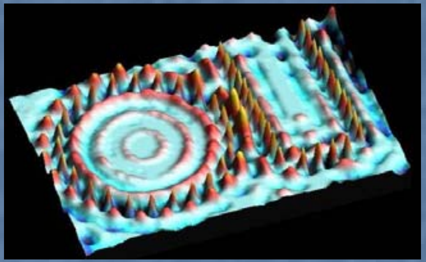
Polarization effects in the optical Aharonov-Bohm oscillations in quantum rings.



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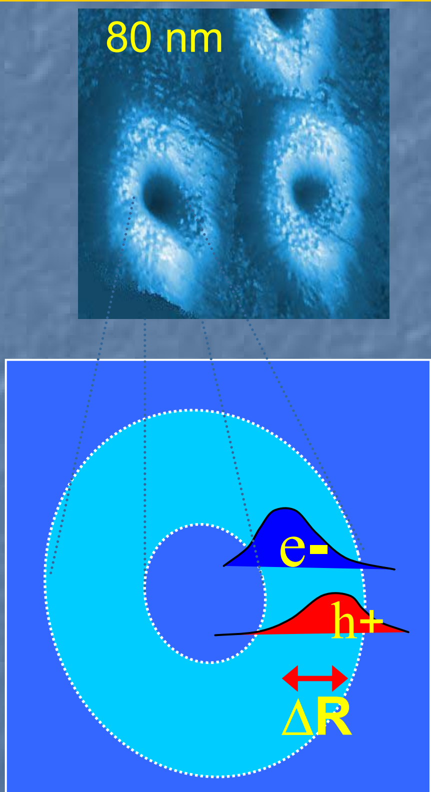
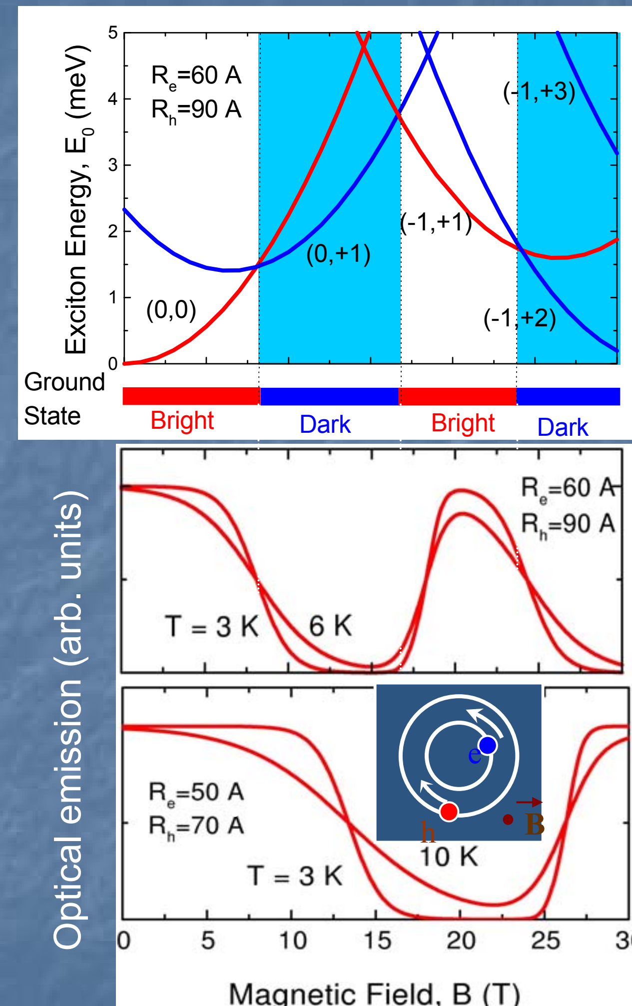
Tigran Shahbazyan - *Jackson State University*

