Near-unity Photoluminescence Quantum Yield (QY) in Monolayer Semiconductors by Electrostatic Doping

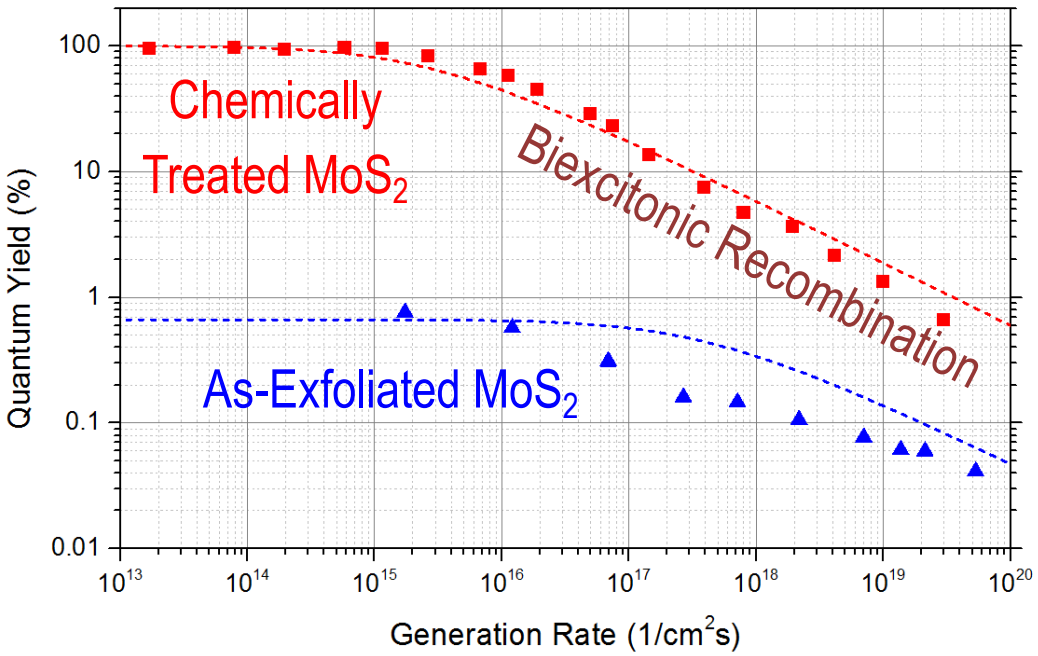
Shiekh Zia Uddin

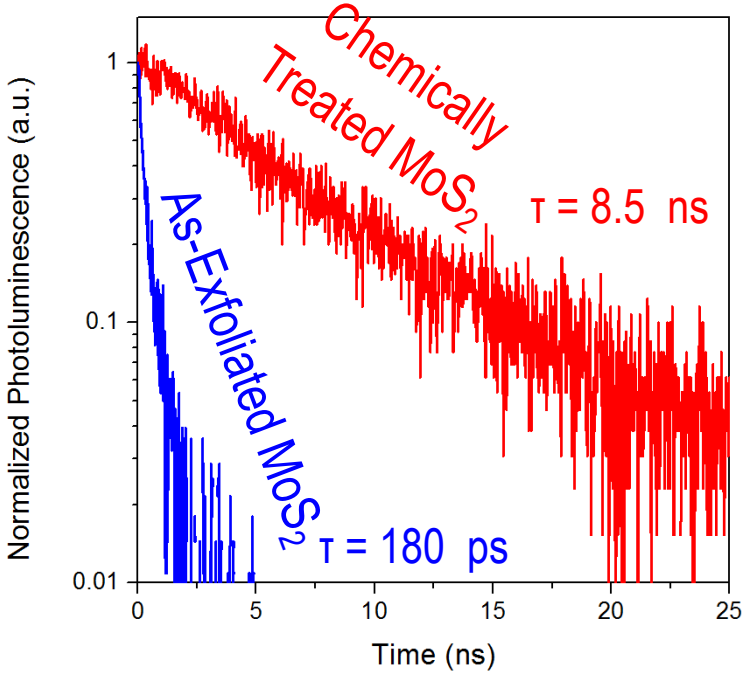
Theme I

PI: Ali Javey

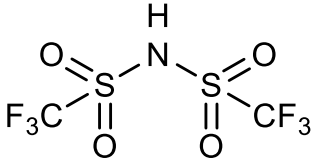
Collaborator: Eli Yablonovitch, Ming Wu

