Nanoscale physics

Composite bipartite particles in terms of deformed quantum oscillators. Relation to entanglement measures

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In the second quantization method for many-body systems the usual quantum oscillator is commonly used. However, composite (quasi)particles cannot be viewed as usual bosons or fermions. Say, the creation and annihilation operators for composite bosons built of two fermions or two bosons, and composite fermions built of boson and fermion (a_μ , b_ν – operators for constituents)

$$A_\alpha^\dagger = \sum_{\mu\nu} \Phi_\alpha^{\mu\nu} a_\mu^\dagger b_\nu^\dagger, \qquad A_\alpha = \sum_{\mu\nu} \overline{\Phi_\alpha^{\mu\nu}} b_\nu a_\mu$$

satisfy commutation relation ($\varepsilon = -1$ for ‘boson + boson’ case and +1 otherwise)

$$[A_\alpha, A_\beta^\dagger]_\pm = \delta_{\alpha\beta} \pm \varepsilon \Delta_{\alpha\beta}, \;\; \Delta_{\alpha\beta} = \sum_{\mu\mu'} (\Phi_\beta \Phi_\alpha^\dagger)^{\mu'\mu} a_{\mu'}^\dagger a_\mu \mp \sum_{\nu\nu'} (\Phi_\alpha^\dagger \Phi_\beta)^{\nu\nu'} b_{\nu'}^\dagger b_\nu,$$

containing deviation $\Delta_{\alpha\beta}$ compared to standard bosonic/fermionic ones. In this work we found the operator realization of certain two-component composite bosons or composite fermions by appropriate deformed oscillators (bosonic or fermionic) defined by deformation structure function $\varphi(N)$, and relations $\tilde{A}^\dagger \tilde{A} = \varphi(N)$, $\tilde{A} \tilde{A}^\dagger = \varphi(N+1)$. That concerns 2-fermionic/2-bosonic composite bosons [1] as well as few-mode cases of composite fermions built of fermion and (deformed) boson [2]. In the former case bipartite entanglement measures are directly related to deformation parameter [3] revealing its physical meaning. For the considered composite fermions, entanglement entropy was also found [2].

The realization of composite (quasi)particles using deformed oscillators can be applied to an effective description of atoms, molecules, excitons, mesons, nuclei, to nanosystems with composite structure, and some quantum information issues.

1. *Gavrilik A. M., Kachurik I. I., Mishchenko Yu. A.* Quasibosons composed of two *q*-fermions: realization by deformed oscillators // J. Phys. A: Math. Theor.-2011.-**44.**- 475303.

2. *Gavrilik A. M., Mishchenko Yu. A.* Entanglement entropy of composite fermions realized by (deformed) fermions vs. that of composite bosons // arXiv:1504.00529.-2015.

3. *Gavrilik A. M., Mishchenko Yu. A.* Entanglement in composite bosons realized by deformed oscillators // Phys. Lett. A.-2012.-**376**.- 1596.