Support: NSF-IMC, NSF-NIRT and NSF-RUI

Optical AB effect in Quantum Rings

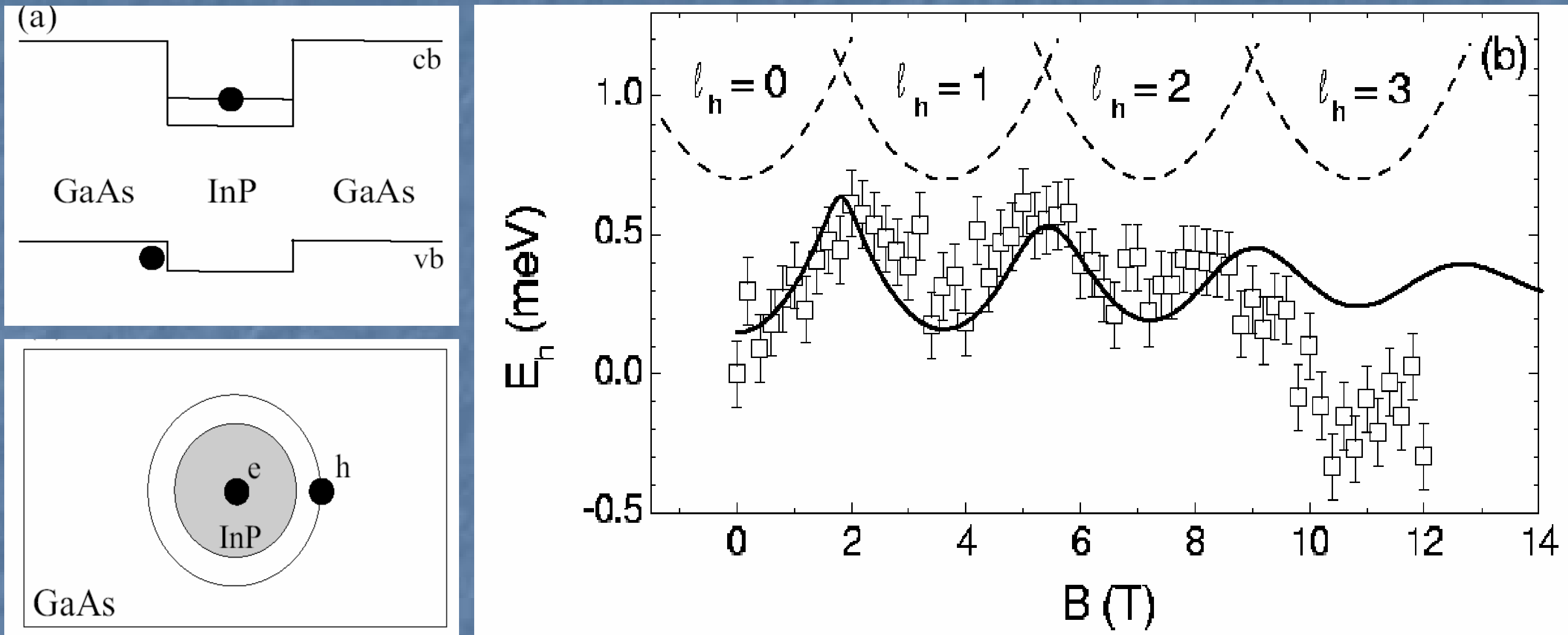
- Alternating "dark" and "bright" exciton ground state as *B* changes.





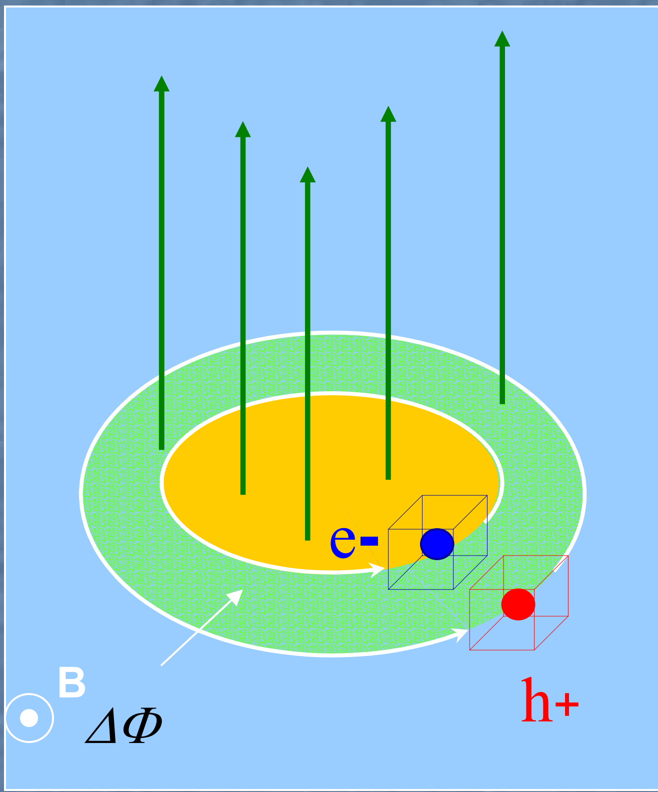
A. O. Govorov et al., PRB **69** 081309(R) (2002)

Optical AB effect in Quantum Rings



- ABE on *neutral* excitons: self-assembled type-II QDs
  - E. Ribeiro *et al.* PRL **92** 126402 (2004)
- Effect of Impurities on PL intensity
  - LDS, S. E. Ulloa, A. O. Govorov, PRB **70** 155318 (2004)

Interacting Polarized Quantum Ring



- Radially polarized ($R_e \neq R_h$) neutral exciton in a magnetic field.
- $L=L_e+L_h$ is a good quantum number.

