Nonlinear feedback control of Marangoni wave patterns in a thin film heated from below

Anna Samoilova*[1,2] and Alexander Nepomnyashchy[3]

[1]Theoretical physics department (Perm, RUSSIA) (PSU) – 614990 Bukirev 15, Perm, Russia, Russia
[2]Technion - Israel Institute of Technology [Haifa] – Technion City, Haifa 3200003, Israel
[3]Department of Mathematics and Minerva Center for Nonlinear Physics of Complex Systems, Technion - Israel Institute of Technology (Technion) – Israel

Abstract

We investigate the effect of nonlinear feedback control on the oscillatory mode of the long-wave Marangoni instability. Thin liquid film heated from below with a deformable free surface atop a substrate of low thermal conductivity is considered. We apply the feedback control based on the measurement of the temperature perturbation on the free surface and imposing a corresponding local change of flux on the solid substrate. We consider both cases of the subcritical and supercritical bifurcation, aiming to change the excitation of convection from subcritical to supercritical, or to stabilize a definite kind of convective pattern. Within lubrication approximation we obtain nonlinear amplitude equations, which describe coupled evolution of the thickness and temperature of thin film in the presence of the nonlinear control. We have performed a weakly nonlinear analysis based on the consideration of the nonlinear interaction of a pair of standing waves propagating at the angle between the wave vectors. That consideration leads to a set of complex differential equations that govern the evolution of wave amplitudes. The nonlinear control allows changing the coefficients that determine the nonlinear wave interaction. We show that by means of quadratic feedback control it is possible to replace a subcritical bifurcation by a supercritical one. Nonlinear interaction of two standing waves under a quadratic control can produce stable structures (traveling squares, traveling rectangles, standing rectangles or alternating rolls), which are always unstable with respect to traveling wave in the uncontrolled case. This research was supported by the Israel Science Foundation (grant No. 843/18)

Keywords: Marangoni convection, instability control, pattern formation

*Speaker