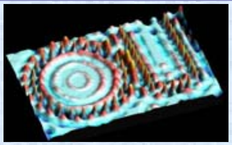
Polarization effects in the optical Aharonov-Bohm oscillations in quantum rings.

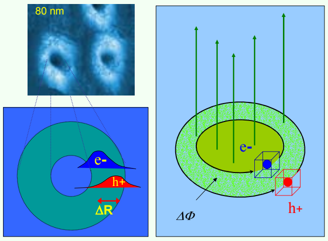
Luis Dias da Silva[1], Sergio Ulloa[1], Tigran Shahbazyan[2]

[1] Department of Physics and Astronomy, Ohio University, Athens, Ohio 45701-2979
[2] Department of Physics, Jackson State University, Jackson, MS 39217

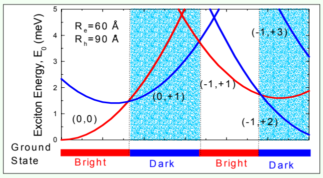


Financial Support:

The optical Aharonov-Bohm effect



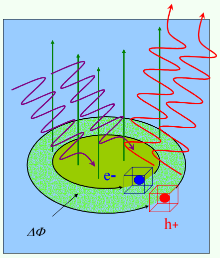
- **Neutral excitons in semiconductor nanorings: different confinements for electrons and holes → radial dipole moment.**



- **A net Aharonov-Bohm phase arises → signatures in the optical emission and absorption of the *Optical AB effect.***

- A.O. Govorov et al *PRB* **66**, 081309(R) (2002)
- E. Ribeiro et al *PRL* **92**, 126402 (2004)

Polarized excitons in quantum rings



- **Our model: a *radially polarized* exciton in a quantum ring or type-II quantum dot.**

- **Electron-hole interaction is *screened* (dieletric material, extra charges, metal contacts, etc.)**

$$H_{\text{exciton}}=\sum_l\left[\varepsilon_e\left(l_e-\phi_e/\phi_0\right)^2+E_g\right]a_l^\dagger a_l+\left[\varepsilon_h\left(l_h+\phi_h/\phi_0\right)^2\right]b_l^\dagger b_l$$
$$-\sum_{l,l'}V_q a_{l+q}^\dagger b_{l'-q}^\dagger b_{l'}a_l-\mu E(t)\sum_l a_l^\dagger b_{-l}^\dagger+h.c$$

Optical absorption

- **We calculate the optical polarizability and optical absorption for this system.**
- **The absorption coefficient has peaks at the energies of the optically active states → *B* dependence.**

Optically active states: (L_{exciton}=0)

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

Optical Polarizability:

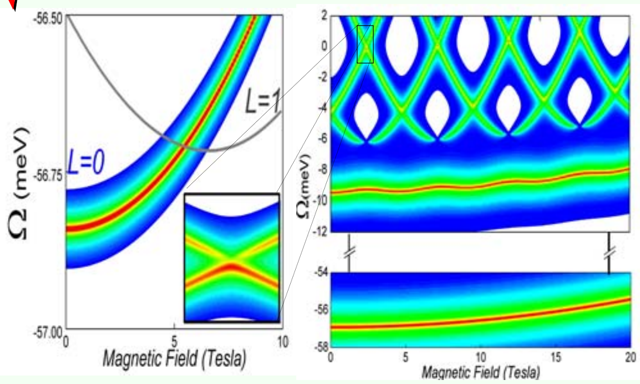
$$P(\omega,B)=2\mu\sum_l p_l(\omega,B)$$

Absorption Coefficient:

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

Absorption spectrum: Results

√ Low screening, small exciton dipole moment:



✓ **Strong *e-h* interaction: large binding gap ΔE; AB oscillations appear in the excited states.**

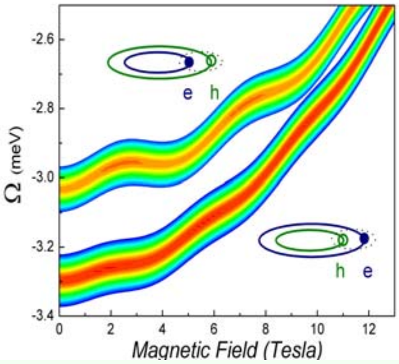
✓ **Ground state is *dark* (L=1) for high fields; Time-resolved PL could probe this AB effect signature.**

✓ **Absorption intensity is non-uniform across anti-crossings in the excited states (inset).**

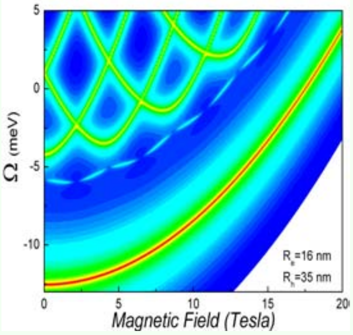
√ High screening, small exciton dipole moment:

✓ **Weak Coulomb interaction: AB oscillations in the *ground-state* peak, in both *position* and *amplitude.***

✓**Effect is larger if electron is in the inner ring: dependence on dipole *orientation.***



√ Low screening, large exciton dipole moment:



✓ **Large $|R_e-R_h|$: increase in the dipole moment.**

✓ **It leads to smaller exciton binding: gap ΔE is reduced.**

✓ **If ΔE < (optical phonon threshold) → possible experimental access to ABE in the excited states.**

For more details:

cond-mat / 0504569