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Ultrasensitive NIR Photodetectors Based on Graphene-$MoTe_2$-Graphene Vertical vdWs Heterostructure

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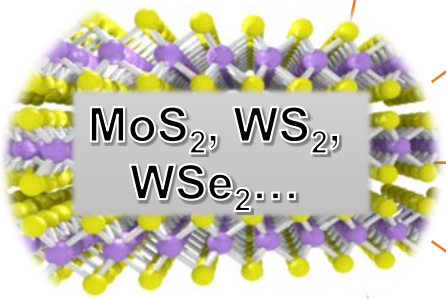
Background and Motivation



transition-metal dichalcogenides (TMDs)

- Ultrathin body
- Strong light-matter interaction
- Flexiblility
- vdWs assembly
- Large band gaps

- Telecommunication
- Remote sensing
- …
- NIR photodetector
- Biological imaging
- …

Background and Motivation

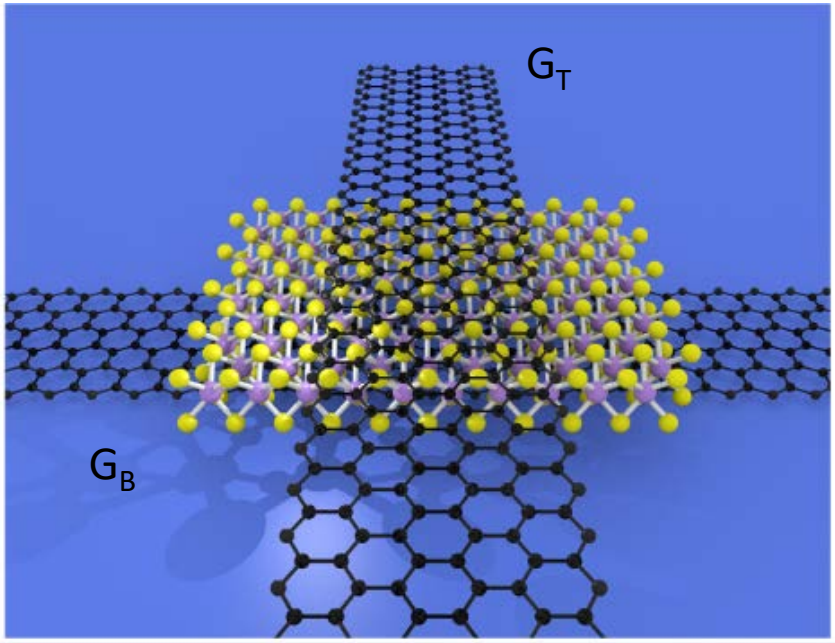
We choose $MoTe_2$, since its bandgap is about 1.0 eV in its bulk form .

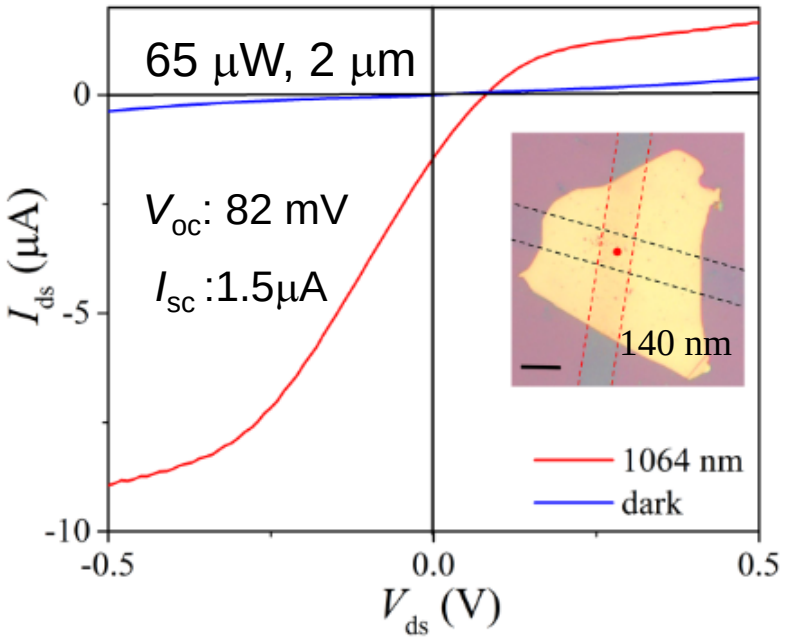
Photoconductors	Photodiodes
☐ High responsivity	☐ Low responsivity
☐ Low speed	☐ High speed
☐ External power supply	☐ Without external power

