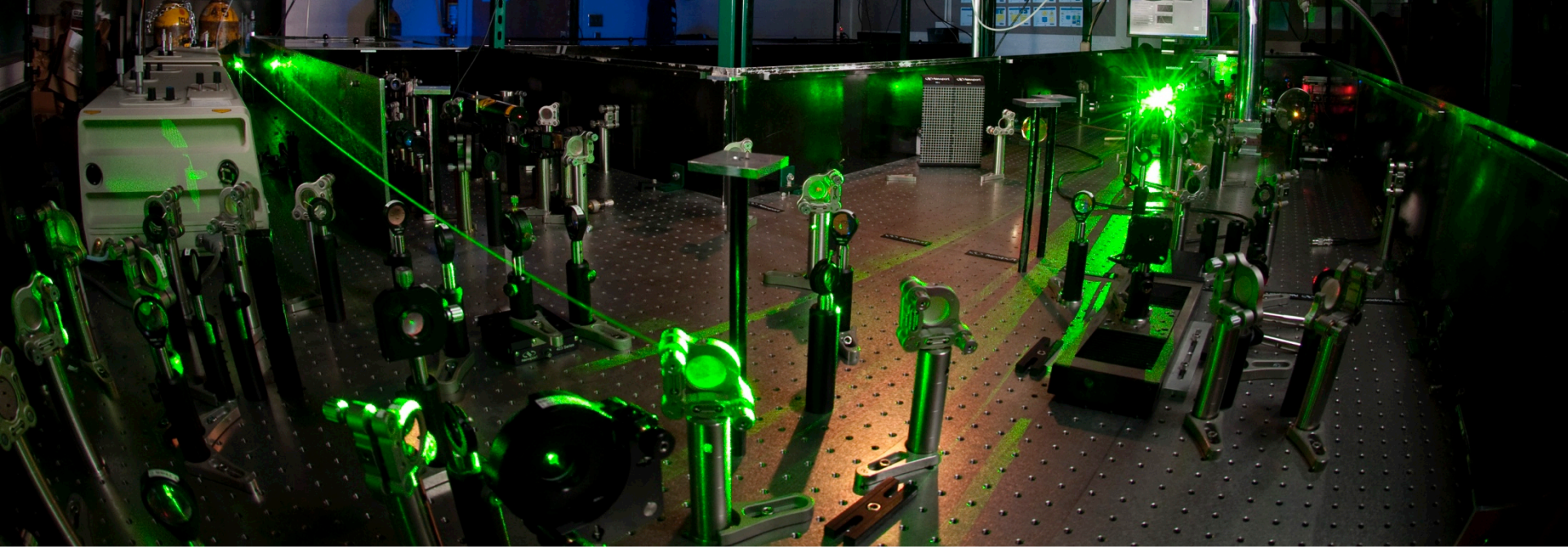


An Introduction to Optical Doping and Improved Carrier Lifetime in Graphene

Samuel D. Lane

University of Kansas

Outline

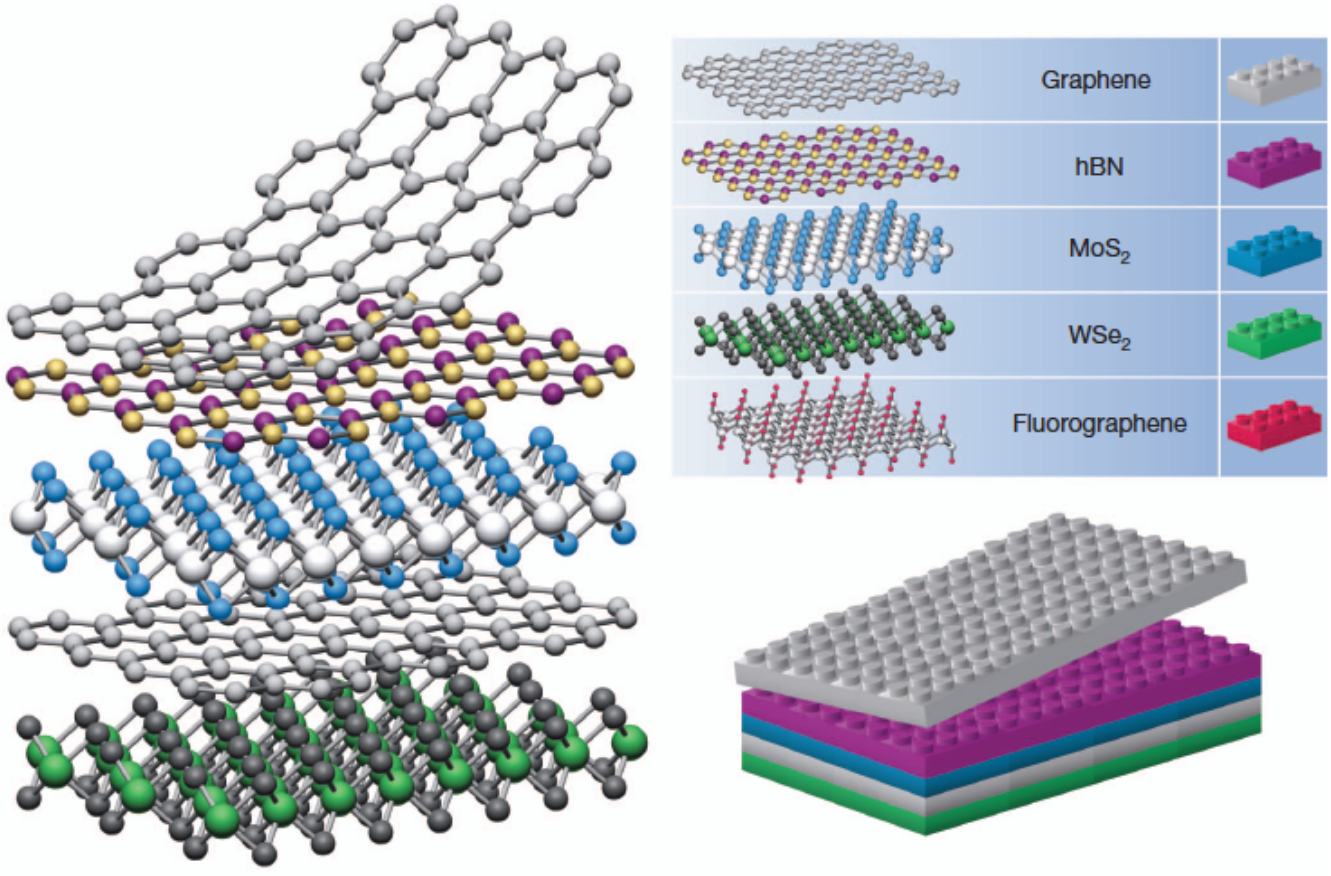
- Motivation
- Introduction to Band Structure
- Introduction to Pump-Probe Spectroscopy
- Band Alignment Engineering
- Experiment and Results
- Conclusion

2D Materials

Graphene family	Graphene	hBN 'white graphene'	BCN	Fluorographene	Graphene oxide
2D chalcogenides	MoS_2, WS_2, $MoSe_2$, WSe_2	Semiconducting dichalcogenides: $MoTe_2$, WTe_2, ZrS_2, $ZrSe_2$ and so on		Metallic dichalcogenides: $NbSe_2$, NbS_2, TaS_2, TiS_2, $NiSe_2$ and so on	
				Layered semiconductors: GaSe, GaTe, InSe, Bi_2Se_3 and so on	
2D oxides	Micas, BSCCO	MoO_3, WO_3	Perovskite-type: $LaNb_2O_7$, $(Ca,Sr)_2Nb_3O_{10}$, $Bi_4Ti_3O_{12}$, $Ca_2Ta_2TiO_{10}$ and so on	Hydroxides: $Ni(OH)_2$, $Eu(OH)_2$ and so on	
	Layered Cu oxides	TiO_2, MnO_2, V_2O_5, TaO_3, RuO_2 and so on		Others	

