Quantum nonlinear spectroscopy via a single spin quantum sensor

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The correlators of a quantum system that can be extracted by classical nonlinear spectroscopy reflect how the quantum system evolves under a classical force. When a quantum sensor is coupled to a quantum system, the effect can be viewed as either the quantum system is driven by the force from the sensor, or the sensor is affected by the noise from the system. The "delayed choice" in quantum mechanics makes it possible to select which of these two "worldviews" is realized by setting the initial state of the sensor before the coupling and selecting a basis to measure the sensor after the coupling. This way, the quantum nonlinear spectroscopy (QNS) can obtain 2^N different types of correlators after N shots of interrogation between the sensor and the system [1], while the classical nonlinear spectroscopy in the same order can determine one type of correlators. In the sense that the scope of accessible correlators by quantum sensing is exponentially larger than those by the classical method, the QNS represents a kind of quantum supremacy in the realm of sensing and metrology. The QNS can be realized using correlations of sequential weak measurements [2] or synthesized quantum channels [3]. I will explain the concept of QNS and several applications, including the classical-noise-free detection of quantum objects [4, 5], distinction between classical and quantum noises [6], approaches to studying non-Gaussian fluctuations in critical quantum many-body systems [7], and loophole-free test of quantum foundation using inequalities involving higher order correlators [8].

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