Grpahene-$MoTe_2$-Graphene Heterostructure

Uniformly large photoresponse area and short transmit distance

- CVD graphene
- Exfoliated $MoTe_2$
- Microscale triangular knife
- PMMA layer
- 1064 nm NIR laser illumination
- Obvious photovoltaic behavior





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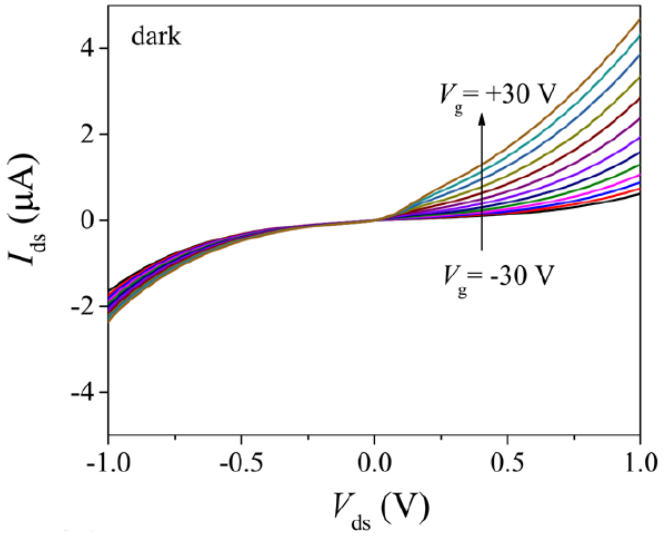
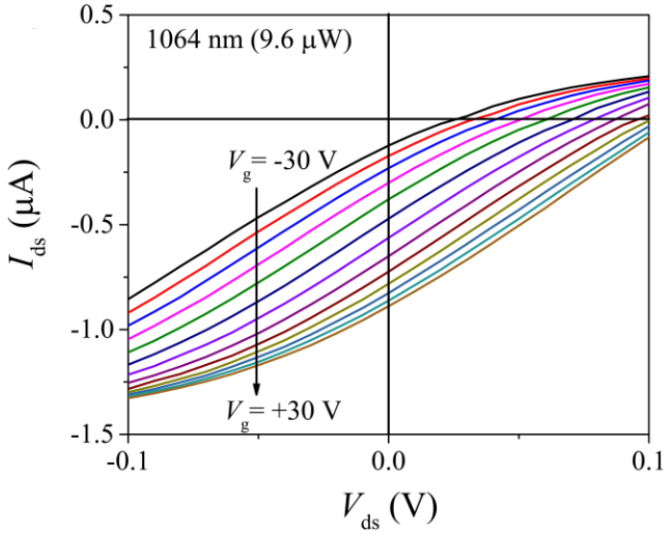
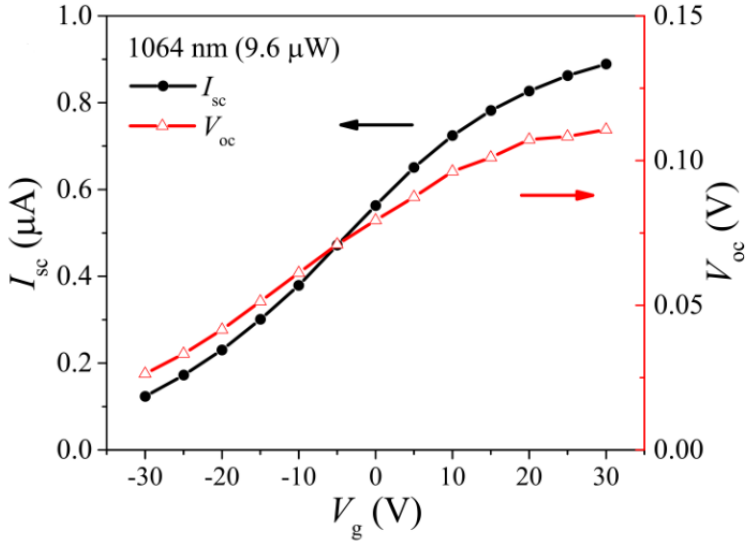
Detailed Electrical and Photoresponse Properties







