Observation of Bright Intralayer Moiré Excitons in $Mg(OH)_2/MoSe_2$ Heterostructure

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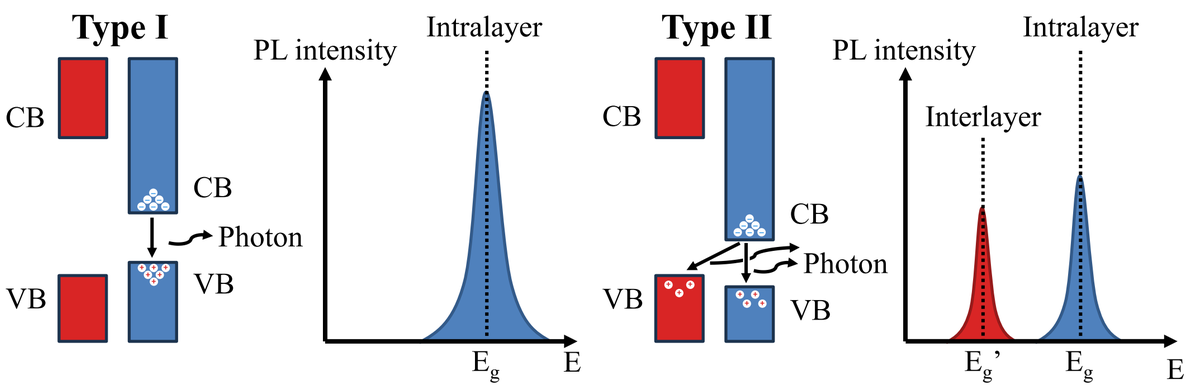
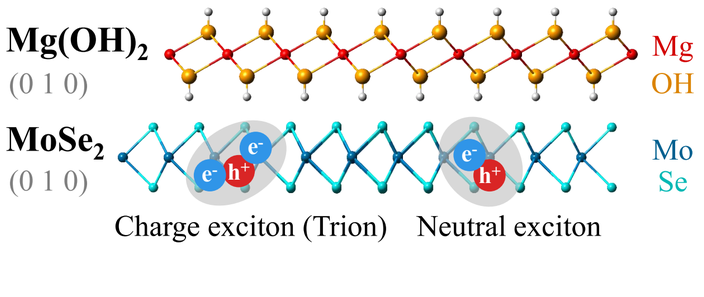
Recent studies of moiré physics in bilayer transition-metal dichalcogenides (TMDs) have largely focused on interlayer excitons, whose photoluminescence (PL) is typically weak and thus less suitable for quantum photonics applications. Here, we demonstrate that intralayer moiré excitons can be formed in a heterostructure composed of insulating $Mg(OH)_2$ and monolayer(ML) $MoSe_2$. Zero twist-angle PL and differential reflectance (DR) spectra reveal distinct moiré exciton features, signifying the formation of intralayer moiré states. Further experiments, including spatial mapping, power-dependent, and polarization-resolved PL spectroscopy, confirm that these moiré excitons exhibit robust interband optical transitions and high emission brightness. Our results establish intralayer moiré excitons as a promising and tunable light-emitting platform, paving the way for future optoelectronic and quantum photonic applications.

