Indirect excitons in high magnetic fields

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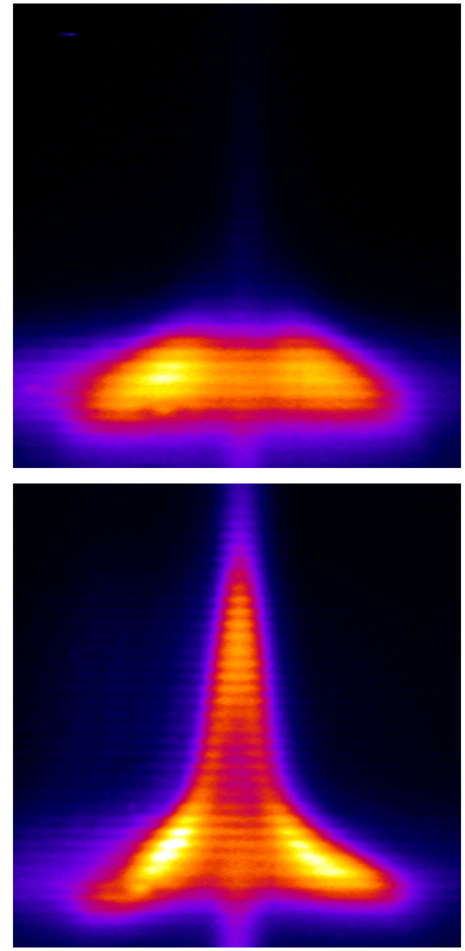

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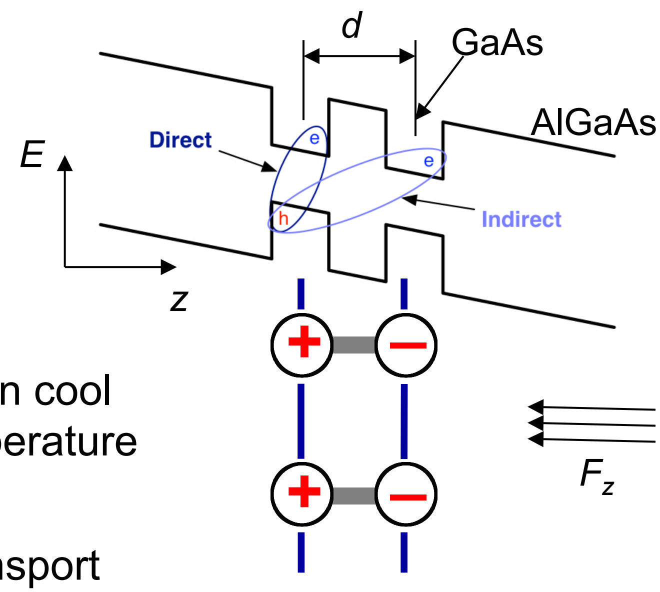
Indirect excitons

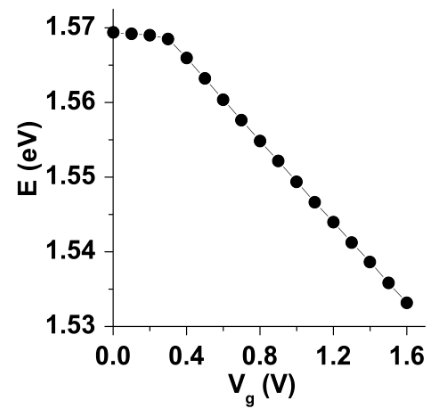
Exciton: bound electron-hole pair

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



Properties:

- bosons
- long and controllable lifetime → excitons can cool to low temperature; → long-range exciton transport
- 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

Excitons in high magnetic fields: Magnetoexcitons

Strong magnetic field regime for composite bosons:
$\hbar\omega_c \geq E_b$
cyclotron energy ≥ binding energy

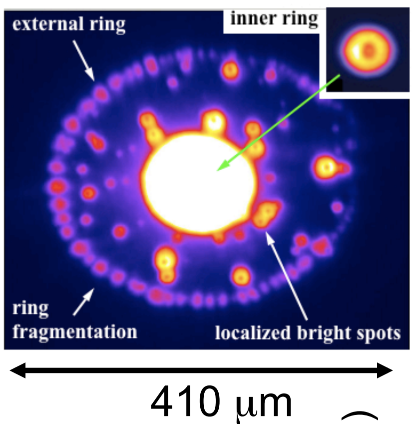
This requires
- ~ 10^6 Tesla for atoms
- ~ 10 Tesla for excitons

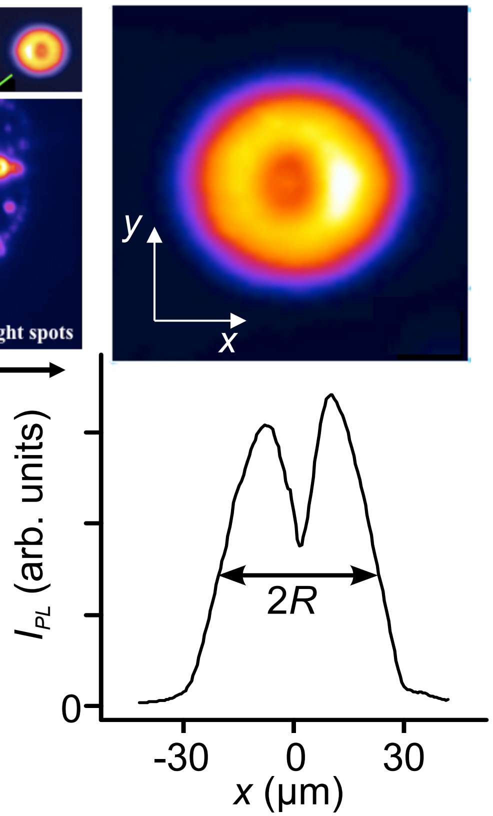
due to large $\hbar\omega_c = \hbar eB/(\mu c)$
and small $E_b \approx (\mu e^4)/(2\varepsilon^4 \hbar^2)$