- The Ids-Vds curves asymmetric transport behaviors.

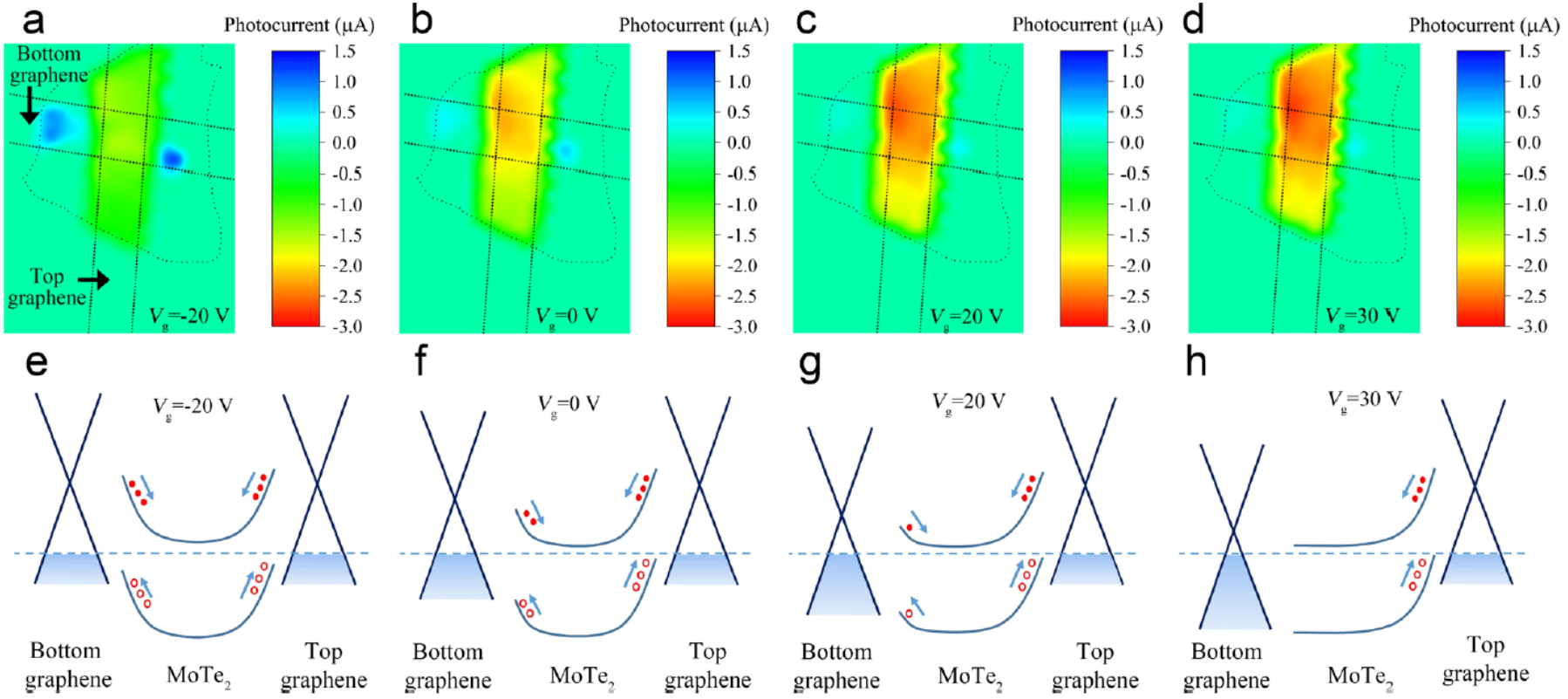
Back-to-back Schottky barriers with different Schottky barrier heights