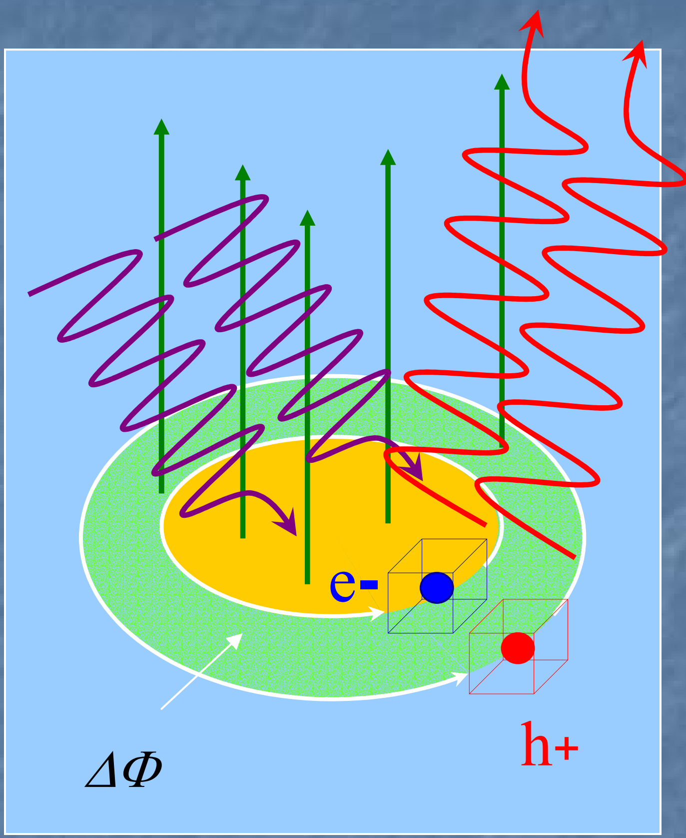
$$H = H_{el} + H_h + V_{e-h}$$

$$H = \sum_l \left[\varepsilon_e \left(l_e - \phi_e/\phi_0 \right)^2 + E_g \right] a_l^\dagger a_l + \left[\varepsilon_h \left(l_h + \phi_h/\phi_0 \right)^2 \right] b_l^\dagger b_l - \sum_{l,l'} V_q a_{l+q}^\dagger b_{l'-q}^\dagger b_{l'} a_l$$

$$\varepsilon_h = \frac{\hbar^2}{2 m_{e(h)}^* R_{e(h)}^2}; \quad V_q = \frac{e^2}{\pi \varepsilon_r \sqrt{R_e R_h}} Q_{|q|-1/2} \left(1 + \frac{\left| R_h - R_e \right|^2}{2 R_e R_h} \right)$$

- ε_r ~10: "Fully interacting"
- ε_r >>10: "Weakly interacting"

Optical Absorption



Coupling to the light:

$$H_{\text{coupling}} = H - \mu E(t)\sum_{l} a_l^{\dagger} b_{-l}^{\dagger} + h.c$$

Optical Polarization ($L_{exciton}$=0):

$$P(\omega,B) = 2\mu\sum_{l}\langle a_l b_{-l}\rangle = 2\mu\sum_{l} p_l(\omega,B)$$

$$\left[\omega - E_g + i\gamma - \varepsilon_e(l+\phi_e)^2 - \varepsilon_h(l+\phi_h)^2\right] p_l + \sum_{l'} V_{l-l'} p_{l'} = \mu E/2$$

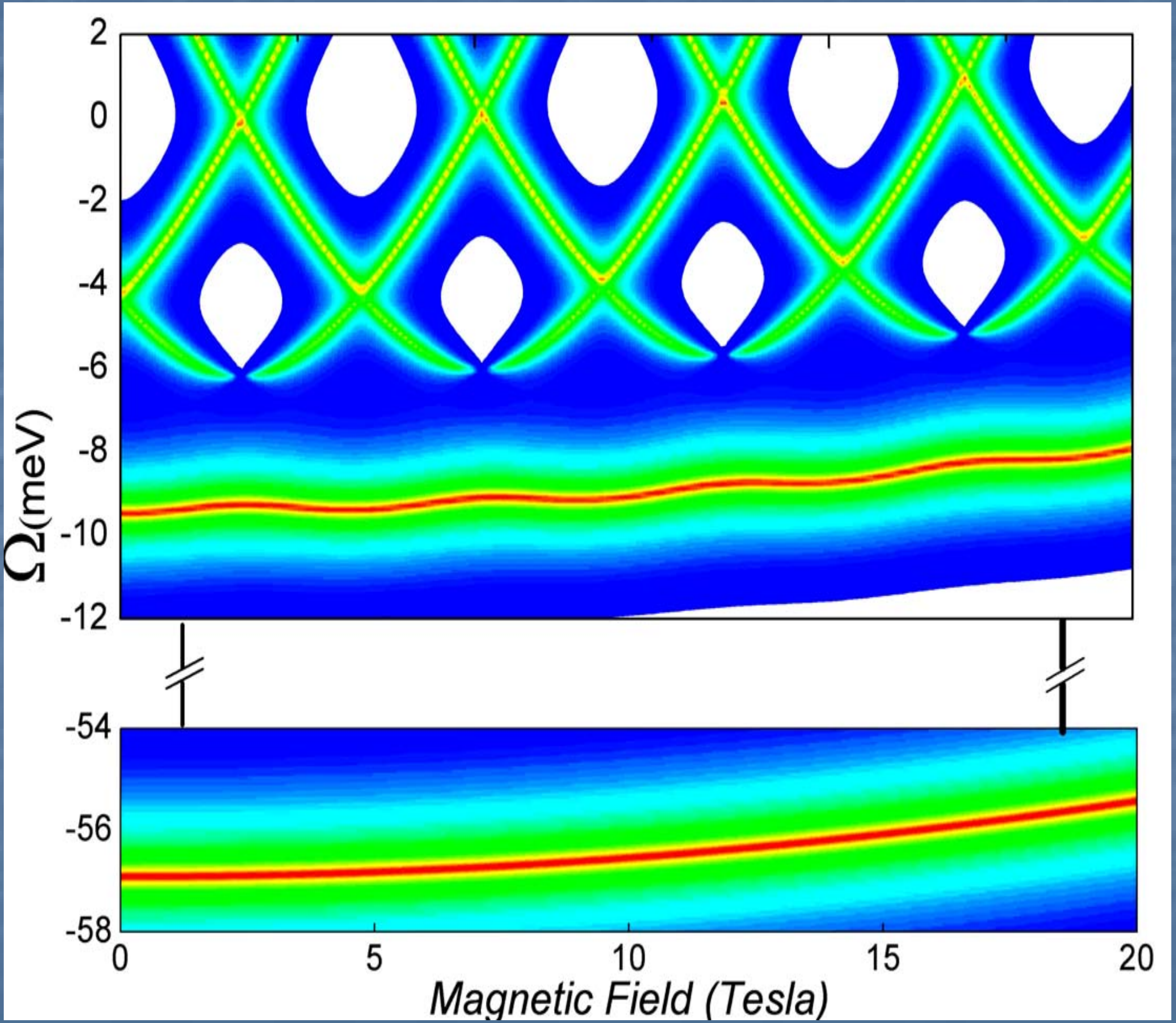
Optically Active states: ($L_{exciton}$=0)

