Spin Currents and Polarization Textures in Optically Generated Indirect Excitons

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Indirect excitons

*Exciton*: bound electron-hole pair

*Properties of Indirect exciton*: electron and hole are confined to spatially separated quantum well layers

*Properties*:
- bosons
- long and controllable lifetime
- built-in dipole moment
- excitons screen disorder
- long-range exciton transport
- control of excitons by voltage: \( \delta E = edF_z \)

These properties allow for
- **basic studies**: exciton transport, spin transport, interaction, kinetics, coherence, condensation, composite bosons in strong magnetic field regime
- **development of excitonic devices**: excitonic transistors, traps, ramps, lattices, conveyers (talk on excitonic devices tomorrow at 12:00 FM3B.5)
Excitons in high magnetic fields: Magnetoexcitons

Strong magnetic field regime for composite bosons:
\[ \hbar \omega_c \geq E_b \]
cyclotron energy \( \geq \) binding energy

This requires
• \( \sim 10^6 \) Tesla for atoms
• \( \sim 10 \) Tesla for excitons

due to large \( \hbar \omega_c = \hbar eB/(\mu c) \)
and small \( E_b \approx (\mu e^4)/(2\varepsilon^4 \hbar^2) \)

because of small mass and \( \varepsilon > 1 \)
strong magnetic field regime for excitons is achieved in the lab

Talk tomorrow on magnetoexcitons at different Landau levels
(12:30 Dynamics in semiconductor QW)

UCSD Optical dilution refrigerator
• 40 mK bath temperature
• 16 Tesla magnetic fields
Exciton pattern formation

Excitons are created at the interface between electron rich regions and hole rich regions.

Spin currents in a coherent exciton gas

- Long range spin currents
- Ballistic exciton transport with coherent spin precession

Polarization textures

<table>
<thead>
<tr>
<th></th>
<th>B = 0</th>
<th>large B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear polarization</td>
<td>Vortex</td>
<td>Spiral</td>
</tr>
<tr>
<td>Circular polarization</td>
<td>Four-leaf</td>
<td>Bell-like with inversion</td>
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\[ E_{\text{ex}} = \frac{1}{2} e, -\frac{3}{2} h \]

A.A. High et al, PRL. 110, 246403 (2013)
Radial exciton polarization currents are associated with spin currents carried by electrons and holes bound into excitons. Electron and hole spin patterns tend to align along the effective magnetic fields given by the Dresselhaus SO interaction.

References:
while the spin relaxation times of free electrons and holes can be short, the formation of a coherent gas of their bosonic pairs results in a strong enhancement of their spin relaxation times, facilitating long-range spin currents.

AA High, et al., PRL (2013)
LBS and external ring: limited control by light

Time-resolved measurements of LBS and external ring yield kinetics of front propagation rather than exciton kinetics.

Measurements of spin current kinetics and optical control of spin currents require realization of spin currents generated by the optical excitation beam.

However, the optical excitation beam heats the exciton gas, so can we have cold optically created excitons?

Cold exciton gas in the inner ring

excitons cool as they travel away from the excitation spot 
→ increased occupation of radiative zone 
→ enhancement of PL intensity 
→ inner ring

Spin currents in exciton inner ring

Consistent with results for coherent spin currents in LBS region due to ballistic exciton propagation with coherent spin precession

\[ P_{lin} = \frac{(I_x - I_y)}{(I_x + I_y)} \]

\[ P_{\sigma} = \frac{(I_+ - I_-)}{(I_+ + I_-)} \]
Spin currents in exciton inner ring vs B

B=0T

$P_{\text{lin}}$

$P_{\text{circ}}$

10µm
Spin currents in exciton inner ring

Linear polarization: function of angle at $r = 12 \, \mu m$

Circular polarization: cut through the center at $x = 0$

$B = 6T$

$P_{\text{lin}}$

$P_{\sigma}$
Coherence measurements: are spin textures correlated with coherence as in LBS region?

Energy-resolved spin patterns
Preliminary results:

Outlook
Potential for optical control and kinetics measurement of spin currents
Conclusion

- Observed long range spin currents in optically generated indirect excitons
- Observed vortex, spiral, four-leaf, and bell-like with inversion polarization textures