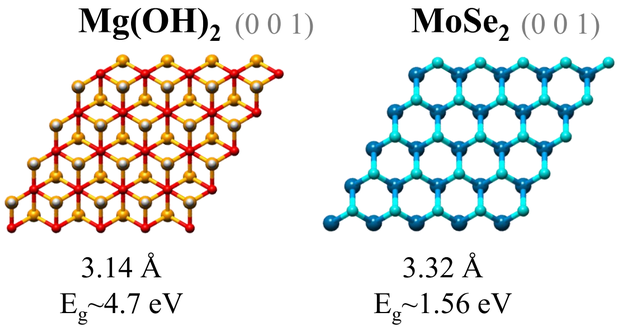
Introduction

Intralayer and Interlayer Exciton

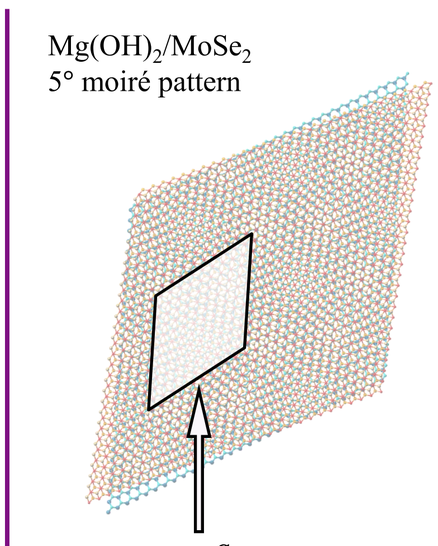


Structure



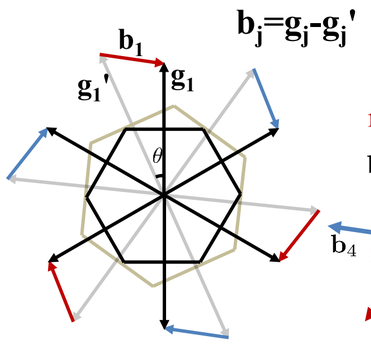


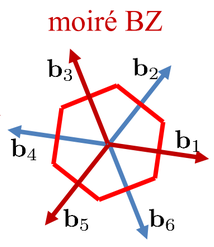
Moiré Pattern



$$a_{\text{moiré}} \approx \frac{a_0}{\sqrt{\theta^2 + \delta^2}} = 3.23 \text{ nm}$$

Moiré Potential





$$\mathcal{H} = \mathcal{H}_0 + V_m$$

Low-energy effective Hamiltonian

$$\mathcal{H}_0 = \frac{\hbar^2 \mathbf{Q}^2}{2M^*}\tau_0 + J|\mathbf{Q}|\tau_0 + J|\mathbf{Q}|[\cos(2\phi_\mathbf{Q})\tau_x + \sin(2\phi_\mathbf{Q})\tau_y]$$

Wu, F., Lovorn, T. & MacDonald, A. H. *Phys. Rev. Lett.* **118**, 147401 (2017)

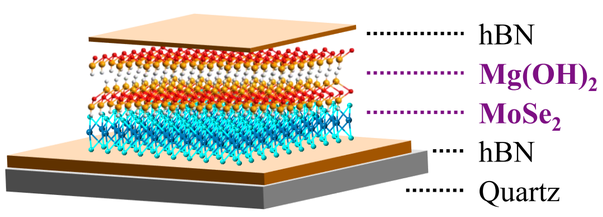
$$V_m = \sum_{j=1}^{6} V_j \exp(i\mathbf{b}_j \cdot \mathbf{r})\tau_0$$

Moiré potential

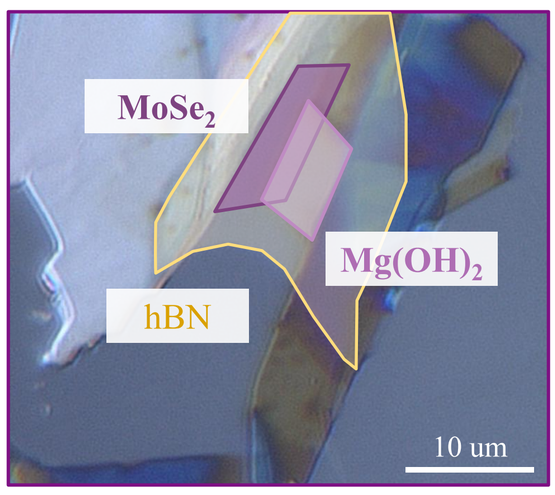
Method

Sample Preparation

Sample Sideview



6000X OM



Optical Measurement at 4K

Photoluminescence (PL)
Differential Reflectometry (DR)