Ambient water vapor and oxygen p-doping of the top graphene

- The I_{sc} and V_{oc} increase with the back-gate

Photocurrent Generation

At V_g=0, the Schottky barrier height at $G_T/MoTe_2$ is higher than that at $G_B/MoTe_2$

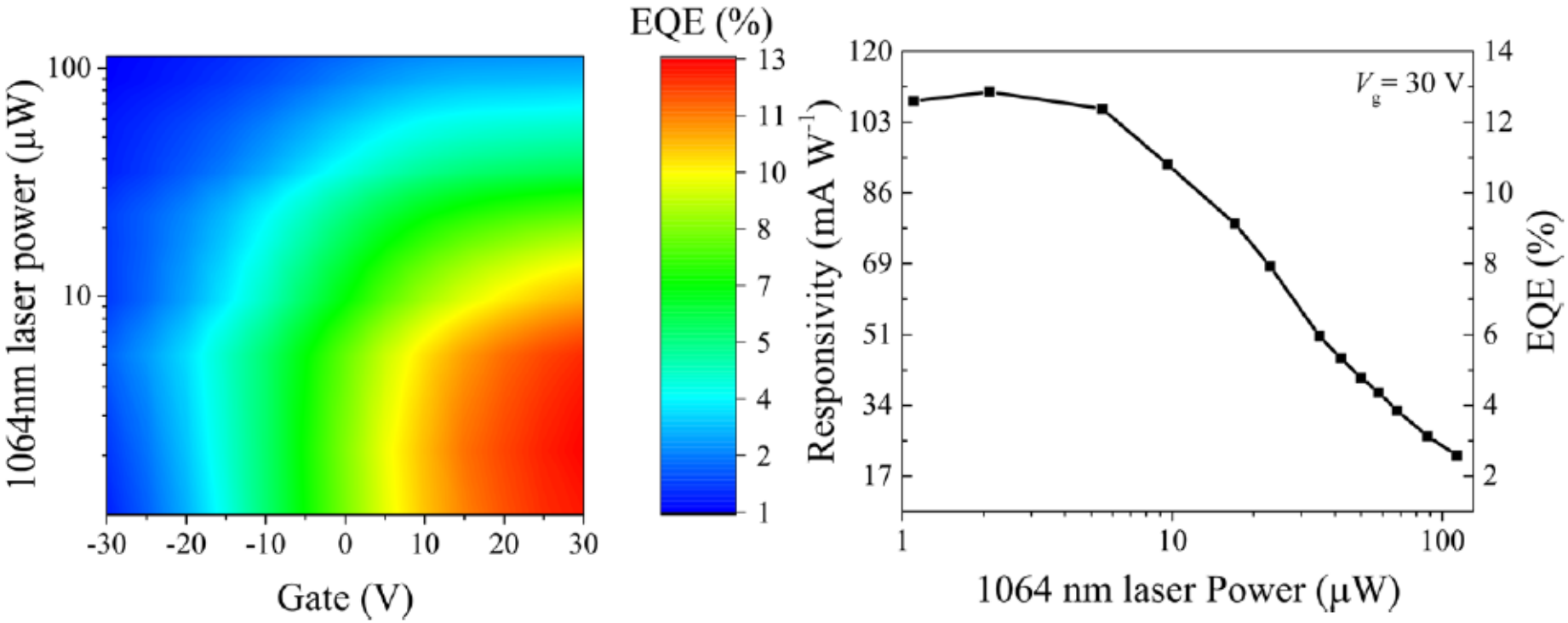


Due to th screening effect from the bottom graphene and $MoTe_2$, the Schottky barrier height at $G_T/MoTe_2$ is less sensitive to the back gate.

