

Observation of Robust Exciton Bose Polarons in Two-Dimensional Semiconductor Heterostructures

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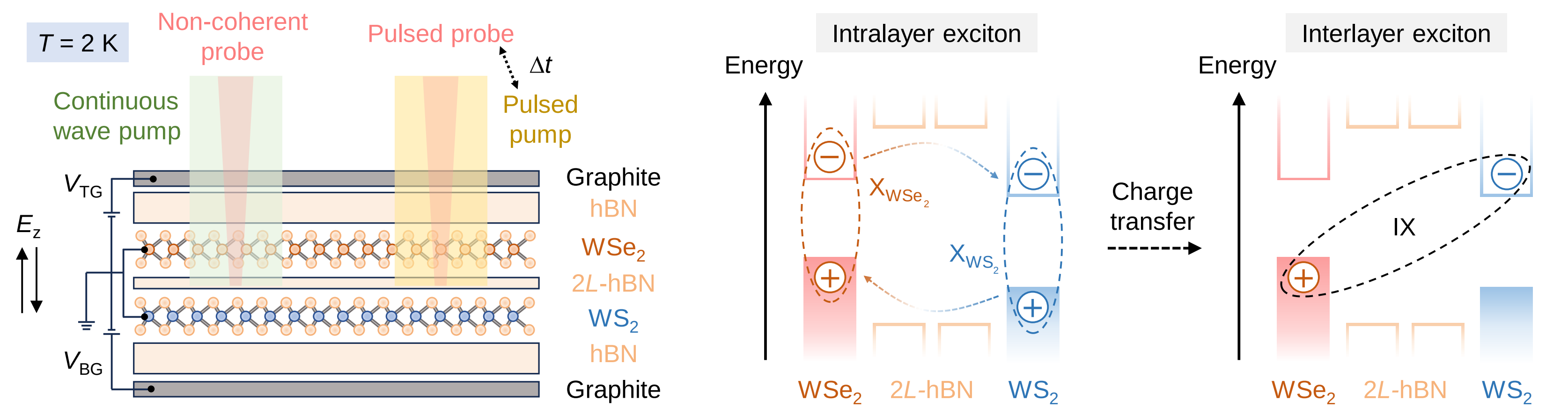


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Abstract

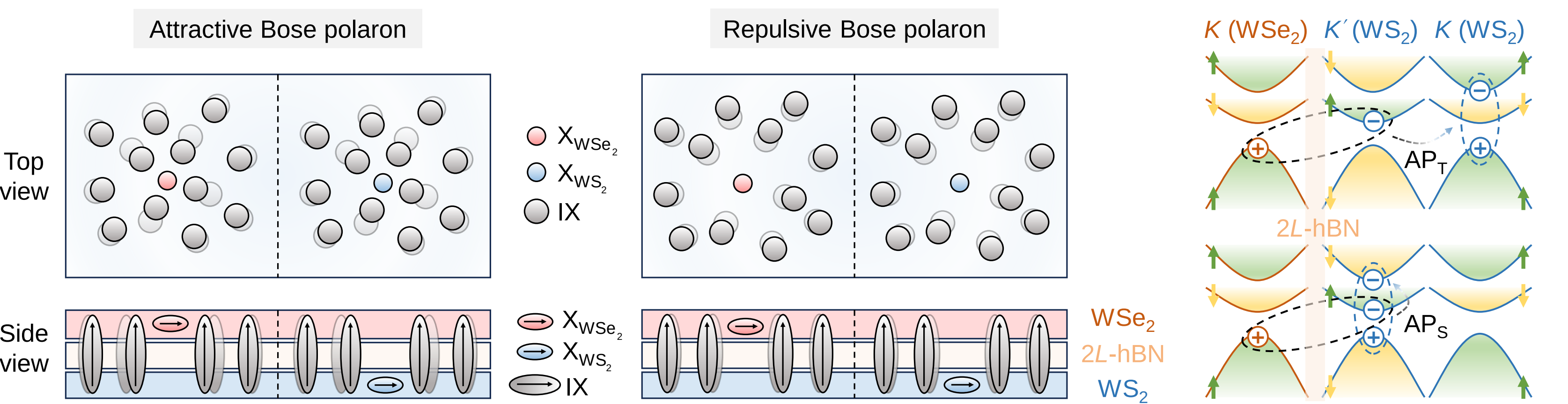
Two-dimensional excitonic quantum matter offers a promising platform for exploring strongly correlated and topological bosonic phases, yet the lack of universal experimental probes remains a major challenge. Inspired by the success of Fermi-polaron spectroscopy in strongly correlated electronic systems, we have **experimentally demonstrated exciton Bose polarons in two-dimensional van der Waals heterostructures**. These quasiparticles emerge when intralayer excitons become dressed by collective excitations of a surrounding interlayer exciton Bose gas, allowing their optical response to encode the many-body properties of the excitonic medium. By combining steady-state and ultrafast pump-probe spectroscopy with electrostatic doping and external electric-field control, we have verified the formation of exciton Bose polarons and investigated their underlying many-body physics. **Our findings establish exciton Bose polaron spectroscopy as a powerful and broadly applicable optical approach for probing correlated excitonic quantum matter**, providing a foundation for future exploration of exotic bosonic phases.