A. K. Geim & I. V. Grigoreiva, *Van der Waals Heterostructures*. Nature **499** 419-425

Van der Waals Heterostructures



A. K. Geim & I. V. Grigoreiva, *Van der Waals Heterostructures*. Nature **499** 419-425

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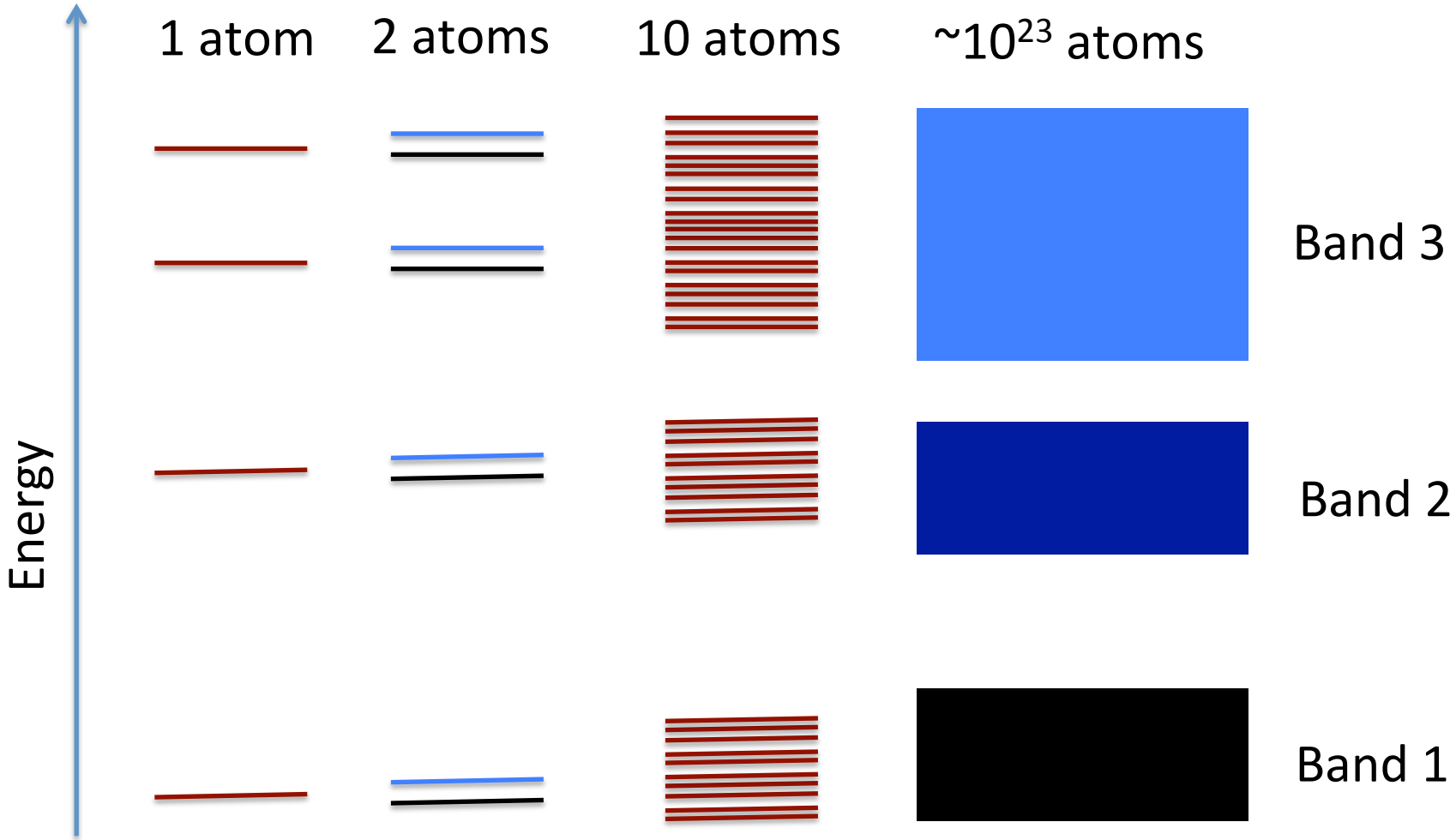
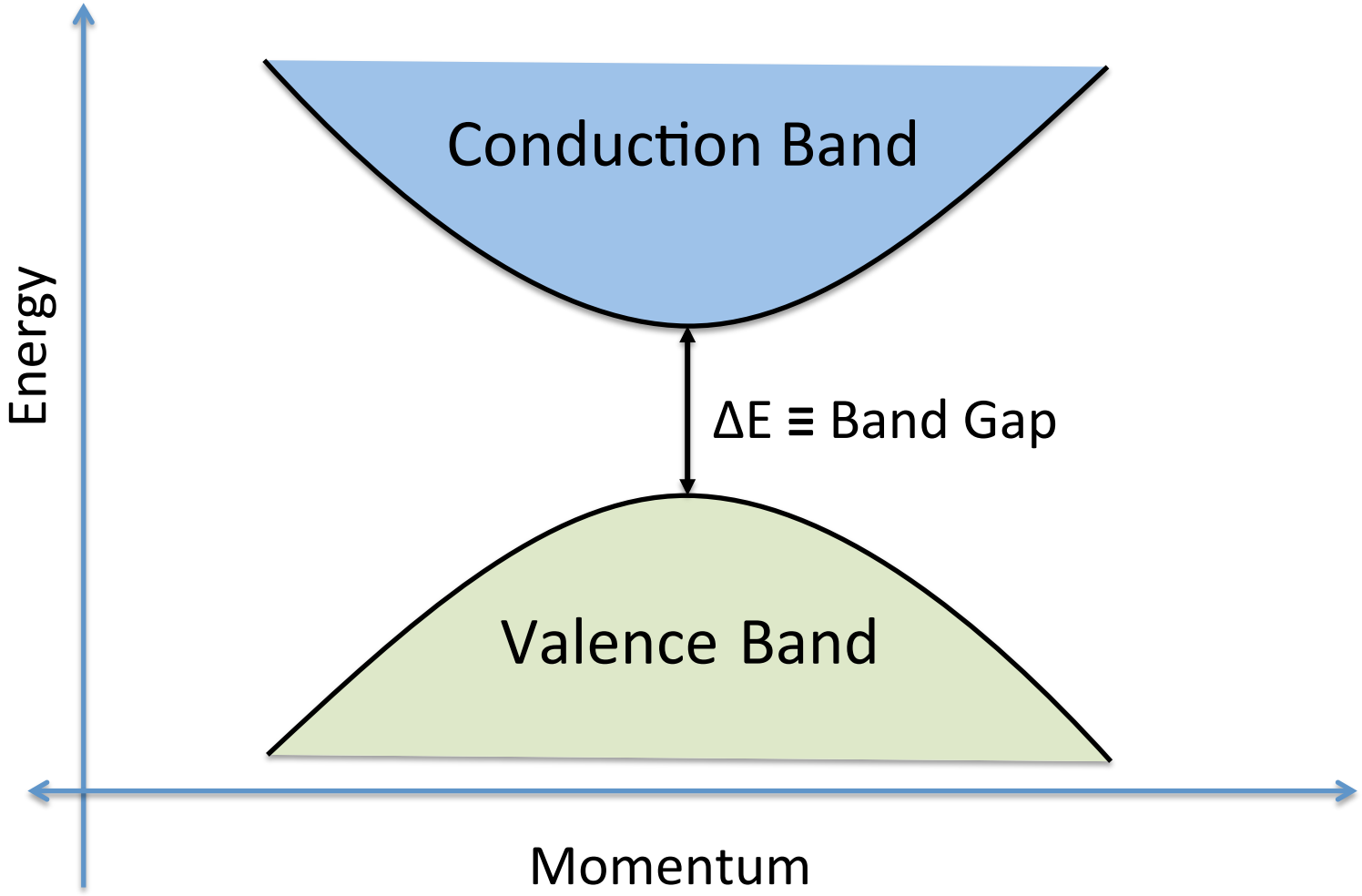
Formation of Electronic Bands



