Dynamics and Instabilities in Series of Coupled Nonlinear Resonators

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ABSTRACT
We explore the wide range of dynamical behaviour that is possible in networks of coupled nonlinear resonators. Our basis system consists of strongly localized photonic crystal cavities with a Kerr nonlinearity. The employed coupled mode equations are more general [1], so that ring resonators and Bragg cavities are also described. Already the simplest circuits, with two or three resonators, exhibit phenomena such as self-pulsing and chaos. The use of semi-analytical theory allows us to distinguish the interesting regions for experiments. We check the theory with rigorous FDTD simulations.
Keywords: nonlinear dynamics, self-pulsing, chaos, micro-cavities, Kerr nonlinearity.

1. DESCRIPTION

We focus on time-domain instabilities and consider e.g. a series of consecutive resonators with a constant input power on one side, see Fig. 1a. Using linear stability analysis it is possible to distinguish between: (S) Steady-state solutions: with a constant (transmitted and reflected) output power. (BI) bistable instability: the conventional, negative-slope repulsive states, (SP) self-pulsing: oscillating output signal. Within the self-pulsing regions we further check for chaos, by determining the maximal Lyapunov coefficient. For three cavities this leads to the graph in the Fig. 1b. We distinguish for these parameters an important region with self-pulsing and chaos. Connections with the well-known gap solitons in conventional Bragg structures can be explored.

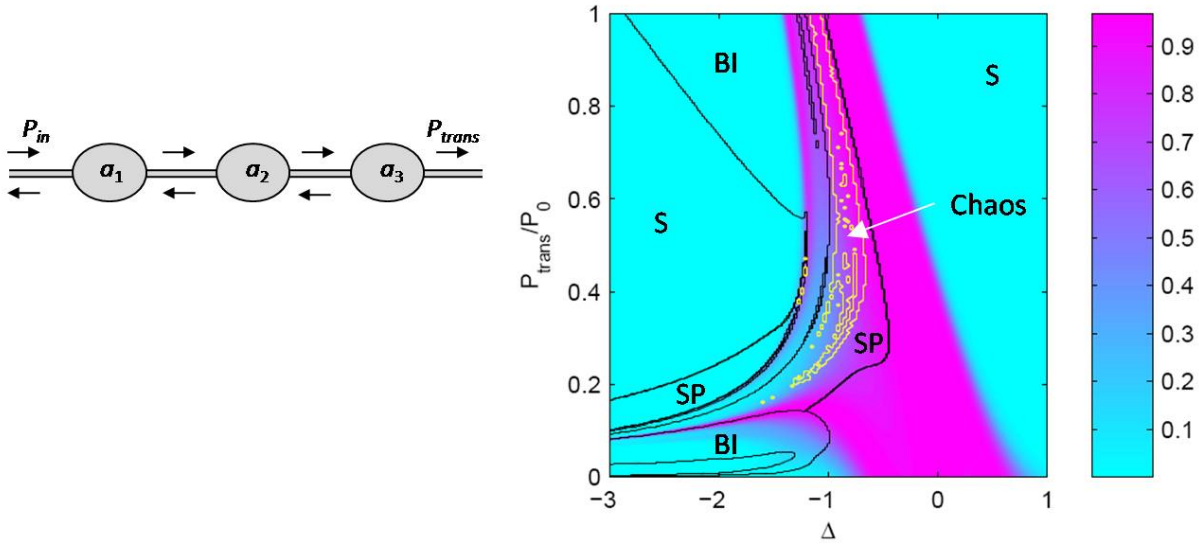

Figure 1: (a) Schematic of the device; (b) Dynamical behaviour of three Kerr cavities. Transmitted power versus normalized detuning. The color bar shows the transmission.

2. CONCLUSION

The fabrication of complex circuits with multiple resonators commits us to examine the possible instabilities that may appear. In addition, the phenomenon of self-pulsing and chaotic behaviour in *passive* structures complements the field of coupled lasers and lasers or amplifiers with feedback. The applications can therefore lead to integrated random bit generators, chaos communications or reservoir computing [2].

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