Optical properties of II-VI semiconductor quantum dots (QDs): Observation of optical Aharonov-Bohm (AB) oscillation and formation of magnetic polaron (MP) in ZnMnTe/ZnSe QDs

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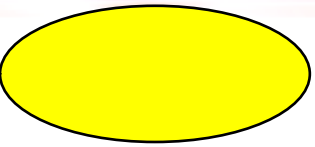
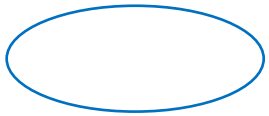
Motivation: optical properties of epitaxial grown QD

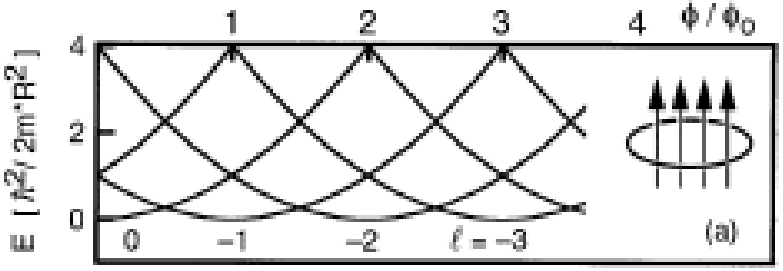


Magnetic semiconductor QD (type-II QD)

Electron orbit



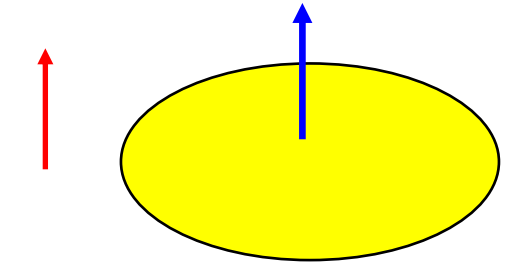
Hole orbit



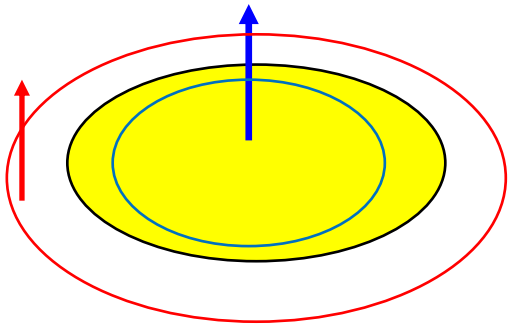
Magnetic flux Δφ
φ_0 =flux quanta

electron

hole

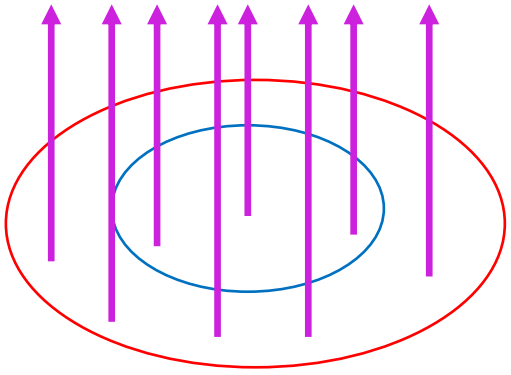


Magnetic field B=0



Magnetic field B>0

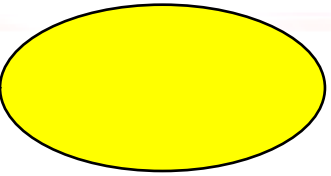
$$E_{exc} = E_g + \frac{\hbar^2}{2MR_0^2}\left(L + \frac{\Delta\Phi}{\Phi_0}\right)^2,$$