Absorption Coefficient:

$$\alpha(\omega,B) = \frac{4\pi\omega}{n\kappa E}\,\mathrm{Im}\,P(\omega,B)$$

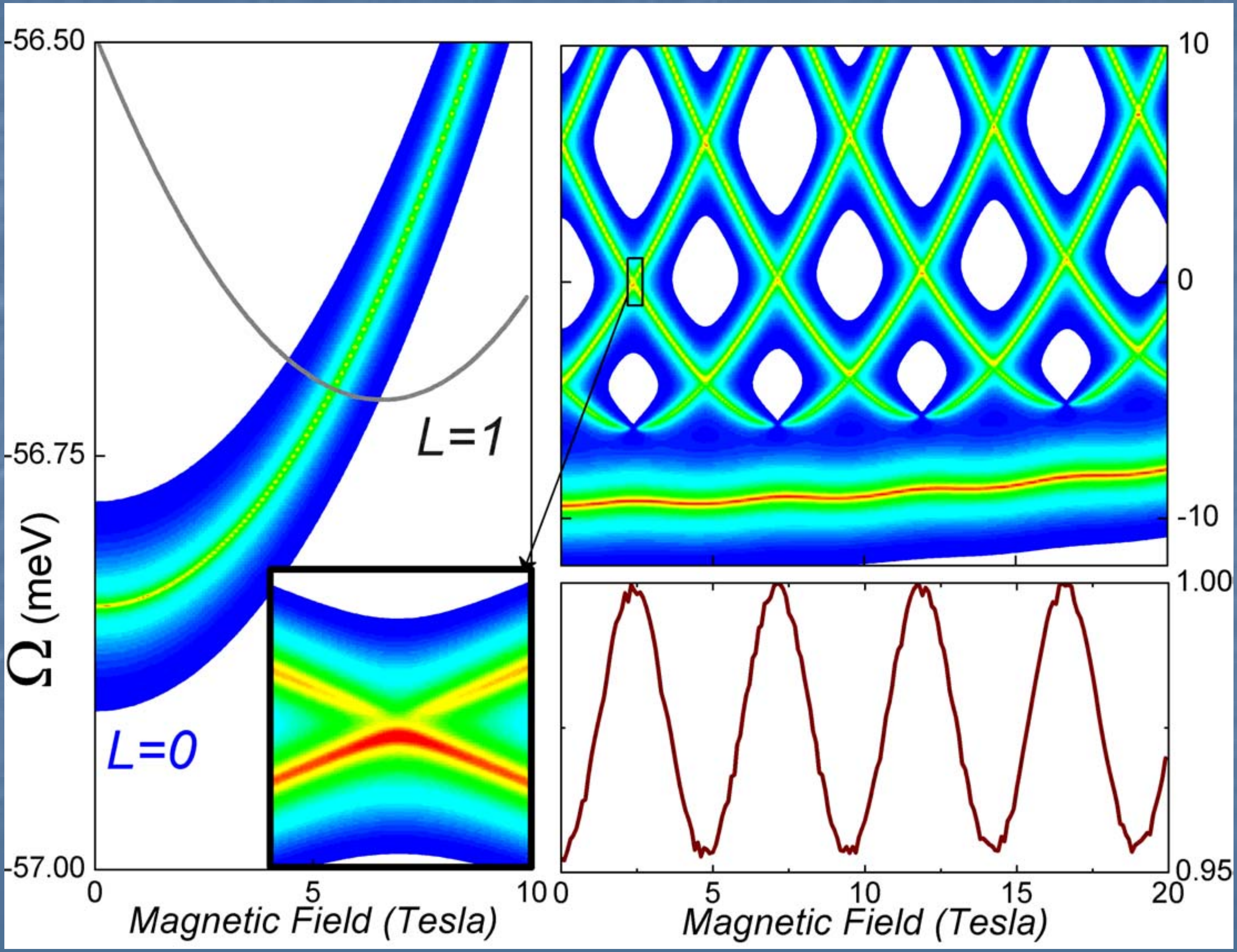
Optical Absorption: Fully interacting

- Absorption peaks follows the L=0 states.
- Gap between GS and (optically active) excited states.
- ABE oscillations in the excited sates.



