Engineering Quantum Confinement in Semiconducting van der Waals Heterostructure

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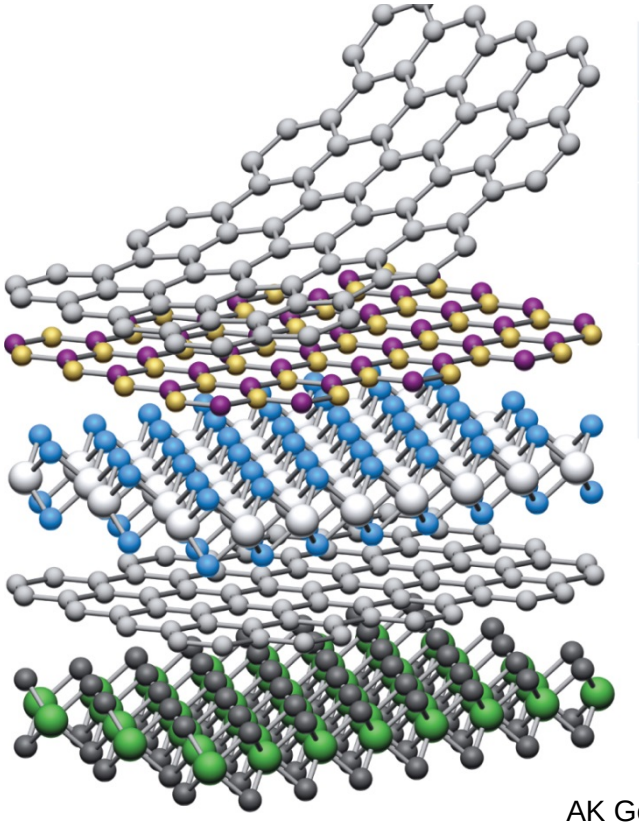

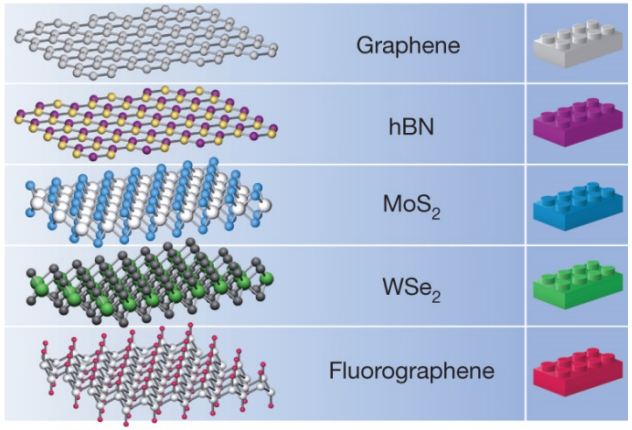

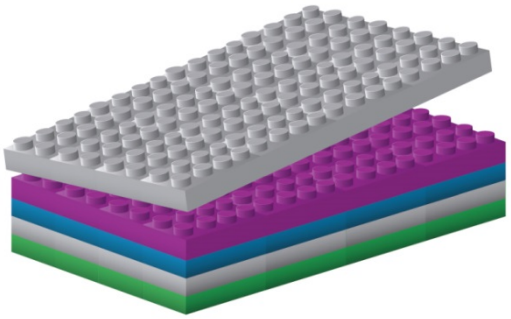

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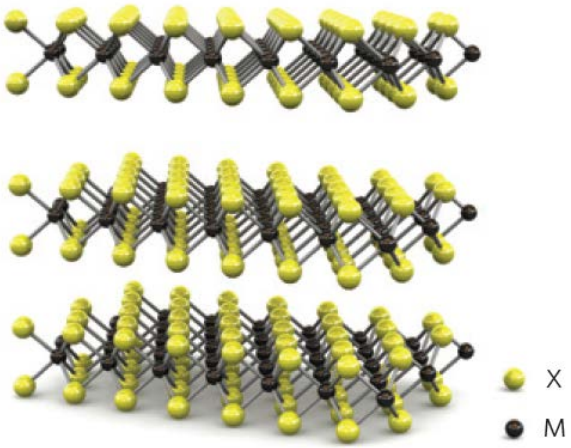
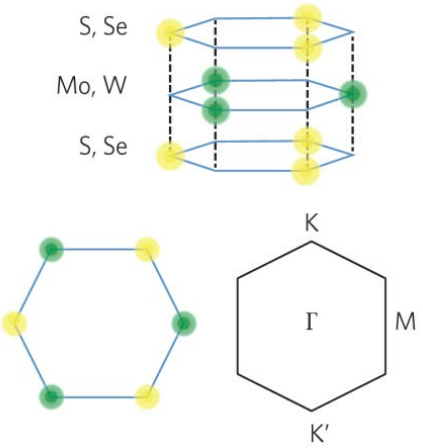
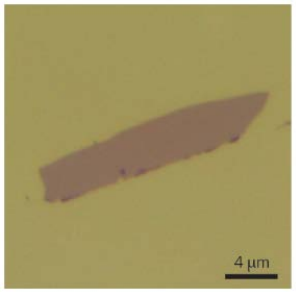
AK Geim & IV Grigorieva *Nature* **499**, 419-425 (2013)