Magnetic field B>0

Observation of optical Aharonov-Bohm oscillation

Motivation: optical properties of epitaxial grown QD



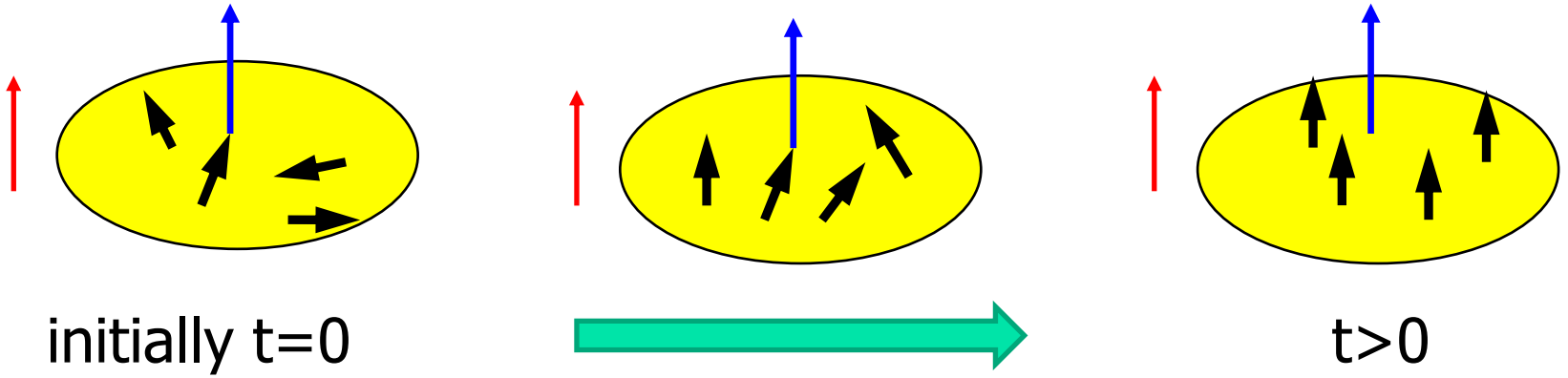
Magnetic semiconductor QD

Mn^{2+} spin

electron

hole

Time resolved photoluminescence is sensitive to probe MP.



initially t=0

t>0

Right after pulse laser excitation

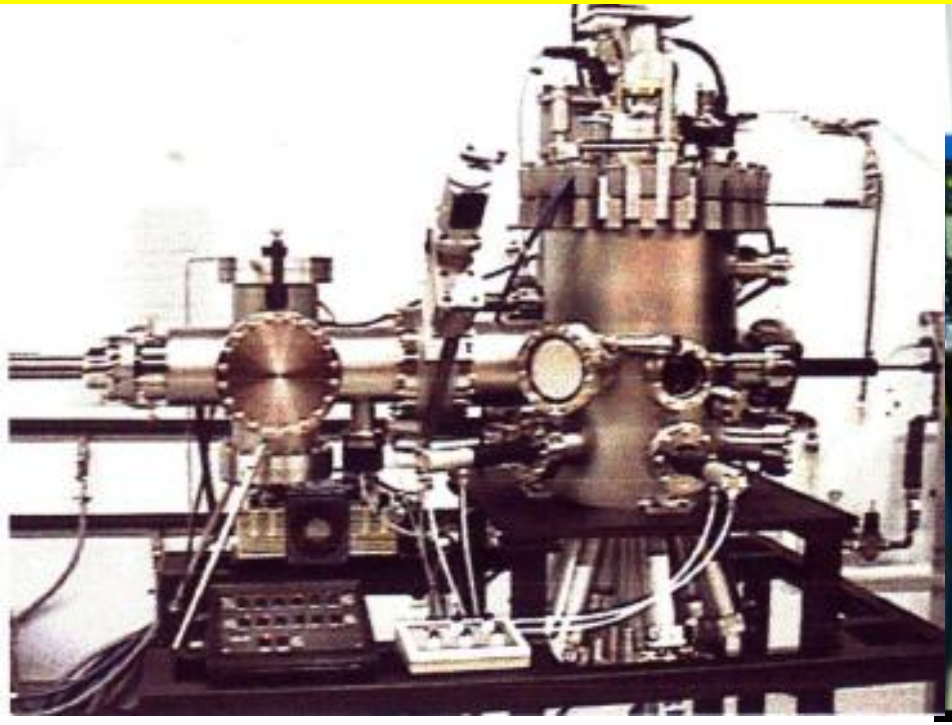
Exchange interaction between hole spin and manganese ion spin

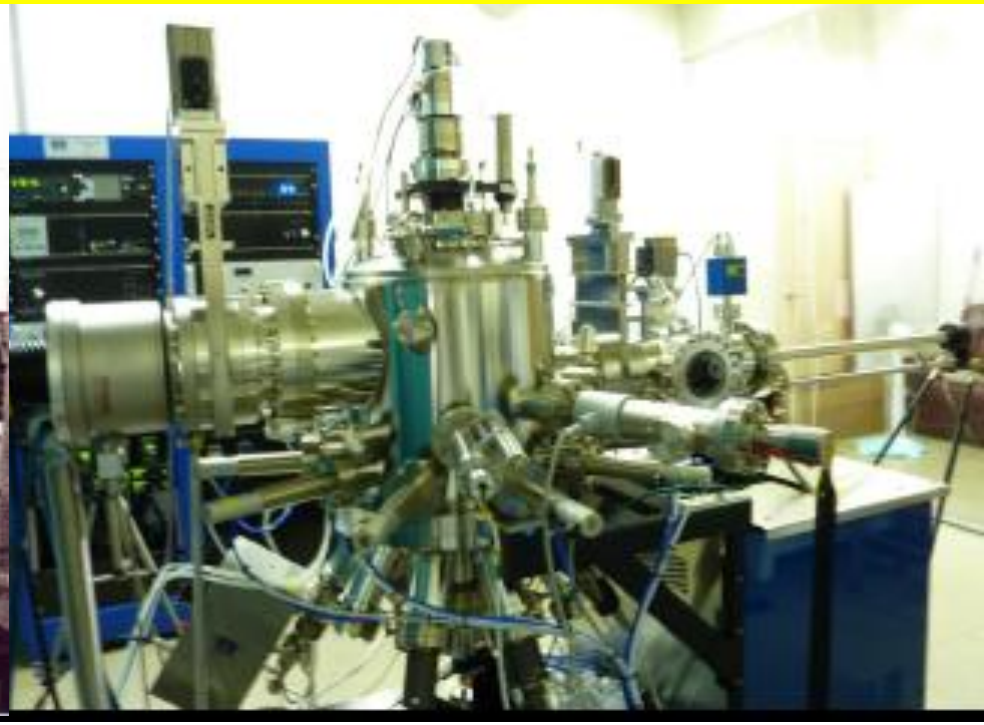
Exciton emission energy decreases with time.