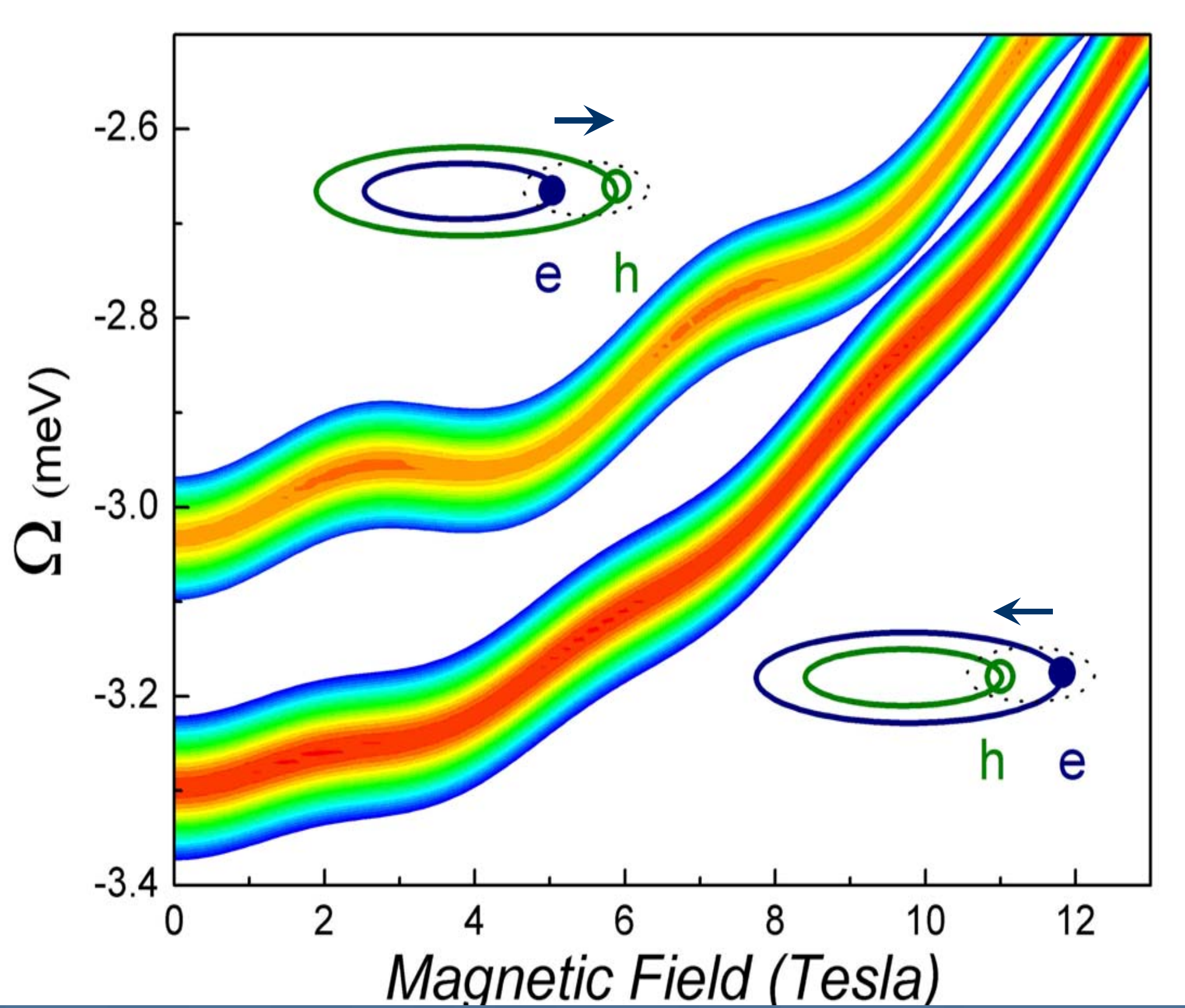
Optical Absorption: Fully interacting.

- Oscillations in peak position (energy) and heigth (absorption strength).
- Ground state becomes "dark".
- Features in the anticrossings on the excited states.



Optical Absorption: Weakly interacting.

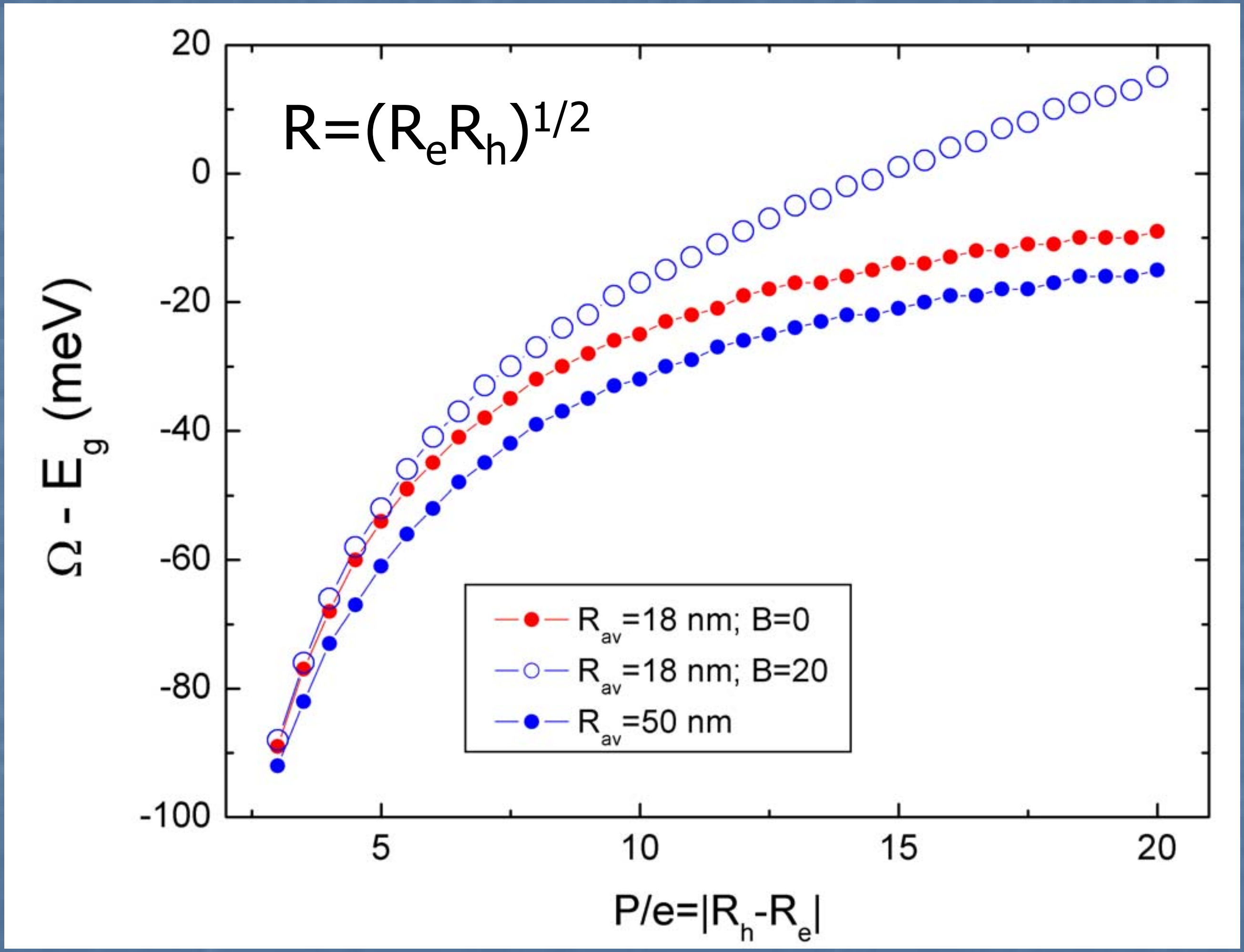
- ABE oscillations in the ground state; modulation in the absorption intensity.
- Direction of the polarization vector: Effect is enhanced when lighter particle (electron) is in the inner radius.