Acknowledgments

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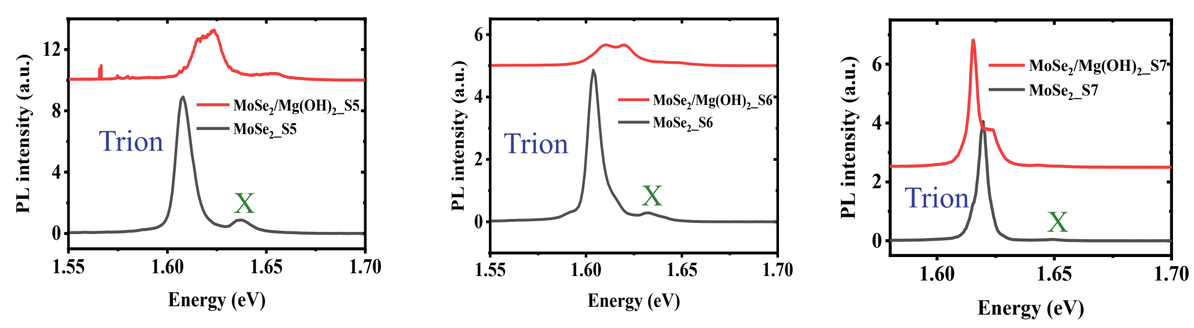
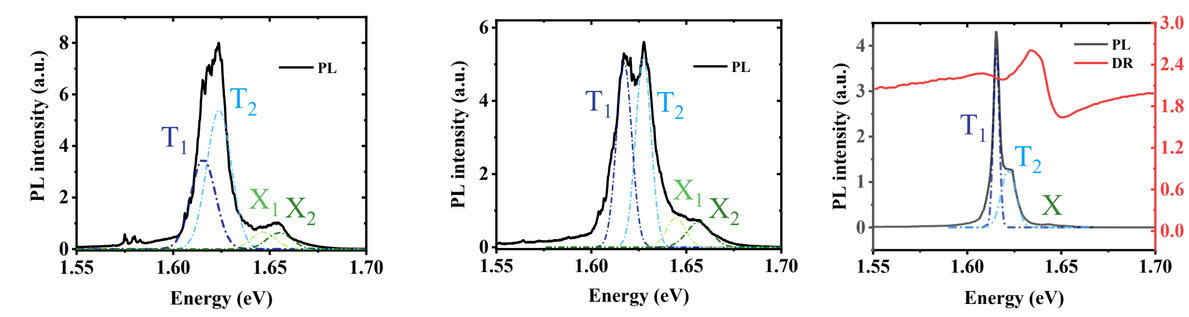
Results