Exciton Formation in the Dual-Gated Device



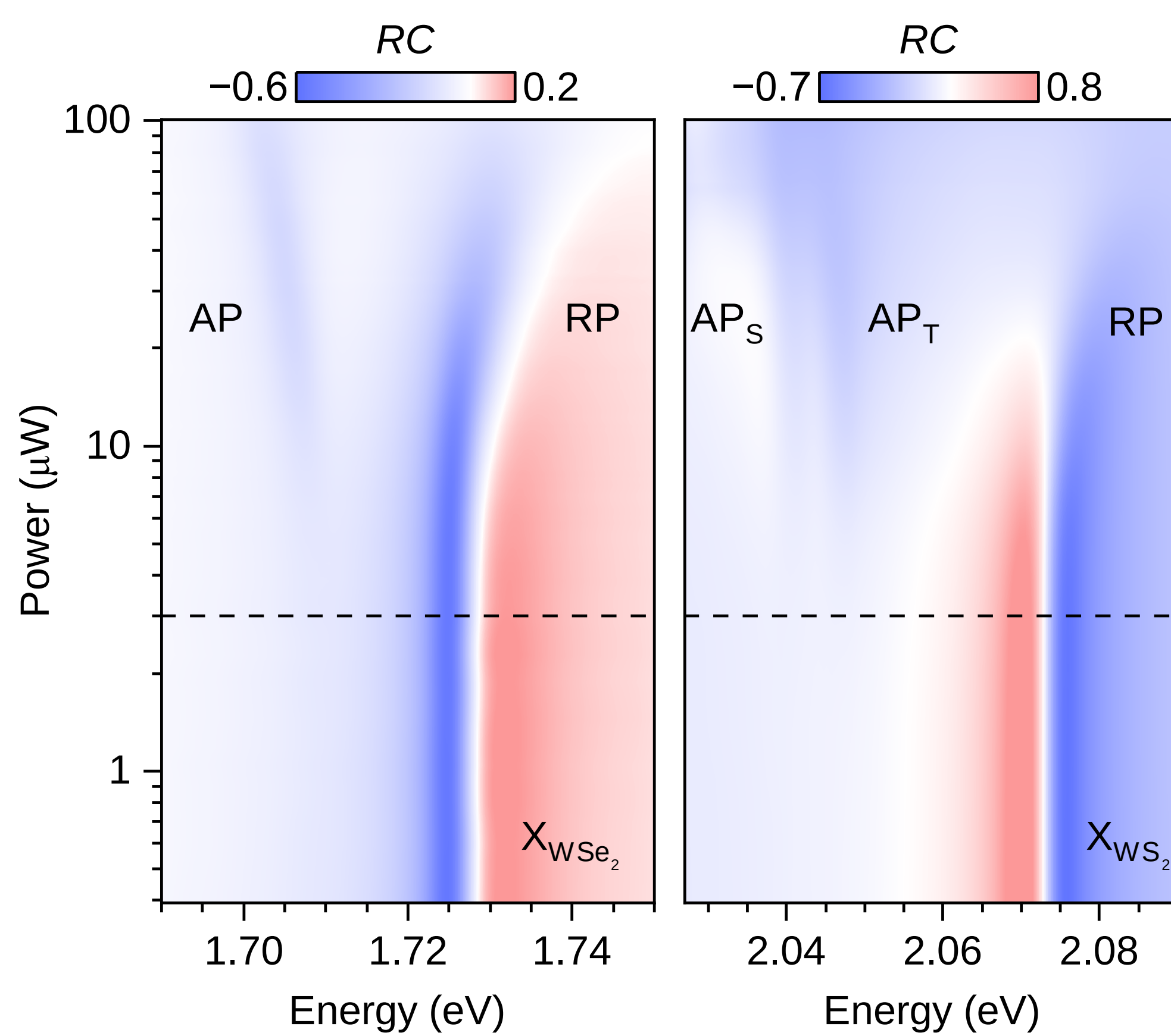
Concept & Design

Schematic of Attractive/Repulsive