Attractive dipolar coupling between stacked exciton fluids

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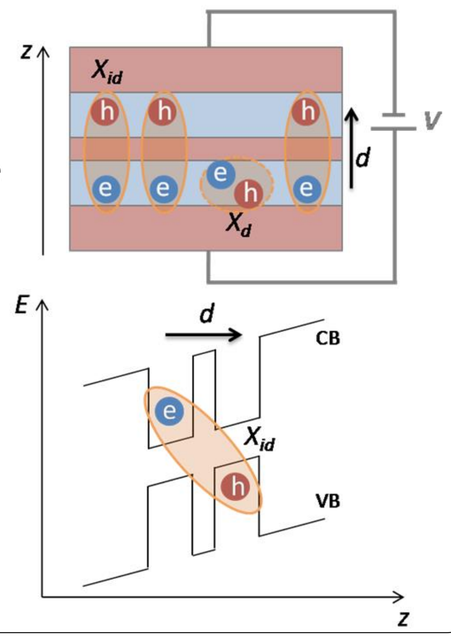
Dipolar excitons

- Excitons are bound electron-hole pairs inside a semiconductor
- Dipolar excitons are created in double quantum wells (DQWs) with external voltage
- Composite bosons
- Low effective mass -> quantum degeneracy at $T \approx 1K$



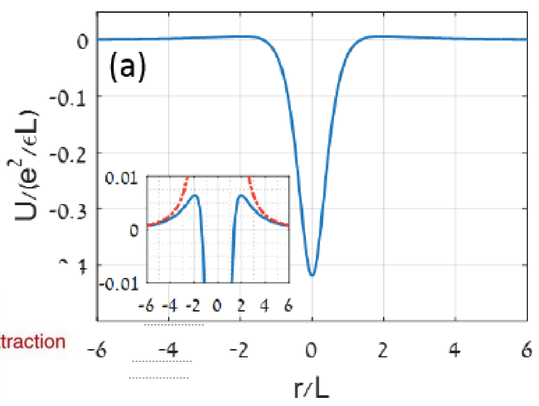
Motivation

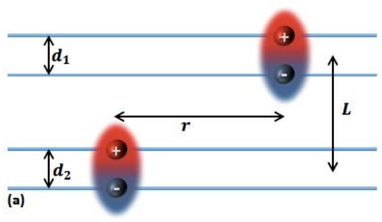
- Explore high density, strong interacting limits in dipolar quantum fluids
- Stacked bilayer structure
- Dipolar bound complexes and new many-body states
- Towards 3D dipolar excitons' correlated states

Theory

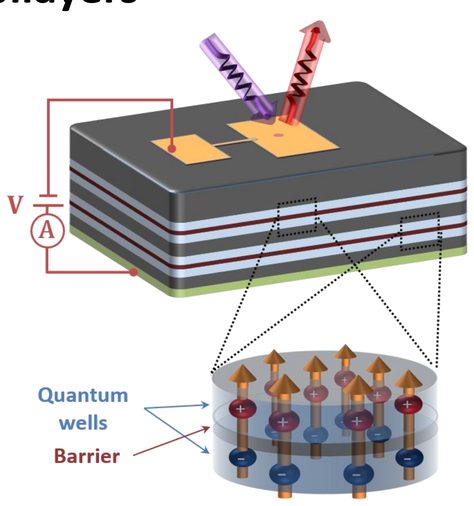
Dipole-dipole interaction

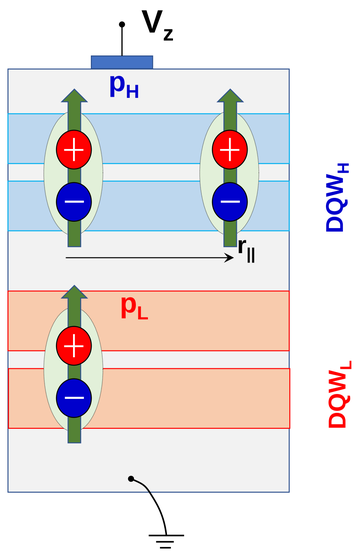
- Long-ranged
- Anisotropic
  - attractive for $r < \sqrt{3}L$
  - repulsive for $r > \sqrt{3}L$