Formation of magnetic polaron (MP).

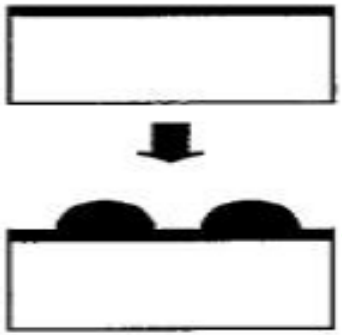
Growth of ZnMnTe magnetic QDs in ZnSe matrix by molecular beam epitaxy

What kind of type-II quantum dots (QDs)? How to grow them?



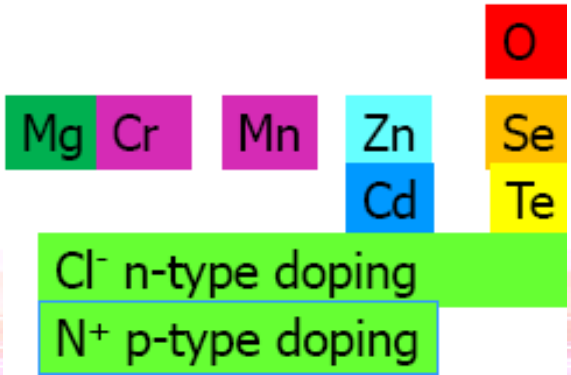


Veeco EPI 620
molecular beam epitaxy (MBE) system



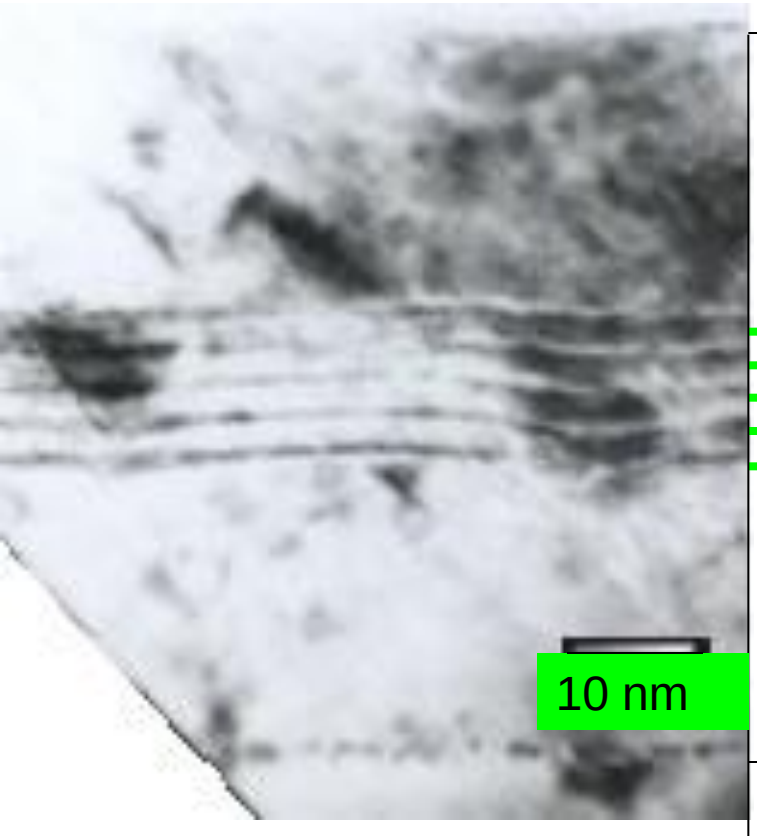
Self-assembled
Quantum dots (QDs)