Exciton Bose Polarons



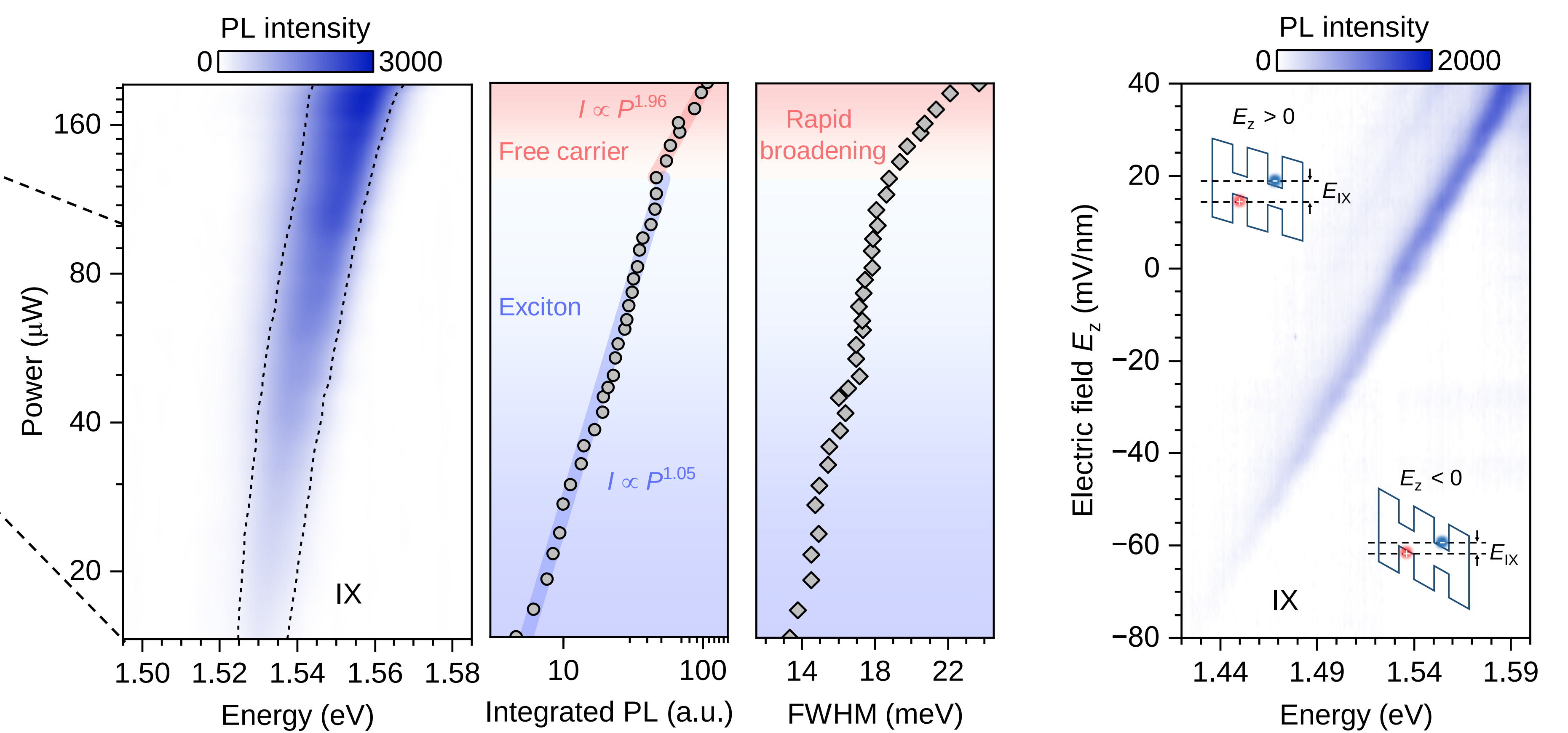
Experimental Results

Signatures of Exciton Bose Polarons in WSe₂/hBN/WS₂



