Chaos Dynamics in Two Dimensional Electron System Irradiated by Radiation in a magnetic field

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Abstract

We investigate the effects of radiation on the cyclotron motion of an electron wave packet in a two dimensional electron system, considering the full quantum dynamics of the system. Interestingly, we find that chaotic effects are induced by radiation in the dynamics of electron wave packet in an applied uniform magnetic field. Chaotic signatures in the dynamics are diagnosed by computing the relevant out-of-time-order correlation function and analyzed by using Poincaré maps. We attribute the appearance of such chaotic transport of electron wave packet to the nonlinear interaction between the optical radiation and internal cooperative oscillating mode produced by the interplay of relativistic (zitterbewegung) and cyclotron oscillations.

Introduction:

The interplay between spin orbit coupling and quantum confinement in semiconductors has attracted great interest .The presence of spin orbit Coupling affects the spontaneously flowing persistent currents in mesoscopic conducting rings. We analyze its dependence on magnetic flux with emphasis on identifying properties to prove the presence and extract the strength of rashba spin splitting in low-dimensional systems [1] . Various sources of inversion broken symmetry give rise to intrinsic spin splitting in semiconductors hetrerostructures [2]. We focus here on the one induced by structural inversion symmetry, i.e., the Rashba effect [3]. We are interested in non-linear behavior of wave packet dynamics in a two dimensional electron system in a uniform magnetic field irradiated by radiation.

Model Hamiltonian:

The Hamiltonian for our system is given by

$$H=\frac{\boldsymbol{\pi}^2}{2m}+\lambda(\boldsymbol{\pi}\times\boldsymbol{\sigma})\cdot\boldsymbol{e_z}-\Delta\sigma_z+eE_x\cos(\omega t)$$

Dynamical equations

$$\frac{d\boldsymbol{x}(t)}{dt}=\frac{\boldsymbol{\pi_x}(t)}{m}+\lambda\boldsymbol{\sigma_y}(t)$$

$$\frac{d\boldsymbol{y}(t)}{dt}=\frac{\boldsymbol{\pi_y}(t)}{m}-\lambda\boldsymbol{\sigma_x}(t)$$

$$\frac{d\boldsymbol{\pi_x}(t)}{dt}=-\frac{\hbar}{ml^2}\boldsymbol{\pi_y}(t)+\frac{\lambda\hbar}{l^2}\boldsymbol{\sigma}_x(t)-eEcos(\omega t)$$