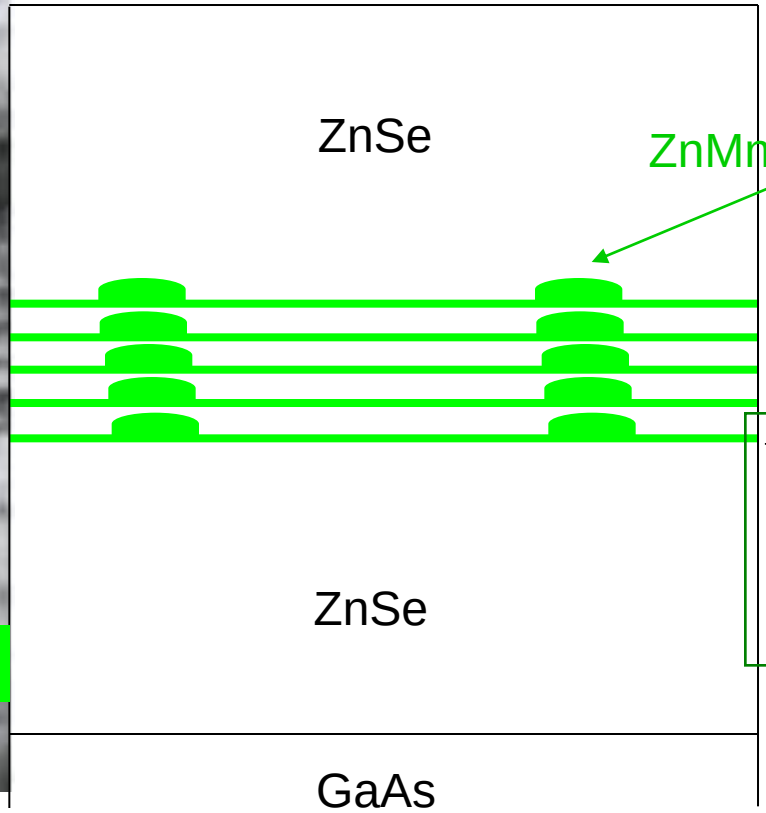
SVT (MBE) system



Growth of ZnMnTe magnetic QDs in ZnSe by molecular beam epitaxy

Cross-section TEM of 2.6 ML ZnMnTe MQDs



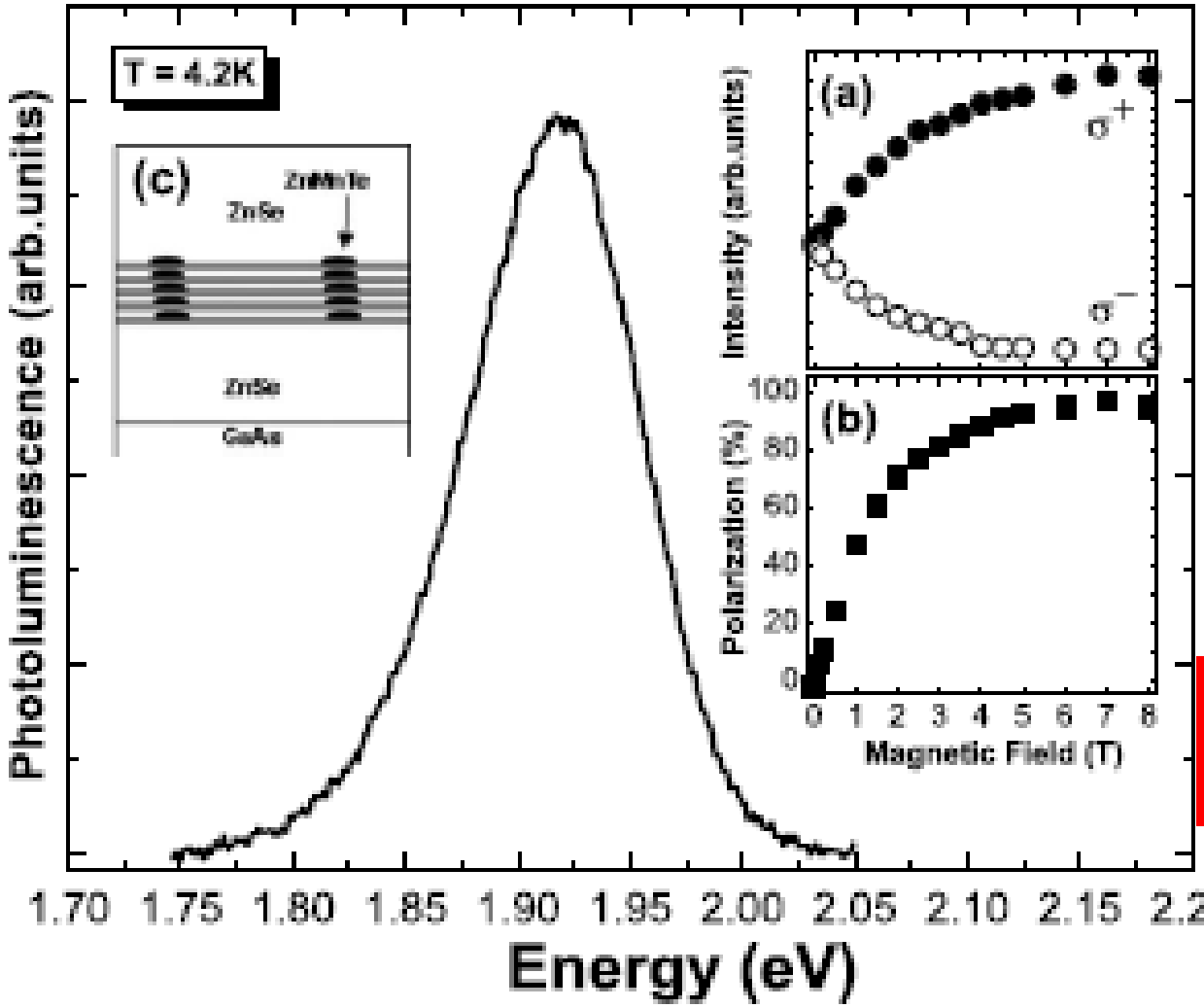


Wetting layer
2.6 monolayers
~1.0 nm

Stranski-Krastanow (SK), 2-D to 3D growth mode

Vertical correlation.