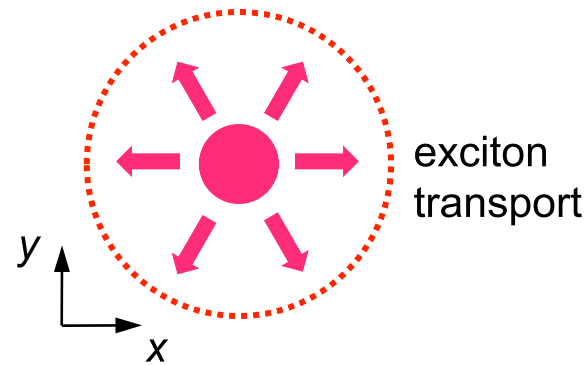
because of small mass and $\varepsilon > 1$
strong magnetic field regime for excitons is achieved in the lab

Optical dilution refrigerator
- 40 mK bath temperature
- 16 Tesla magnetic fields

Inner ring in the exciton emission pattern





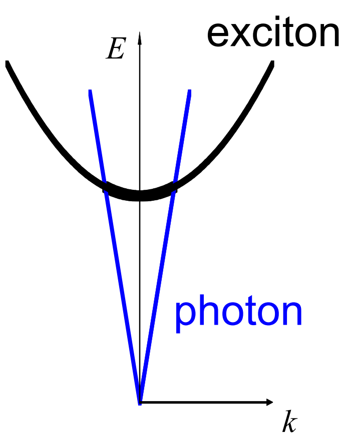


excitons cool as they travel away from the excitation spot
→ increased occupation of radiative zone
→ enhancement of PL intensity
→ inner ring

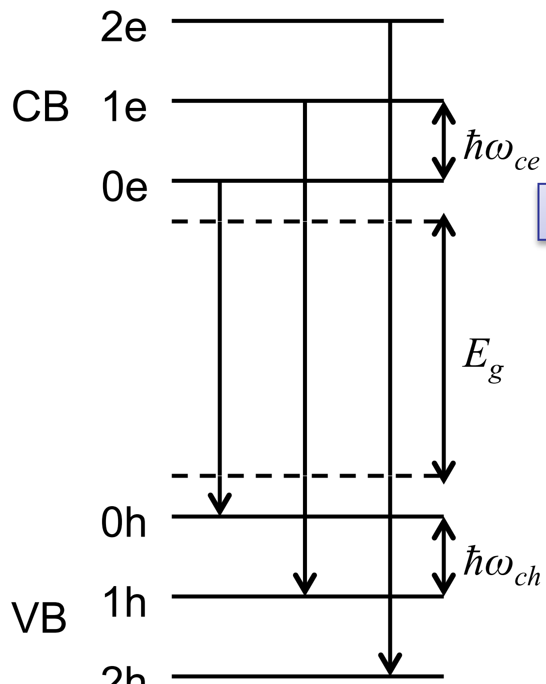
L.V. Butov *et al*, *Nature* **418**, 751 (2002)
A.L. Ivanov *et al, EPL* **73**, 920 (2006)
A.T. Hammack *et al, PRB* **80**, 155331 (2009)
Y.Y. Kuznetsova *et al, PRB* **85**, 165452 (2012)