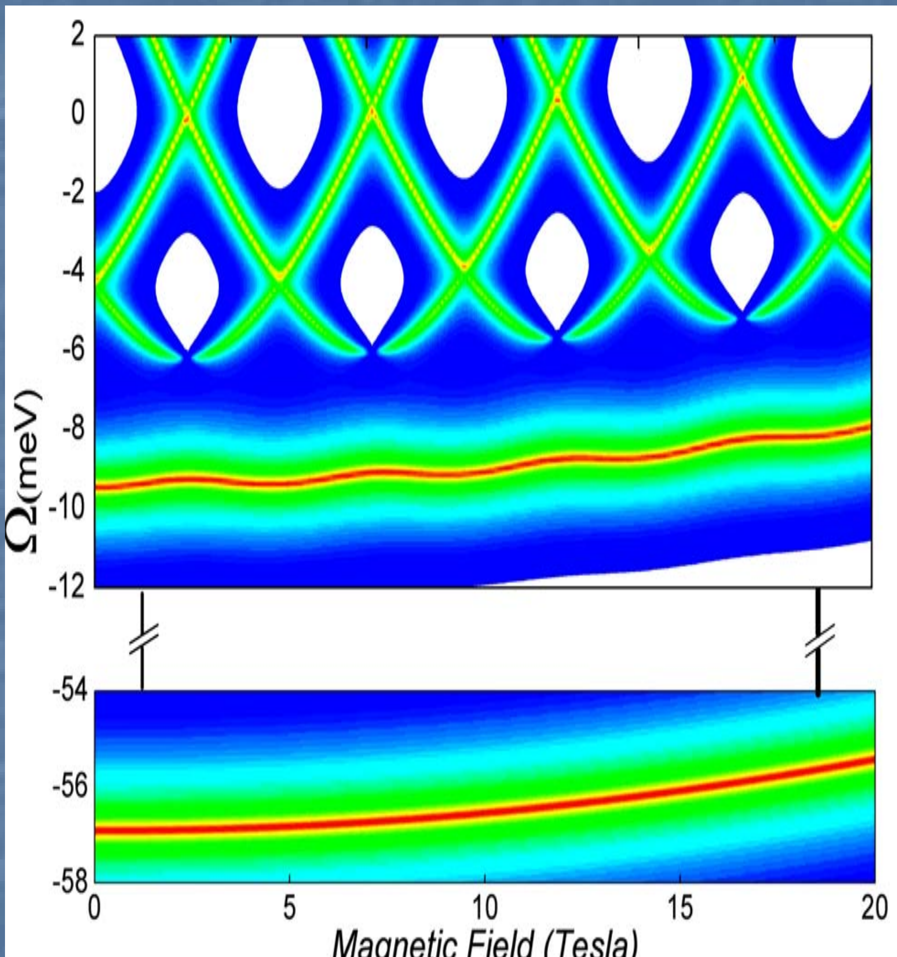
Radial Polarization effect

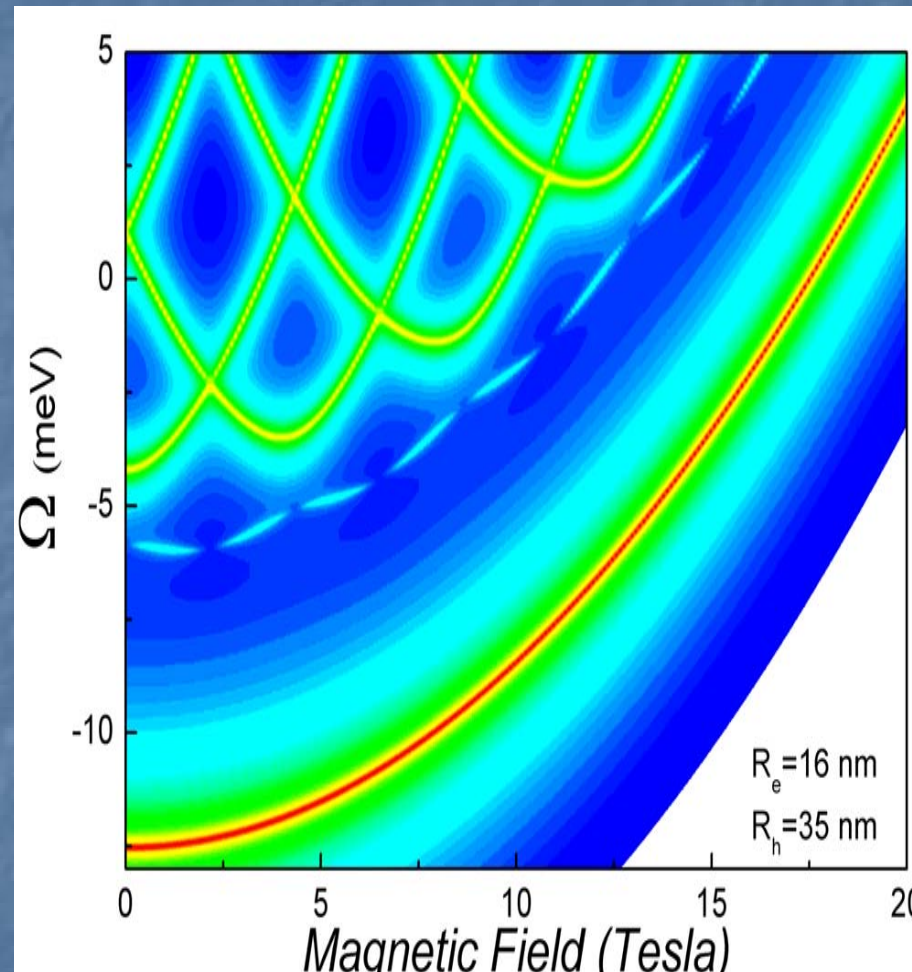
- Binding energy decreases as the electric dipole moment increases.

- Details of the saturation curve change for different R_e,R_h.