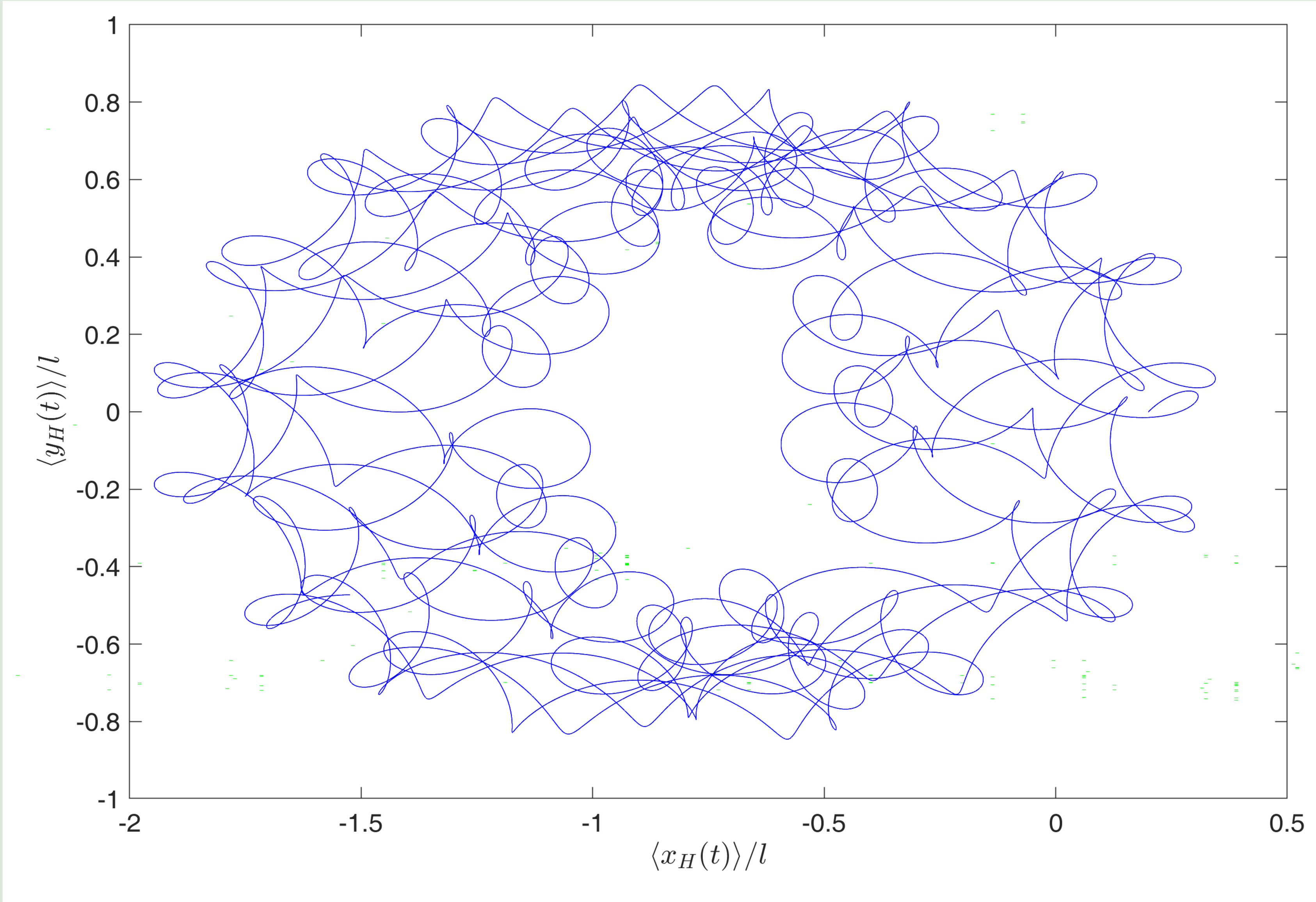
$$\frac{d\boldsymbol{\pi_y}(t)}{dt}=\frac{\hbar}{ml^2}\boldsymbol{\pi}_x(t)+\frac{\lambda\hbar}{l^2}\boldsymbol{\sigma}_y(t)$$

$$\frac{d\boldsymbol{\sigma_x}(t)}{dt}=\frac{2\lambda}{\hbar}\boldsymbol{\pi_x}(t)\boldsymbol{\sigma_z}(t)+\frac{2\Delta}{\hbar}\boldsymbol{\sigma_y}(t)$$

