Information-Theoretical Approaches to Measurement and Control of Novel Quantum Excitations in Condensed Matter

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Nowadays, information-theoretical concepts have been widely used in various branches of modern physics. This is because there are many complementary concepts to traditional ideas in theoretical physics. For instance, the entanglement entropy represents the amount of nonlocal correlation, and singular value decomposition (SVD), a kind of principle component analysis, is a key technique for tensor-network algorithms that generate precise variational ansatz. We expect that these concepts provide us with novel ways of representing and observing quantum excitations realized in quantum many-body systems. However, it is still challenging to find direct relationship among entanglement, SVD, and nonlocal excitations due to strong correlation. Our broad goal is to apply these theoretical ideas to the development of spectroscopic techniques in condensed matter physics.

Here, I am going to present a method of extracting a set of possible nonlocal excitations in our target quantum spin systems [1]. The method is based on SVD for a spin correlation matrix. The method enables us to reconstruct the wavefunction information of the ground state. I also mention close relationship between correlation matrix and entanglement spectrum [2]. In addition to the SVD analysis, we try to construct a theory of entanglement generation for remote electron-phonon systems after photoirradiation [3]. The scope of this work is to understand how photoirradiation creates entanglement among remote phonons which do not directly couple with photons. We focus on time evolution of various entanglement measures among photons, electrons, and phonons. Finally, we briefly mention nonlocal generalized quantum measurement [4]. This method enables us to observe the entangled nature of a photon pair by an alternative entangled photon pair. Although high coherence of quantum beam is necessary, this type of quantum-optical measurement scheme may be promising for new measurement technologies in condensed matter physics.

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