Excitons in high magnetic fields

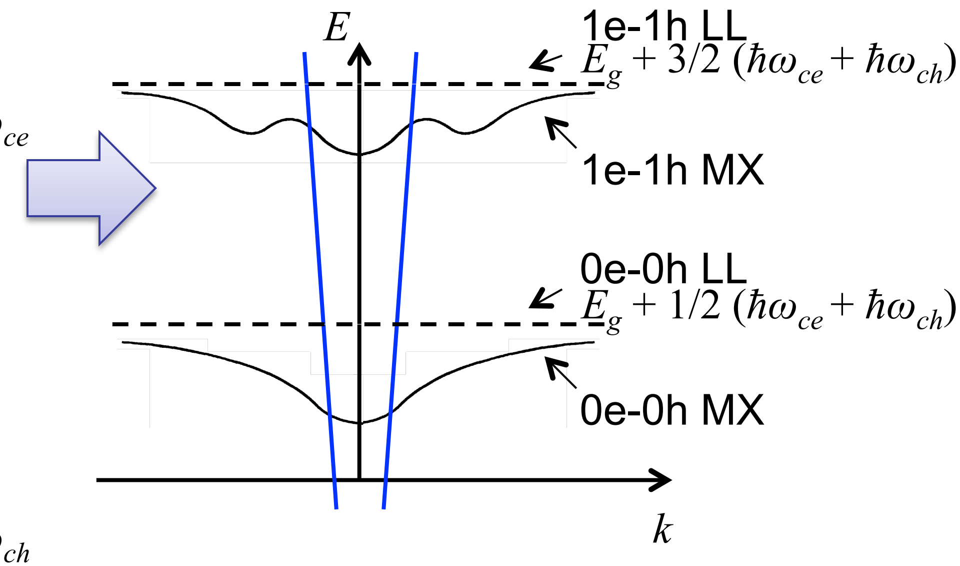
B = 0



High B
Landau levels for e and h



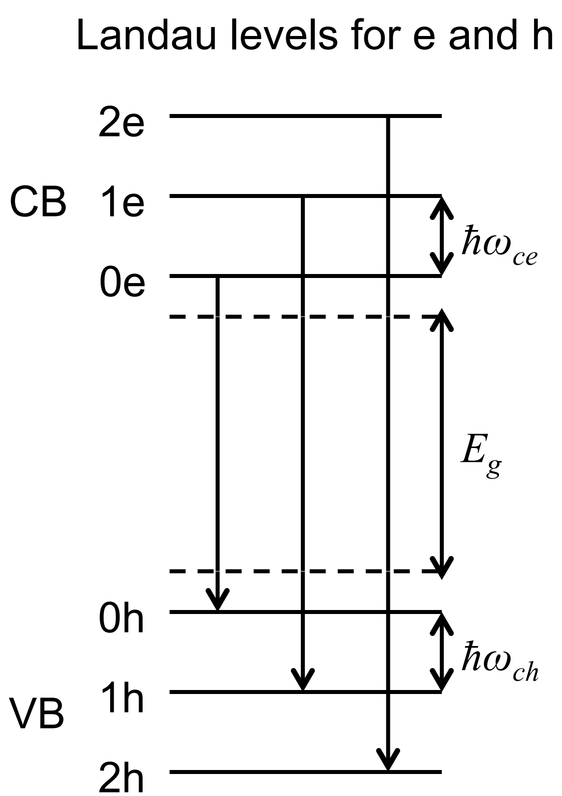
magnetoexciton

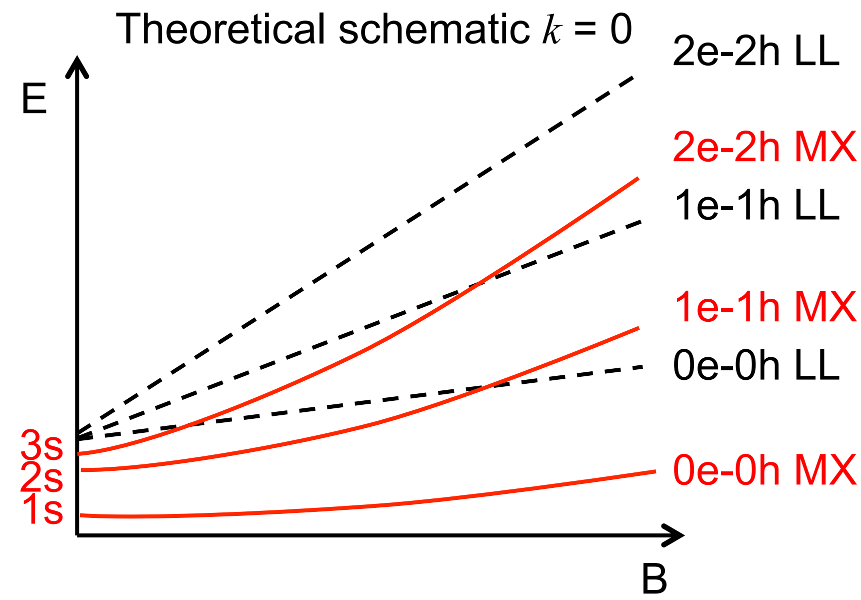


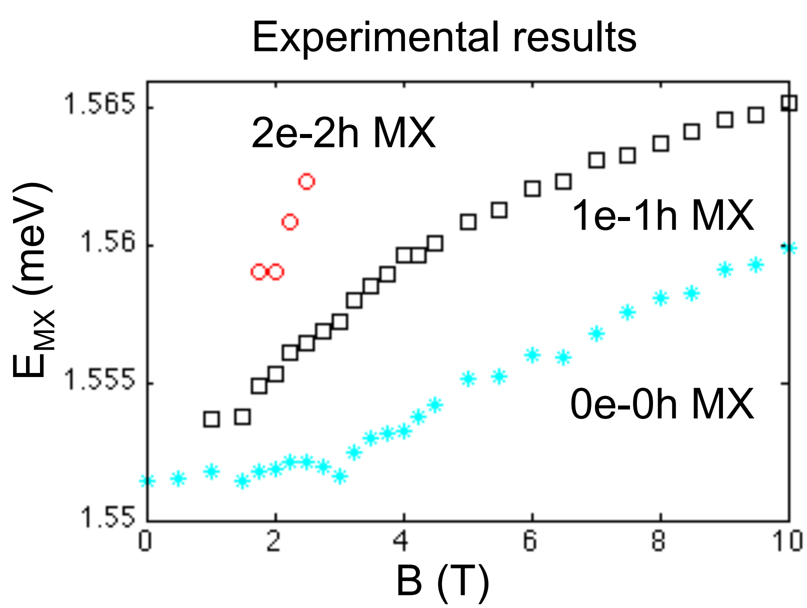
Can use excitation power to control filling factor $\nu = n/n_0$ even at constant B

3D ME: L. P. Gor'kov and I. E. Dzyaloshinskii, JETP **26**, 449 (1968)
2D ME: I. V. Lerner and Yu. E. Lozovik, JETP **51**, 588 (1980)
Finite B 2D ME: Lozovik *et al,* PRB **65**, 235304 (2002)