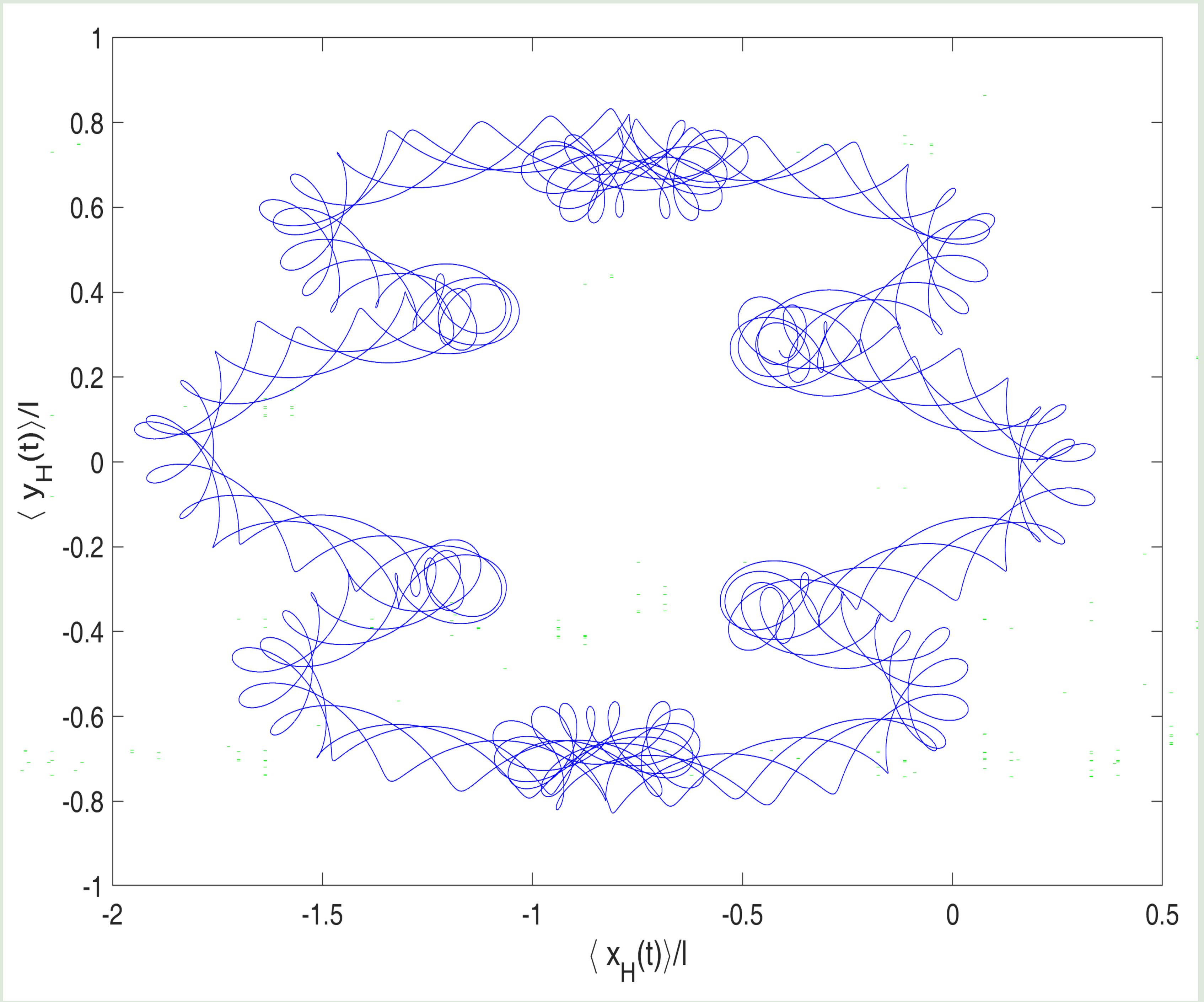
$$\frac{d\boldsymbol{\sigma_y}(t)}{dt}=\frac{2\lambda}{\hbar}\boldsymbol{\pi_y}(t)\boldsymbol{\sigma_z}(t)-\frac{2\Delta}{\hbar}\boldsymbol{\sigma_x}(t)$$

$$\frac{d\boldsymbol{\sigma_z}(t)}{dt}=-\frac{2\lambda}{\hbar}\boldsymbol{\sigma}_x(t)\boldsymbol{\pi}_x(t)-\frac{2\lambda}{\hbar}\boldsymbol{\sigma_y}(t)\boldsymbol{\pi_y}(t)$$

Numerical Simulations and Results:



$\theta=\frac{\pi}{3}$ and $\varphi=\frac{2\pi}{3}$



$\theta=\frac{\pi}{4}$ and $\varphi=\frac{2\pi}{3}$

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[1] J. Splettstoesser, M. Governale and U. zulicke Phys. Rev B 68 , 165341 (2003)

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