More About Electronic Bands



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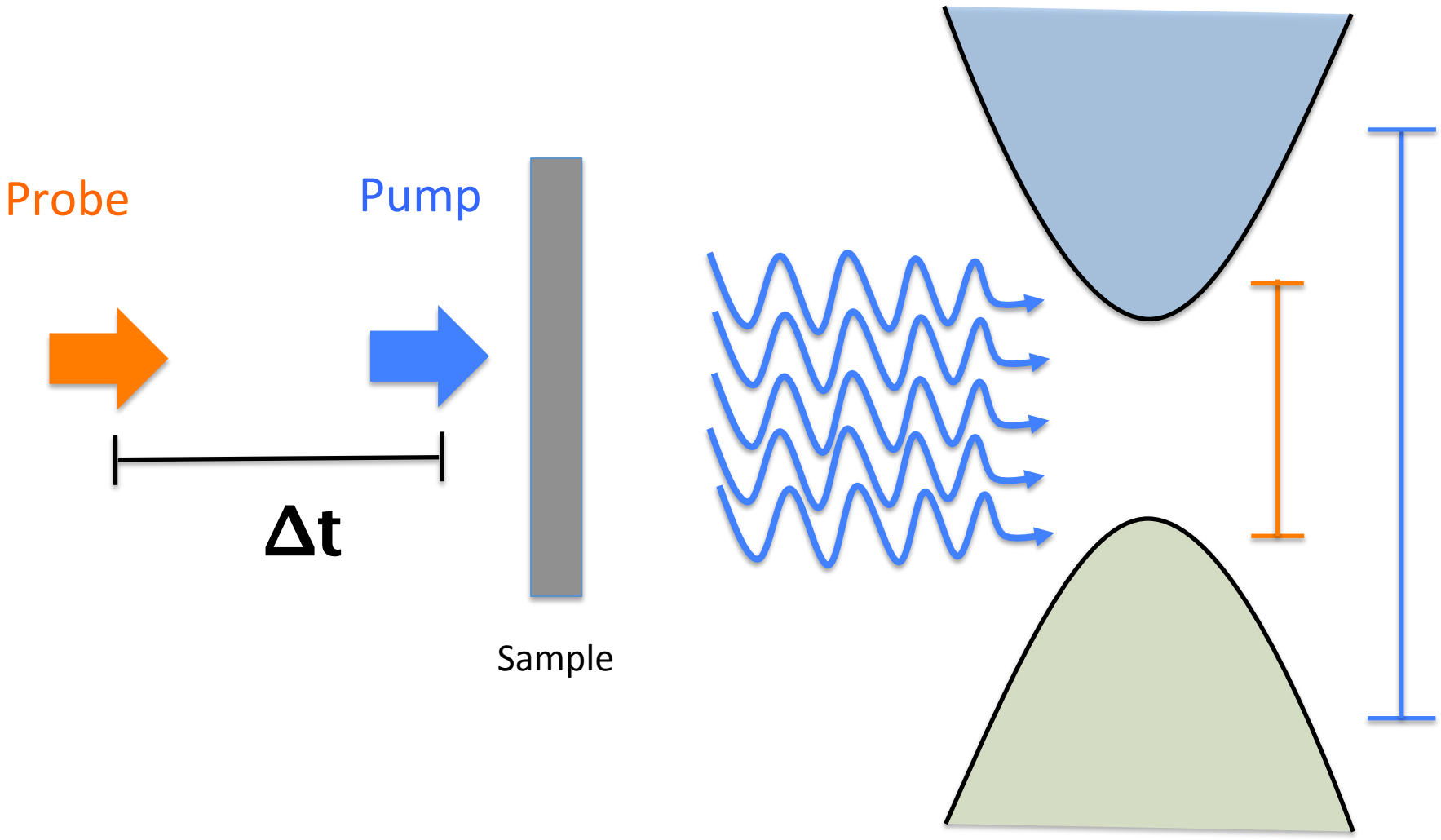
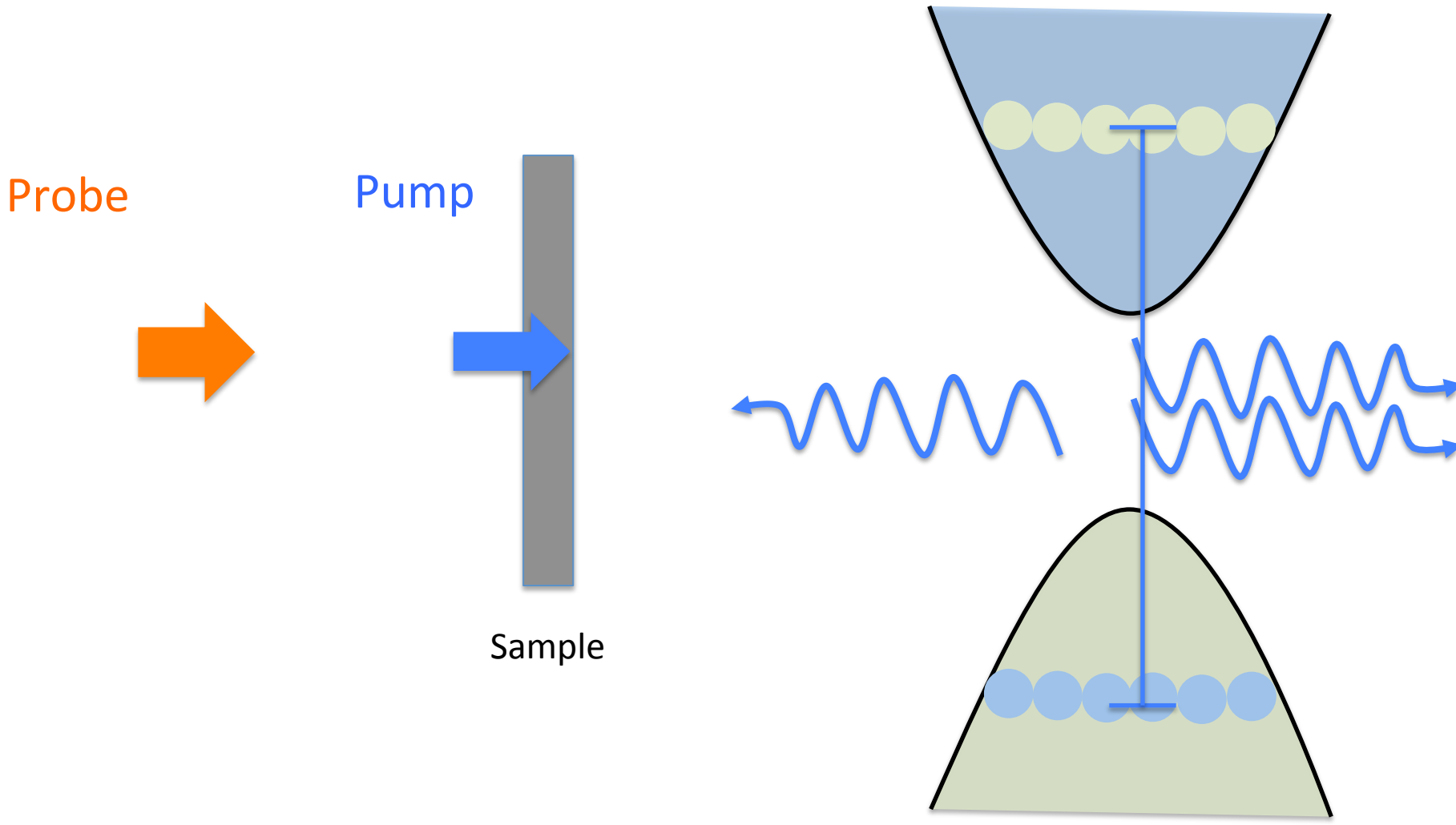
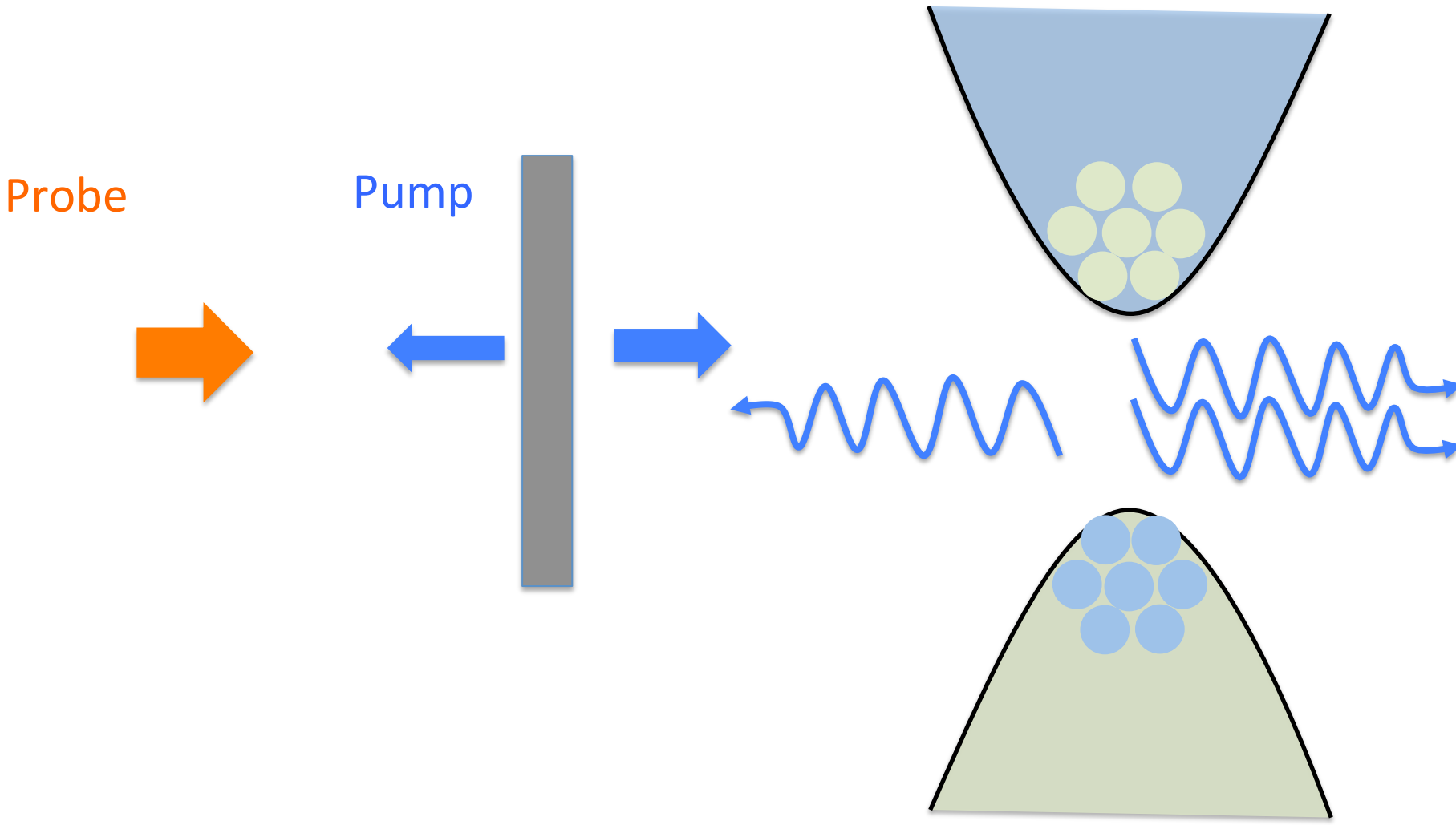
Basics of Pump-Probe Spectroscopy