Background: Photoluminescence Quantum Yield in MoS_2





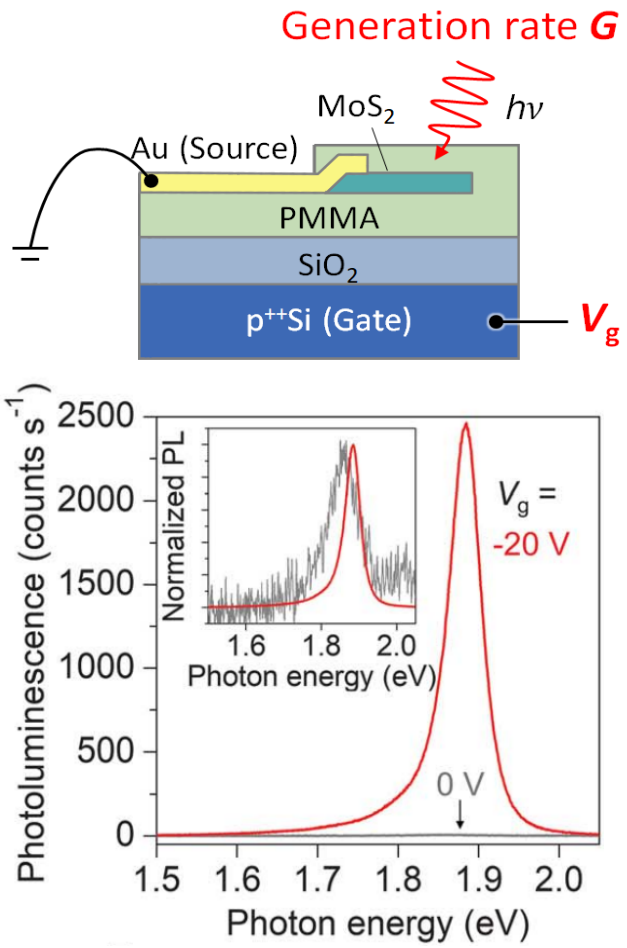
- MoS_2 monolayer shows near-unity PL QY after TFSI treatment.
- The first time recognizing the pump-dependent excitonic nature in 2D semiconductors.

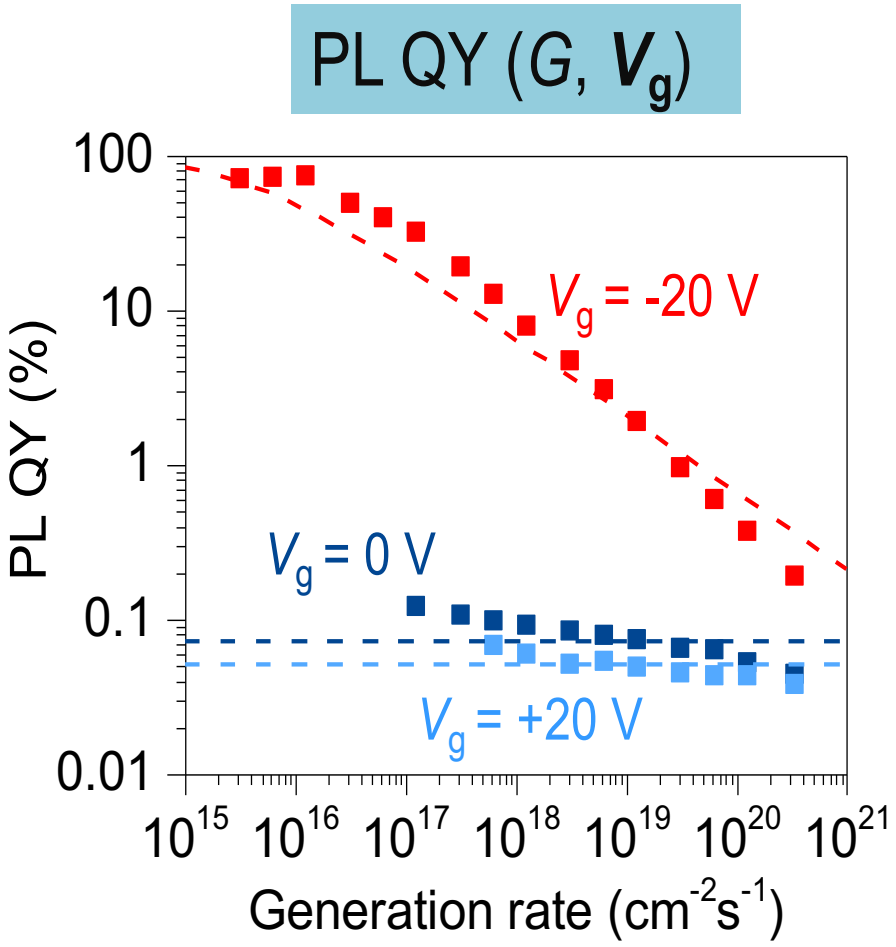


Chemical Treatment: TFSI (Organic Superacid)

