Spatiotemporal Chaos in Complex Oscillatory Media

R. Kapral

University of Toronto, Chemical Physics Theory Group
Department of Chemistry
Toronto, Ontario M5S 3H6, Canada

It is well known from experiment and theory that oscillatory reaction-diffusion systems may display a variety of spatiotemporal structures including spiral waves and defect mediated chemical turbulence. A number of less well known dynamical phenomena that these systems may exhibit will be described. If the local dynamics of the medium has a more complex oscillatory structure, say, arising from a period doubling cascade to chaos, spiral waves contain line defects where a suitably defined phase of the oscillation jumps by multiples of 2 pi. Spatiotemporal chaos involving line defects develops through nonequilibrium phase transitions. It is characterized by the continual formation and destruction of line defects and has statistically stationary properties.

The origins of these phenomena will be described and schemes for their analysis will be presented. The talk will serve as an introduction to the experimental observations of some of these phenomena by Park and Lee, presented in this School.

Spatiotemporal Dynamics in the Resonantly-Forced Complex Ginzburg-Landau Equation

Periodically forced oscillatory reaction-diffusion systems near the Hopf bifurcation can be modeled by the resonantly-forced complex Ginzburg-Landau (RFCGL) equation. The nature of this equation will be discussed. The remainder of the talk will focus on the 2:1 and 3:1 strong resonance regimes.

The Ising and Bloch fronts seen in the 2:1 resonant regime will be described, with special emphasis on the phenomena that occur when the forcing amplitude varies randomly in space (both quenched and dynamic disorder). In the 3:1 resonant locking regime the RFCGL equation has three stable fixed points corresponding to the phase-locked states in the underlying reaction-diffusion system. Phase fronts separate spatial domains containing the phase-locked states. When the Ginzburg-Landau equation parameters lie in the Benjamin-Feir unstable regime, the phase fronts have a turbulent internal spatiotemporal structure. As the forcing intensity is changed, the intrinsic width of a front grows until, at a critical value, the front ``explodes" and the turbulent interfacial zone expands to fill the entire domain. The scaling properties of this transition will be explored and it will be shown that the front width and spatial and temporal correlations diverge as the critical forcing intensity is approached.

These results will be compared with similar behavior seen a coupled map model with period-three local dynamics. The phenomena can be probed by experiments on periodically forced light sensitive reaction-diffusion systems.