Basics of Pump-Probe Spectroscopy



Basics of Pump-Probe Spectroscopy



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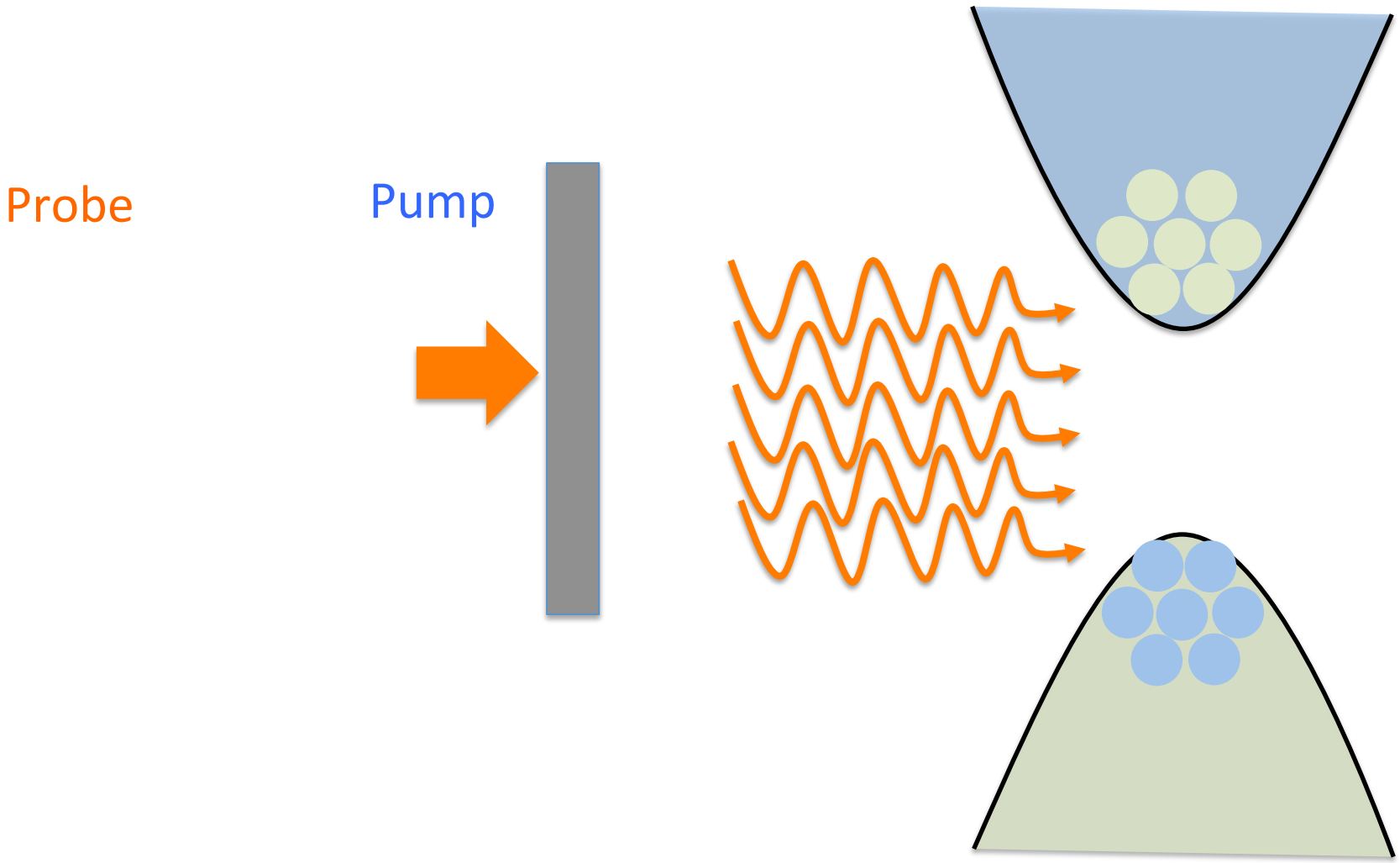
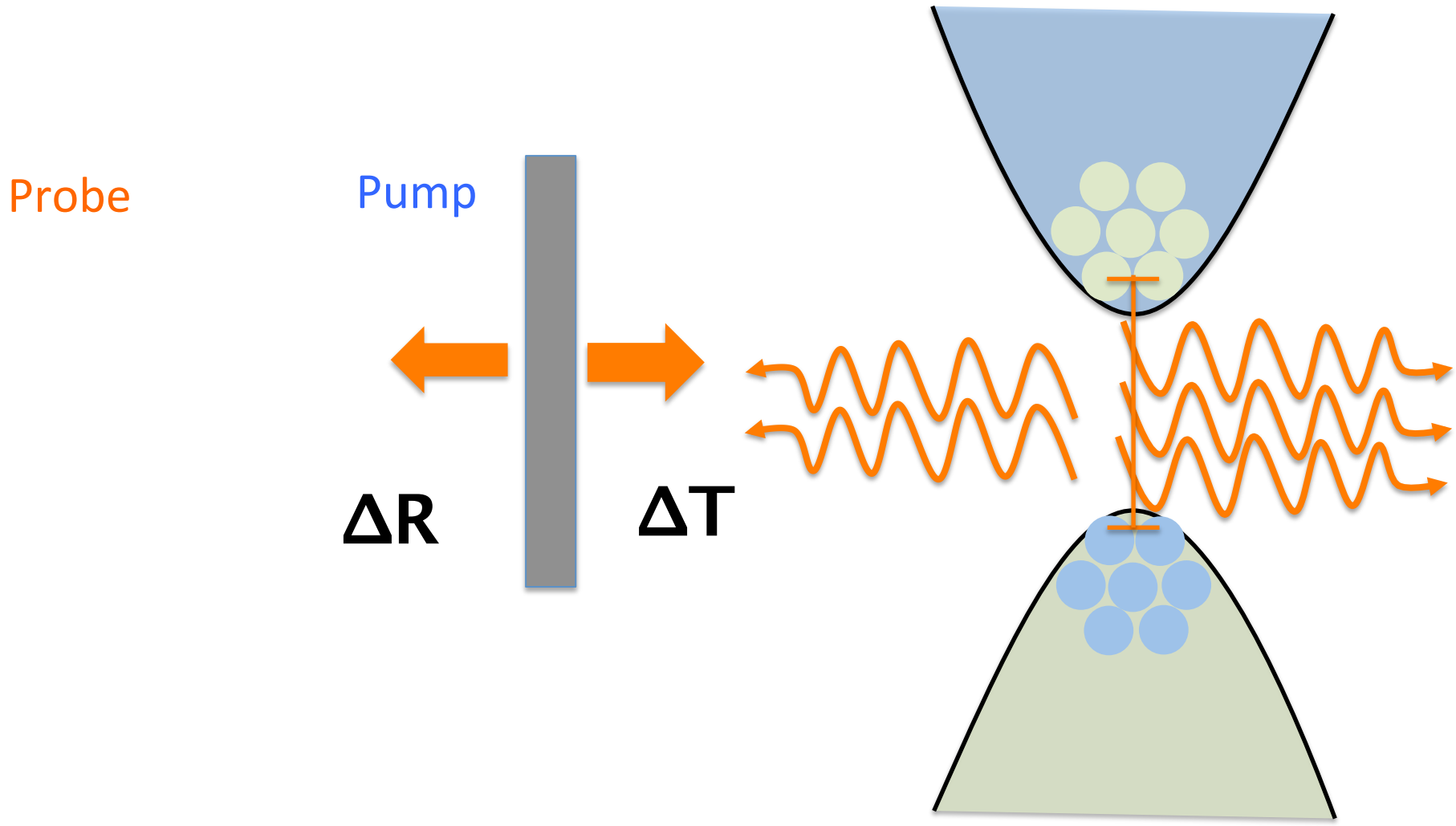
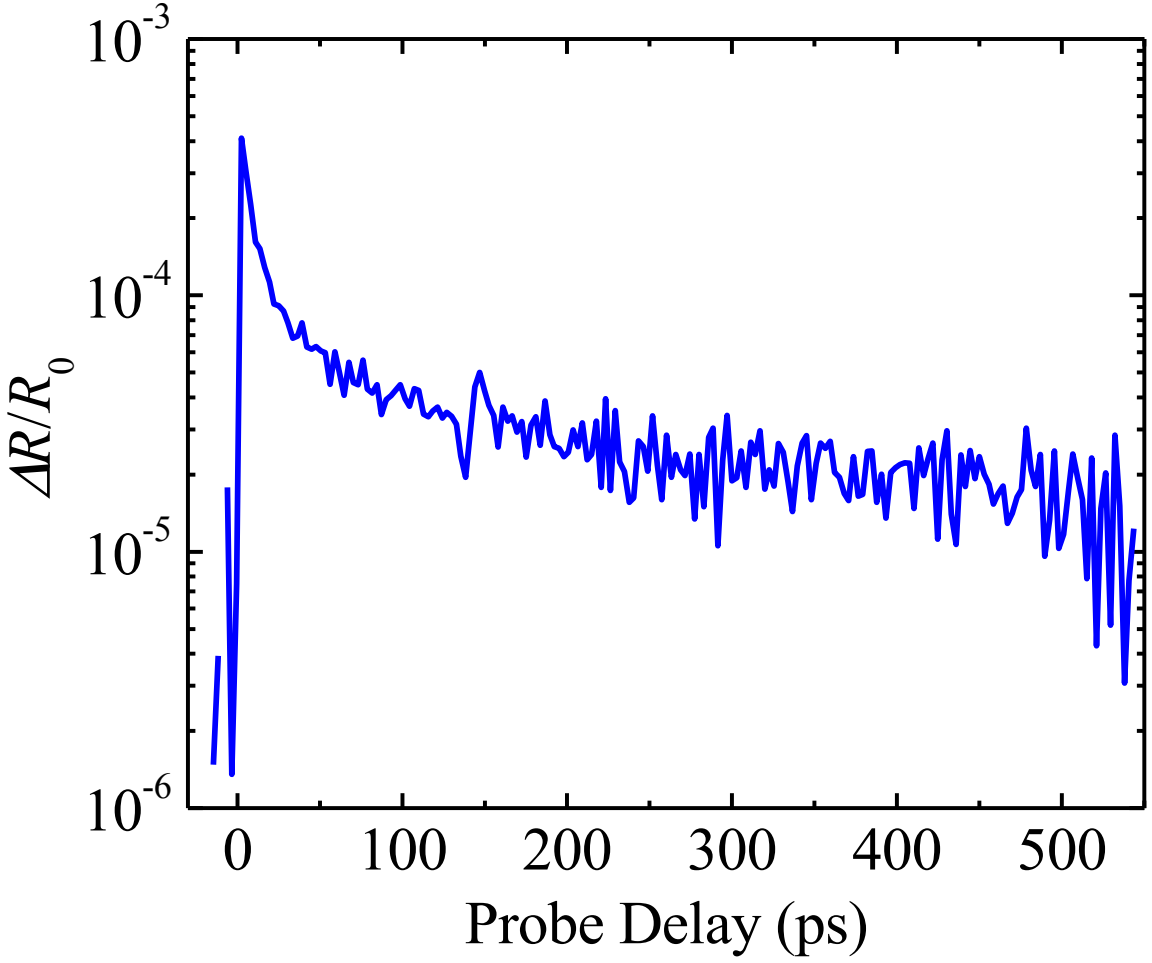