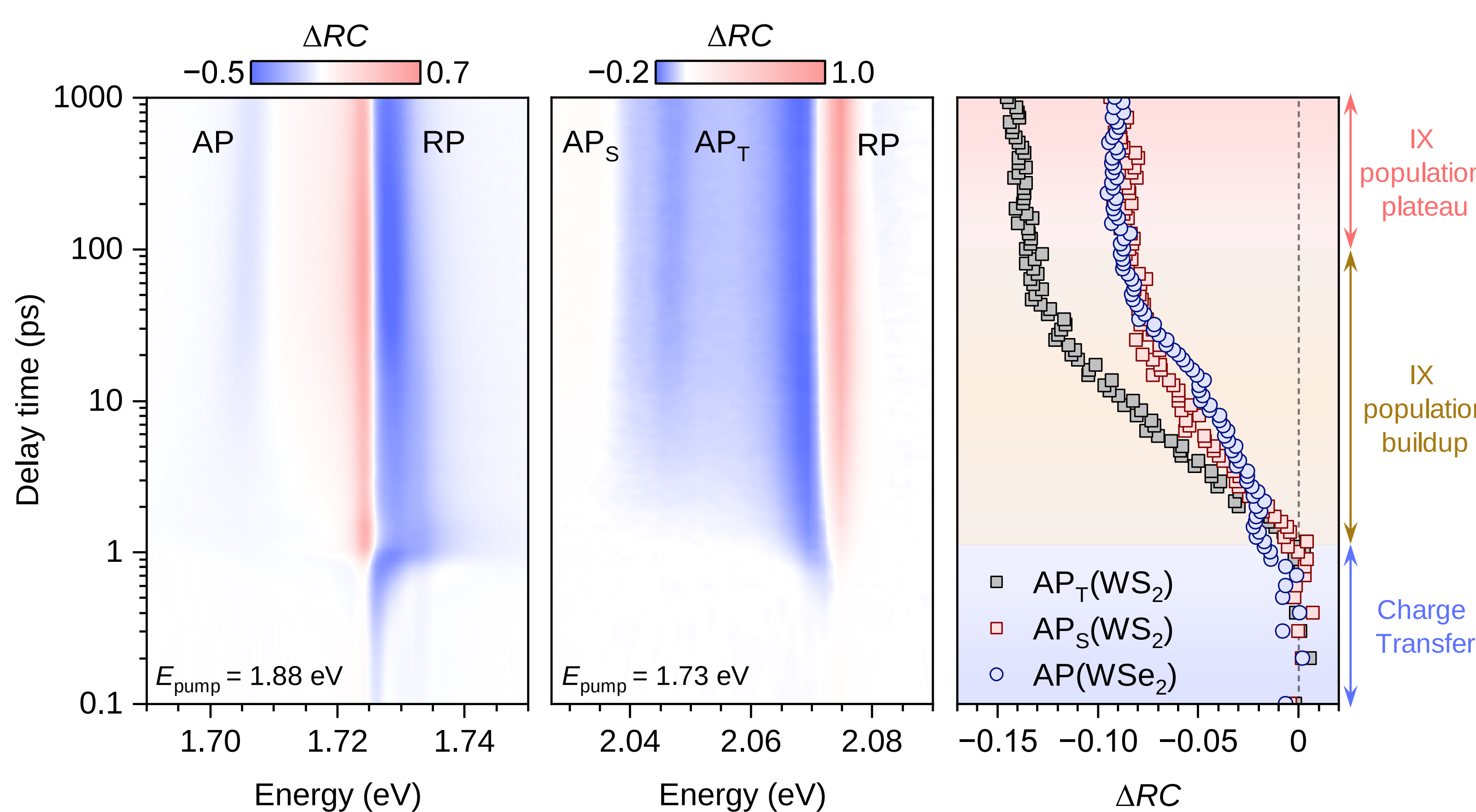
CW pump-probe spectroscopy shows the evolution of attractive/repulsive Bose polarons.

