

Optical thermodynamics: From basic principles to optical pressure and thermalization

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We review our recent results in the emerging field of optical thermodynamics. In this respect, we have developed a unified framework that can be applied to effectively any optical setting. We explain that each system under study can be associated with a different set of natural extensive variables of entropy. At this point, several thermodynamic approaches exist for analyzing optical forces in multimoded settings. Here, we develop a new theoretical methodology that unifies these perspectives in a variety of different configuration, irrespective if they are discrete or continuous. By studying Su-Schrieffer-Heeger lattices, we elucidate the thermodynamics of polyatomic chains and show that intercell and intracell bonds can display different optical forces. In addition, we provide a thermodynamic formalism to predict and understand the optical pressure at the equilibrium arising in arrangements characterized by a continuous index variation and apply our results to graded-index fibers.

We also analyze the transition of a system to the final thermal state via nonlinear interaction. We focus on the case of photonic lattices, and analyze how thermalization is affected by the lattice geometry, the optical temperature, and the nonlinearity. We utilize a one-dimensional Su-Schrieffer-Heeger lattice as the simplest topological model to investigate the thermalization process of multiband systems in both topologically trivial and nontrivial regimes. Specifically, we identify that thermalization develops in three stages: (i) out-of-equilibrium dynamics, (ii) prethermal stage and (iii) final thermalization. Each individual band constitutes a subsystem that prethermalizes to the Rayleigh-Jeans distribution predicted from its power and internal energy. Each individual band constitutes a subsystem that prethermalizes to the Rayleigh-Jeans distribution predicted from its power and internal energy. We find that this leads to a continuously varying prethermalization that eventually relaxes to the final thermal state (a dynamically evolving prethermal state). The presence of topological edge states can accelerate the thermalization process, although prethermal states exist both in the topologically trivial and nontrivial regimes.