Multi-stability and chaotic transient LFF dynamics in semiconductor lasers with time-delayed optical feedback

Cristina Masoller

Departament de Fisica i Enginyeria Nuclear, Universitat Politecnica de Catalunya, Colom 11, E-08222 Terrassa, Barcelona, Spain

Multi-stability of coexisting attractors often results in long chaotic transients, in particular, in networks of coupled systems and in time-delayed systems. In the case of systems with delayed feedback loops, the delay in the feedback can induce a set of coexisting attractors which do not exist in the un-delayed case. Coexistence of attractors can lead to long transients before a system reaches a stationary state, and noise can turn the transient dynamics into noise-sustained dynamics.

I will illustrate these ideas about the interplay of multi-stability, noise, and transient dynamics using as an example a semiconductor laser with optical feedback from an external mirror. The feedback has a time delay because of the finite round-trip time of the light in the external cavity. The delayed optical feedback induces a set of coexisting fixed points which are called external cavity modes (ECMs). The regime of low-frequency fluctuations (LFF) is a feedback-induced regime where the laser output intensity randomly and abruptly drops to zero and recovers gradually. Based on the standard model for semiconductor lasers with optical feedback (the Lang- Kobayashi model), LFFs have been understood as due to chaotic itinerancy among destabilized ECMs. However, in the deterministic Lang- Kobayashi model and for a large range of realistic parameters, the LFFs are a transient dynamics towards a stable ECM. This transient can become, in the presence of noise, a noise-sustained chaotic behavior. I will present a statistical analysis of the lifetime of the LFF regime and discuss the possibility of controlling the LFF lifetime via fine tuning the laser parameters that control the position of the coexisting ECM fixed points in the phase space.