



University of
Salford
MANCHESTER

Turing instability: a universal route to spontaneous spatial fractals

Huang, JG, Christian, JM, McDonald, GS and Chamorro-Posada, P

Title	Turing instability: a universal route to spontaneous spatial fractals
Authors	Huang, JG, Christian, JM, McDonald, GS and Chamorro-Posada, P
Publication title	Technical Digest: European Optical Society Annual Meeting
Publisher	European Optical Society
Type	Conference or Workshop Item
USIR URL	This version is available at: http://usir.salford.ac.uk/id/eprint/18304/
Published Date	2008

USIR is a digital collection of the research output of the University of Salford. Where copyright permits, full text material held in the repository is made freely available online and can be read, downloaded and copied for non-commercial private study or research purposes. Please check the manuscript for any further copyright restrictions.

For more information, including our policy and submission procedure, please contact the Repository Team at: library-research@salford.ac.uk.

Turing instability: a universal route to spontaneous spatial fractals

J. G. Huang¹, J. M. Christian², G. S. McDonald², P. Chamorro-Posada³

¹Advanced Technology Institute, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, Surrey GU2 7XH, United Kingdom

²Joule Physics Laboratory, School of Computing, Science and Engineering, Institute for Materials Research, University of Salford, Salford M5 4WT, U.K.

³Departamento de Teoría de la Señal y Comunicaciones e Ingeniería Telemática, Universidad de Valladolid, ETSI Telecomunicación, Campus Miguel Delibes s/n, 47011 Valladolid, Spain

email: J.Huang@surrey.ac.uk

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].

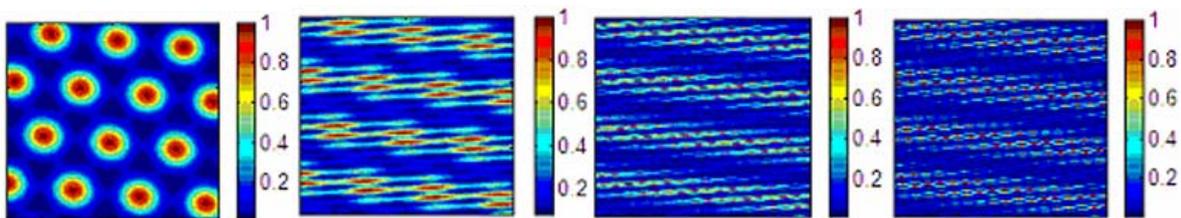


Fig1. Transverse intensity distributions. Transition from a simple Turing-instability pattern (hexagon) to a fractal mode in a pure-absorptive nonlinear cavity. Self-similar structure persists down to scale-lengths of the order of the optical wavelength.

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

- [1] A. M. Turing, *Phil. Trans. Roy. Soc. London B*, **237**, 37, 1952
- [2] J. G. Huang and G. S. McDonald, *Phys. Rev. Lett.*, **94**, 174101, 2005
- [3] G. P. Karman, G. S. McDonald, G. H. C. New and J. P. Woerdman, *Nature*, **402**, 138, 1999; J. G. Huang, J. M. Christian and G. S. McDonald, *J. Opt. Soc. Am. A*, **23**, 2768, 2006
- [4] S. Sears, M. Soljacic, M. Segev, D. Krylov and K. Bergman *et al.*, *Phys. Rev. Lett.*, **84**, 1902, 2000