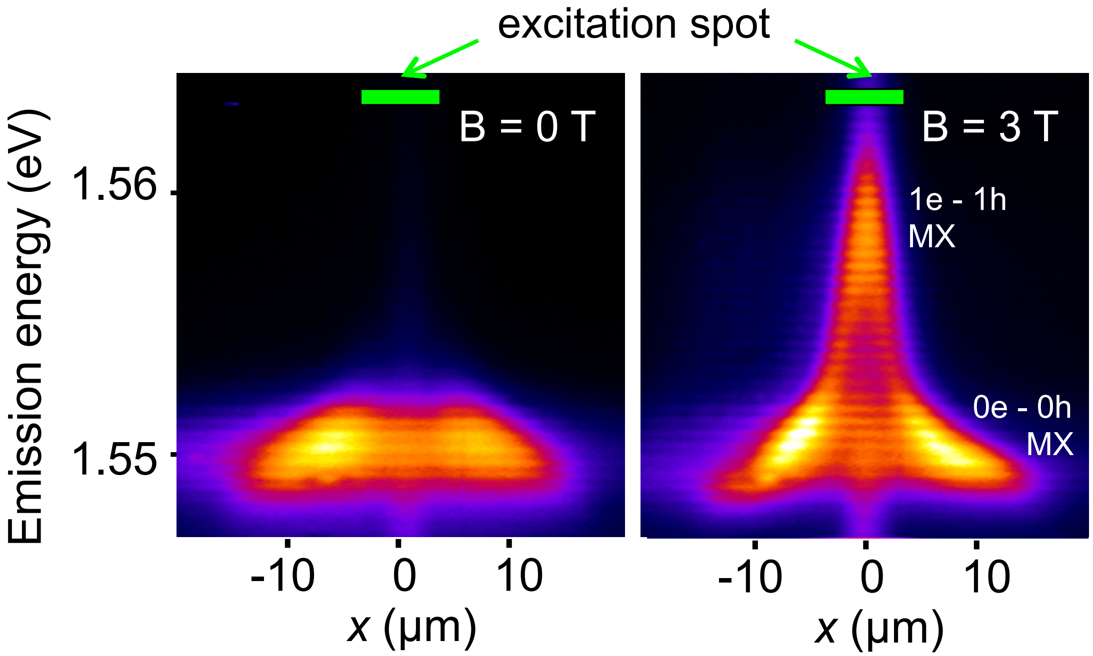
Excitons in high magnetic fields

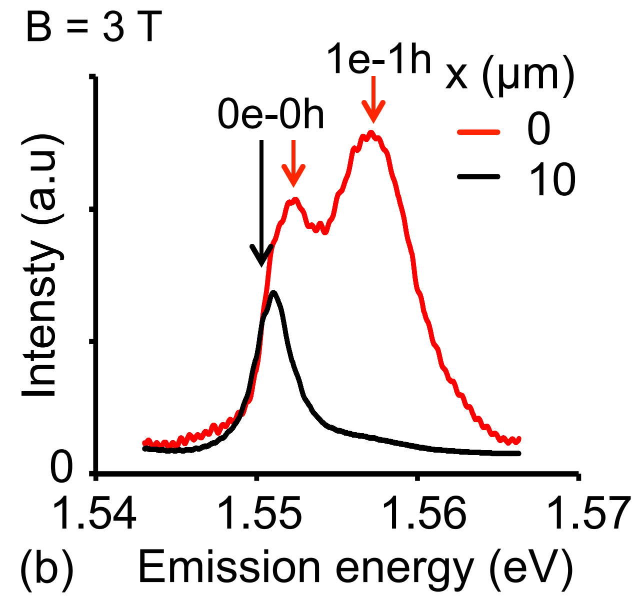


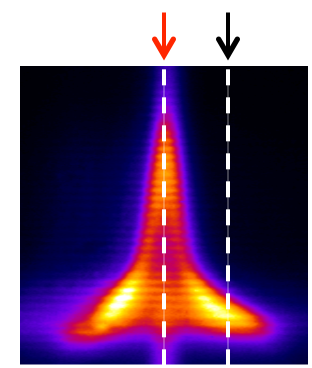




Exciton emission pattern in high magnetic fields