Photocurrent @ $G_B/MoTe_2$ ↓

Photocurrent @ $G_T/MoTe_2$ ↑

NIR Photoresponse Performance

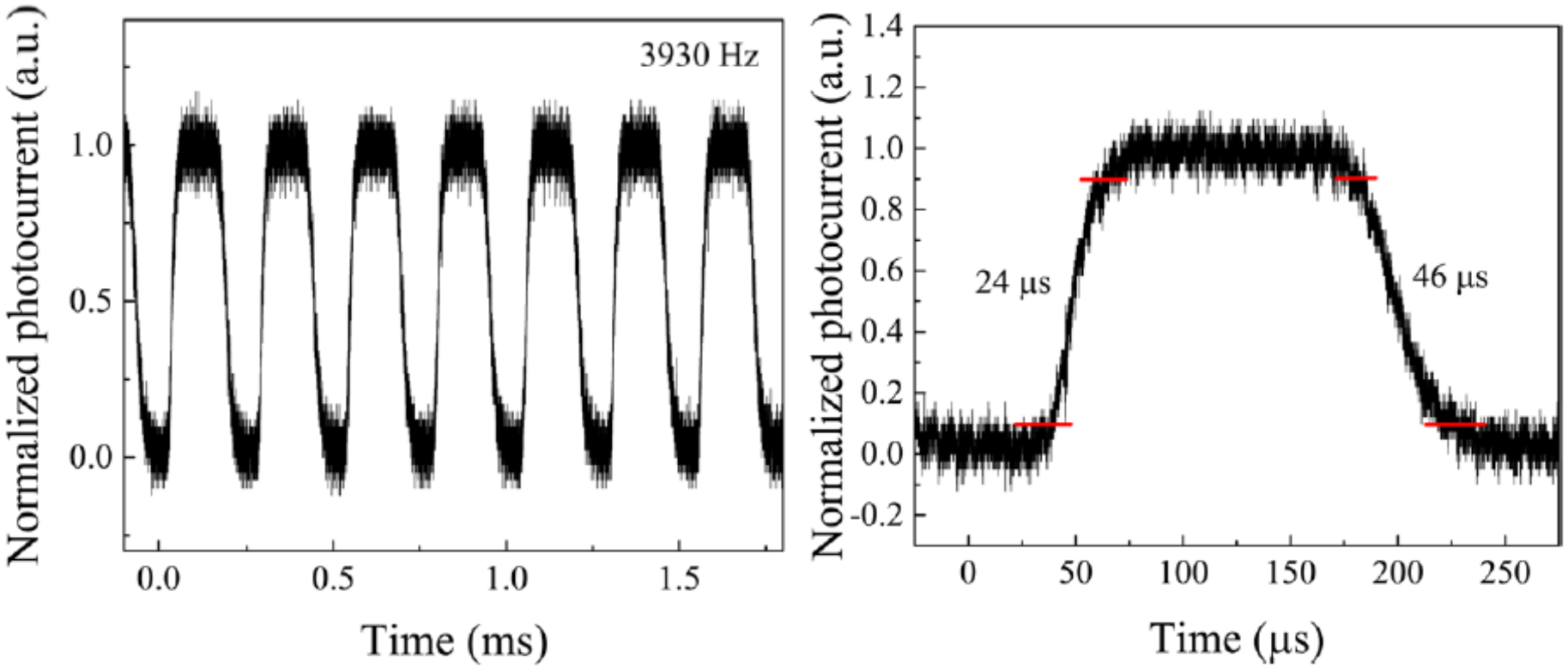


- Back-gate voltage
- Laser power

When the power < 5 μW

- Responsivity ~ 110 mA W^{-1}
- EQE ~ 12.6%

