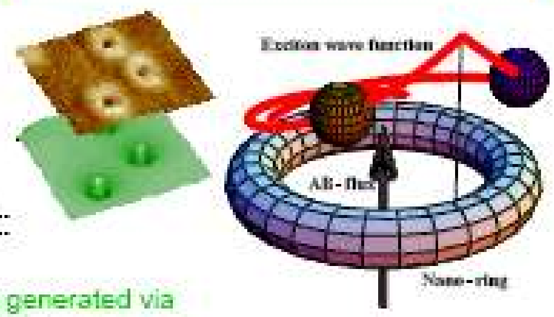
Efecto Aharonov-Bohm para un excitón

The excitonic AB effect for nano-rings

Nano-sized rings with radius of 30-50nm exist:

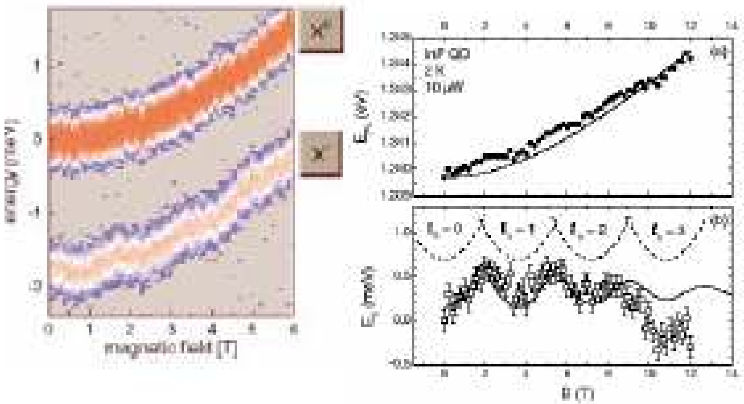


Excitons are being generated via photoluminescence. What about Aharonov-Bohm effect for this nano-geometry and neutral (quasi-)particle?

Experiments

initially for **trions**
[Bayer, *et al.*, PRL 90, 186801 (2003)]

recently also for excitons:
[E. Ribeiro *et al.*, PRL 92, 126401 (2004)]



Modelos

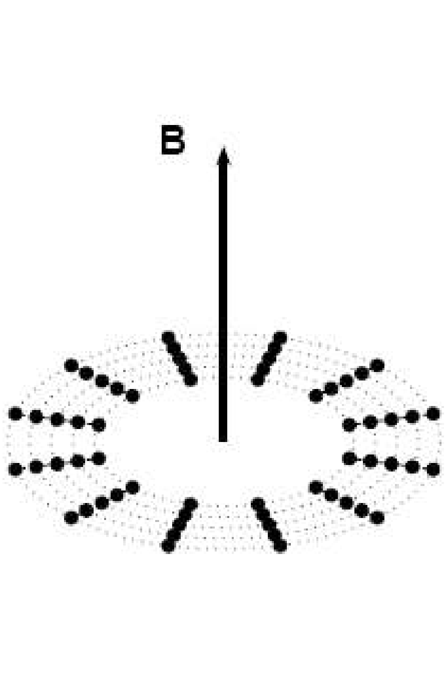


FIG. 12: Sketch of the model. (Left) The lattice is a 2D system of N rings and M sites in each ring. (Right) The lattice is a system of N stacked rings and M sites in each ring. Each system is subject to an uniform magnetic field $\mathbf{B}$ perpendicular to the rings, with Φ the magnetic flux

Hamiltoniano

$$\hat{H} = -\gamma \sum_{n=1}^{N} \sum_{m=1}^{M} a^\dagger_{n,m} a_{n,m} b^\dagger_{n,m} b_{n,m} \tag{17}$$
$$- \sum_{n=1}^{N-1} \sum_{m=1}^{M} t_n^\perp \left[a^\dagger_{n,m} a_{n+1,m} + a^\dagger_{n+1,m} a_{n,m} + \mu \left(b^\dagger_{n,m} b_{n+1,m} + b^\dagger_{n+1,m} b_{n,m} \right) \right]$$
$$- \sum_{n=1}^{N} \sum_{m=1}^{M} t_n^{||} \left[e^{2\pi i \varphi_n / M} \left(a^\dagger_{n,m} a_{n,m+1} + \mu b^\dagger_{n,m+1} b_{n,m} \right) + e^{-2\pi i \varphi_n / M} \left(a^\dagger_{n,m+1} a_{n,m} + \mu b^\dagger_{n,m} b_{n,m+1} \right) \right]$$

$$\varphi_n = \Phi_n / \Phi_0$$

$$t_n^\perp = \frac{\epsilon}{(r_{n+1} - r_n)^2}, \quad t_n^{||} = \frac{\epsilon}{4 r_n^2 \sin^2(\pi / M)},$$

