A toy theory of the onset of multiple-pulsing instabilities in a soliton laser

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ABSTRACT

Passively mode-locked lasers produces extremely short pulses of light. The pulsed state emerges starting from an incoherent initial state, as a result of the soliton-like dynamics of the laser, a case of self-organization. These lasers have fascinatingly rich dynamical behavior particularly as the laser energy is increased, strengthening the nonlinear effects.

In this work, we report experimental observation of a period-doubling route to pulse breakdown as the energy is increased. A simple analytical model, based on coupled difference equations, qualitatively explains the experiments. The period-doubling transitions do not necessarily lead to chaotic behavior, in contrast to similar discrete maps. Our toy theory models this complicated system as a set of difference equations (a finite dimensional phase space) riding on top of underlying dynamics described by a nonlinear partial differential equation (equivalent to an infinite-dimensional phase space). It is remarkable that these two vastly different sorts of dynamics co-exist stably.