Evidence for Interlayer Exciton Regime Driven Polarons



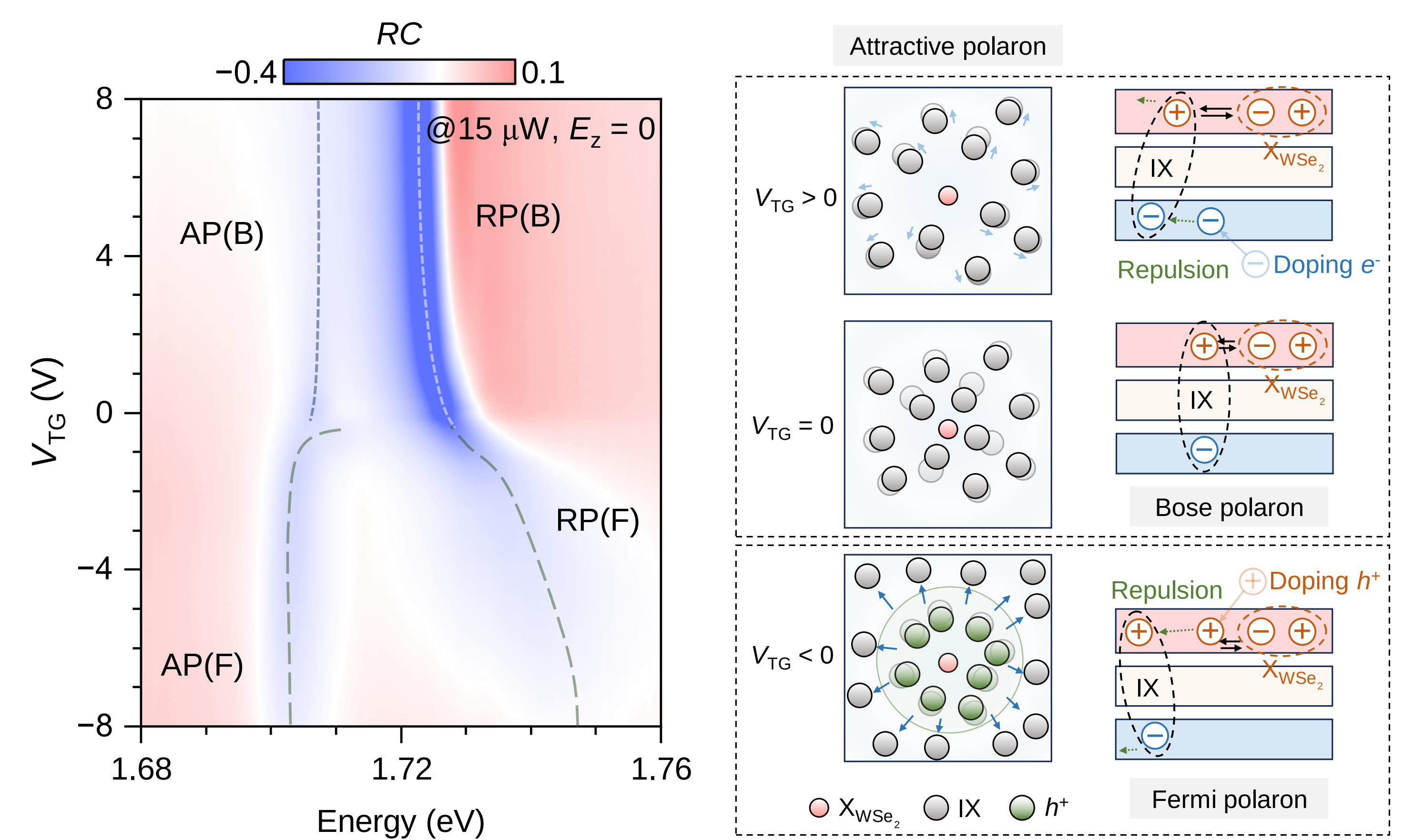
Power-/Electric-field-dependent photoluminescence spectra support the coexistence of IXs and polarons.

Ultrafast Dynamics of Exciton Bose Polarons



Ultrafast pump-probe spectroscopy reveals consistent AP dynamics (related to IX) in WSe₂ and WS₂.

Bose-to-Fermi Polaron Transition



A Bose-to-Fermi polaron transition emerges upon electrostatic hole doping of WSe₂.

Conclusions and Outlook

- Observing **exciton Bose Polarons** in the **dual-gated WSe₂/hBN/WS₂** device.
- Revealing a **Bose-to-Fermi polaron transition** during **electrostatic doping**.
- Exciton Bose polarons could serve as a probe to **address emergent excitonic quantum phase**, e.g., topological exciton insulator and exciton Wigner crystal.

Acknowledgements

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