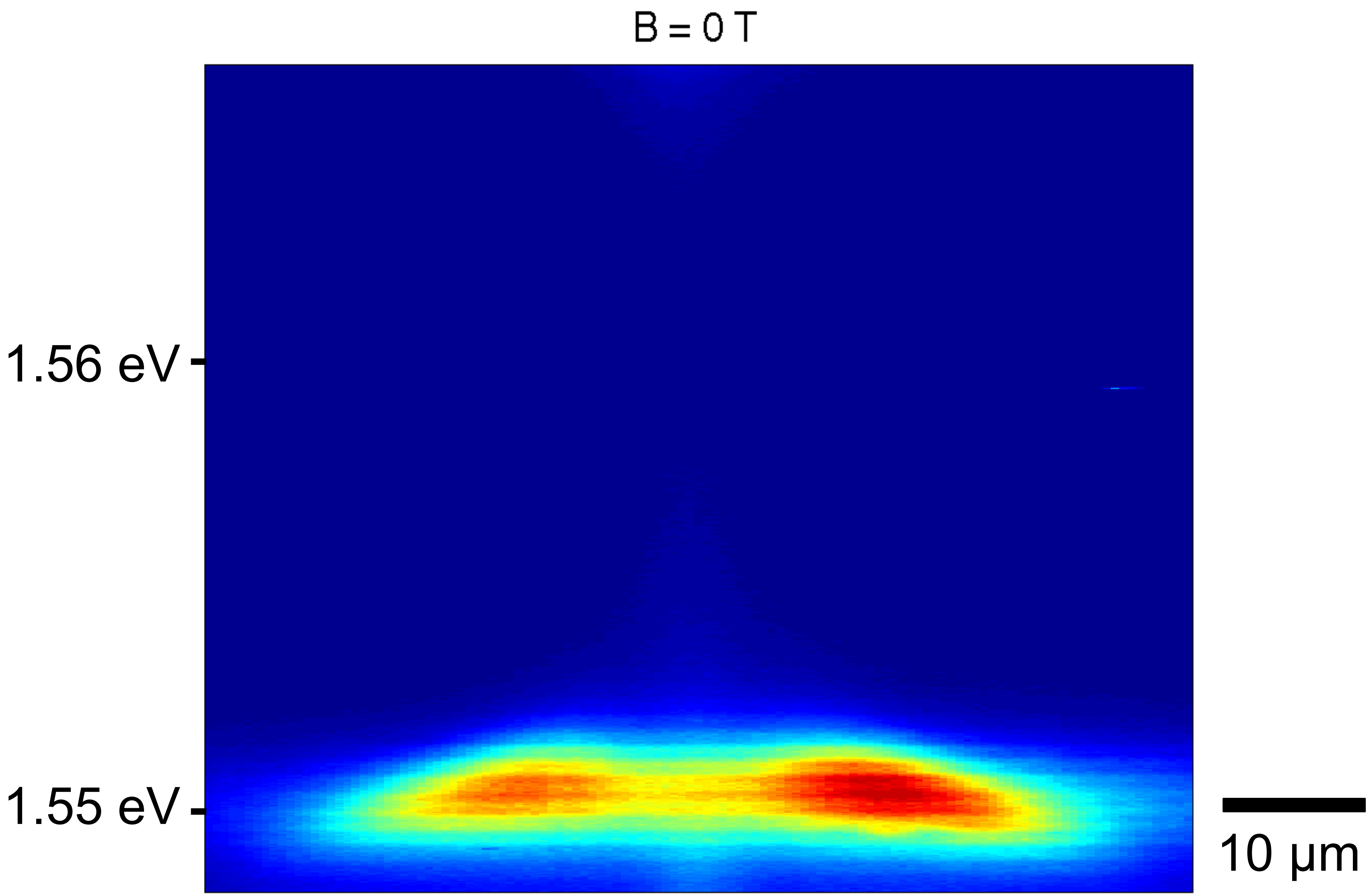


0e - 0h MX PL extends beyond the excitation spot
→ magnetoexciton transport

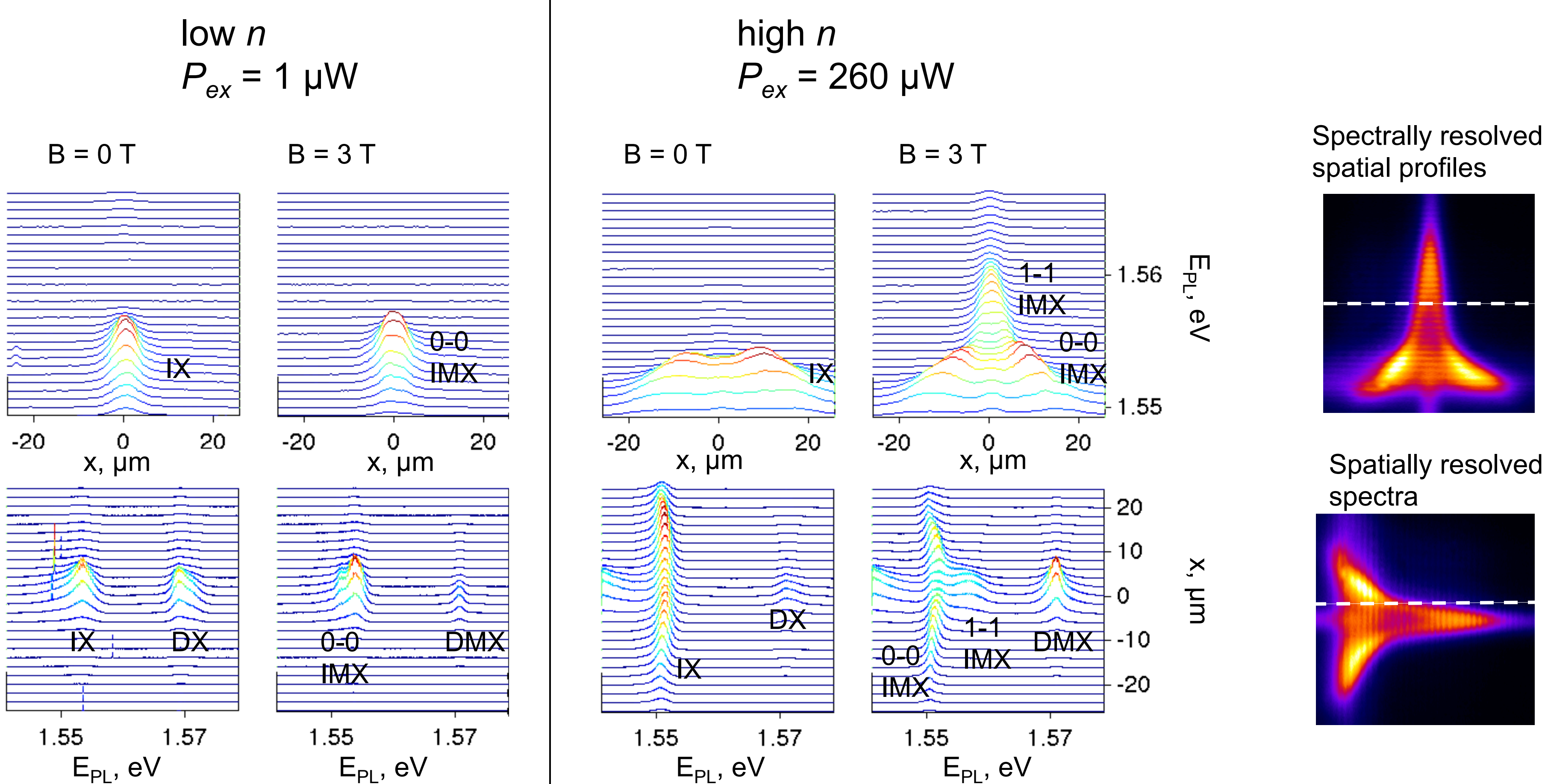
0e - 0h MX PL intensity enhanced outside the excitation spot
→ magnetoexciton inner ring

