Quantum Decoherence Theory

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The investigation of quantum decoherence has received tremendous attentions in recent years due to the rapid development of quantum information processing. The decoherence effects are the most difficult problem that one has to overcome for any successful quantum information processing. In the literature, most of the treatments to decoherence are based on master equations under the Born-Markov approximation. However, the efficiency of quantum information processing strongly depends on how fast the quantum operations can be, while the fast quantum operations requires strong couplings among constitutes in the devices. Both the fast quantum operations where Markov approximation fails and strong couplings for which Born approximation is not applicable require a non-perturbative and non-Markovian treatment to various decoherence problems in quantum information processing. In this talk, I will report some of our recent progress. We utilize the coherent state path integral approach to reformulate Feynman-Vernon influence functional theory, which makes the influence functional theory applicable to arbitrary open quantum system. Non-Markovian decoherence dynamics is thus completely governed by a closed-time effective action with fully taking into account the back-reaction effects from its environments. The exact master equation and the transient current are derived within this framework, which recover all the relevant results obtained from Schwinger-Keldysh's non-equilibrium Green function approach. The Born-Markov master equation and the Büttiker-Landauer current that widely used in the literature are reproduced from our theory at well-defined limits. To be specific, I will concentrate on the mechanism of intrinsic and/or extrinsic loss of quantum coherence in various quantum devices and quantum measurement through transient transport for quantum information processing.