Transformación de operadores

$$\mathbf{a}^{\dagger}_{n,l} = \frac{1}{\sqrt{M}} \sum_{r=1}^{M} \tau_l^{-r} a^{\dagger}_{n,r}, \quad \mathbf{b}^{\dagger}_{n,l} = \frac{1}{\sqrt{M}} \sum_{r=1}^{M} \tau_l^{-r} b^{\dagger}_{n,r}$$

where $\tau_l = e^{ik_l}$, been $k_l = 2\pi l/M$, with l integer

$$\begin{aligned} \widehat{H} \; = \; & -\frac{\gamma}{M} \sum_{n=1}^{N} \sum_{r=1}^{M} \sum_{r'=1}^{M} \sum_{t=1}^{M} \sum_{t'=1}^{M} \delta_{r+pt,r'+t'} \mathbf{a}^{\dagger}_{n,r} \mathbf{a}_{n,r'} \mathbf{b}^{\dagger}_{n,t} \mathbf{b}_{n,t'} \\ & -2 \sum_{n=1}^{N} \sum_{l=1}^{M} t_n^{\parallel} \cos(k_l - 2\pi\varphi_n/M) \mathbf{a}^{\dagger}_{n,l} \mathbf{a}_{n,l} - t^{\perp} \sum_{n=1}^{N-1} \sum_{l=1}^{M} (\mathbf{a}^{\dagger}_{n,l} \mathbf{a}_{n+1,l} + \mathbf{a}^{\dagger}_{n+1,l} \mathbf{a}_{n,l}) \\ & -2\mu \sum_{n=1}^{N} \sum_{l=1}^{M} t_n^{\parallel} \cos(k_l + 2\pi\varphi_n/M) \mathbf{b}^{\dagger}_{n,l} \mathbf{b}_{n,l} - \mu t^{\perp} \sum_{n=1}^{N-1} \sum_{l=1}^{M} (\mathbf{b}^{\dagger}_{n,l} \mathbf{b}_{n+1,l} + \mathbf{b}^{\dagger}_{n+1,l} \mathbf{b}_{n,l}). \end{aligned} \tag{21}$$

Un electrón (hueco) aislado

$$|\mathbf{a}^{\dagger}_{n,l}>=\mathbf{a}^{\dagger}_{n,l}|0> \quad (n=1\ldots N)$$

$$q_n = 2t^{||}_n \cos(k_l - 2\pi\varphi_n/M).$$

$$H^e_l = -\begin{bmatrix} q_1 & t^{\perp} & 0 & . & . & 0 \\ t^{\perp} & q_2 & t^{\perp} & 0 & . & 0 \\ 0 & . & . & . & . & . \\ . & . & . & . & . & t^{\perp} \\ 0 & . & . & 0 & t^{\perp} & q_N \end{bmatrix},$$

$$|\phi^e_l(p)>=\sum_{n=1}^{N} c^e_{n,l}(p)|\mathbf{a}^{\dagger}_{n,l}>$$

$$|\phi^h_l(p)>=\sum_{n=1}^{N} c^h_{n,l}(p)|\mathbf{b}^{\dagger}_{n,l}>$$

Excitón

$$|\phi_l^e(p)\phi_{l'}^h(p') >= \sum_{n=1}^{N}\sum_{n'=1}^{N} c_{n,l}^e(p)c_{n',l'}^h(q)|\mathbf{a}_{n,l}^\dagger \mathbf{b}_{n',l'}^\dagger >$$