Coherent Aharonov-Bohm oscillation in ZnMnTe/ZnSe quantum dots PRB77, 241302(2008)



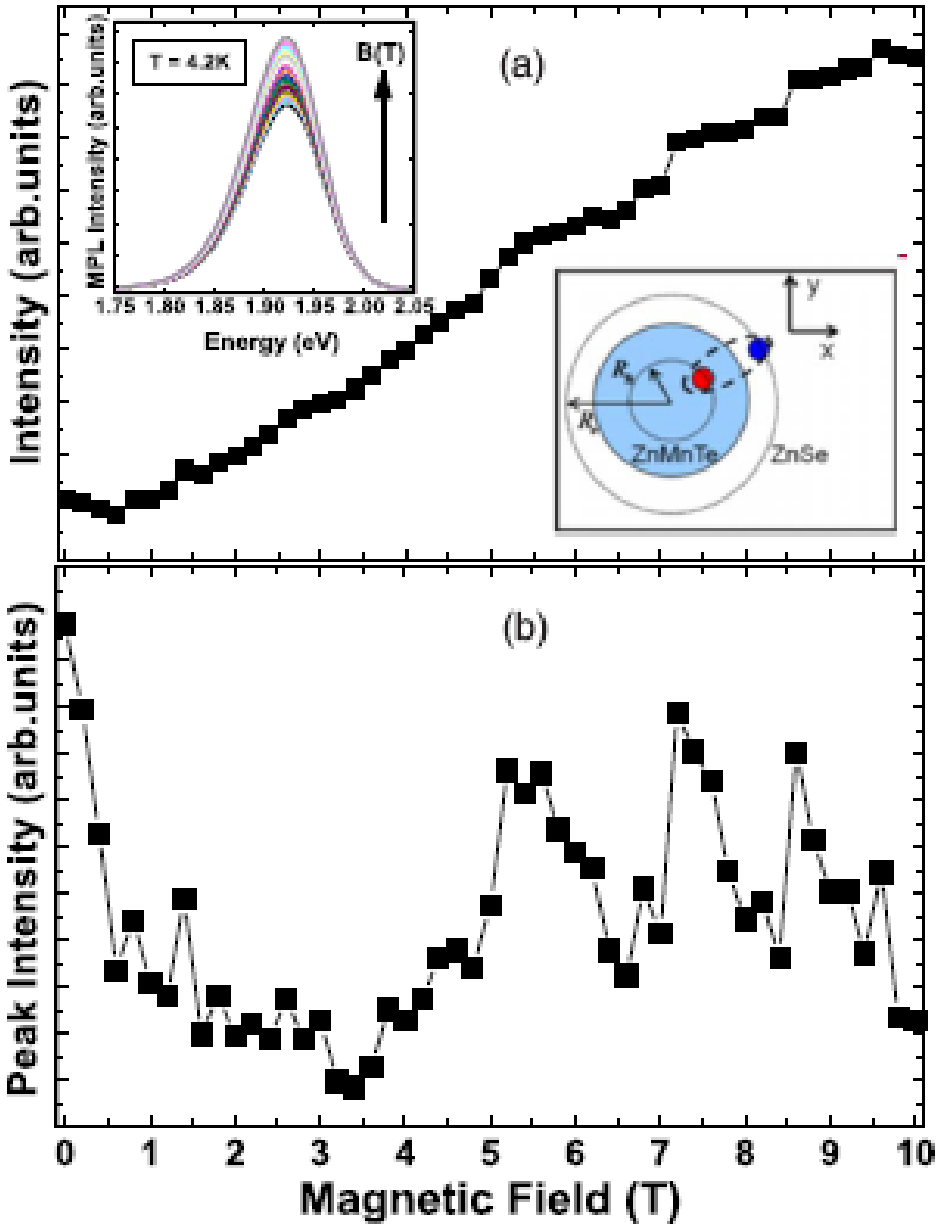
PL analyzed by σ_+ and σ_- polarization

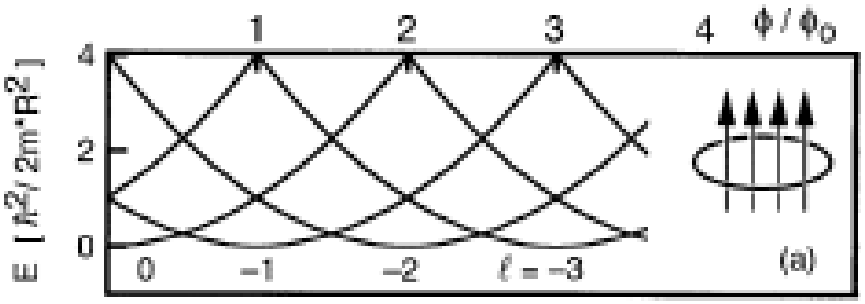
$P=(I_+-I_-)/(I_++I_-)$ >0 for $B>0$

Signature of magnetic semiconductor QDs.

