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Turing instability: a universal route to spontaneous spatial fractals

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Summary

We present the first predictions of spontaneous spatial fractal patterns in nonlinear ring cavities. New analyses reveal multi-Turing spectra characteristic of susceptibility for spontaneous fractals. Extensive computer simulations confirm theoretical predictions.

Turing instability is the tendency of the uniform states of a system to become spontaneously patterned in the presence of any small fluctuation [1]. Archetypal Turing-instability patterns include hexagons, squares, stripes, and rings. These simple structures are universal in Nature, and characterized by a single dominant scale-length. Recently [2], we proposed that a multi-Turing instability may result in another type of universal pattern: fractals. Fractals possess proportional levels of detail spanning decades of scale-length, and are thus inherently scaleless. This prediction was confirmed in analysis of a classic photonic system (the diffusive Kerr slice with a single feedback mirror). The growth of such multi-scale patterns is entirely due to intrinsic nonlinear dynamics. They are thus physically distinct from fractal mode patterns of unstable-cavity lasers [3], and optical fractals that rely on system changes for introducing each scale-length [4].

Fig1. Transverse intensity distributions. Transition from a simple Turing-instability pattern (hexagon) to a fractal mode in a pure-absorptive nonlinear cavity. Self-similar structure persists down to scale-lengths of the order of the optical wavelength.

Here, we present the first predictions of spontaneous spatial fractal patterns in nonlinear ring cavities. This includes the first reported spatial fractals arising from purely-absorptive nonlinearity. New analyses reveal multi-Turing spectra characteristic of susceptibility for spontaneous fractals. Computer simulations
consider both one and two transverse dimensions (see Fig. 1), and quantify the fractal properties of the generated patterns. A range of results will be reported, including the proposal of a new kind of “fractal soliton”.

References