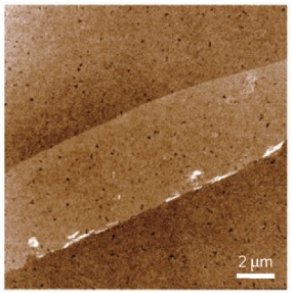
2D TMDC – MX_2

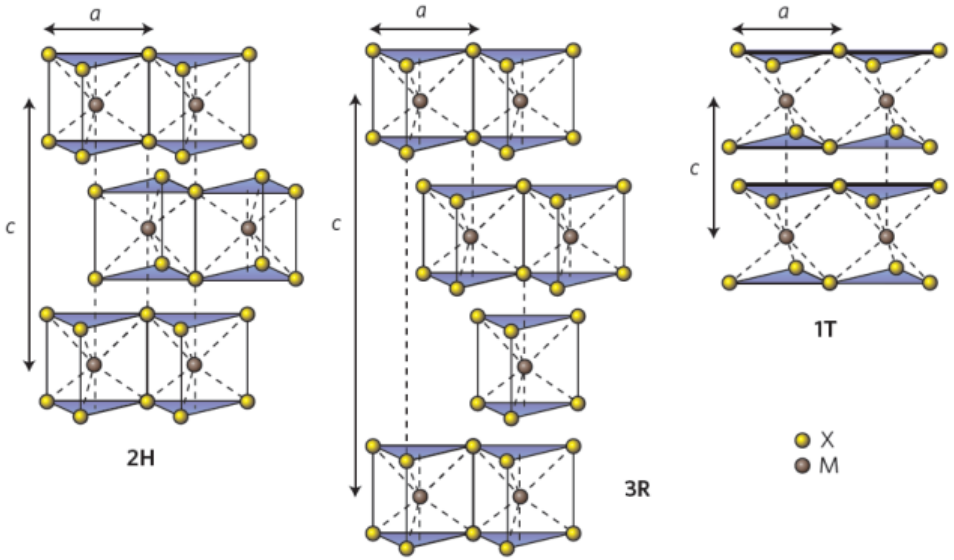


22 Ti Titanium 47.867	23 V Vanadium 50.9415		16 S Sulfur 32.06
40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenur 95.96	34 Se Selenium 78.96
72 Hf Hafnium 178.49	73 Ta Tantalum 180.947...	74 W Tungsten 183.84	52 Te Tellurium 127.60
104 Rf Rutherfordiu (267)		106 Sg Seaborgium (271)	