1e - 1h MX transport distance is smaller than for 0e - 0h MX
→ energy relaxation and density decay

Exciton emission pattern in high magnetic fields

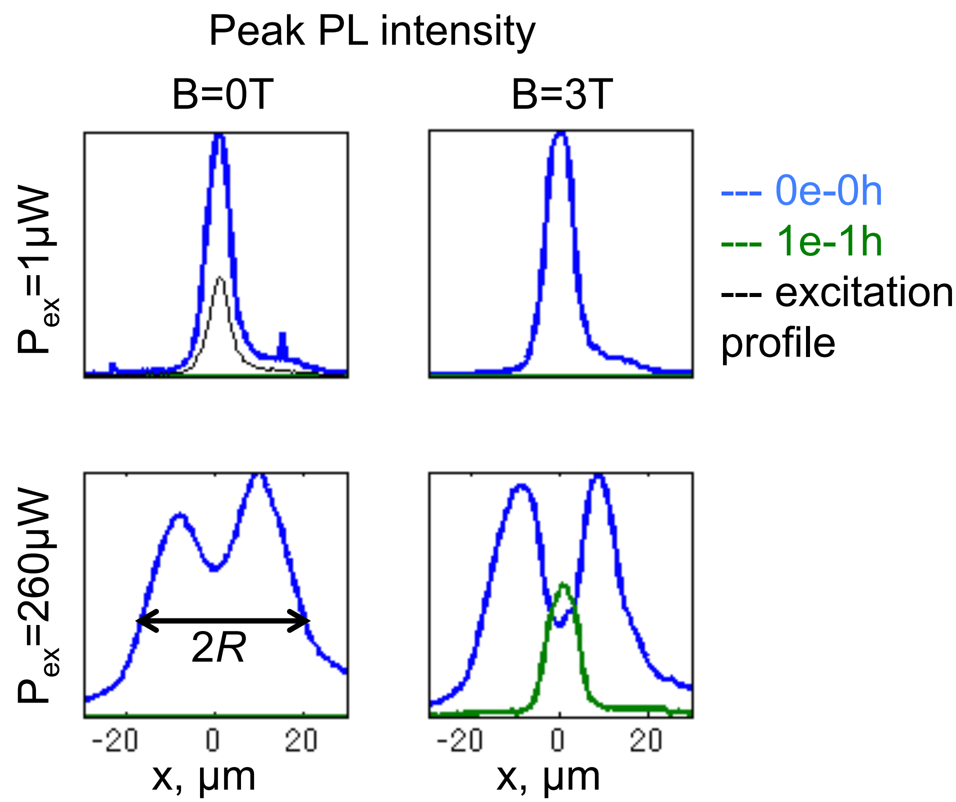


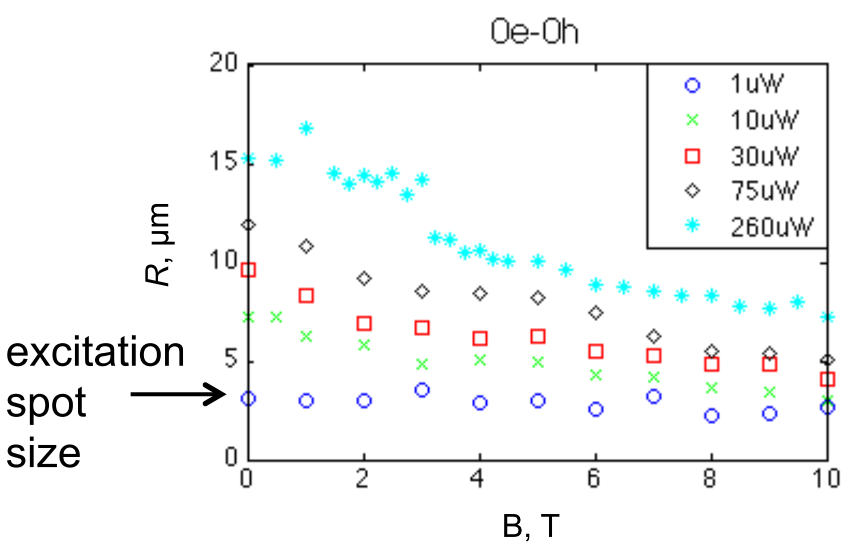
Spatial and energy profiles of indirect magnetoexciton emission