Basics of Pump-Probe Spectroscopy



Differential Reflection Example



N. Kumar, Q. Cui, F. Ceballos, D. He, Y. Wang, and H. Zhao, Phys. Rev. B 89, 125427 (2014)

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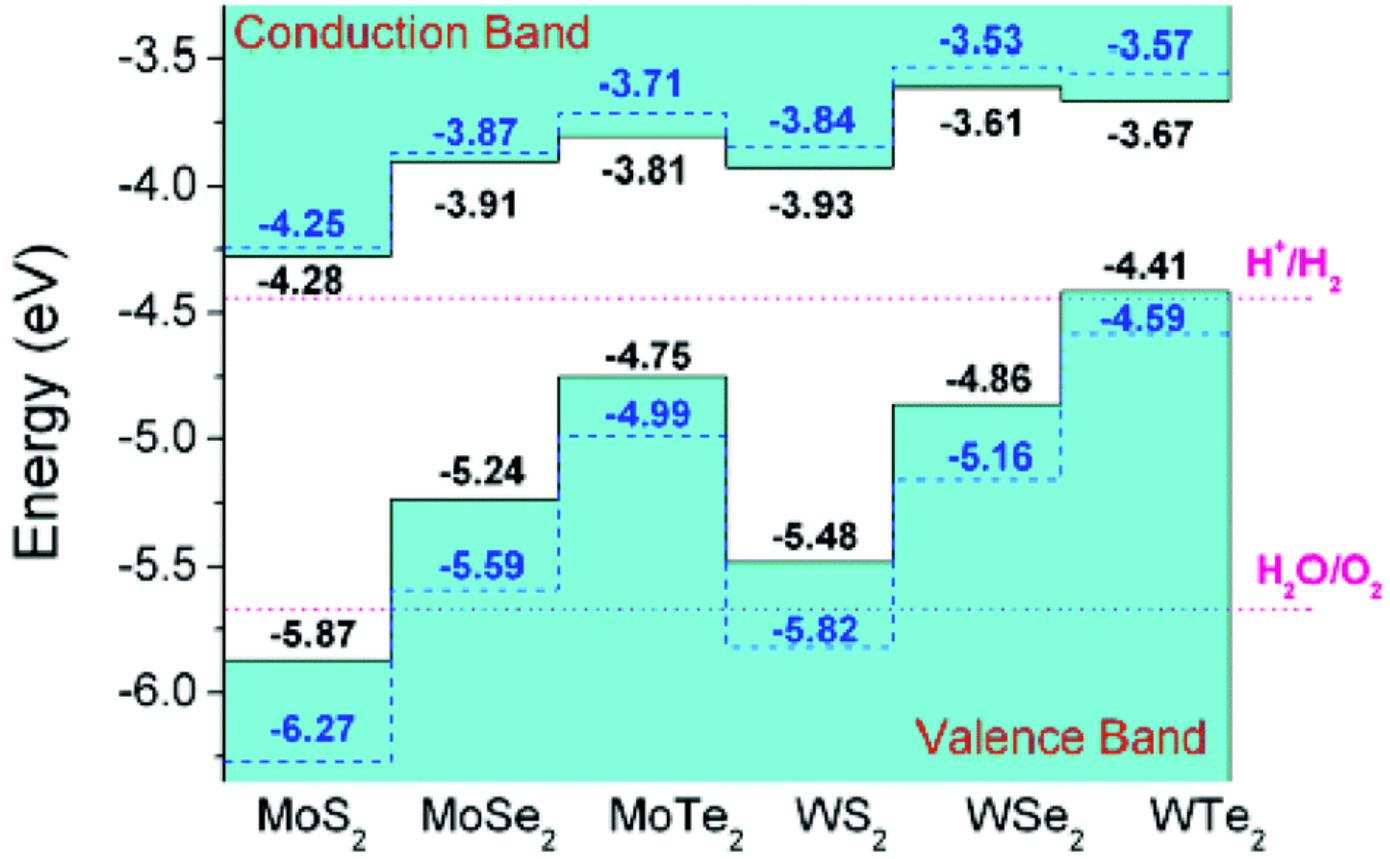
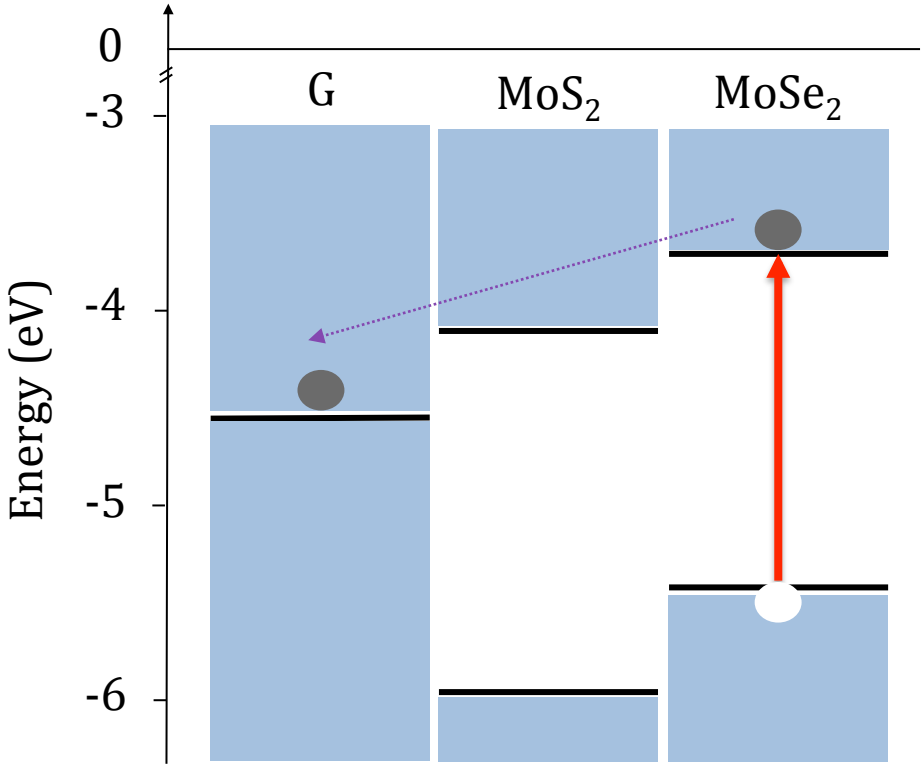
Band Alignment Engineering



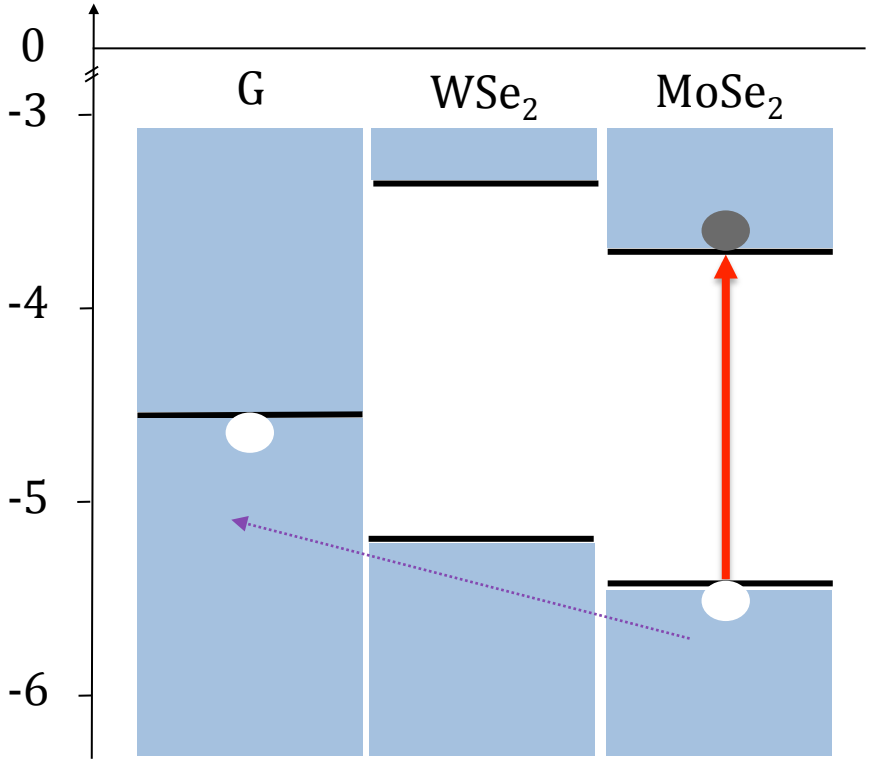
S. Lee and Z. Zhong, *Nanoelectronics circuits based on two dimensional atomic layer crystals.* Nanoscale 2014, 6, 13283-13300

