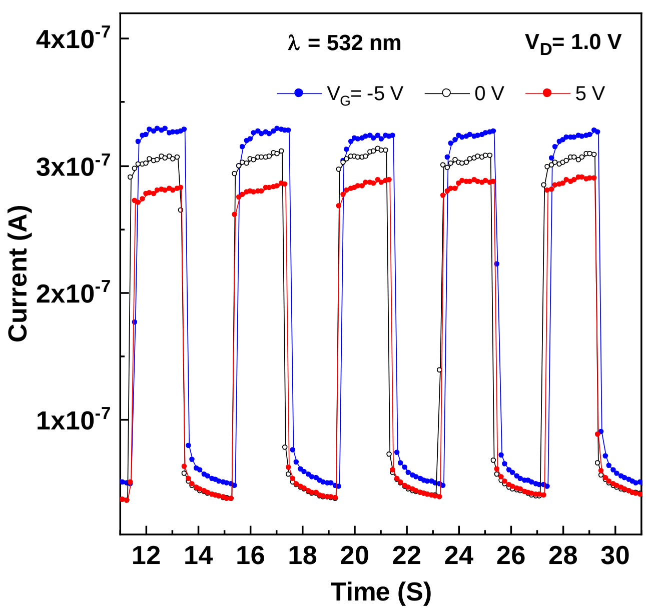


Figure S-8. Device III. Time-resolved photo-response of the device at 532 nm. Different colors denote the different gate voltages applied under illumination.

5. Graphene property

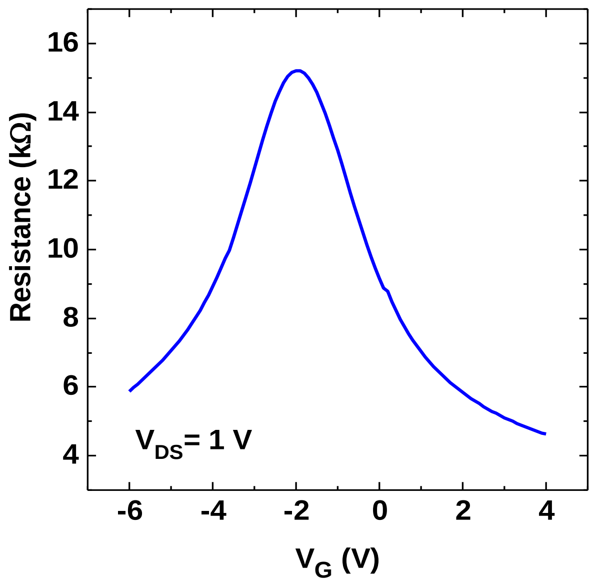


Figure S-9. Graphene FET. Total resistance versus V_G. Graphene is slightly n-type doped. The channel size of the graphene FET (width × length) is 30 × 30 μm^2.