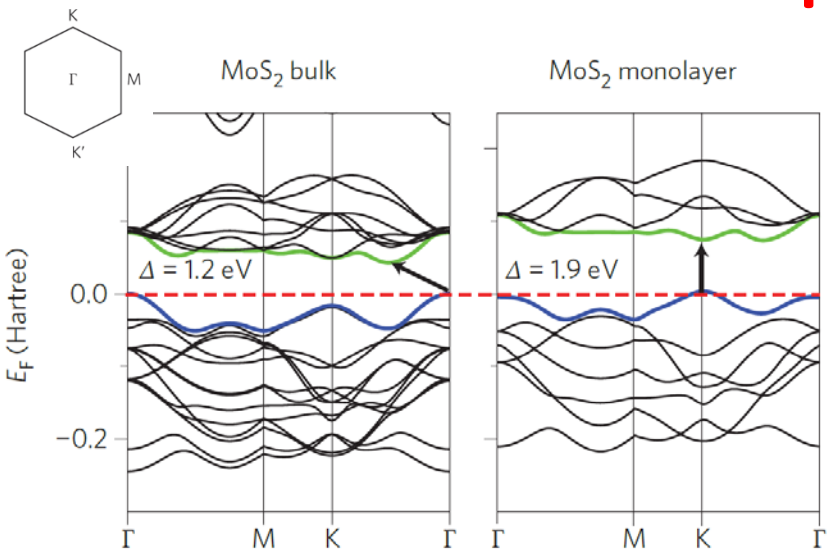


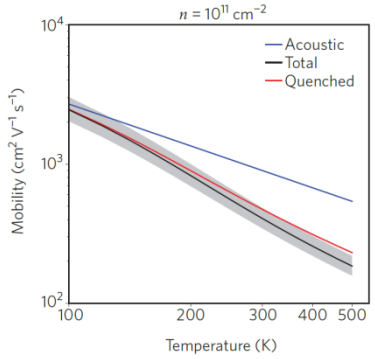


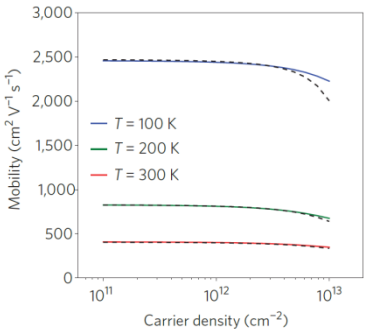




MoS_2

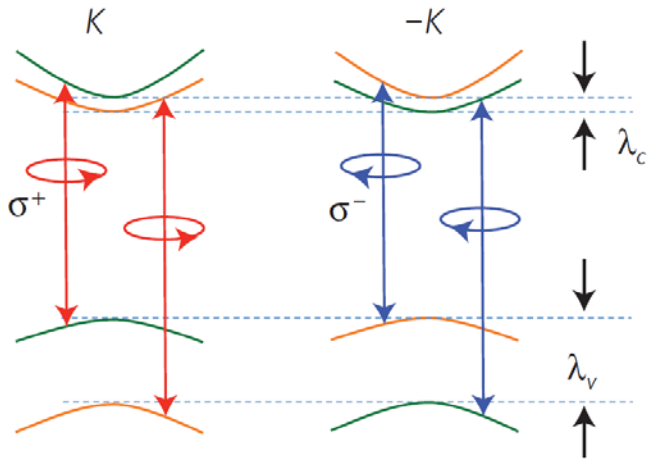


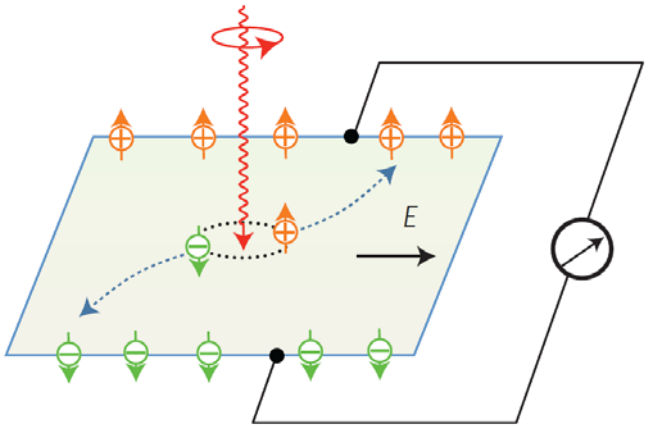




	MoS_2	$MoSe_2$	WS_2	WSe_2
Band masses (in m_0)[5]	~0.5	~0.6	~0.4	~0.4
Conduction band spin-orbit splitting (meV)[36]	~−3	~−20	~30	~35
Valence band spin-orbit splitting (meV)[5,36]	~150	~180	~430	~470