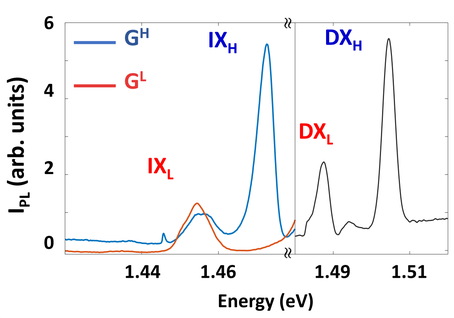


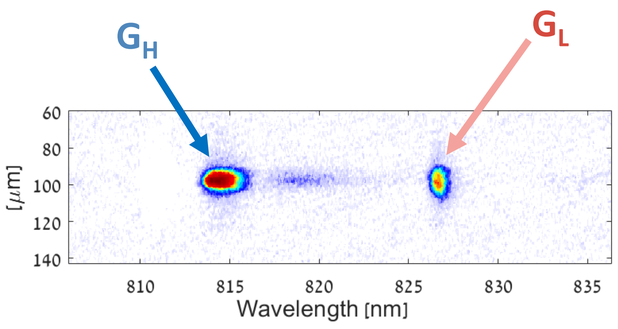
Stacked semiconductor bilayers





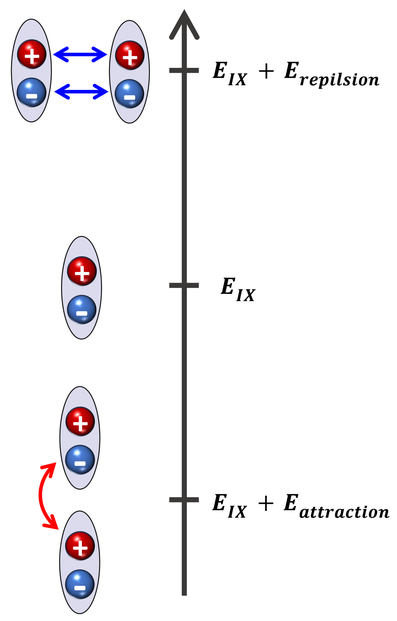
- Different well widths lead to different exciton energies
  → excitation selectivity and spectral separation
  → Measure energy shifts

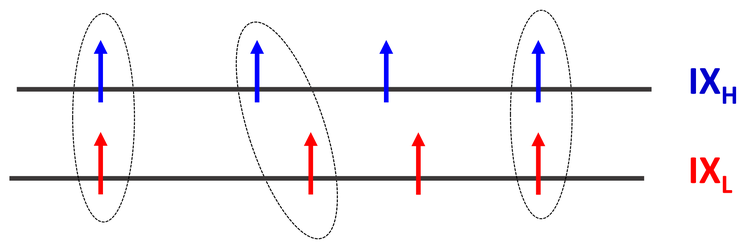




Naïve model: dipolar exciton molecules

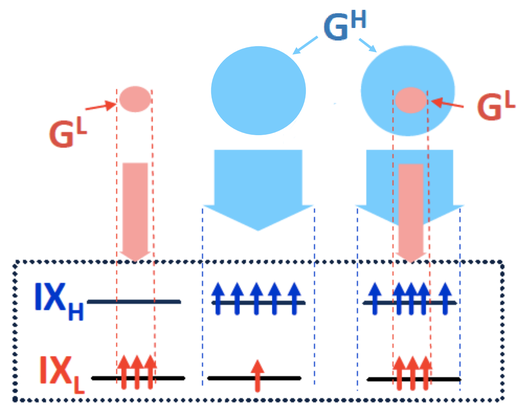
- Two –body dipolar exciton bound state is predicted → "molecules"
- Typical binding energy of a few tenths of meV in GaAs structures

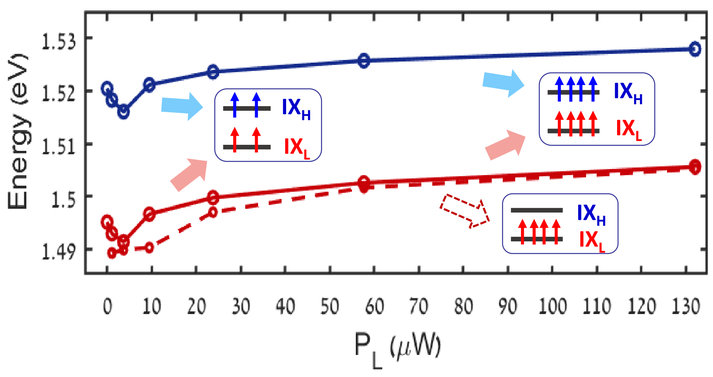


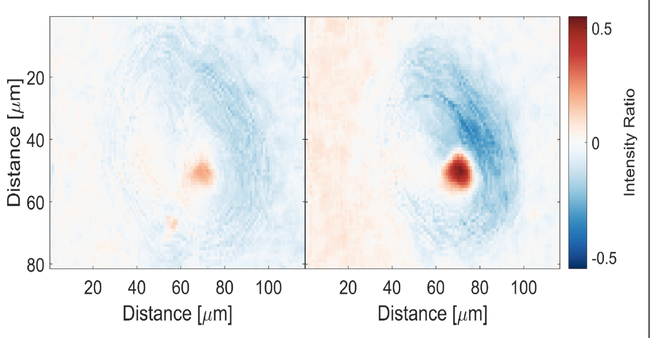


Experiment

- Attractive interaction detected for the first time
- Surprising non-monotonic dependence on the cloud density
  → Important dipolar correlations unique to dense, strongly interacting dipolar solid-state systems







- Energy shifts reaching up to 7 meV, larger than theory predicts for just two-body attraction! → many body effects?

New model: Dipolar polaron model

- Single static dipolar exciton in one layer interacting with an exciton fluid in the other layer
- Mutual deformation of the exciton clouds induced by inter-layer interaction

Weak nonresonant excitation of both layers + strong excitation of IX_L:

→ **Experimental results qualitatively agree with the polaron model!**

Conclusion and Outlook

- The magnitude and density dependence of the energy shift is accounted for by a many-body dipolar polaron model
- Probing inter-layer coupling strengths
- Extend the single-impurity polaron model

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