Quantum chaotic patterns in the electron-phonon Jahn-Teller systems

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We study the statistics of the excited energy levels in a class of systems of electron-phonon interaction represented by the generalized two-level Jahn-Teller (JT) $E \otimes (b_1 + b_2)$ model with quantum Hamiltonian $\hat{H} = \Omega(b_1^\dagger b_1 + b_2^\dagger b_2 + 1)I + \alpha(b_1^\dagger + b_1)\sigma_z - \beta(b_2^\dagger + b_2)\sigma_x$ [1] (b_i are phonon (boson) operators, and 2×2 Pauli matrices σ_i account for two electron levels, Ω is frequency of phonons 1 and 2). Compared to the exciton models the system includes the phonon-2 assistance in tunneling between levels; the generalization of the conventional JT system is achieved by assuming different coupling strengths $\alpha \neq \beta$ (due to spacial anisotropy of a crystal in real systems).

Nonequivalence of the phonon-electron coupling constants results in the symmetry lowering (violation of the rotation symmetry of the JT model). As a consequence, the individual energy levels become extremely irregular and the corresponding wavefunctions exhibit fractal properties [2]. At the level of statistical description however the system acquires novel universalities which stand close to the known quantum chaotic patterns. These universalities appear to be irrelevant to the actual values of coupling strengths provided they differ enough one from another.

The distribution of nearest-neighbour level spacings in the domain of model parameters with mostly developed quantum chaos is shown to be close to the novel class of semi-Poisson distribution $P(S) \sim 4S\exp(-2S)$ typical, e.g. for the metal-insulator (M-I) transition in the Anderson model [2]. The vicinity to this model is also supported by the long-range statistical measure $\bar{\Delta}_3$ whose slope (spectral compressibility) appears to tend to the value (0.5/15) predicted for the said intermediate statistics [3]. Similar results emerge from the study of the fractal dimensions of the wavefunctions. The exposed results allow us to suggest that the class of investigated electron-phonon models pertains to a class of systems sharing a novel universal statistics one of whose representative is the Anderson model at the point of M-I transition.

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