Broken inversion symmetry
Spin-Orbit Coupling





Spin Hall Effect
&
Valley Hall Effect

MoS_2 vdW Stack

Top hBN
80nm

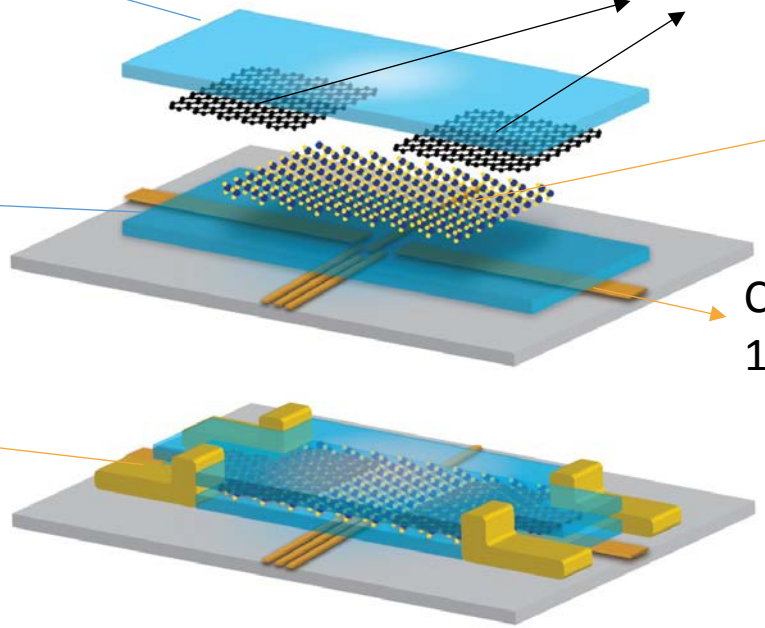
n-doped Graphene

Bottom hBN
60nm

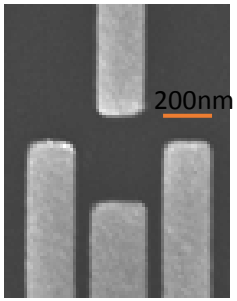
3L MoS_2

Cr/PdAu
1/5nm

Cr/Pd/Au
1.5/5/120nm



Ar Glove Box !