M. Amani, D. H. Lien, D. Kiriya, et al, *Science*, 350, 1065-1068, 2015

Near Unity PL QY in MoS_2 by Electrostatic Doping

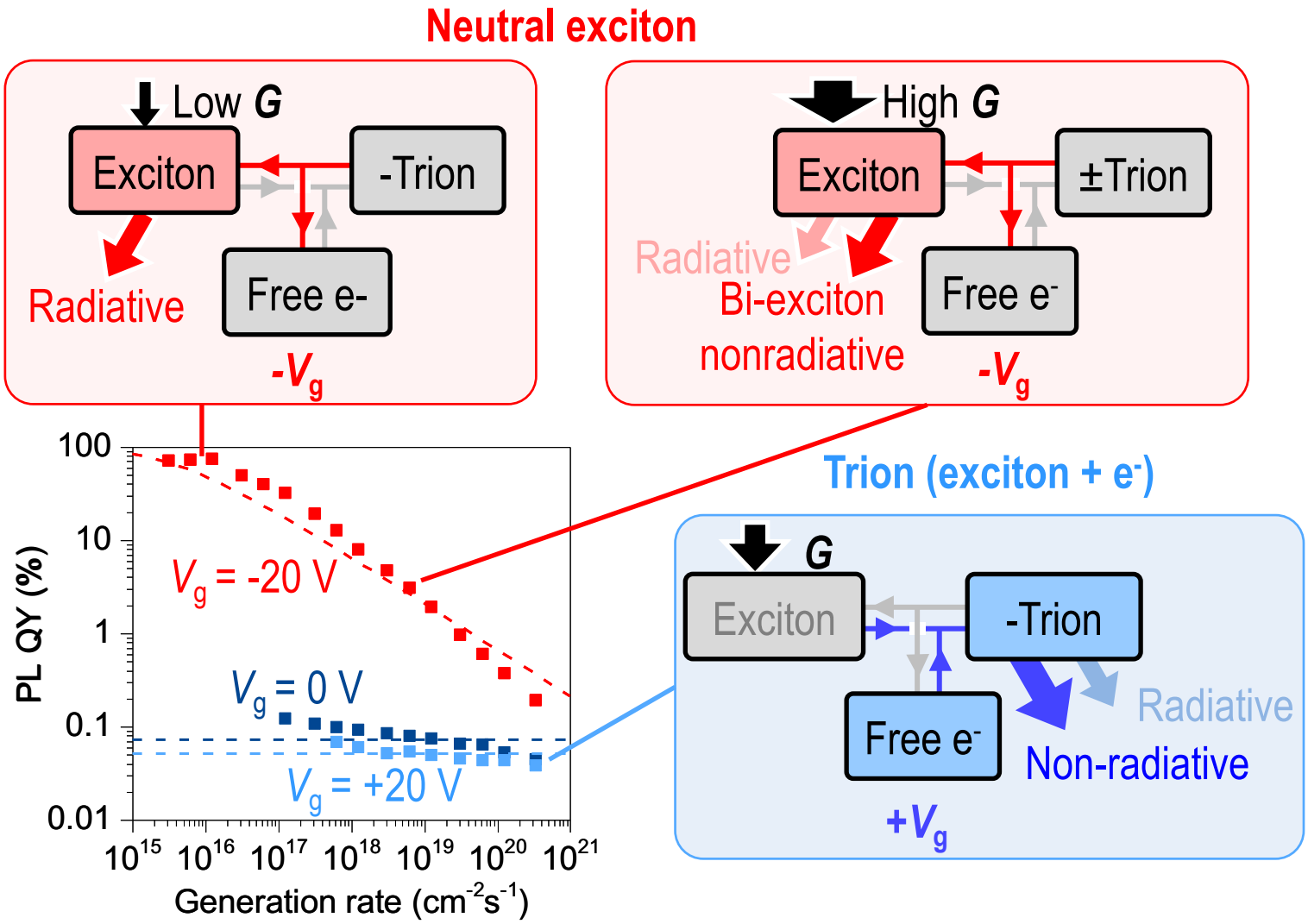




~100% PL QY is achieved in an **untreated MoS_2**

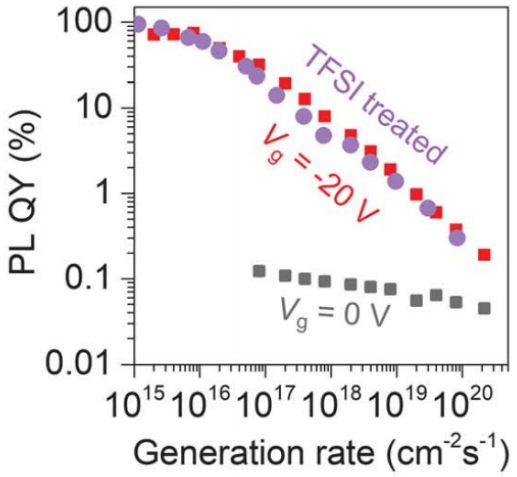
D. H. Lien, S. Z. Uddin, et al, *Science,* 364, 468-471,2019.