Photoluminescence (PL) spectrum of ZnMnTe/ZnSe QDs.

Coherent Aharonov-Bohm oscillation in ZnMnTe/ZnSe quantum dots PRB77, 241302(2008)

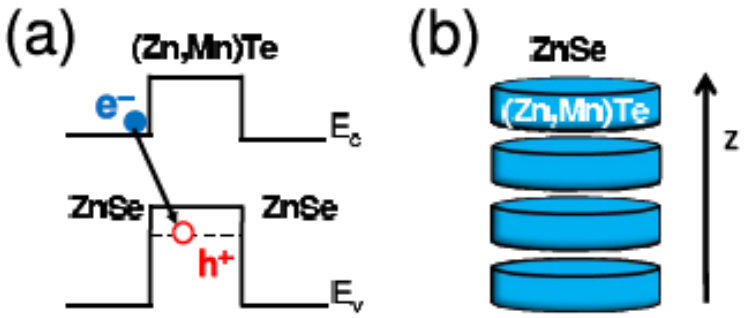


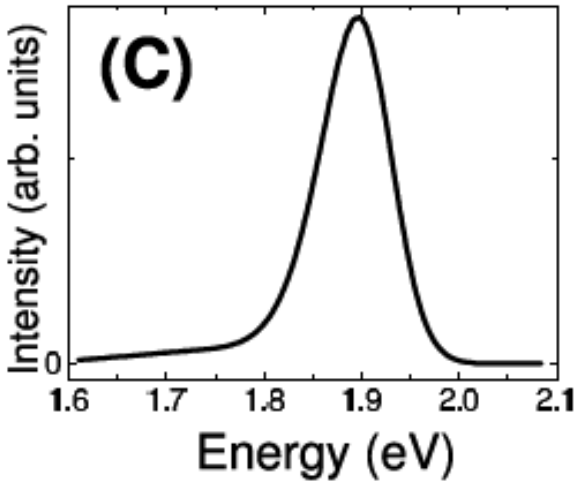


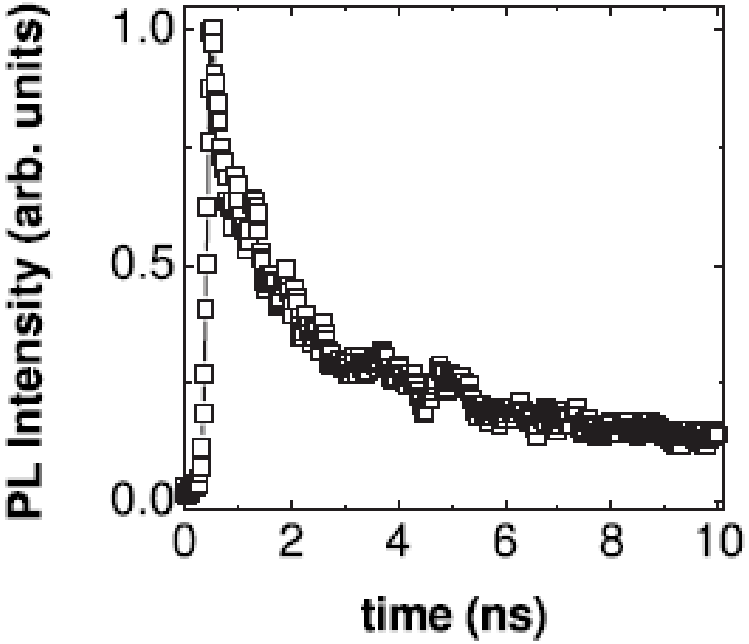
$$E_{exc} = E_g + \frac{\hbar^2}{2MR_0^2}\left(L + \frac{\Delta\Phi}{\Phi_0}\right)^2$$

Observation of optical Aharonov-Bohm oscillation

Robust magnetic polarons in ZnMnTe/ZnSe quantum dots PRB82, 195320(2010)

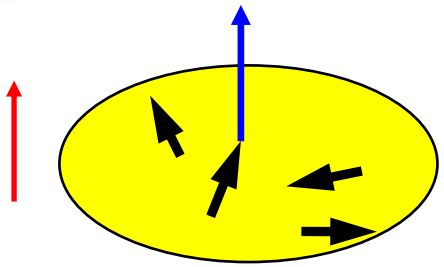




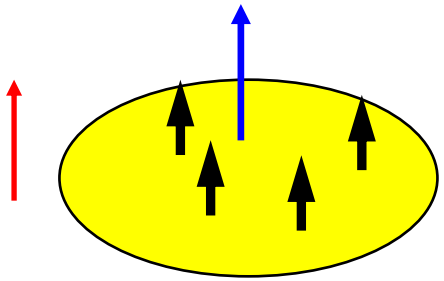


Photoluminescence (PL) spectrum of ZnMnTe/ZnSe QDs.