Band Alignment Engineering

Example 1

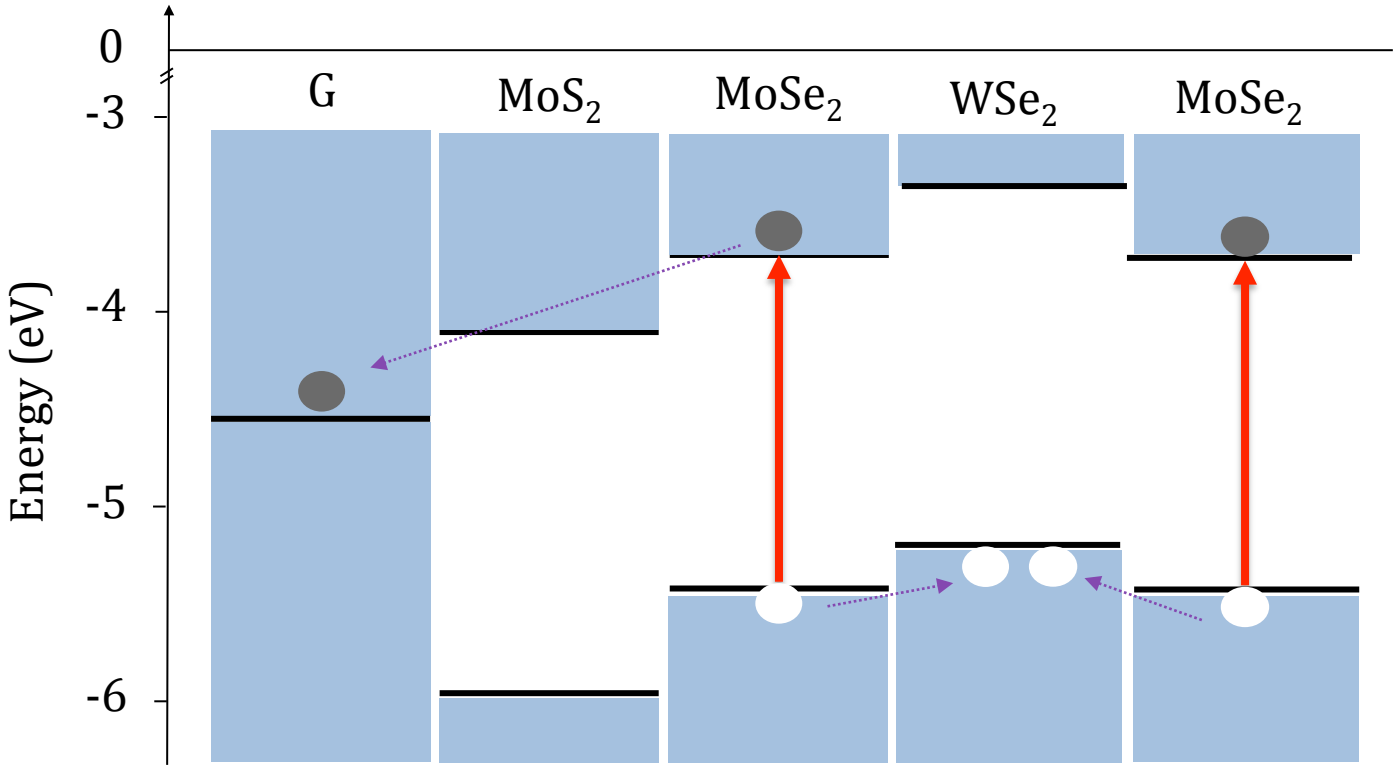


Example 2



Band Alignment Engineering

Example 3



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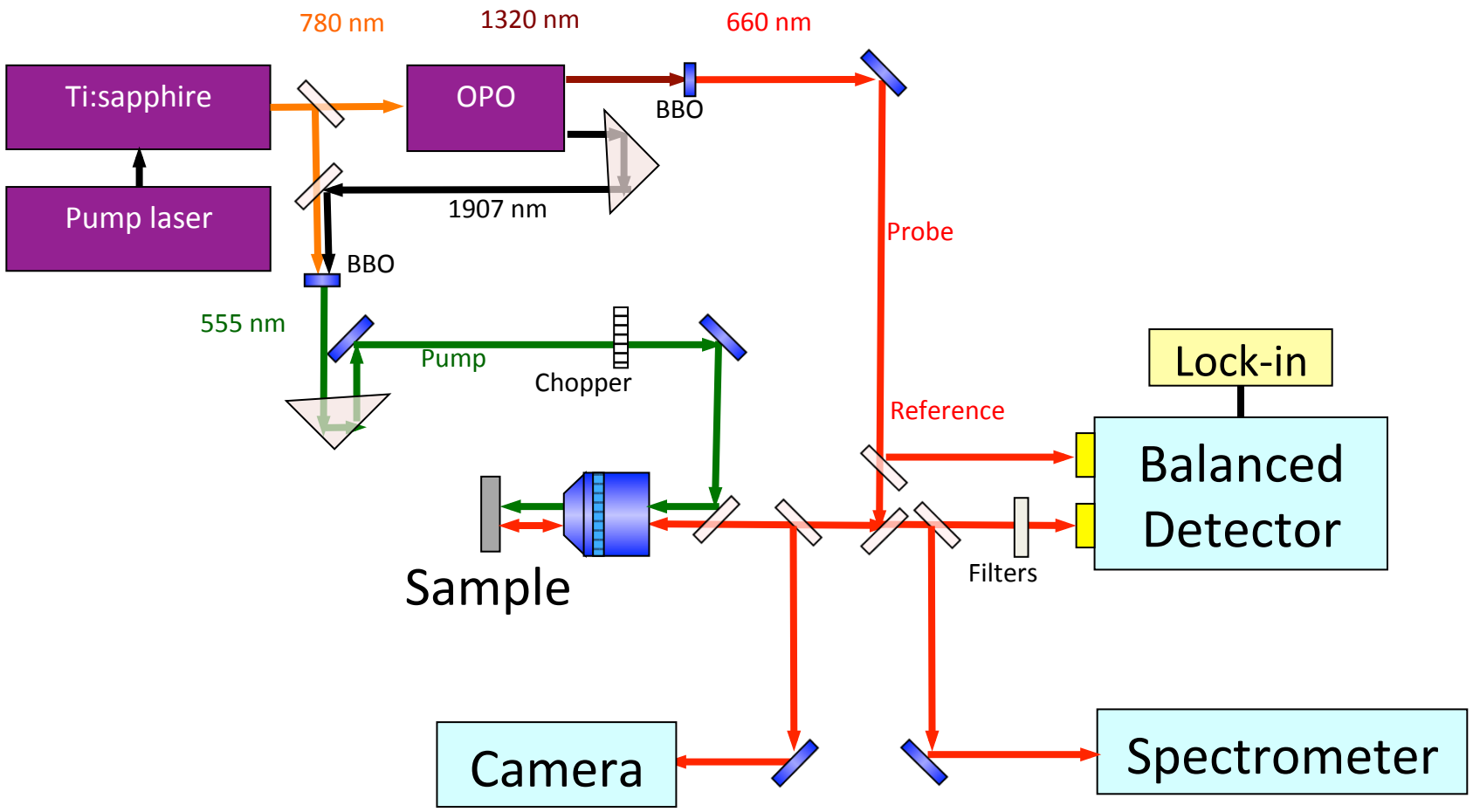
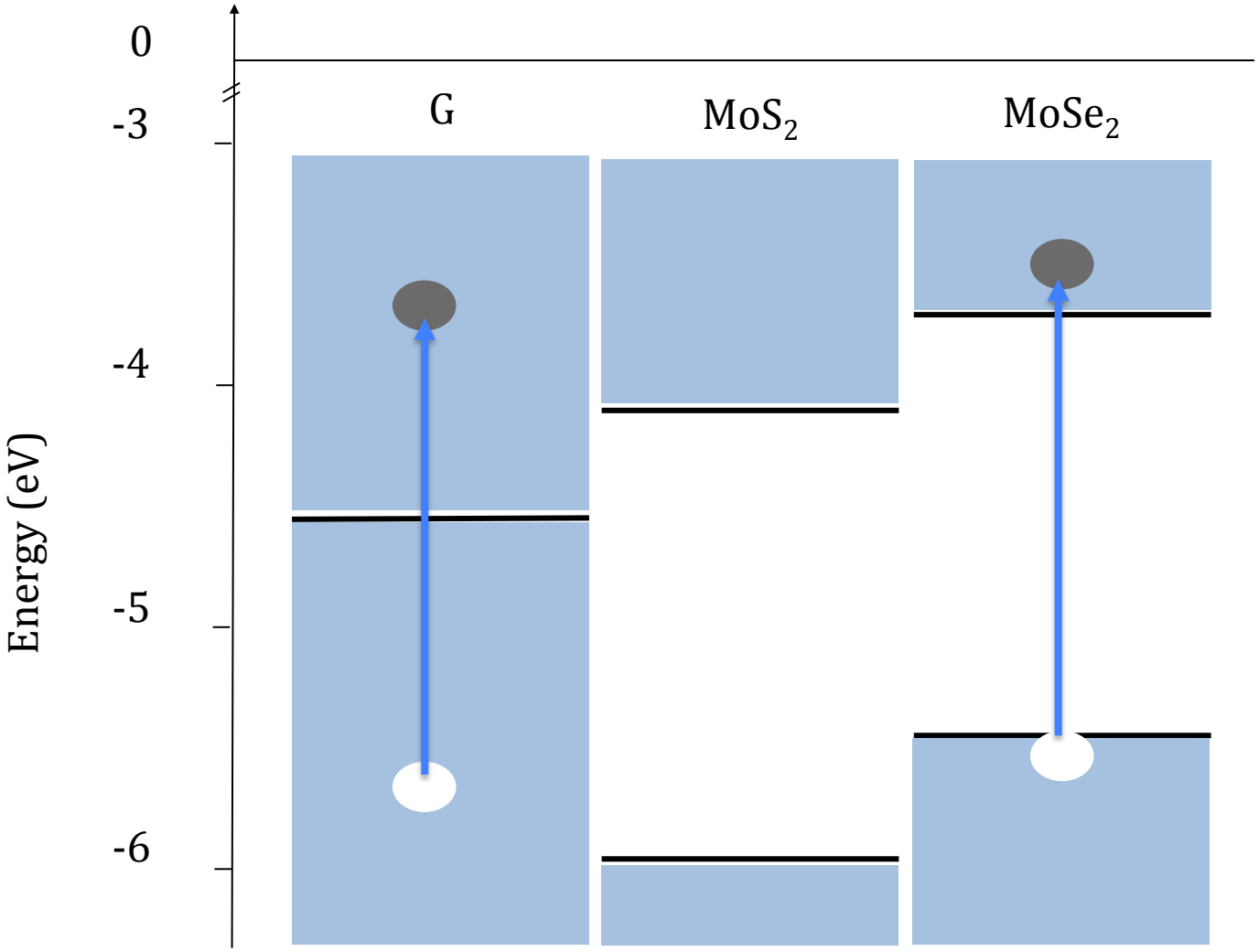
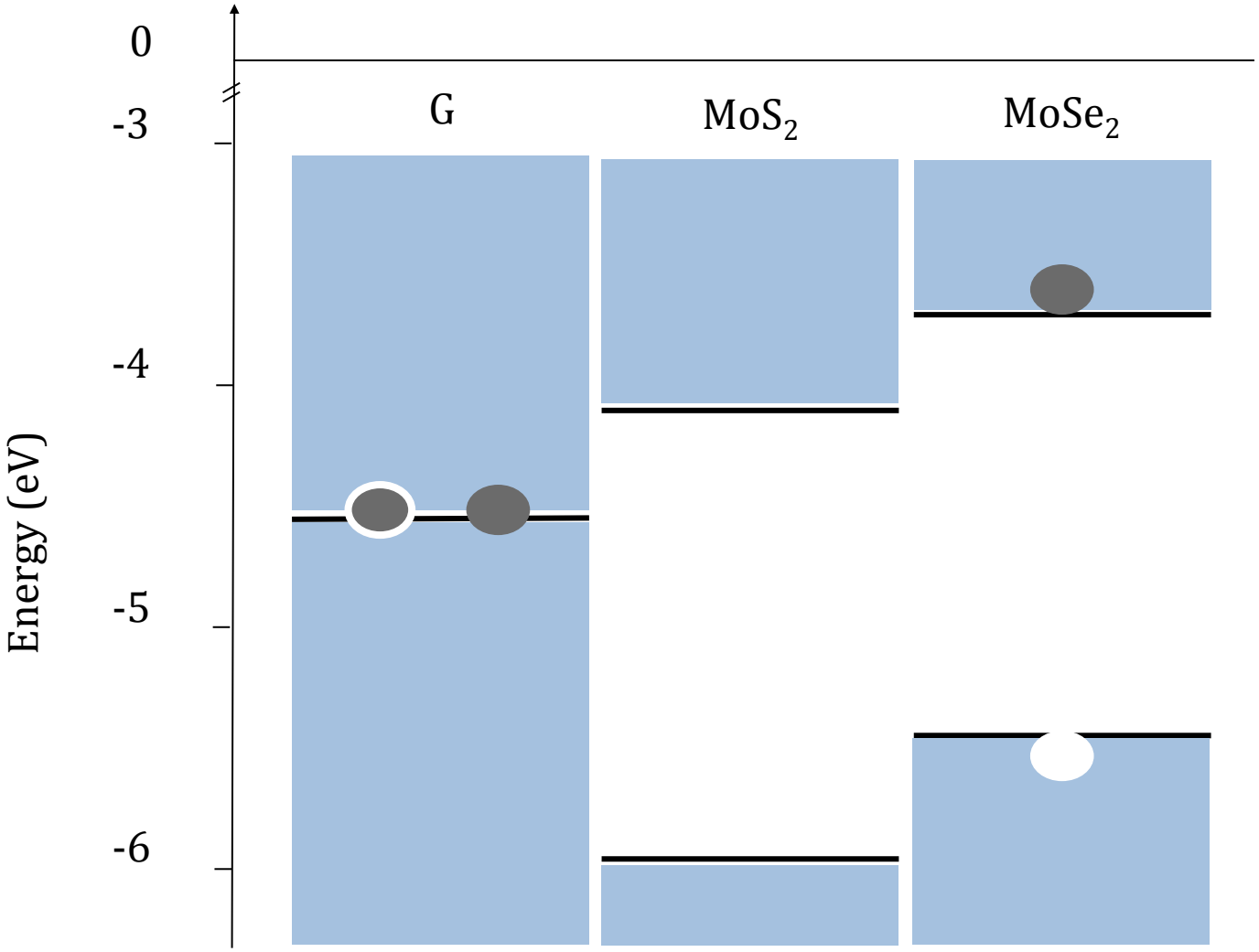
Experimental Setup