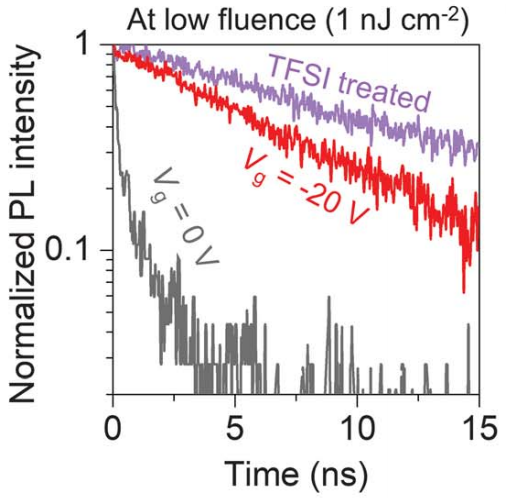
Excitons and Trions in Monolayer MoS_2

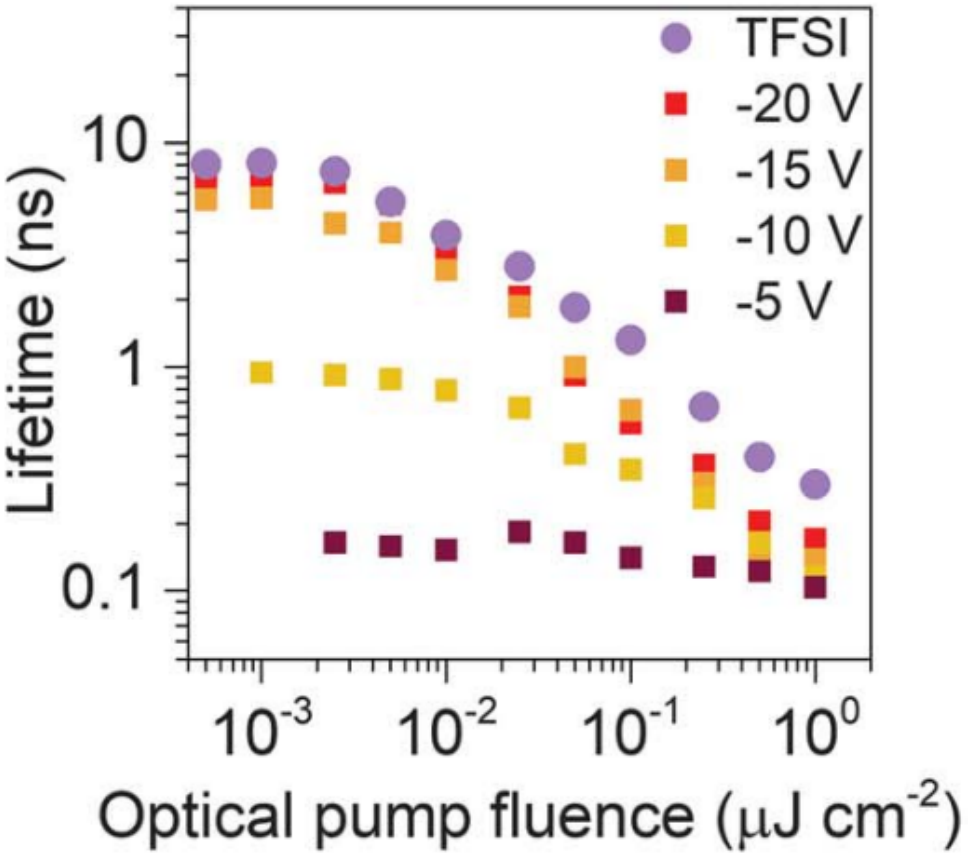


At low pump neutral exciton is entirely radiative.