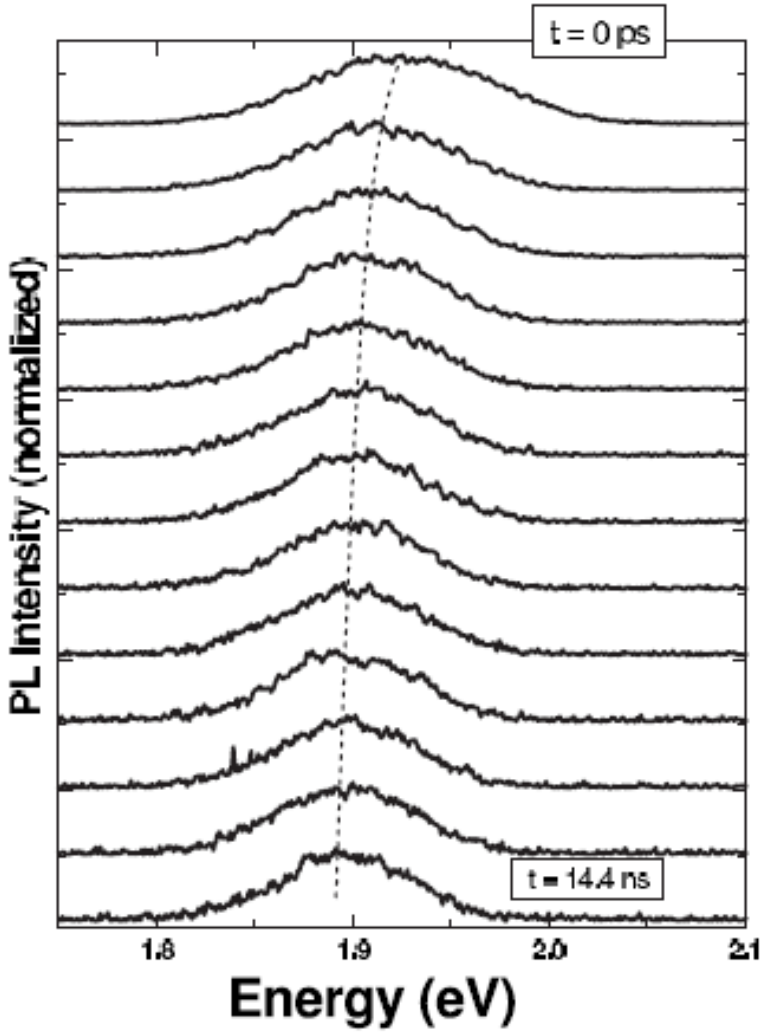
Robust magnetic polarons in ZnMnTe/ZnSe quantum dots PRB82, 195320(2010)



initially t=0



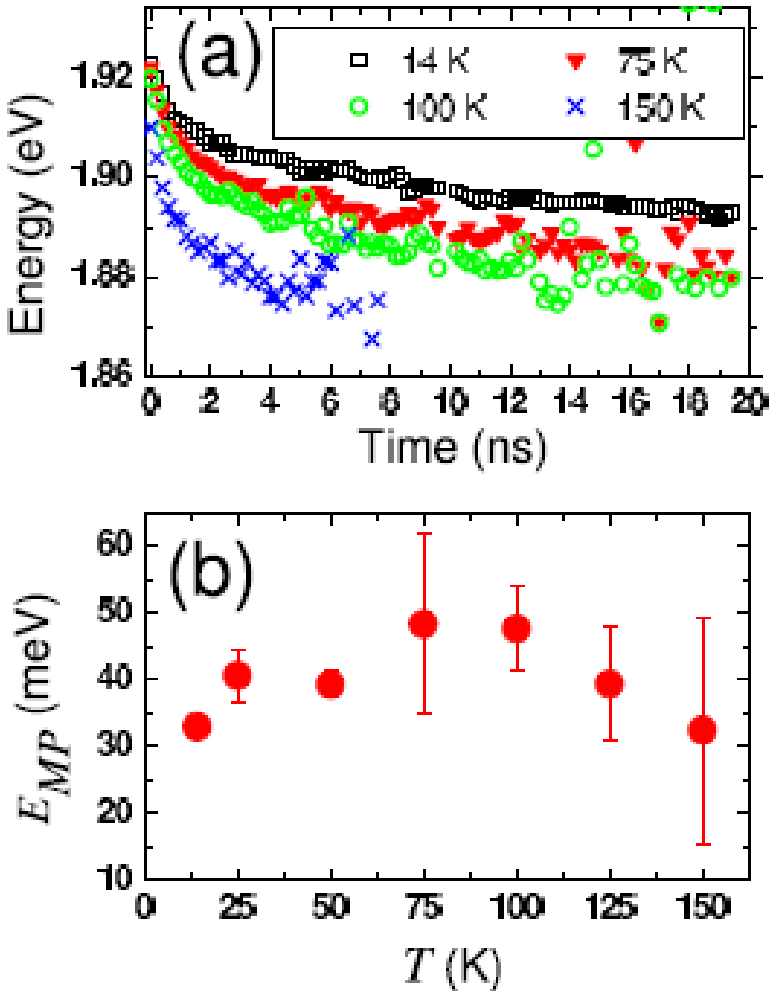
t>0



PL spectra as a function of time.

Formation of magnetic polaron (MP).