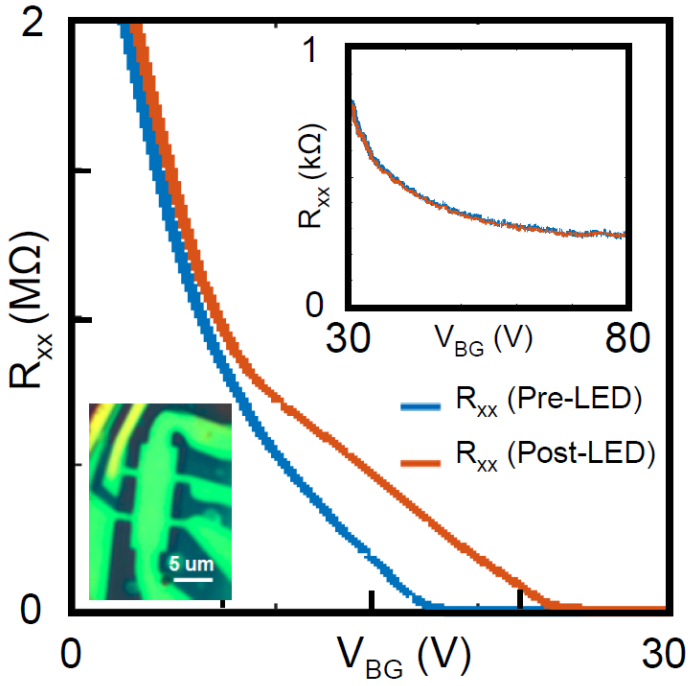
Device Characterization

V_{BG} to tune carrier density

$V_{LOCAL\ BG}$ = 10V

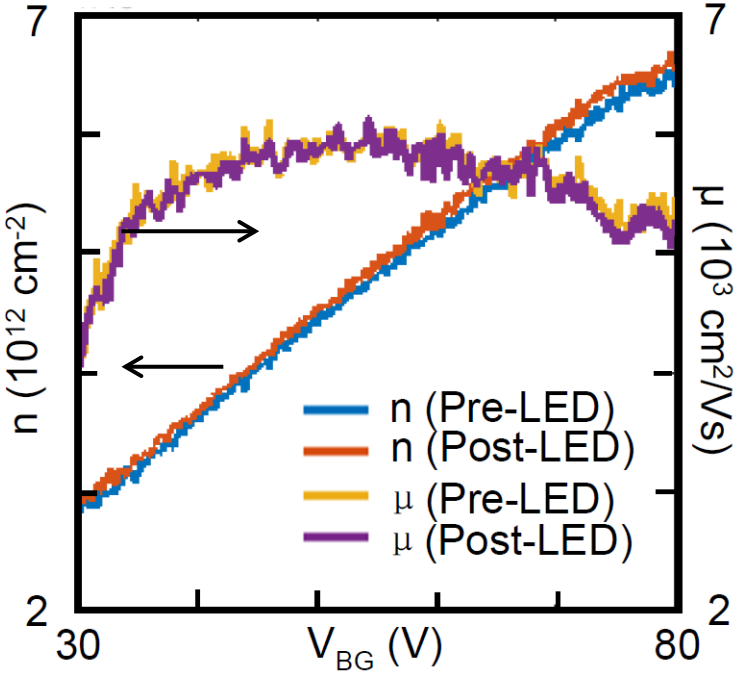
20sec Infra-Red LED Illumination

1.7K



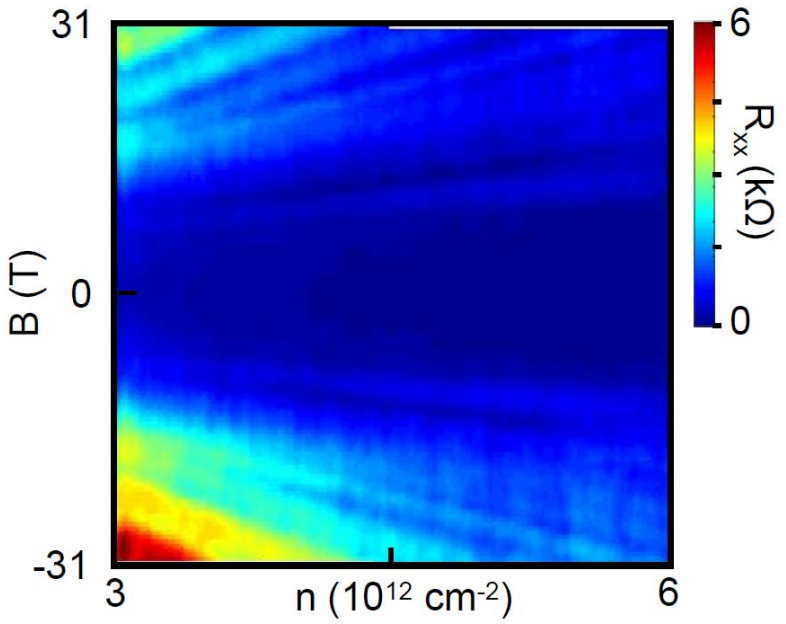
n-type FET Behaviour

Metal-insulator transition

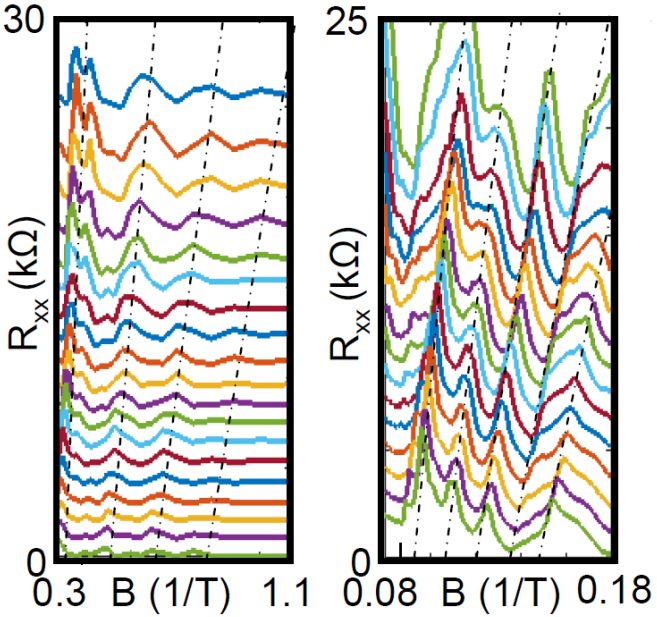


LED shifts threshold from 17 to 22

Magnetic Field Measurements



