



University of
Salford
MANCHESTER

Multi-Turing instability spectra and spatial fractals in absorptive systems

Christian, JM, Bostock, C, McDonald, GS and Huang, JG

Title	Multi-Turing instability spectra and spatial fractals in absorptive systems
Authors	Christian, JM, Bostock, C, McDonald, GS and Huang, JG
Publication title	
Publisher	
Type	Conference or Workshop Item
USIR URL	This version is available at: http://usir.salford.ac.uk/id/eprint/32868/
Published Date	2014

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.

Multi-Turing instability spectra and spatial fractals in absorptive systems

J. M. Christian¹, C. Bostock¹, G. S. McDonald¹, and J. G. Huang²

¹ *Materials & Physics Research Centre, University of Salford, Greater Manchester M5 4WT, U.K.*

² *Faculty of Advanced Technology, University of Glamorgan, Pontypridd CF27 1DL, U.K.*

Spontaneous optical pattern formation in ring cavities containing saturable absorbers has been increasingly studied over the past two decades, with models often based on the two-level Maxwell-Bloch equations. Linear stability analysis of the weakly-absorptive system tends to be fraught with complexity, and leads ultimately to a threshold instability spectrum for Turing patterns that possesses comparable multiple minima [Patrascu *et al.*, *Opt. Commun.* **96**, 433 (1992)] – a *multi-Turing spectrum* that we have proposed as a universal signature for predicting a system’s innate capacity to generate spontaneous spatial fractals [Huang and McDonald, *Phys. Rev. Lett.* **95**, 174101 (2005)]. Taking the mean-field limit decreases the overall complexity of the problem [Firth and Scroggie, *Europhys. Lett.* **26**, 521 (1994)] but the multi-Turing spectrum vanishes, leaving only a single instability lobe which provides no obvious mechanism by which fractal patterns can emerge.

Here, we consider two reduced models of a two-level saturable-absorber system without recourse to mean-field theory [Huang, Christian, and McDonald, *J. Nonlin. Opt. Phys. Mat.* **21**, 1250018 (2012)]. Our analysis begins with the thin-slice approximation, capturing the interplay between the circulating cavity field, a diffusive population difference (driven by local light intensity), and the classic ring cavity boundary condition (lumping together periodic pumping, coupling-mirror losses, and interferomic mistuning). Simulations have shown that emergent spatial patterns can be both simple (single-scale) and fractal (multi-scale) in character. More recently, we have gone beyond the thin-slice limit and applied our approach to bulk geometries (where light-medium interaction lengths become finite and can no longer be ignored). Theoretical analysis still predicts a multi-Turing spectrum under the conditions of an instantaneous local medium response (i.e., no diffusion) and paraxial diffraction (i.e., nonlinear Schrödinger-type governing equation). This key result suggests that the multi-Turing mechanism may be truly universal, arising in even the simplest models of a bulk absorptive cavity.