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Complexity & optical feedback in a simple nonlinear Fabry-Pérot cavity

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ABSTRACT

The nonlinear Fabry-Pérot (FP) cavity is a generalization of the classic diffusive Kerr slice with a single feedback mirror [D'Alessandro & Firth, Phys. Rev. Lett. vol. 66, 2597 (1991)]. Despite its tantalizing simplicity, analysis of FP geometry (where the slice is effectively sandwiched between two parallel plane mirrors) has proved to be a non-trivial problem that remains open: it is the epitome of a complex system capturing the interplay between diffraction (in the free-space path), counter-propagating waves, light-medium coupling (transverse diffusion of carriers driven by local incoherent light intensity), a host of cavity effects (periodic pumping, mirror losses, interferomic mistuning), and dynamical effects on multiple time-scales.

Our analysis begins by considering an instantaneous medium response in the plane-wave limit (where transverse effects such as diffraction and diffusion are neglected). Even with these simplifications the FP cavity routinely exhibits remarkably complicated behaviour that we have investigated as functions of system parameters (such as slice reflectivity and mistuning). Time series have permitted visualization of phase-space attractors, and bifurcation diagrams have revealed that Ikeda-type instabilities [Ikeda *et al.*, Phys. Rev. Lett. vol. 45, 709 (1980)] can dominate system dynamics. Our more recent research has used linear analysis to calculate the threshold spectrum for spontaneous pattern-forming instabilities in the presence of transverse effects, and simulations have confirmed new theoretical predictions. Emergent spatial structures may be either *simple* (characterized by a single dominant scale-length) or *fractal* (comprising decades of scale with comparable amplitude) in nature [Huang & McDonald, Phys. Rev. Lett. vol. 95, 174101 (2005)].