1D Cuts at different carrier density



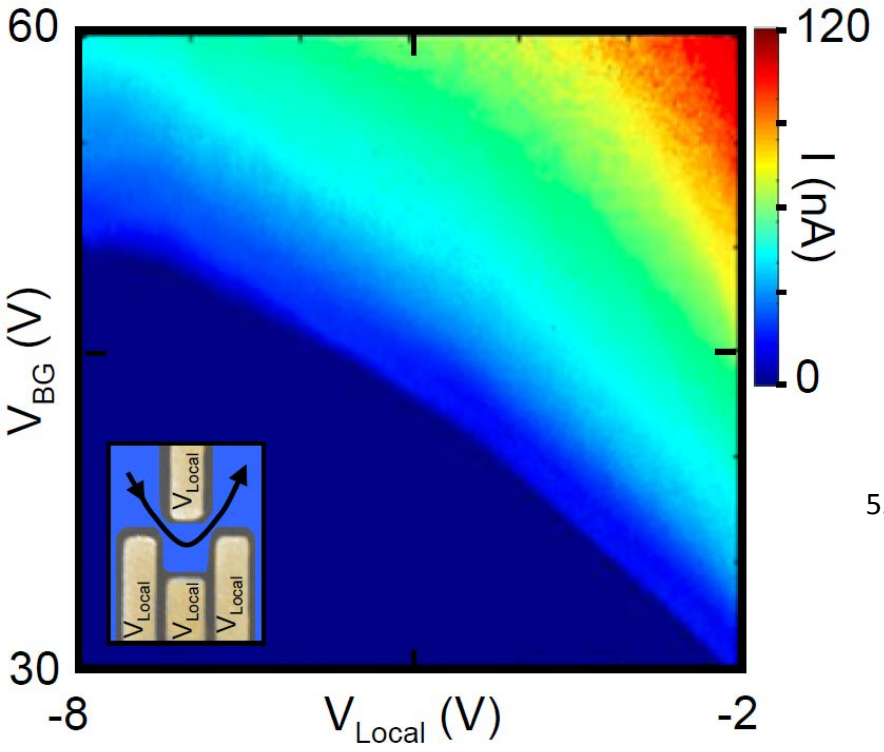
SdH starting around 1T $\Longrightarrow$ mobility of 10.000 cm^2/Vs

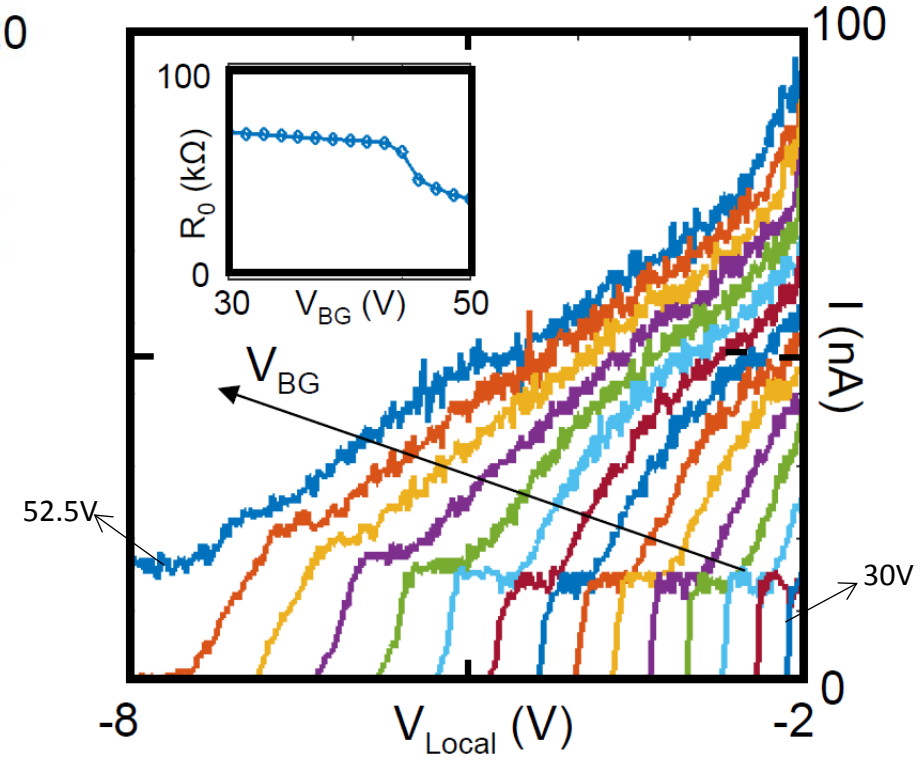
SdH peak near 3T develops into 2peaks $\Longrightarrow$ partial symmetry breaking (?)

Full symmetry breaking of levels
Complex valley-spin dynamics near band edges
Possible formation of parallel 2DEGS

?