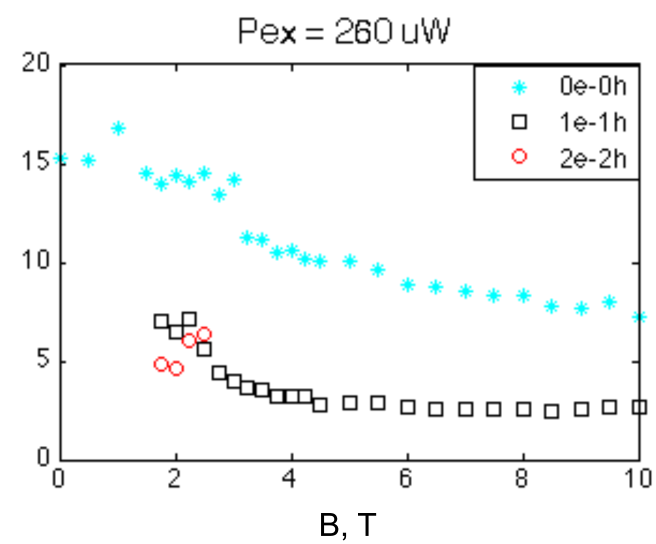


Kinetics of indirect magnetoexcitons

- At low densities, MX localized
  At high densities, MX delocalized
- MX transport length decreases with increasing *B*
- 0e-0h MX PL: ring shape
  1e-1h and 2e-2h MX PL: bell-like shape
- 0e-0h MX travel farther than 1e-1h and 2e-2h MX







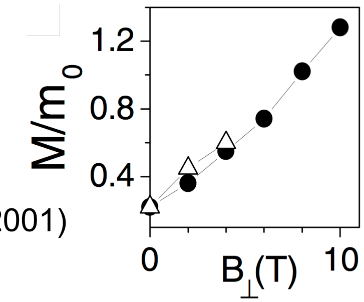
Kinetics of indirect magnetoexcitons

- At low densities, MX localized
  At high densities, MX delocalized

→ disorder screening

- MX transport length decreases with increasing *B*

→ effective mass increase
L.V. Butov *et al*, PRL **87** 216804 (2001)