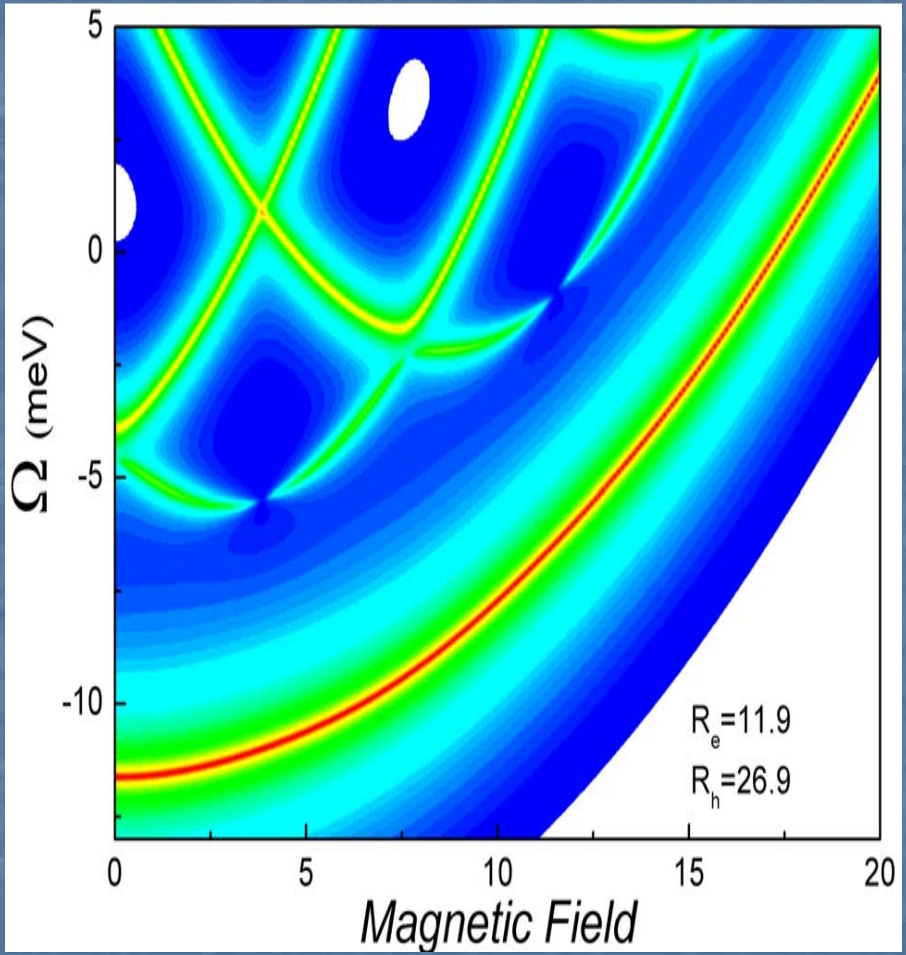
Optical Absorption: Strong Polarization

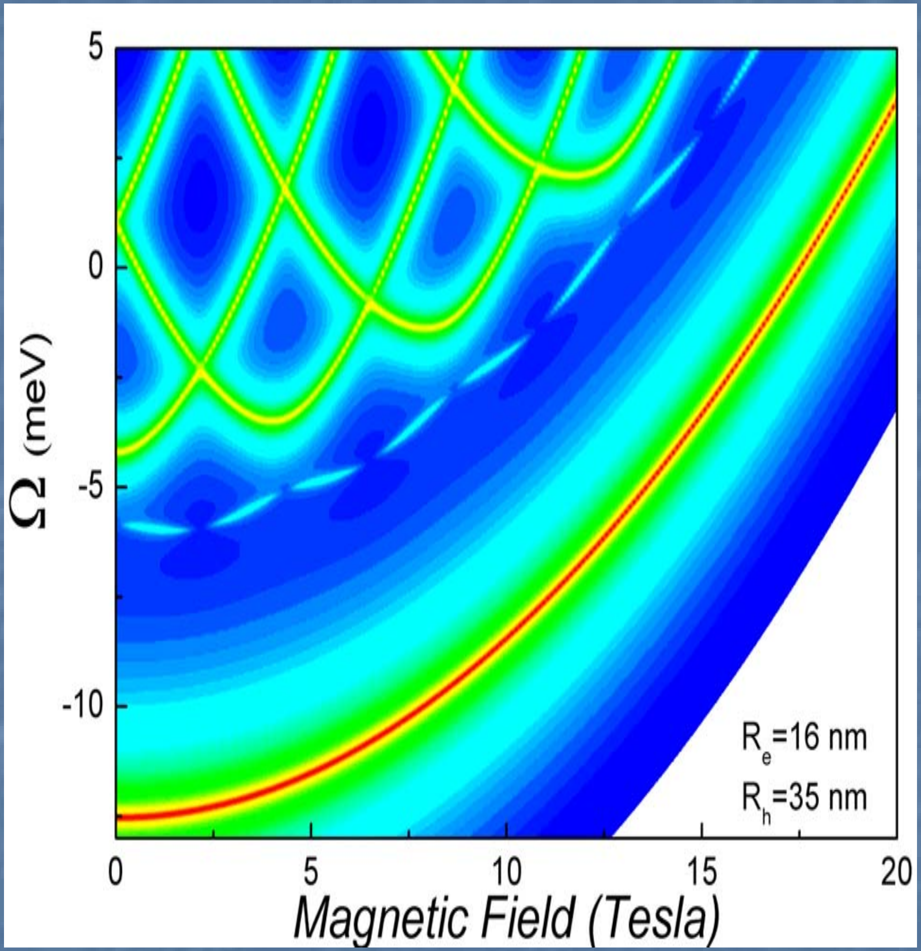




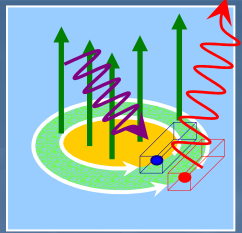
Gap decreases when the dipole moment is large.

Optical Absorption: Strong Polarization

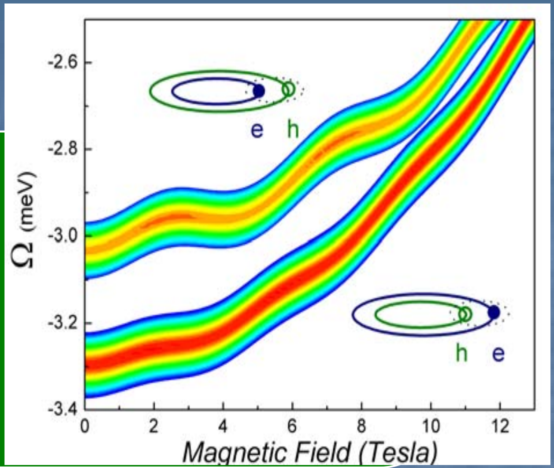




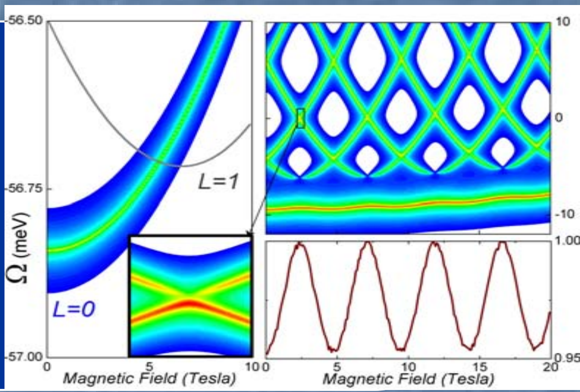
Dipole moment changes ABE oscillations in the excited states.



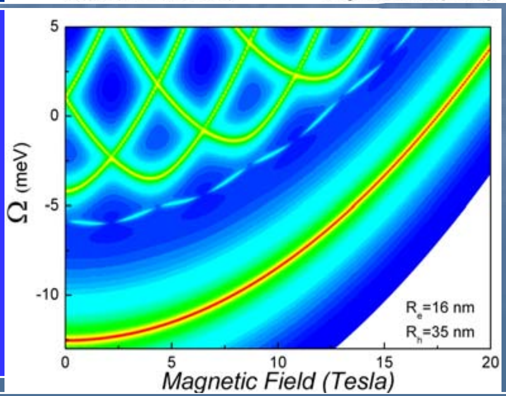
Conclusions



- Exciton radial polarization strongly affects the optical absorption/emission in quantum rings.
- Weakly interacting QR: Absorption peak oscillates (signature of ABE).



- Fully interacting QR: ABE structure on excited states.
- Exciton lifetime changes as a function of field (Ground state becomes dark).



- Large dipole moment: lower the gap between the GS and the optically active excited states.
- Gap lower than the optical phonon threshold: experimentally probe of ABE in the excited states.