Quantized Conductance in QPC





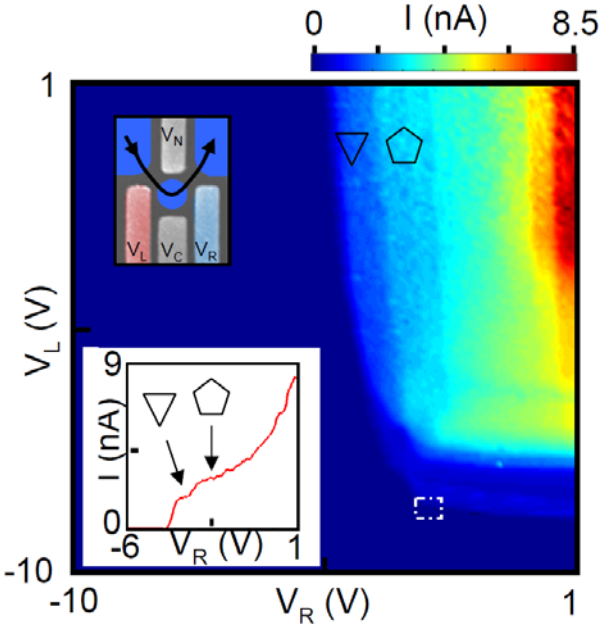
1mV AC excitation
0 DC bias
On-off ratio of 10^6

