Nonequilibrium thermodynamics of quantum coherence beyond linear response

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Quantum thermodynamics allows for the interconversion of quantum coherence and mechanical work. Quantum coherence is thus a potential physical resource for quantum machines. However, formulating a general nonequilibrium thermodynamics of quantum coherence has turned out to be challenging. In particular, precise conditions under which coherence is beneficial to or, on the contrary, detrimental for work extraction from a system have remained elusive. We here develop a generic dynamic-Bayesian-network approach to the far-from-equilibrium thermodynamics of coherence. We concretely derive generalized fluctuation relations and a maximum-work theorem that fully account for quantum coherence at all times, for both closed and open dynamics. We obtain criteria for successful coherence-to-work conversion, and identify a nonequilibrium regime where maximum work extraction is increased by quantum coherence for fast processes beyond linear response.