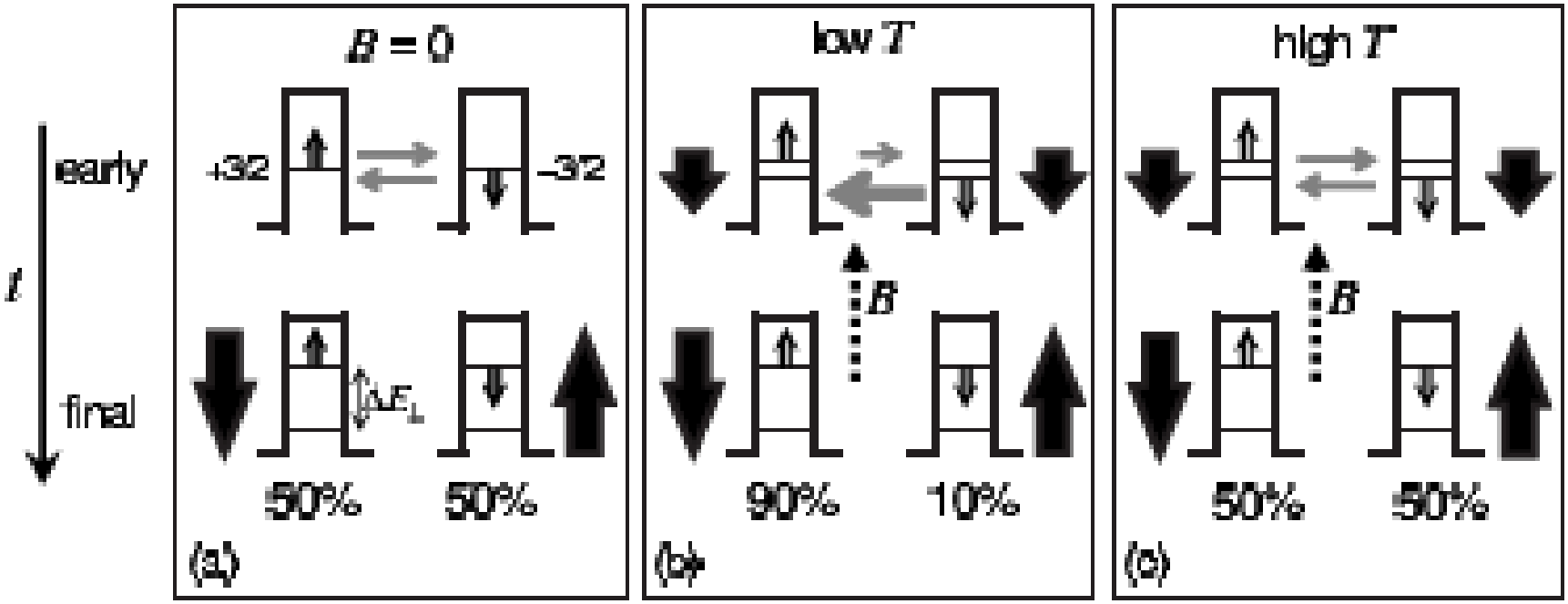
Robust magnetic polarons in ZnMnTe/ZnSe quantum dots PRB82, 195320(2010)



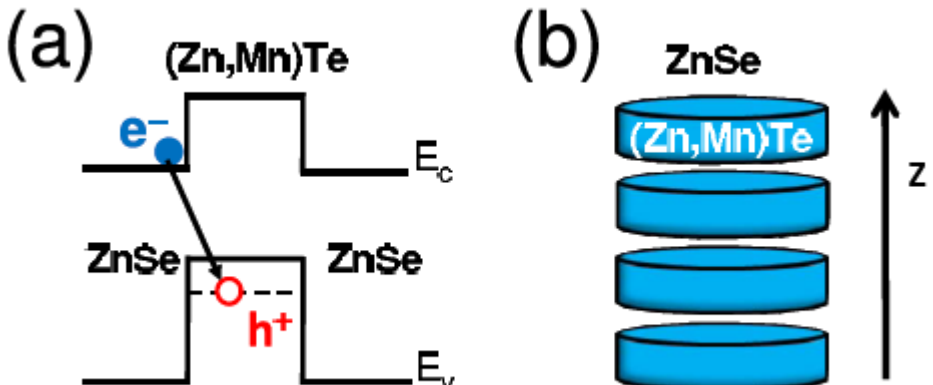
$$E_{\mathrm{MP}} = \mu_0^{-1}(J_{ex}/2g\mu_B N_0)^2 \eta(E_{\mathrm{MP}}/k_B T)\Omega_{eff}^{-1}\chi(T)$$

(a) Time dependence of peak PL energy for T=14 to 150K.
(b) Temperature dependence of the magnetic-polaron formation energy.

Robust magnetic polarons in ZnMnTe/ZnSe quantum dots PRB82, 195320(2010)



Schematic illustration of the magnetic-polaron formati



Conclusion

We have grown type-II ZnMnTe/ZnSe magnetic semiconductor quantum dots. Robust magnetic polarons and coherent Aharonov-Bohm oscillations were observed.