Time dependent Spin observables of impurities in a quantum corral

D. Tielas,[1,2,*] M. Reboiro,[1,2] and O. Civitarese[1]
[1]*IFLP - CONICET, Department of Physics, University of La Plata, c.c. 67 1900, La Plata, Argentina*
[2]*Faculty of Engineering, University of La Plata, Argentina*

We consider time dependent spin variables of impurities placed inside a quantum corral [1–3]. In particular we have studied the dependence of spin observables, like the spin squeezing factor and total spin alignment for impurities [4, 5], located on the semi-major axis of an elliptic quantum corral, interacting with the electrons confined within. The Hamiltonian of the system is writing $H = H_o + H_I$ where the H_0 is the unperturbed Hamiltonian of electrons and impurities, and H_I is the interaction among then , that is

$$H_0 = \sum_{\alpha} \epsilon_\alpha (n_{\alpha,\uparrow} + n_{\alpha,\downarrow}) + \sum_i \Delta_i S^z_i, \;\; H_I = J \sum_i \boldsymbol{\sigma}_i \mathbf{S}_i. \quad (1)$$

In these expressions ϵ_α, Δ_i and J are the energies of the electrons, impurities, and the interaction strength.

The electron-spin operators are represented in terms of creation and annihilation operators weighted by the spatial wavefunctions of electrons,resulting from the treatment of the elliptic quantum corral, $\varphi_{i\alpha}$, calculated at the site "r_i" of the impurities.

$$\sigma^z_i = \frac{1}{2} \sum_{\alpha,\beta} \varphi^*_{i\alpha} \varphi_{i\beta} (c^\dagger_{\alpha\uparrow} c_{\beta\uparrow} - c^\dagger_{\alpha\downarrow} c_{\beta\downarrow}),$$

$$\sigma^+_i = \frac{1}{2} \sum_{\alpha,\beta} \varphi^*_{i\alpha} \varphi_{i\beta} c^\dagger_{\alpha\uparrow} c_{\beta\downarrow} = (\sigma^-_i)^\dagger,$$

$$n_{\alpha,\uparrow(\downarrow)} = c^\dagger_{\alpha\uparrow(\downarrow)} c_{\alpha\uparrow(\downarrow)}.$$

In order to evaluate spin observables, we have solved the eigenvalue problem, and selected some of the eigenfunctions. Particularly, we have chosen those wave functions whose properties have been reported in Ref. [3], in order to compare our results with some of the experimentally studied configurations of a quantum corral. Then, we have calculated the expectation value of the total spin, on the states whose quantum numbers have been determined by the measured densities, by adding the spin interactions with a pair of impurities placed along the semi-major axis, near the focuses of the elliptical corral, and calculated the time evolution of spin-squeezing factor [4].

These results depend on the position of the impurities, the adopted wavefunctions and the strength of the couplings[7]. However, as we have verified in performing the calculations, it is indeed possible to find out a set of highly localized spatial density distributions for which the spin squeezing, phenomena may appear.

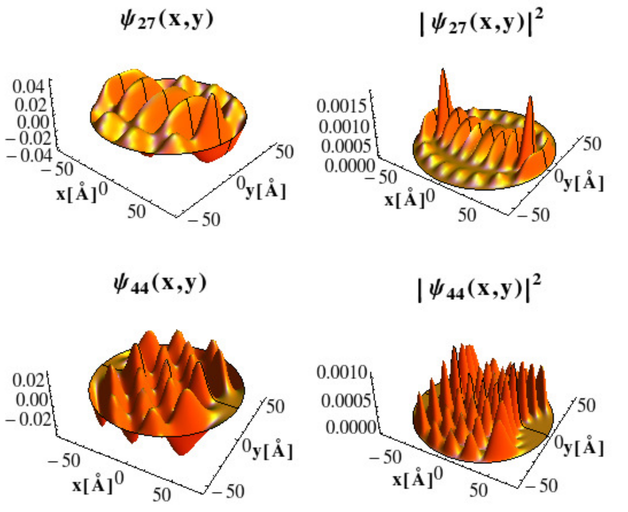

FIG. 1. Spatial amplitude $\psi_{nl}(x,y)$ and probability $|\psi_{nl}(x,y)|^2$ for a quantum corral with semi-axes $a = 78.3\overset{o}{A}$, $b = 55\overset{o}{A}$, in the configurations $(nl) = (2,7)$ and $(4,4)$.

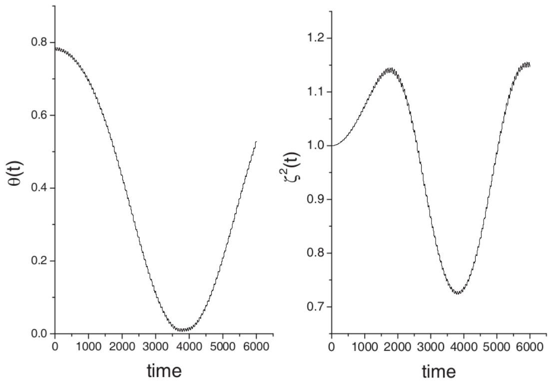

FIG. 2. Spin-squeezing factor $\zeta^2(t)$, and total spin polar angle $\theta(t)$ for impurities placed, on the major semi-axe, near the focuses of the ellipse ($x_f = \pm 38.2\overset{o}{A}$). For an coherent spin state as inictial condition. The time is measured in units of inverse-energy (since $\hbar = 1$)

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[*] tielas@fisica.unlp.edu.ar