Temporal Photoresponse



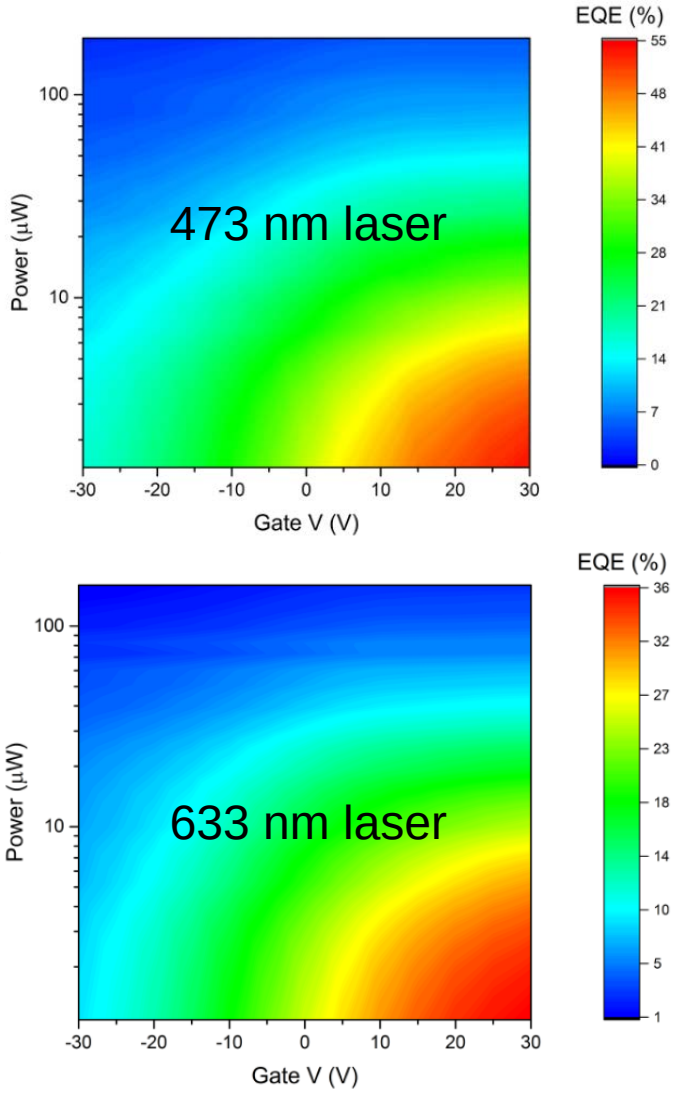
- Rise and fall times: 24 μs, 46 μs
- Considering the intrinsic response time of the mechanical chopping process (~10μs), the rise and fall times are even shorter.

