

Spontaneous Symmetry Breaking of Light in Ring Resonators

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The Lugiato-Lefever (LL) equation [1] has been used to model a variety of nonlinear quantum optical systems [2]. One of its major successes has been in describing light propagating in fibre loops and micro-ring resonators. A system of two coupled LL equations:

$$\frac{\partial E_{\pm}}{\partial t} = -(1 + i\theta)E_{\pm} + i\sigma \frac{\partial^2 E_{\pm}}{\partial \tau^2} + E_{in} + i\eta (A|E_{\pm}|^2 + B|E_{\mp}|^2) E_{\pm} \quad (1)$$

can be used to describe the interaction of either two circularly polarised fields [3] or two counter-propagating fields circulating in micro-ring resonators. The latter was experimentally studied in [4]. In (1) E_{\pm} are the two circulating fields, θ , the detuning, σ controls the dispersion, E_{in} is the input pump, η is proportional to the Kerr medium response, while A and B characterise the self and cross modulation couplings. Note that the values of the constants A and B vary between configurations and applications.

We show that a symmetry breaking bifurcation of the equal amplitude homogeneous stationary state may occur, as illustrated in FIG. 1, when increasing E_{in} . The emergence of this symmetry breaking bubble depends on the cavity detuning θ being above a threshold value θ_{min} which, in turn, depends critically on the ratio B/A via:

$$\theta_{min} = \frac{\sqrt{3 - (B/A)^2 + 2(B/A)}}{1 - (B/A)} \quad (2)$$

This result is part of a wider analysis of symmetry breaking phenomena in micro-ring resonators. Practical applications of these devices, such as frequency comb generation, Sagnac interferometry, chip-based nonreciprocal operation, optical gyroscopes, isolators and circulators based on the Kerr effect, require careful predictions about the onset of the symmetry breaking bifurcation.

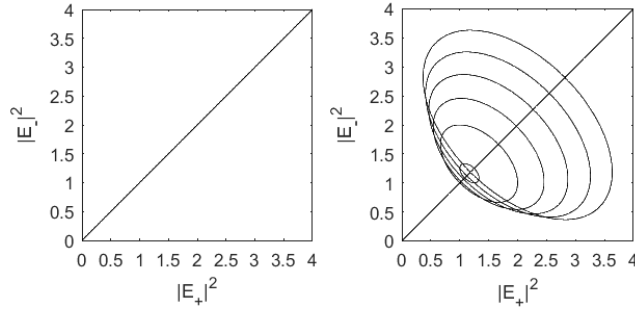


FIG. 1. Field amplitudes of the homogeneous stationary state of (1). Left: For a detuning below threshold. Right: For six different detunings above threshold showing the emergence of the symmetry breaking bifurcation.

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