Effect of TFSI is Electron Counterdoping

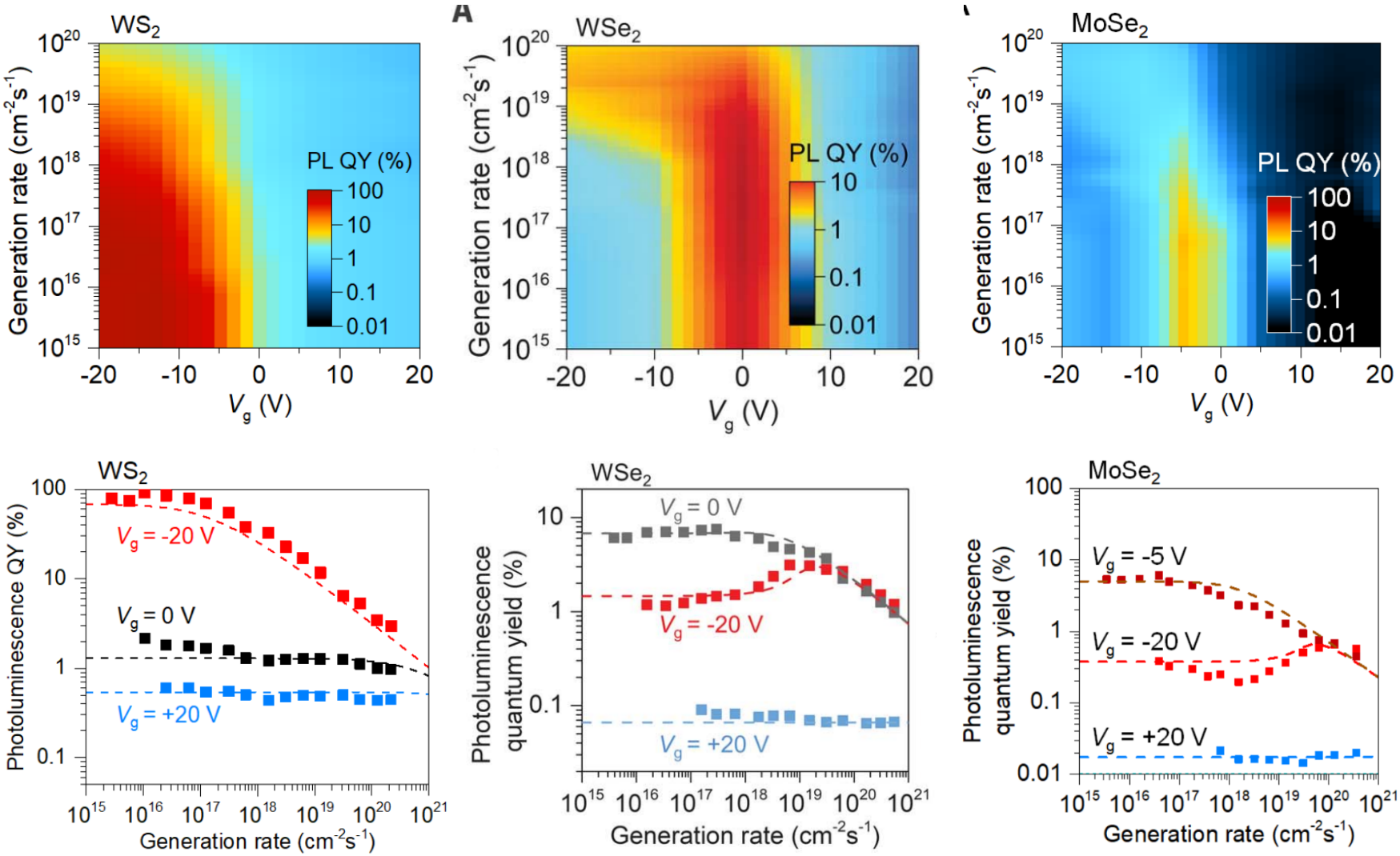




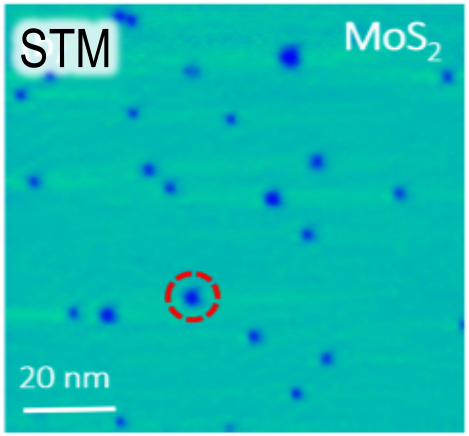


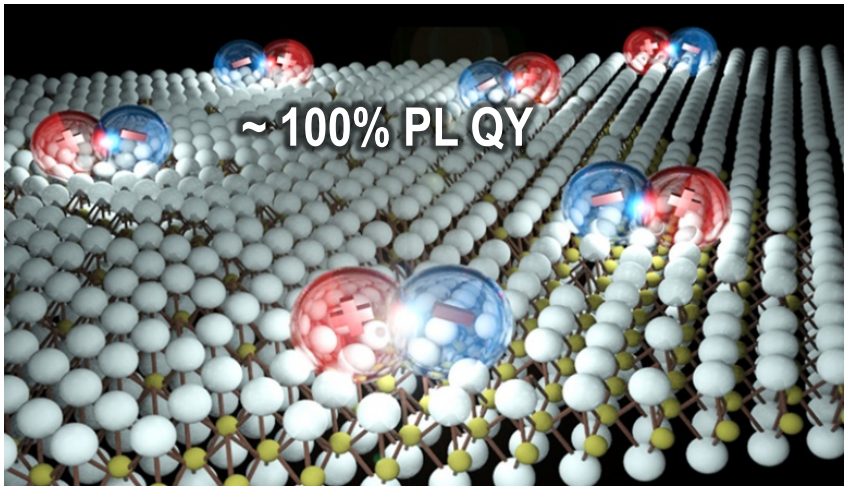
Lewis acid nature of TFSI is well established in organic chemistry

PL QY as a Function of Gate Voltage and Pump



Conclusions and Future Directions





Recombination of neutral exciton is **entirely radiative** even in the presence of a **high native defect density**.

Light emitting region in TMDC devices has to be undoped.

Future direction:

- How to suppress biexciton annihilation?
- Is it applicable to other excitonic systems?

