Local density of states and discrete time crystalline behavior in photonic temporal crystals

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Over the last few decades, one of the most prominent strategies for controlling light-matter interaction has been the use of space-periodic photonic structures such as photonic crystals and metamaterials. However, recent advances in time-varying photonics necessitate an extension of the theory to account for the temporal-variation-induced modification of light-matter interaction. One such example is the photonic temporal crystal (or photonic Floquet medium), whose optical properties are time-periodically modulated. The band structures of linear photonic temporal crystals are characterized by non-Hermiticity and are known to exhibit momentum gaps, the edges of which are non-Hermitian degeneracies, or exceptional points. In the first part of the presentation, we show that the local density of states and, consequently, the rate of spontaneous emission are non-zero at the momentum gap edges, highlighting the importance of the non-orthogonality of photonic Floquet eigenstates and the role of the Petermann factor in the photonic temporal crystal. In the second part, we demonstrate that discrete time crystalline behavior can be observed in a photonic temporal crystal, in which the many-body effect is revealed by nonlinearity. Experimentally, this spontaneous discrete time translational symmetry breaking is observed in a nonlinear microwave temporal crystal. Specifically, rigid commensurate and incommensurate subharmonic responses to the driving period are confirmed in the presence of spatial and temporal disturbance.

Relevant papers

[1] K Lee, J Son, J Park, B Kang, W Jeon, F Rotermund, B Min, "Linear frequency conversion via sudden merging of meta-atoms in time-variant metasurfaces," Nature Photonics 12 (12), 765-773 (2018)
[2] S Lee, J Park, H Cho, Y Wang, B Kim, C Daraio, B Min, "Parametric oscillation of electromagnetic waves in momentum band gaps of a spatiotemporal crystal," Photonics Research 9 (2), 142-150 (2021)
[3] J Park, B Min, "Spatiotemporal plane wave expansion method for arbitrary space–time periodic photonic media," Optics Letters 46 (3), 484-487 (2021)
[4] K Lee, J Park, S Lee, S Baek, J Park, F Rotermund, B Min, "Resonance-enhanced spectral funneling in Fabry–Perot resonators with a temporal boundary mirror," Nanophotonics 11 (9), 2045-2055 (2022)
[5] J Park, H Cho, S Lee, K Lee, K Lee, HC Park, JW Ryu, N Park, S Jeon, B. Min, "Revealing non-Hermitian band structure of photonic Floquet media," Science Advances 8 (40), eabo6220 (2022)