Steps of 4 e^2/h expected

R_0 resistance contribution

Control device with split gates → Multiple quantized conductance steps

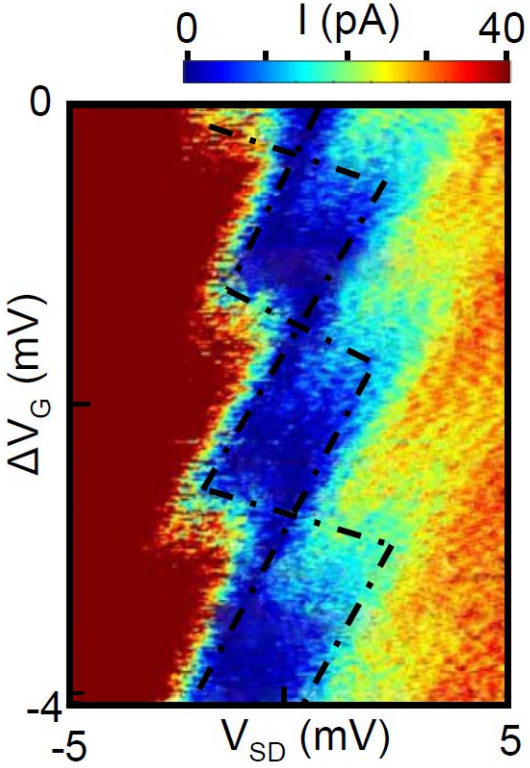
Quantum Dot

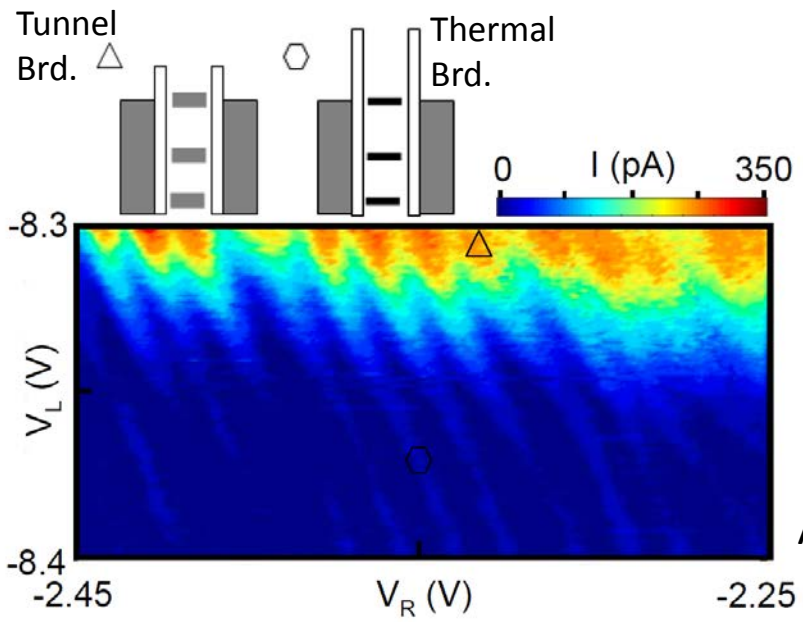


V_N = -8V
V_C = -10V

Left Tunnel Coupling → V_L
Right Tunnel Coupling → V_R

Independent
Tunnel
Coupling





Constant slope
↓
Uniform QD formation

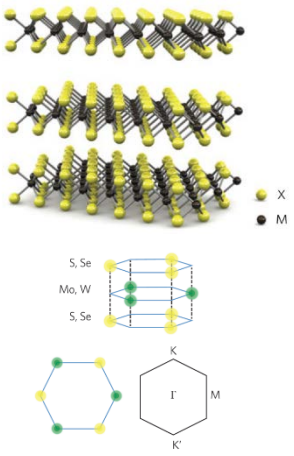
NO
Accidental QD formation

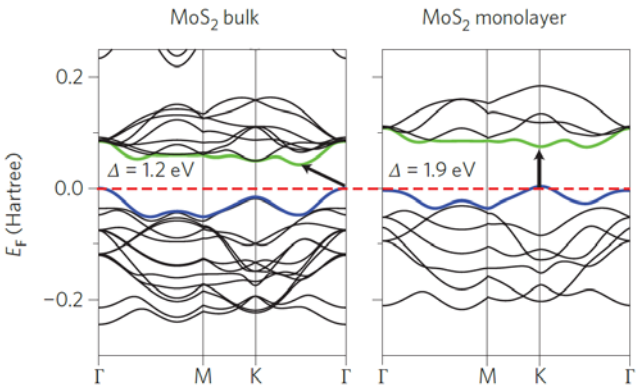
$E_C \approx 2\ meV$

↓

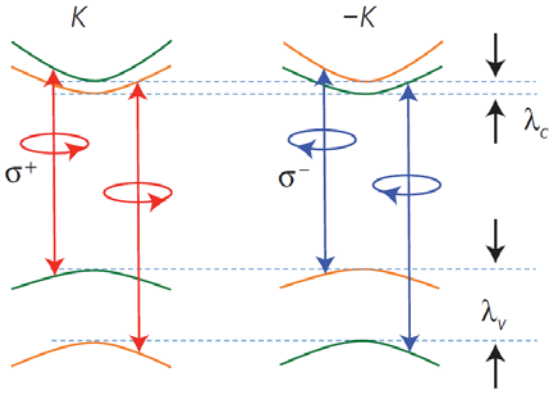
$r \approx 70\ nm$

Summary

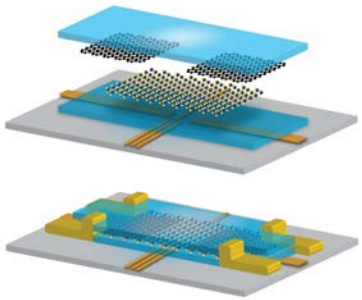




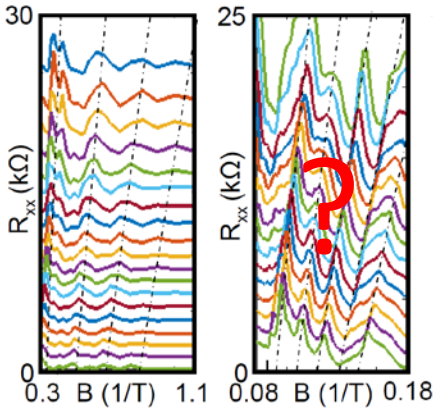
Indirect – Direct Band Gap



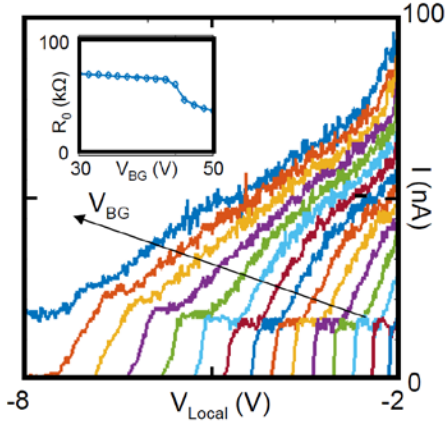
Valley-spin locking



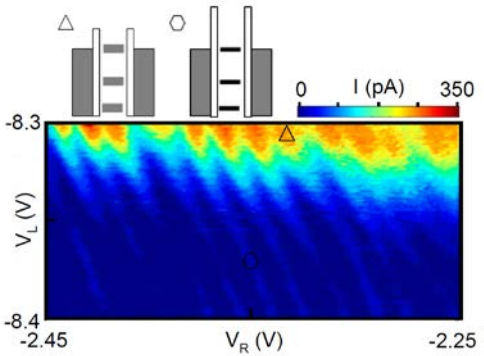
MoS_2 vdW



B field



QPC



Quantum Dot