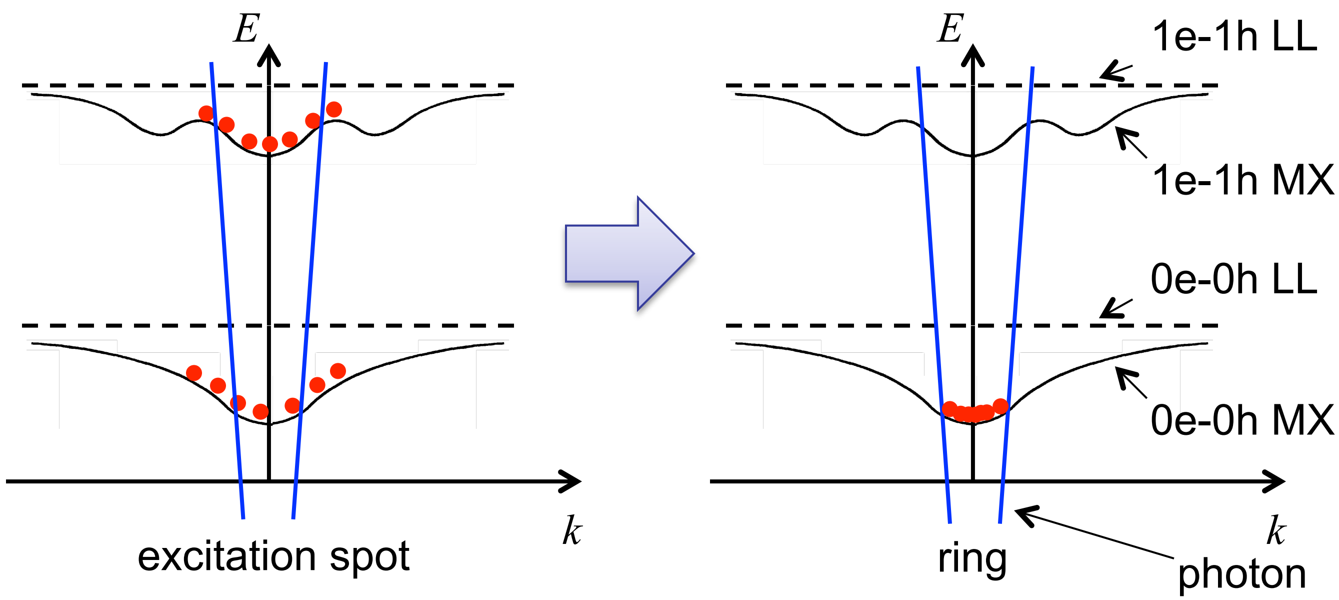


- 0e-0h MX PL: ring shape
  1e-1h and 2e-2h MX PL: bell-like shape

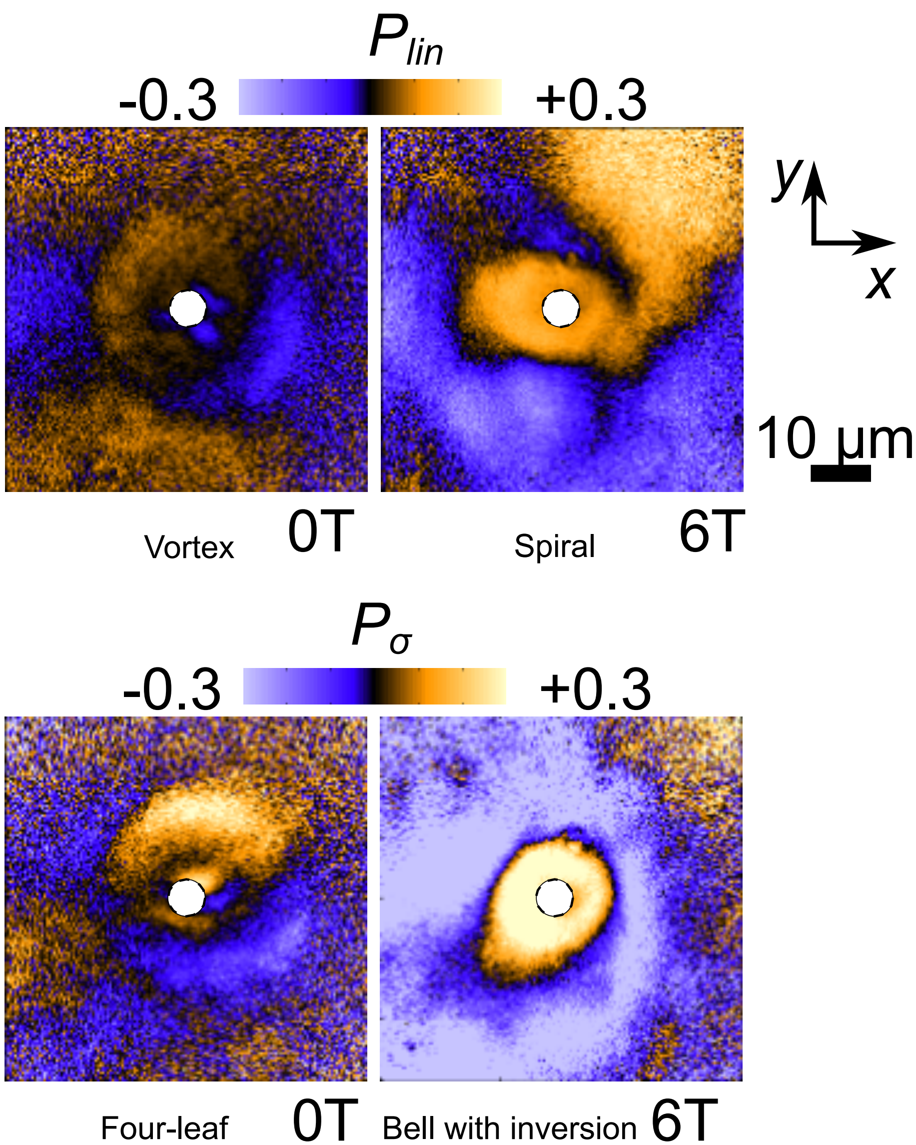
→ increased occupation of radiative zone away from excitation spot

- 0e-0h MX travel farther than 1e-1h and 2e-2h MX

→ energy relaxation and density decay



Poster MoP23: Spin currents in exciton inner ring



Inner ring polarization patterns

	B = 0	**large B**
linear	Vortex	Spiral
circular	Four-leaf	Bell-like with inversion

Conclusions

- At low densities, magnetoexcitons are localized.

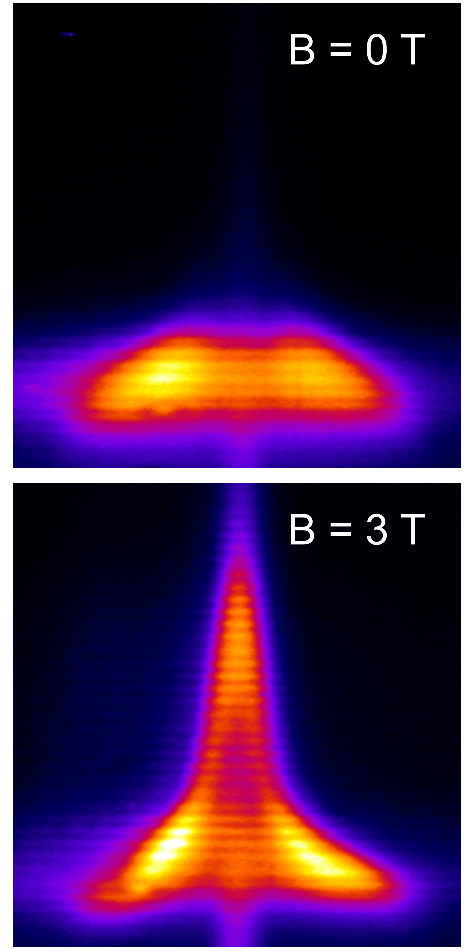
  At high densities, magnetoexcitons are delocalized: magnetoexciton transport.

- Magnetoexciton transport length decreases with increasing magnetic field.

- 0e-0h magnetoexciton PL has ring shape.

  1e-1h and 2e-2h magnetoexciton PL has bell-like shape.

- 0e-0h magnetoexcitons have higher transport distance than 1e-1h and 2e-2h magnetoexcitons.



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