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# Classical–Quantum Correspondence in Photonic Temporal Crystals

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In this work, we develop a quantum electrodynamical framework for photonic temporal crystals (PTCs), bridging classical momentum gaps and fully quantum phenomena within a single theoretical model. Building on previous studies of non-Hermitian band structures in time-periodically modulated media [1-4], we show that a PTC can be quantized through a Floquet Hamiltonian where the photonic modes form a synthetic lattice in momentum–Floquet space. A key insight is that the exponential field growth seen in classical PTCs corresponds, quantum-mechanically, to a localization–delocalization transition of photon wavefunctions. At critical momenta (i.e., the edges of the momentum gap), photon number states become delocalized, triggering exponential increases in photonic energy.

Notably, when a two-level atom couples to these modes in a single-frequency cavity, conventional Rabi oscillations can be dramatically altered by the large continuum of Floquet–photonic states. Rather than exhibiting recurrent population exchange, the atomic state irreversibly decays into a half-and-half mixed state, even though there is only one nominal cavity resonance, illustrating how time-periodic modulation effectively expands the available photonic Hilbert space [4]. These results highlight that, despite the overall Hamiltonian being Hermitian, classical pseudo-Hermitian features emerge through Floquet band folding and interplay with quantum light–matter interactions. Beyond clarifying the classical–quantum correspondence of PTCs, this framework opens avenues for exploring photon pair creation, squeezing, and tailored non-equilibrium light-matter interactions [4, 5].

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