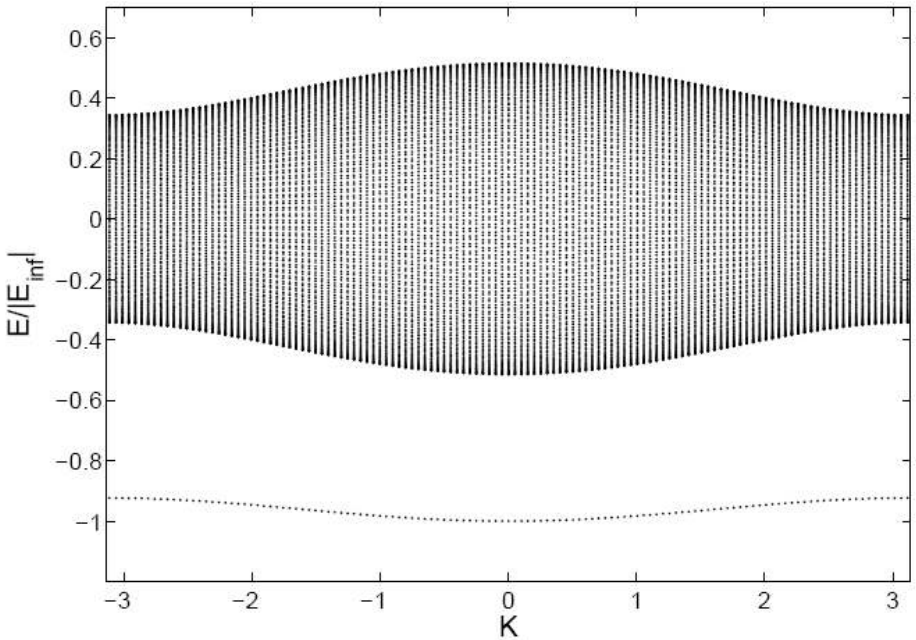
$$\det(I - \gamma M^{-1}F(E)) = 0.$$

$$F_{n,n'}(E) = \sum_l \sum_p \sum_{p'} \frac{c_{n,l}^e(p)c_{n',l}^{e*}(p)c_{n,Q-l}^h(p')c_{n',Q-l}^{h*}(p')}{E_l^e(p) + E_{Q-l}^h(p') - E}.$$