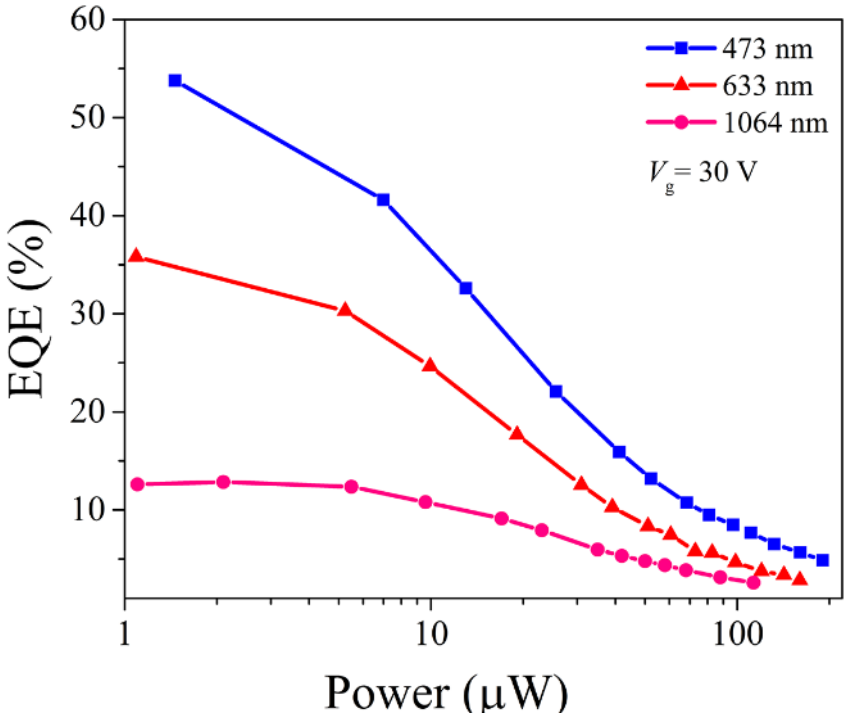
Comparison

Materials	V_{ds} (V)	Responsivity (mA W^{-1})	Response time (ms)	Wavelength
$MoTe_2$	0	110	0.024	1064 nm
b-P	0.2	<5	1	400 - 997 nm
b-P/MoS_2	3	153.4	0.015	1550
MoS_2	0.8	5200	44500	1070 nm
MoS_2	1	0.09	-	850 nm
MoS_2/Si	0	300	0.003	808
Bi/WS_2/Si	0	420	<100	635
MoS_2	0	68	-	633 nm
MoS_2	0	220	<0.05	488 nm
WS_2	0	>100	-	488 nm
SnS_2	2	8.8	0.005	457 nm
InSe	10	1.57×10^5	40-50	633
InSe	1	4×10^7	1	633
InSe	50	486	0.06	543

An overall high performance

Photoresponse Properties in Visible Range



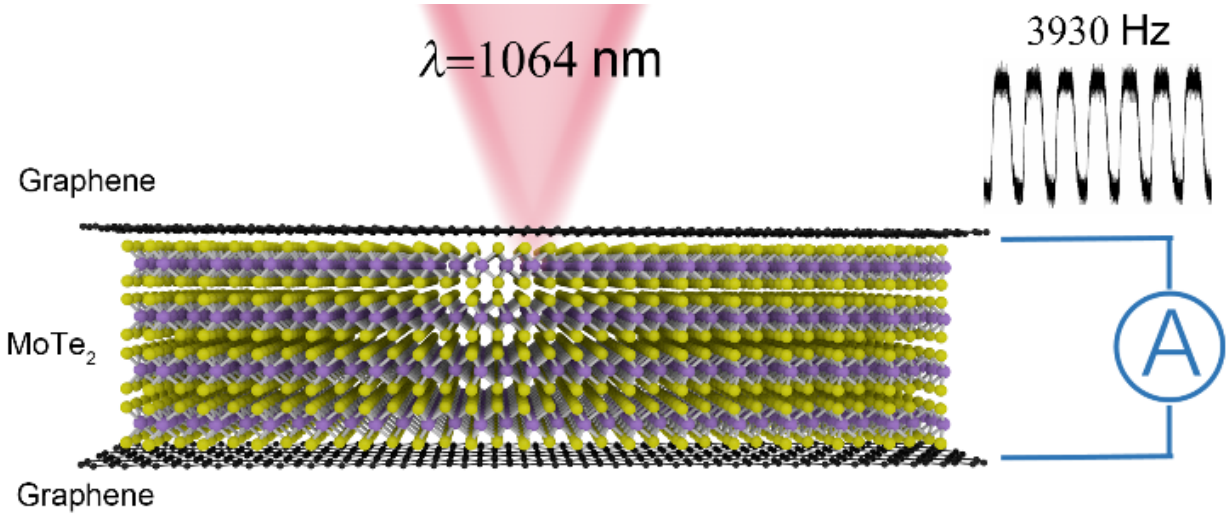


@ 473 nm, R ~ 205 mA W^{-1} (EQE ~ 53.8%)

@ 633 nm, R ~ 183 mA W^{-1} (EQE ~ 35.8%)

Conclusion

- Graphene-$MoTe_2$-Graphene vertical vdWs heterostructure, which has uniformly large photoresponse area and short transmit distance between the source and drain
- Self powered with high responsivity(110 mA W^{-1}), high speed (24 μs) in the NIR range
- Photo response can be tuned by the back-gate voltage