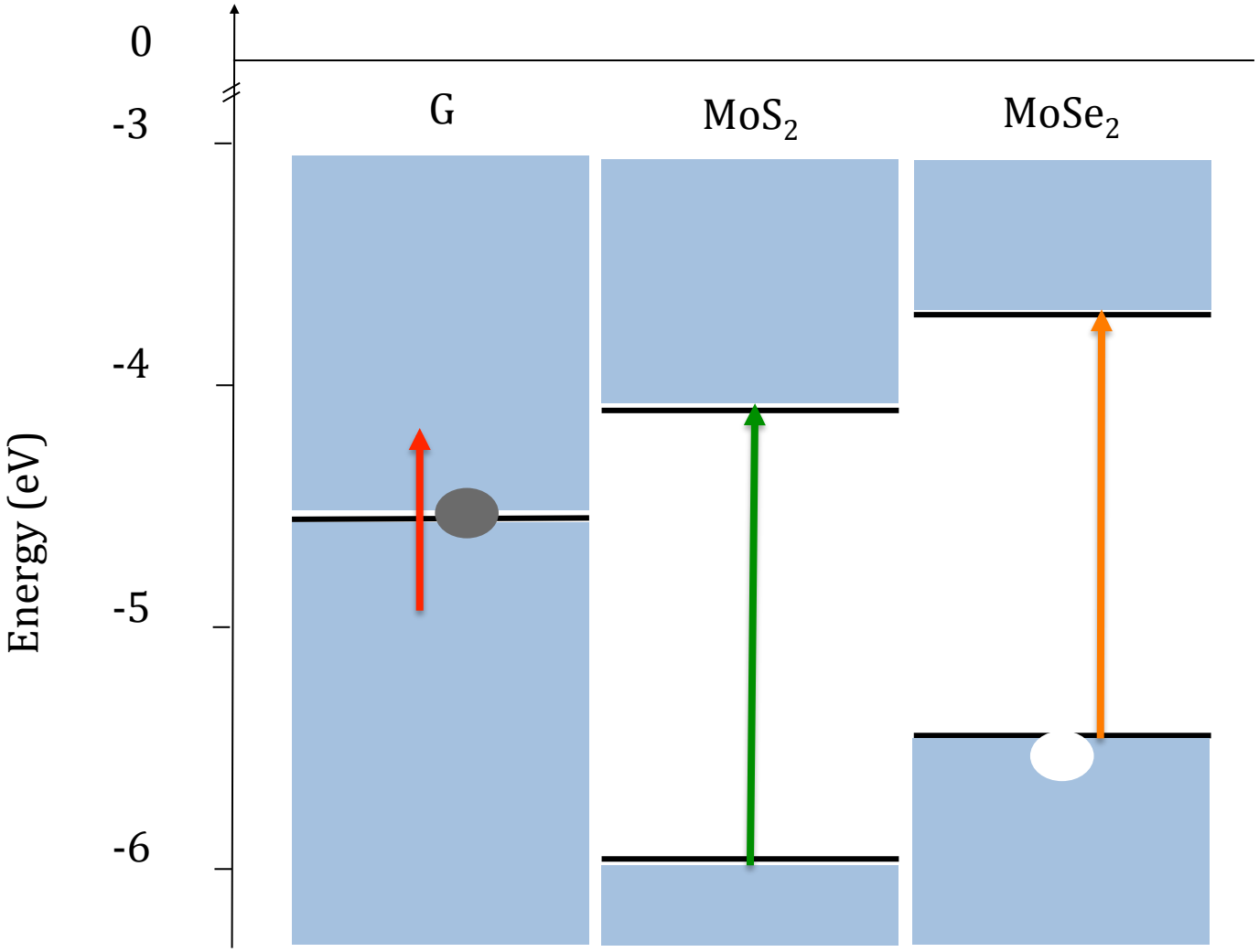
Layer Selective Pump Probe



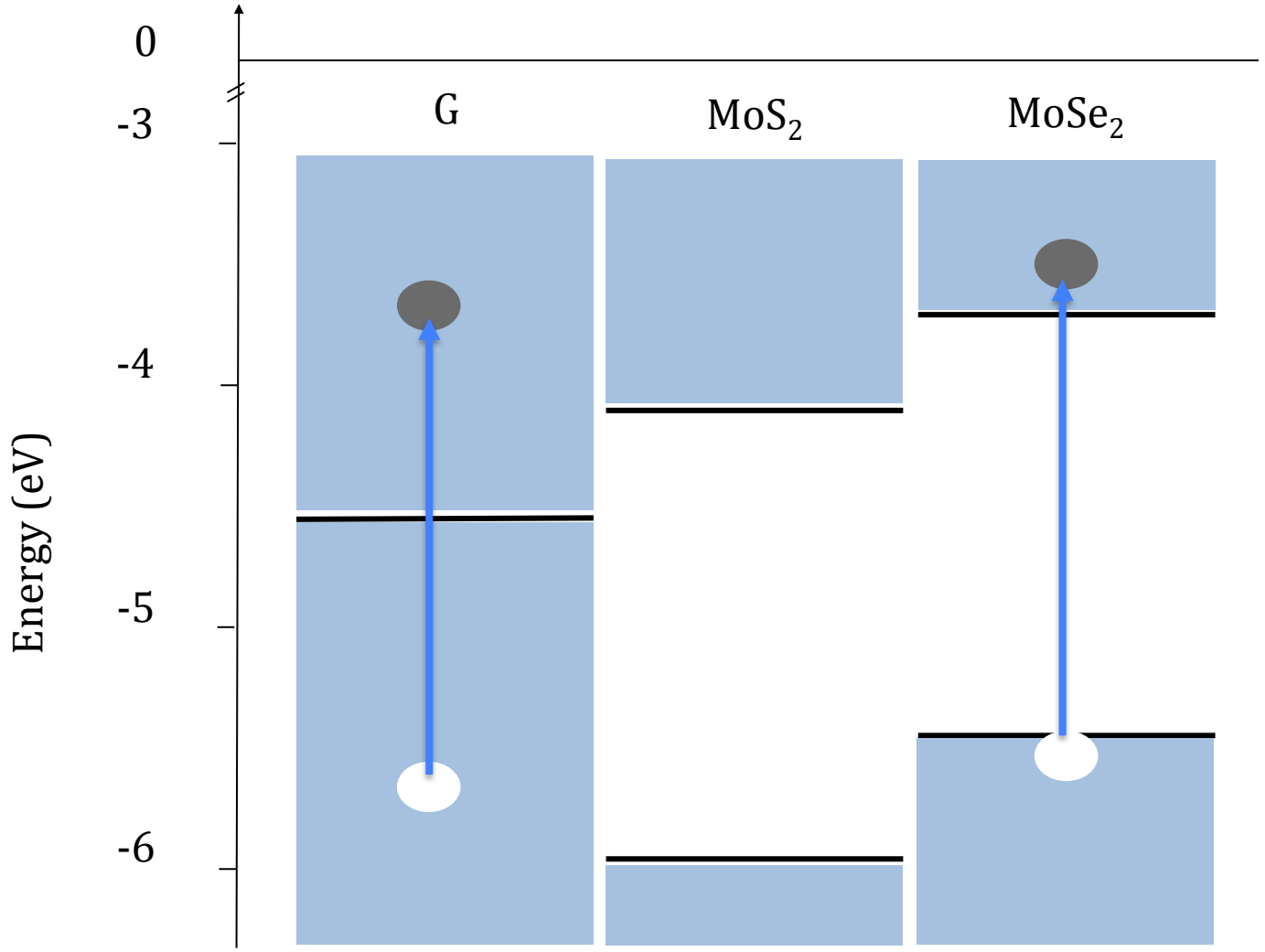
Layer Selective Pump Probe



Layer Selective Pump Probe



Carrier Dynamics in Multiple layers



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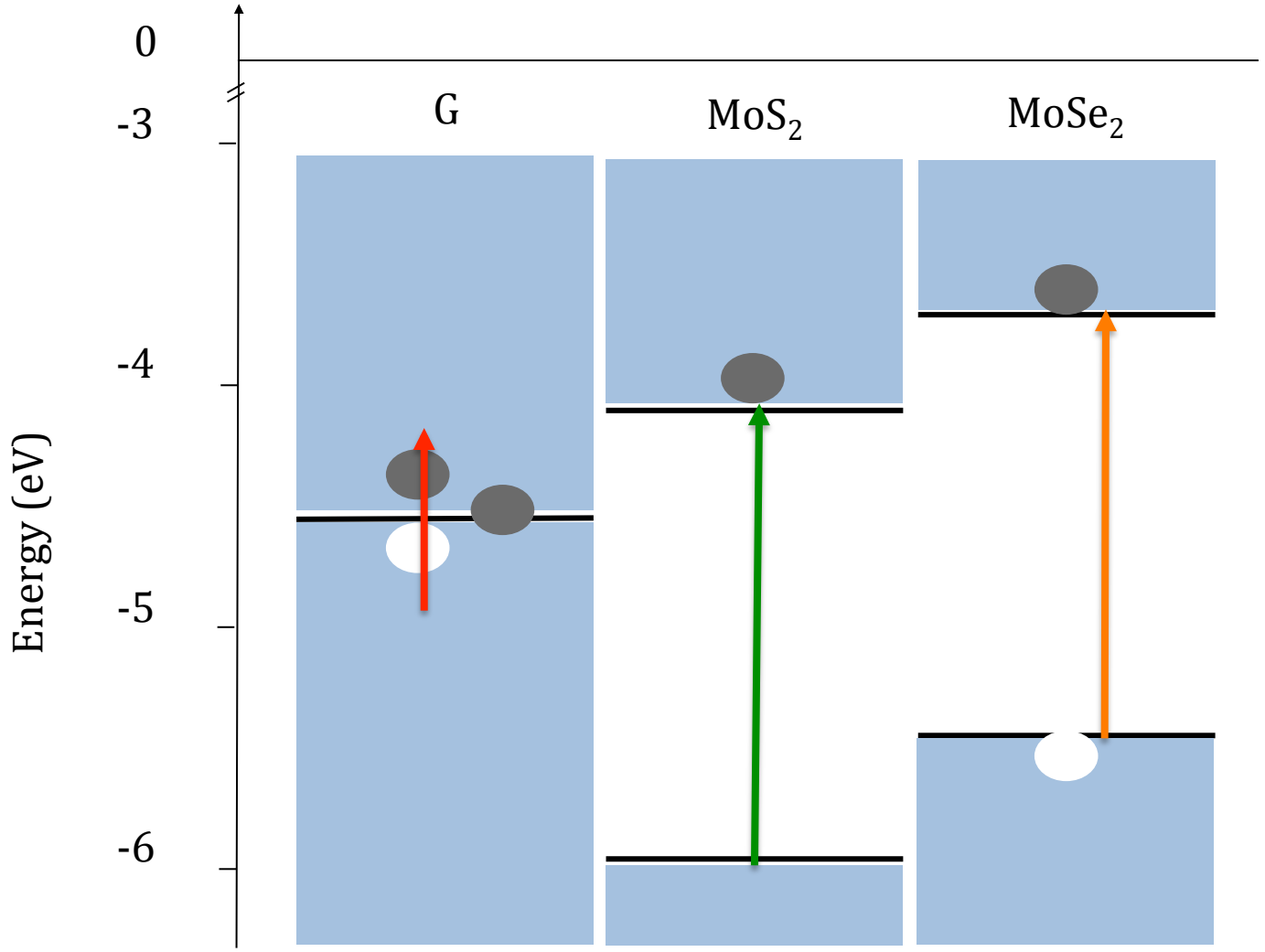
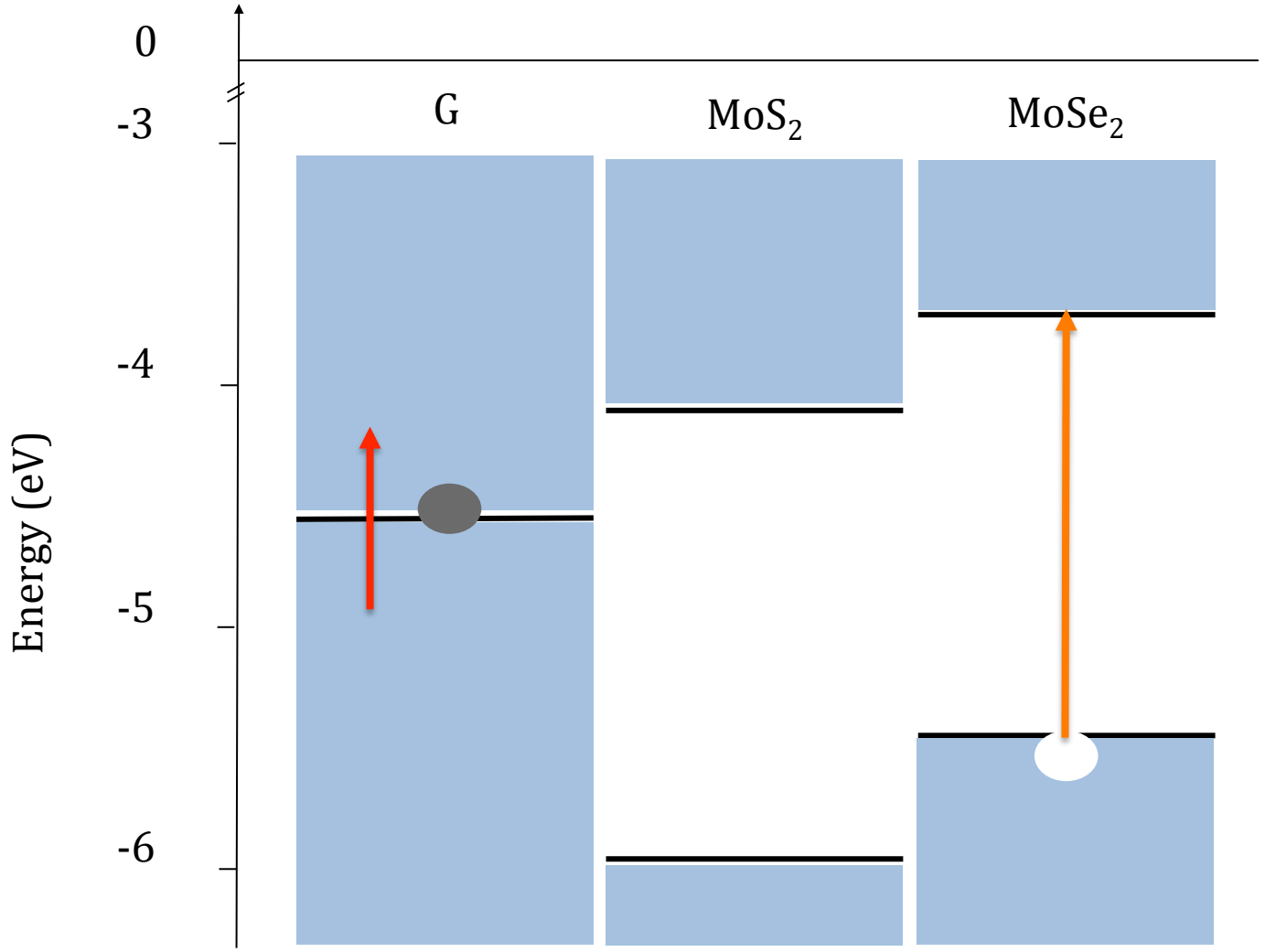
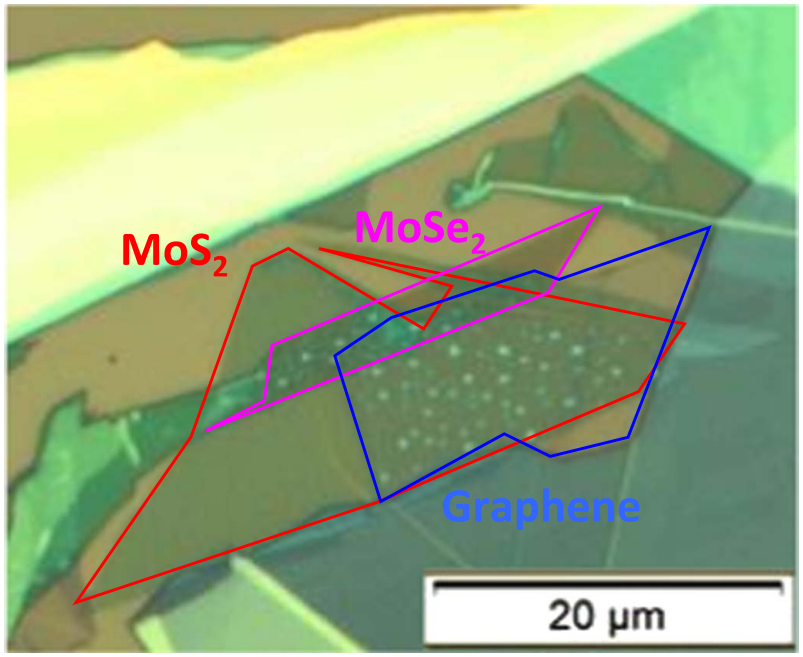


Carrier Dynamics in Multiple layers

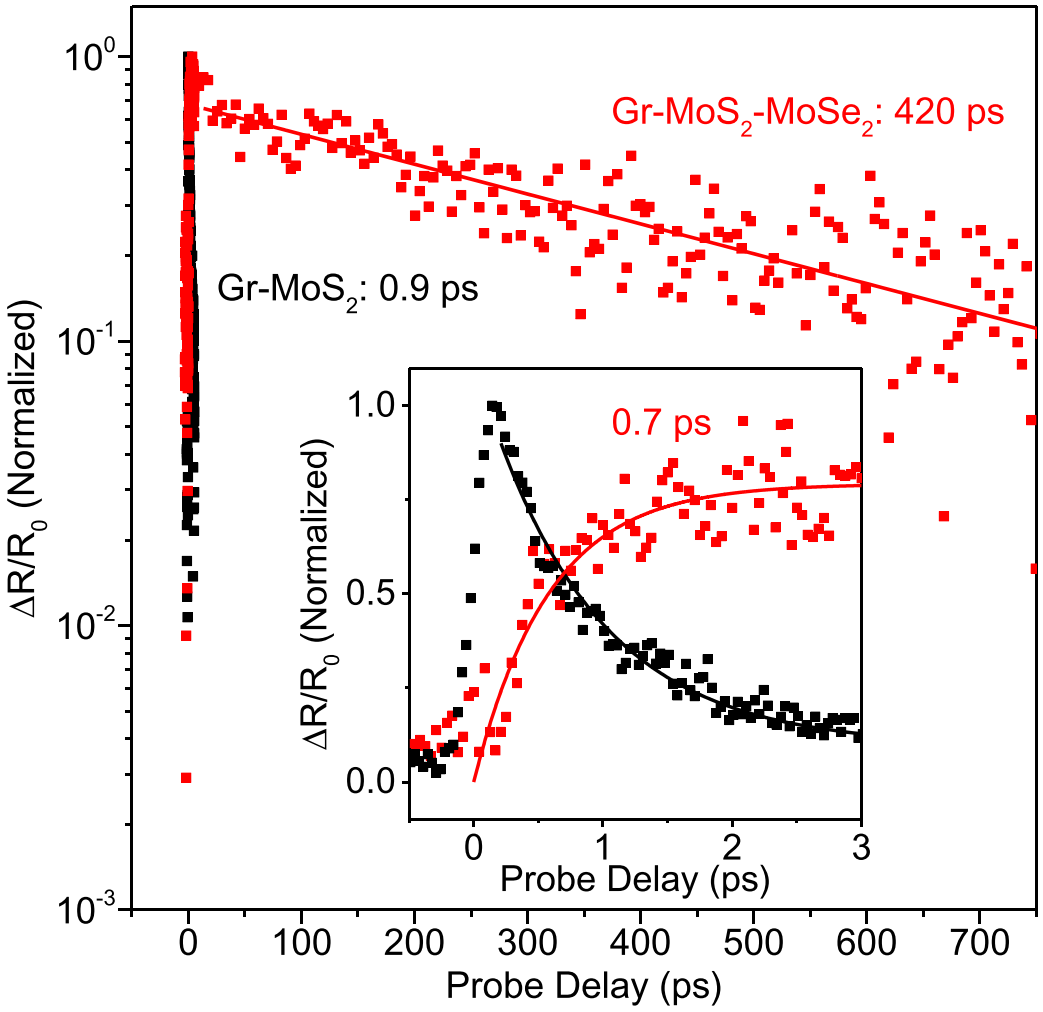


Sample

(c)



Results


Gr-MoS2-MoSe2: 420 ps
Gr-MoS2: 0.9 ps
0.7 ps
ΔR/R0 (Normalized)
Probe Delay (ps)
10^0
10^-1
10^-2
10^-3
0
100
200
300
400
500
600
700
1.0
0.5
0.0
1
2
3

Acknowledgements

Ultrafast Laser Lab

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Qiannan Cui

Matt Bellus

Shekhar Adhikari

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DMR-1505852

EPS-0903806

IIA-1430493

50266-DNI10

Questions?