



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

This thesis entitled, “*Dynamics of Spiral and Scroll Waves: An Experimental and Numerical Study*” deals with understanding the dynamics of two dimensional (2D) spiral and three dimensional (3D) scroll waves, specifically found in reaction diffusion systems.

The cause of cardiac arrhythmia and its effect on human health is of paramount interest to researchers across varied field. It is known that life threatening arrhythmias like ventricular tachycardia and fibrillation are a result of anomalous behavior of electrical waves in the heart. These waves, that look like spiral and scrolls, can also anchor to small obstacles (i.e. ischemic or scar tissues, collagen fibers, or coronary vessels) generating stationary electrical signals, that are disruptive to regular cardiac activity. Hence, scroll waves of reentrant activity and their interactions can be said to pose a serious threat to cardiac health. This thesis outlines the results of experimental and theoretical study spiral and scroll waves carried out in a reaction diffusion system. The research has been primarily focused on 3D waves and its behavior in heterogeneous medium.

The Belousov-Zhabotinsky (BZ) reaction is one of the most widely studied reaction diffusion systems, in which different kinds of waves can be generated. It sustains similar wave forms as in the cardiac tissue. A brief introduction to the field of Nonlinear Dynamics and motivation of the thesis is given in chapter 1. Chapter 2 describes the details of the experimental and theoretical methods used in our study. It also gives a gist of the dynamics of the waves formed two and three dimensions.

Chapter 3 illustrates the detailed study of the effects of reactant concentrations on the dynamics of spiral waves in the Belousov-Zhabotinsky reaction. Methodical investigations were performed over a parameter space where there is spontaneous formation of spiral waves. We have studied the dynamics of spiral waves in a thin layer of the BZ system varying the concentrations of sulphuric acid, sodium bromate and

malonic acid. The main purpose is to study the change in excitability and the corresponding signatures in wave characteristic. It was found that the period and wavelength decreases with increase in concentrations of sulphuric acid and sodium bromate, whereas the velocities of the waves increase. In contrast, there was no significant change with change in concentration of malonic acid. The core of the spiral becomes smaller with increase in concentration of sulphuric acid and sodium bromate, and increases with increase in malonic acid concentration. The experimental results compare well with that of the numerical predictions.

Chapter 4 elaborates pinning and unpinning of three dimensional scroll vortices around heterogeneities. Scroll waves can attach themselves to unexcitable obstacles, and this sometimes highly elongates their life span. Hence, the unpinning and annihilation of these vortices have attracted much attention in recent decades. In this work, we study the influence of a thermal gradient on scroll waves pinned to inert obstacles in the Belousov-Zhabotinsky reaction. Under a temperature gradient, scroll rings were seen to unpin from these obstacles, thus strikingly reducing their lifetimes. These results were also reproduced by numerical simulations using the Barkley model.

Chapter 5 discusses the study of the effect of external gradients and their varying orientation on the scroll waves. In this study, we have tried to control the position of a scroll wave by different kinds of field gradients like thermal and electrical and compared their individual effects. In the presence of a single field, the scroll aligns perpendicular and moves towards the anode or hot end of the field. In the presence of an electric field and a thermal gradient aligned perpendicular with respect to one another, the scroll moves in a diagonal direction between the anode and hot end. Though, qualitatively the effects of the two gradients on scroll waves are similar, the effect of the electric field is much more significant as compared to the thermal gradient.

Chapter 6 explains the interaction of two scroll waves in experiments with the Belousov-Zhabotinsky reaction. We show that depending on their mutual orientation, two scroll rings can push each other away and rupture on touching the system boundary, or they can reconnect to form a single, large ring. The reconnected filament has extended lifetimes, which could have serious implications in systems where they occur. The experimental results are explained on the basis of a simple numerical model.