$MoSe_2/Mg(OH)_2$ vs. $MoSe_2$ ML in different 0° twisted sample



Splitting of $MoSe_2/Mg(OH)_2$ Trion & Neutral Exciton

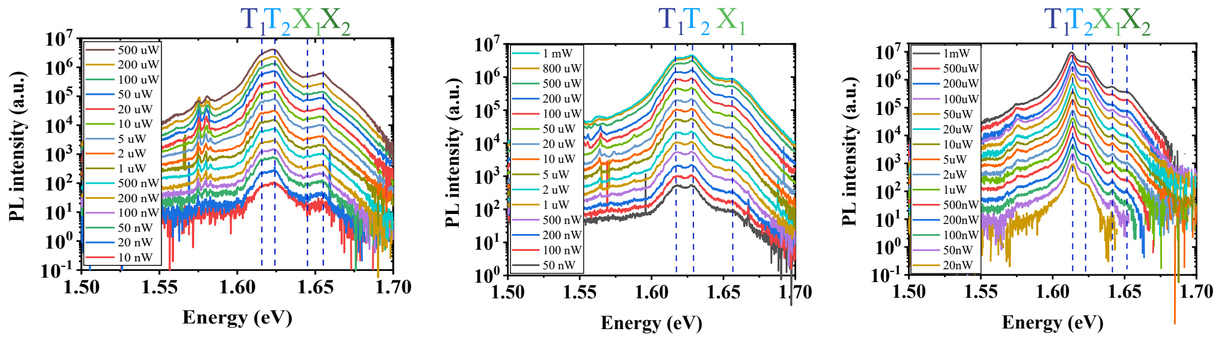


Splitting of T: 8 meV
Splitting of X: 10 meV

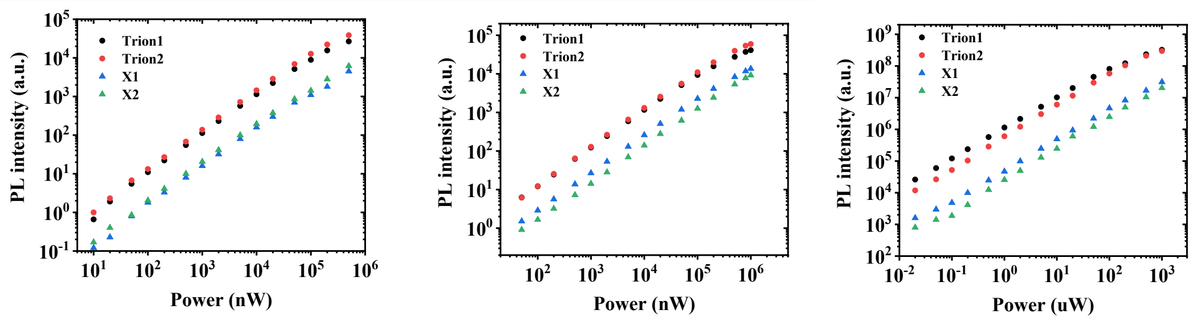
Splitting of T: 11 meV
Splitting of X: 12 meV

Splitting of T: 8 meV

Power-dependent PL of $MoSe_2/Mg(OH)_2$



Area-power relation of $MoSe_2/Mg(OH)_2$

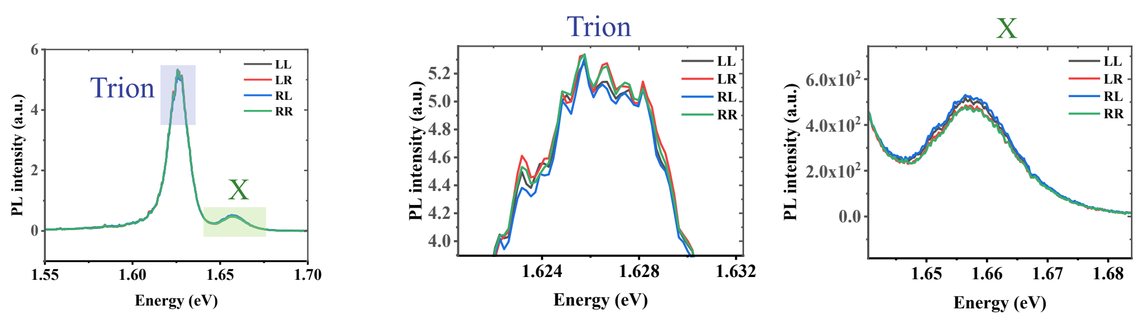


Slope of T_1/T_2: 0.982/0.992
Slope of X_1/X_2: 0.970/0.971

0.965/0.907
0.942/0.951

0.999/0.999
0.999/0.999

Polarization-resolved PL of $MoSe_2/Mg(OH)_2$ (S5)



Conclusion

1. It shows the $Mg(OH)_2/MoSe_2$ system is dominated by intralayer exciton.
2. The similar saturation effect indicates the splitting peaks also have high DOS.
3. Future studies will focus on tuning the twist angle to verify the Moiré effect.