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Low-order momentum correlation functions of the symmetric Tamm-Dancoff q-bosons, derived via under-trace operations

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Using the set of independent Symmetric Tamm-Dancoff (STD) type q-deformed quantum oscillators [1] with the standard linear-in-N Hamiltonian, we construct respective gas of q-bosons. Such a deformed q-Bose gas model admits [2] exact analytic expressions for the r-particle momentum correlation function, and corresponding intercepts, of any rth order. This is the third example of deformed oscillators' based Bose gas model, along with the qp-Bose gas model [3] and the μ-deformed one [4] (based on Jannussis's oscillator), where correlation average $\langle (a_{\mathbf{k}}^\dagger)^r (a_{\mathbf{k}})^r \rangle$ was calculated explicitly. In view of the formal resemblance between the qp-bracket and the STD deformation structure function, with N-multiplier ignored, we apply the idea of the derivation from [3] for qp-bosons, to the current case of STD q-bosons.

Indeed, using just under-trace algebraic operations, for the STD q-bosons in a fixed $\mathbf{k}$-mode we find
$\langle a^\dagger a \rangle_{\rm STD} = \frac{1}{(e^{\beta\omega}-q)^2} \left\{ \left\langle \frac{\left[a,[a,a^\dagger]_q\right]_q a^\dagger}{\varphi_{\rm STD}(N+1)} \right\rangle + \frac{[1]_q^{\rm STD}!\, e^{\beta\omega}}{{\rm Tr}\, e^{-\beta\omega N}} \right\}$
versus $\langle a^\dagger a \rangle_{qp} = \frac{[1]_{qp}!}{e^{\beta\omega}-q} \left\langle [a,a^\dagger]_q \right\rangle$ for qp-bosons, see [3]. What concerns the quadratic correlations, using the same approach of under-trace transformations we derive
$\left\langle a^{\dagger 2} a^2 \right\rangle_{\rm STD} = \frac{1}{(e^{\beta\omega}-q^2)^3 (e^{\beta\omega}-1)^3} \left\{ \left\langle \sum_{i=0}^{4} A_i(q)\, {\rm g}_q(N+1+i)\, {\rm g}_q(N+i) \cdot q^{-2N} \right\rangle \right.$
$\left. -\, (e^{\beta\omega}-1)\, {\rm g}_q(0) P_2(q; e^{\beta\omega}) \right\} \,+\, \varphi_{\rm STD}(2)! \frac{e^{\beta\omega}-1}{(e^{\beta\omega}-q^2)^3}$
where underlying role belongs to the double commutator as well, through ${\rm g}_q(N)$-function, $[a,[a,a^\dagger]_q]_q = -{\rm g}_q(N+1)\, q^{1-N} \cdot a$, and $P_2(q; e^{\beta\omega})$ is some quadratic polynomial in $e^{\beta\omega}$, with coefficients depending on q.

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