SCCS 2013

Spontaneous symmetry-breaking & spatial fractal patterns in optical models

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KEYWORDS

fractal patterns, Kerr effect, optical cavities, simple patterns, Turing instability.

ABSTRACT

A modern understanding of the origin of pattern and form in Nature lies in Alan Turing's seminal work from 1952 [Turing, Phil. Trans. Roy. Soc. Lond. B vol. 237, 37 (1952)]. His proposal – that the uniform states of a sufficiently stressed system can become susceptible to spontaneous pattern-forming instabilities in the presence of vanishingly-small background fluctuations (symmetry-breaking perturbations) – has become a lynchpin for describing the birth of emergent simple patterns (such as stripes, hexagons, and squares) in a wide class of nonlinear reaction-diffusion models.

Of particular interest in this presentation is spatial pattern formation in optical systems [Arecchi *et al.*, Phys. Rep. vol. 318, 1 (1999)]. We will present an overview of our latest research demonstrating that a generalization of Turing's ideas – *multi-Turing instability spectra* [Huang & McDonald, Phys. Rev. Lett. vol. 95, 174101 (2005)] – can provide a universal mechanism for the spontaneous emergence of spatial fractals (patterns with proportional levels of details spanning decimal orders of scale). Extensive numerical calculations have provided compelling evidence suggesting that this route-to-fractality is independent of both nonlinearity (e.g., dispersive or absorptive) and boundary conditions [e.g., single feedback-mirror, cavity (uni- and bi-directional geometries), and counterpropagating-beam]. Recent research highlights to be discussed include a new analysis of pattern formation in a dispersive ring cavity filled with a Kerr-type host medium. Our approach accommodates a more complete description of high spatial frequencies (necessary for an accurate description of fractals) by going beyond the traditional paraxial approximation [McLaughlin *et al.*, Phys. Rev. Lett. vol. 54, 681 (1985)].