Thank You

Javey Lab Members:

Der-Hsien Lien

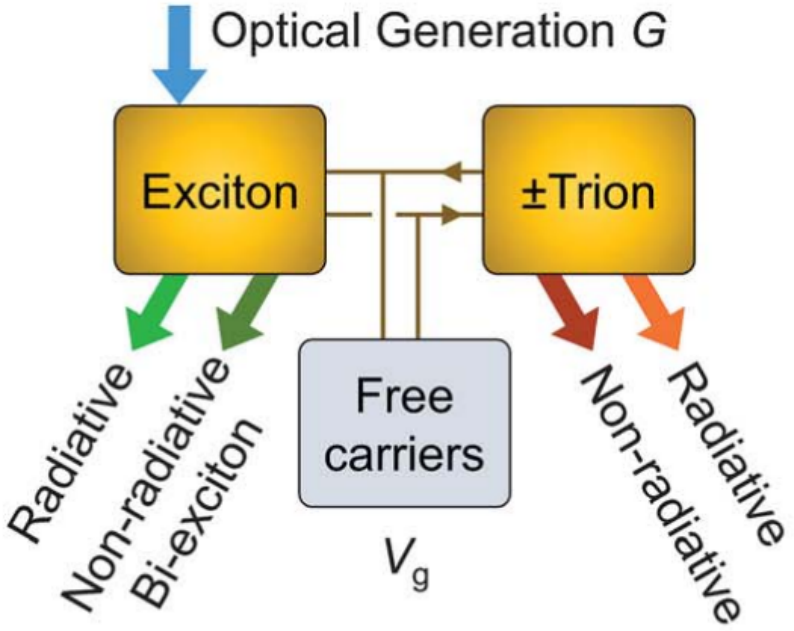
Hyungjin Kim

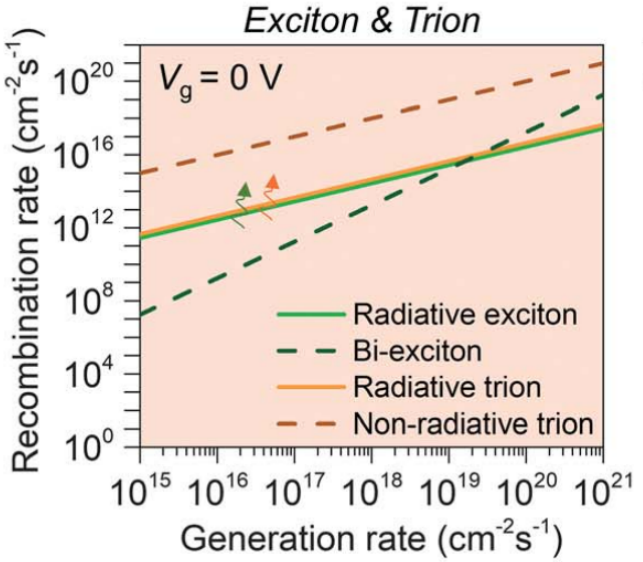
Matthew Yeh

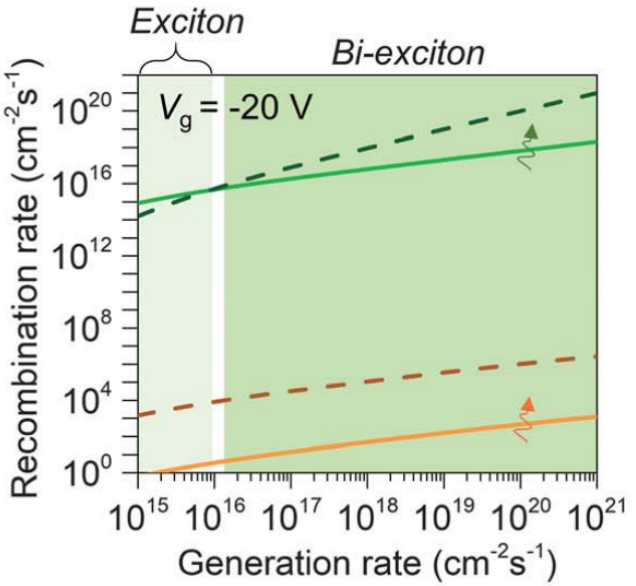
Matin Amani

Shiekh Zia Uddin

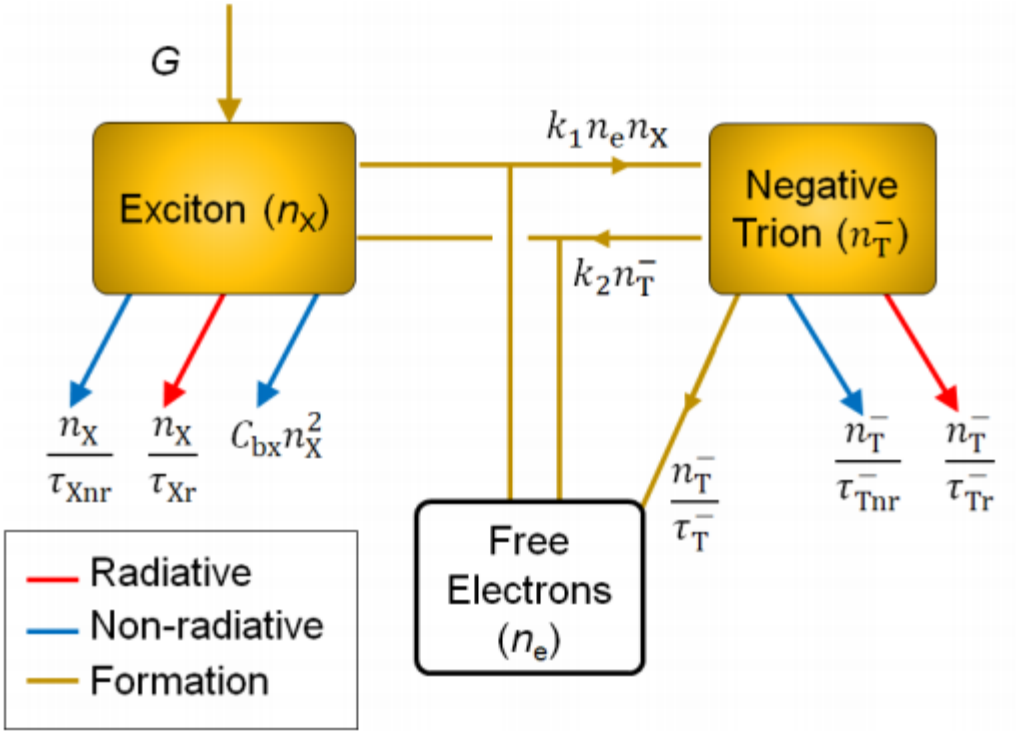
Supporting Slide 1: Kinetic Model