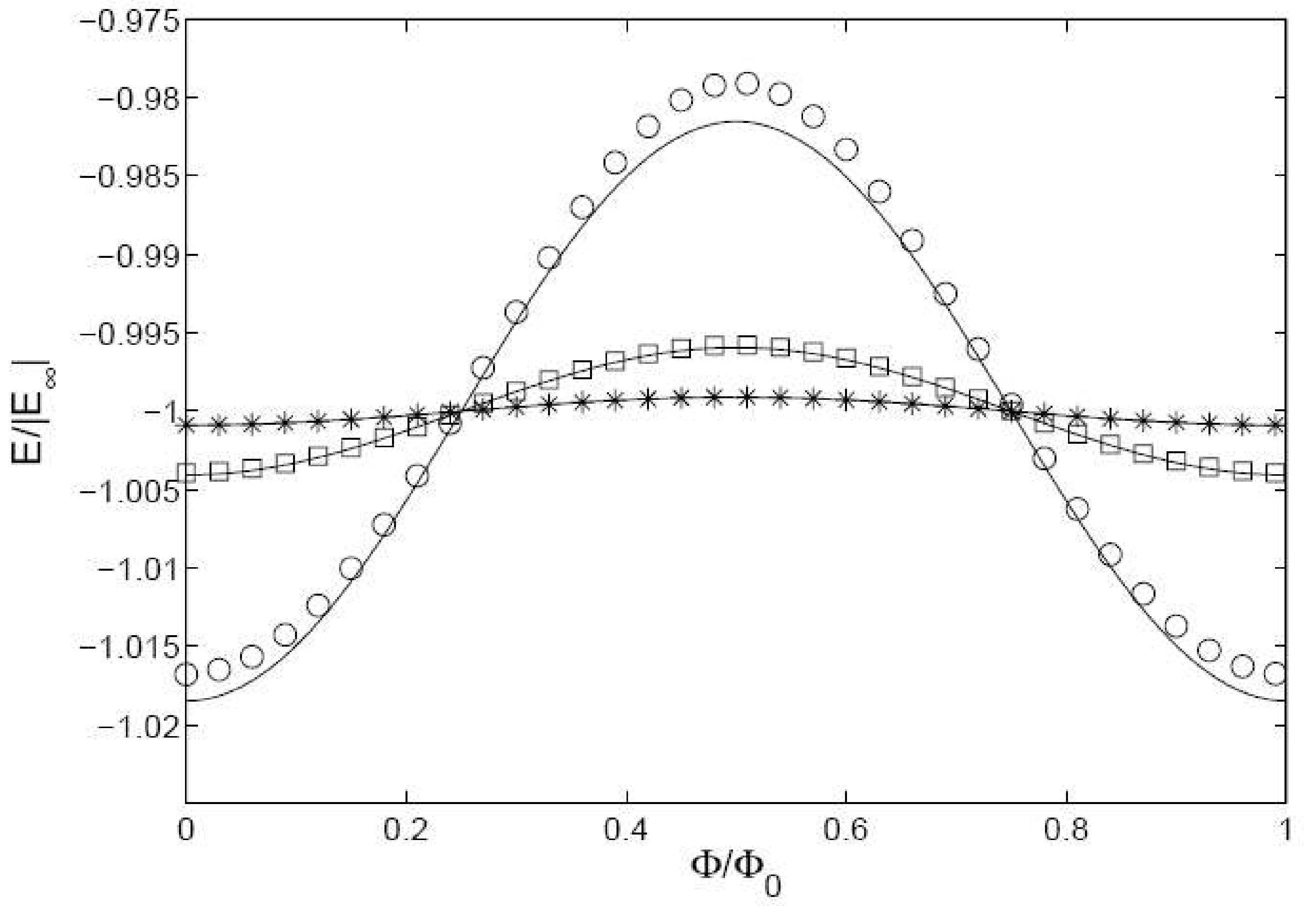
Caso de un solo anillo

$$\frac{\tan(M\nu)}{\sin(\nu)} = \frac{2|q|}{\gamma}\left[1 - \frac{\cos(M\theta)}{\cos(M\nu)}\right]$$

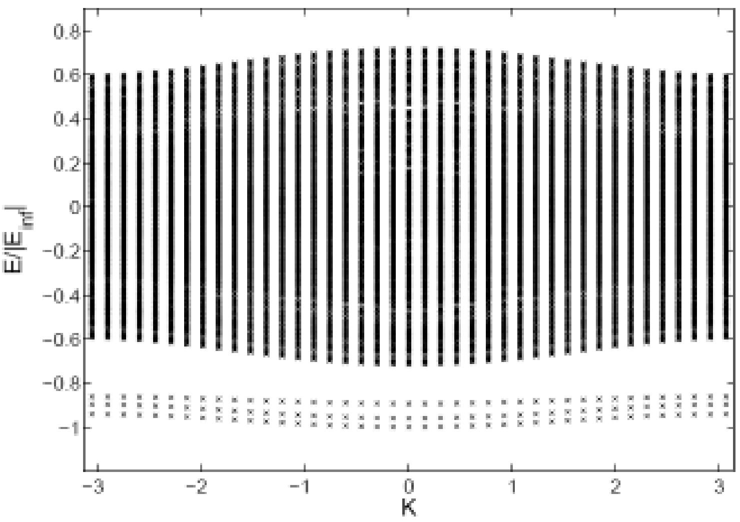
where $q = t_1^{\|} e^{2\pi i\varphi/M}(\mu + e^{-iK_Q})$, $\theta =$arg(q) and $\cos(\nu) = -E/2|q|$.

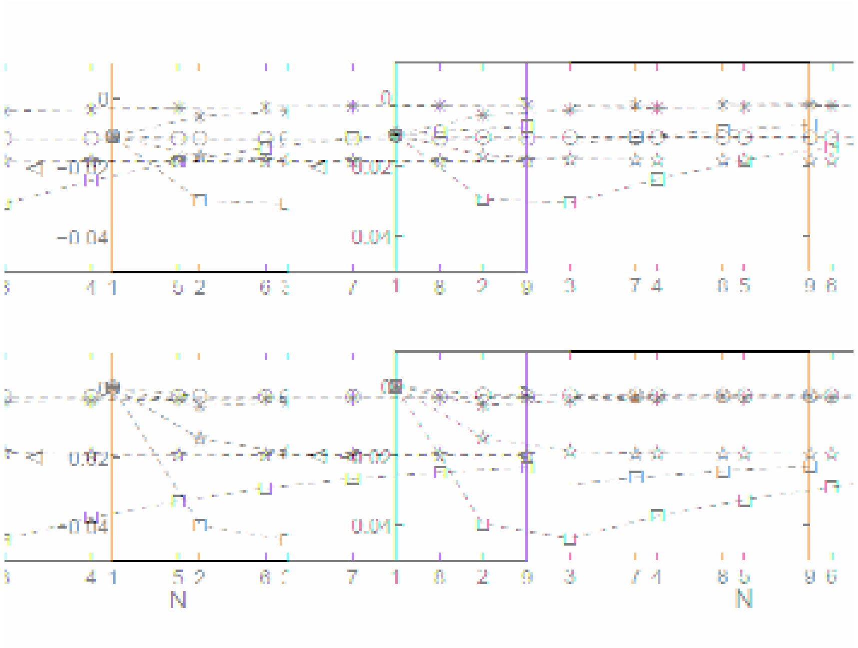


Un solo anillo (II)



Caso general





Método para mantener las oscilaciones AB

Trabajos en curso

- Sistema de dos electrones (spin!)
- Trión (excitón cargado)