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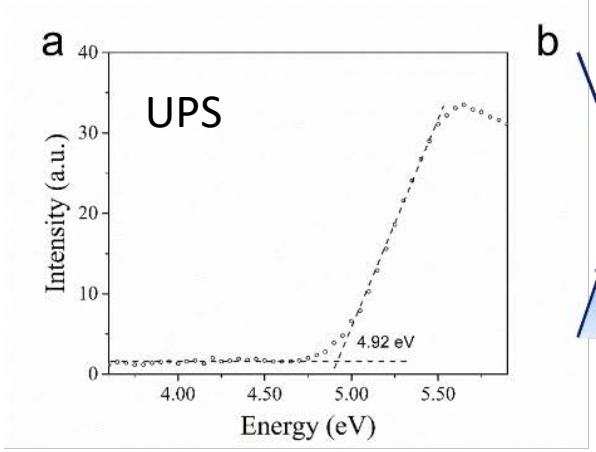

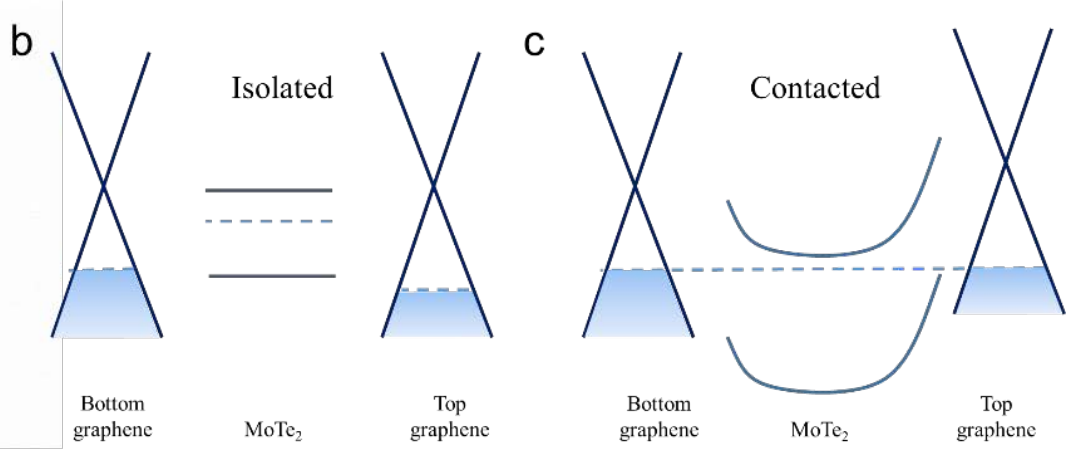

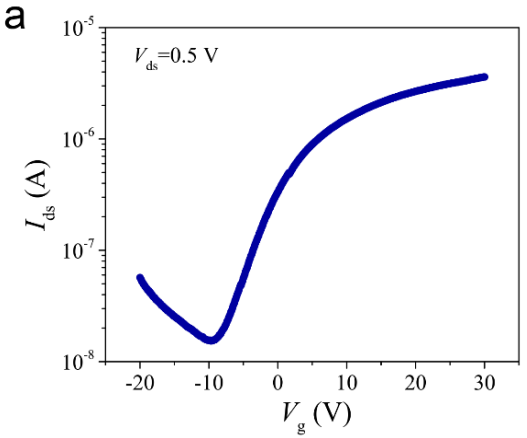

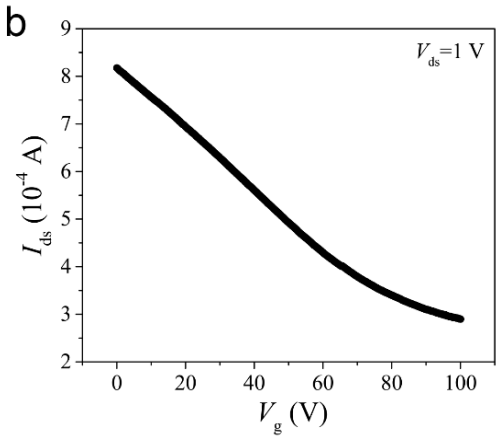

The work function of $MoTe_2$ was reported to be 4.1~4.3 eV.