Supporting Slide 2: Kinetic Model



$$N - P = C_{OX}(V_g - V_{th})/q$$

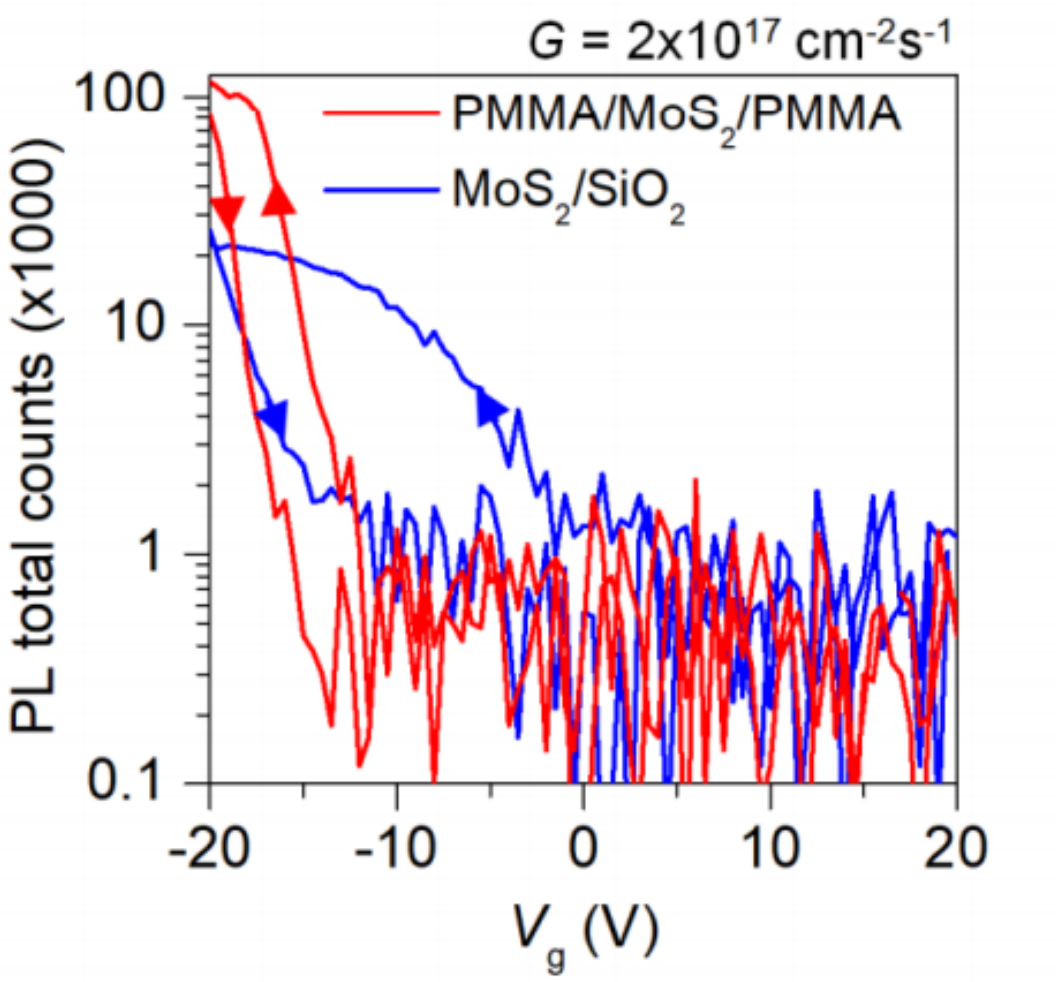
$$N = n_e + n_T^-$$

$$n_T^- = T^- n_e n_X$$

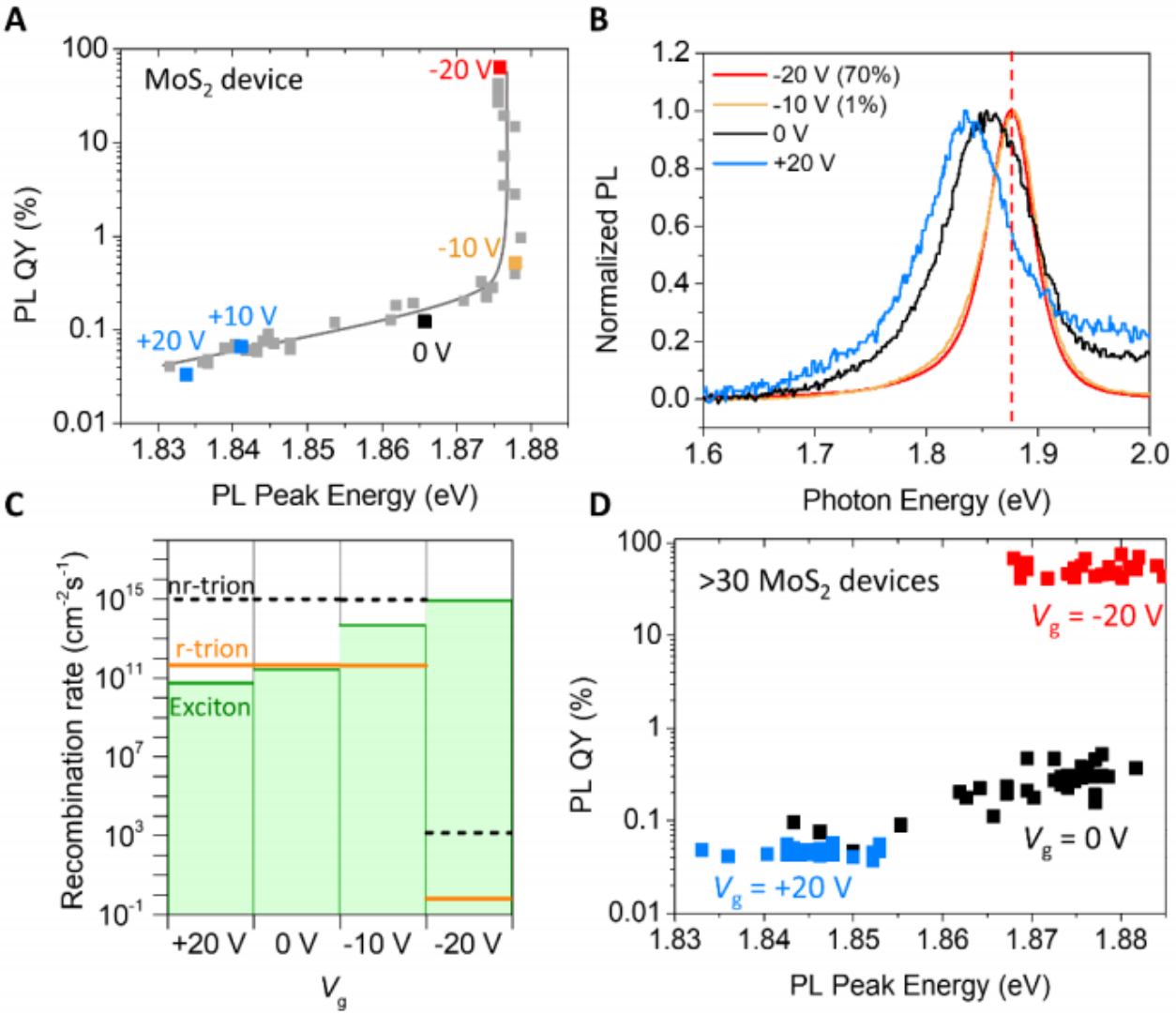
$$G = \left(\frac{1}{\tau_{Xr}} + \frac{1}{\tau_{Xnr}}\right) n_X + \left(\frac{1}{\tau_{Tr}^-} + \frac{1}{\tau_{Tnr}^-}\right) n_T^- + C_{bx} n_X^2 = \frac{n_X}{\tau_X} + \frac{n_T^-}{\tau_T^-} + C_{bx} n_X^2$$

$$QY = \frac{1}{G}\left(\frac{n_X}{\tau_{Xr}} + \frac{n_T^-}{\tau_{Tr}^-} + \frac{n_T^+}{\tau_{Tr}^+}\right)$$

Supporting Slide 3: Why PMMA



Supporting Slide 4: PL Peak Shift



Supporting Slide 5: TRPL