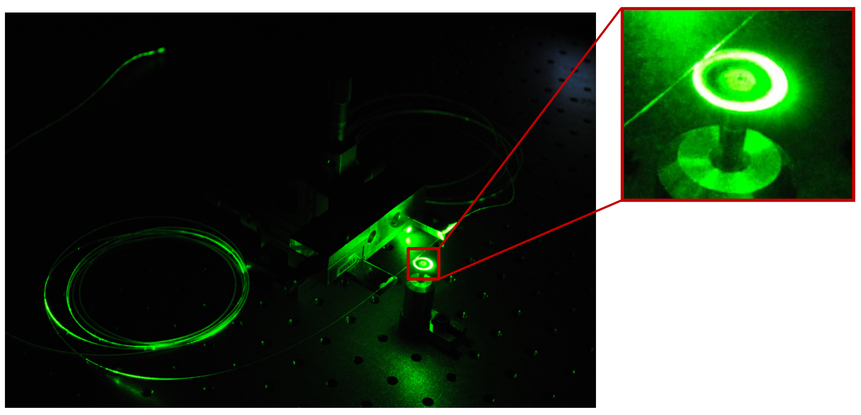
Stability Analysis of the Lugiato-Lefever Model for Kerr Optical Frequency Combs

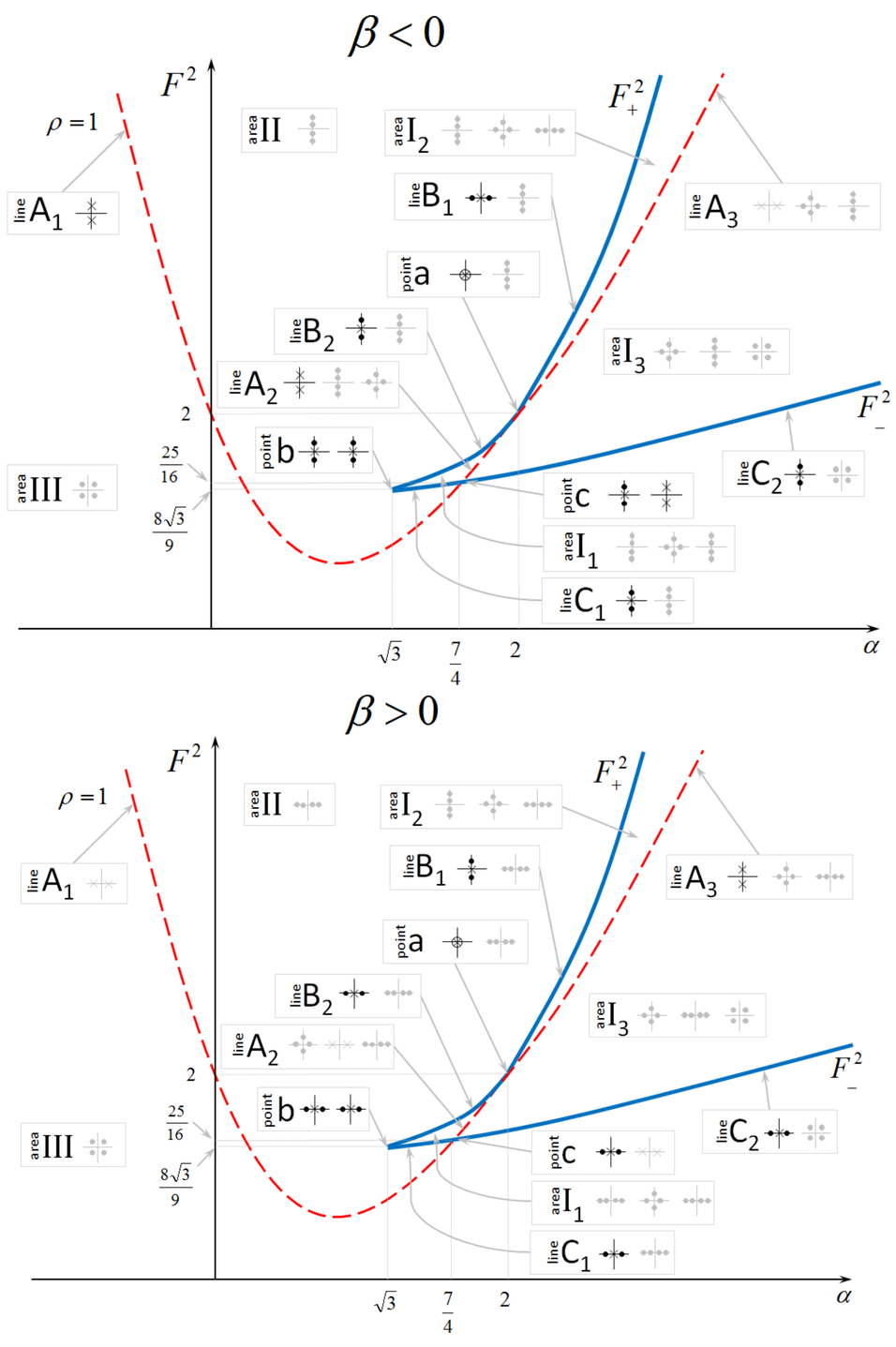
System under study

A continuous-wave laser with a very narrow linewidth is used to pump a nonlinear dielectric cavity. After polarization control, the laser beam is coupled into a resonant cavity mode using evanescent fields. The intra-cavity photons interact through four-wave mixing (FWM) and generate the optical-frequency comb, which can be extracted and monitored with an optical spectrum analyzer thanks to the evanescent coupling.



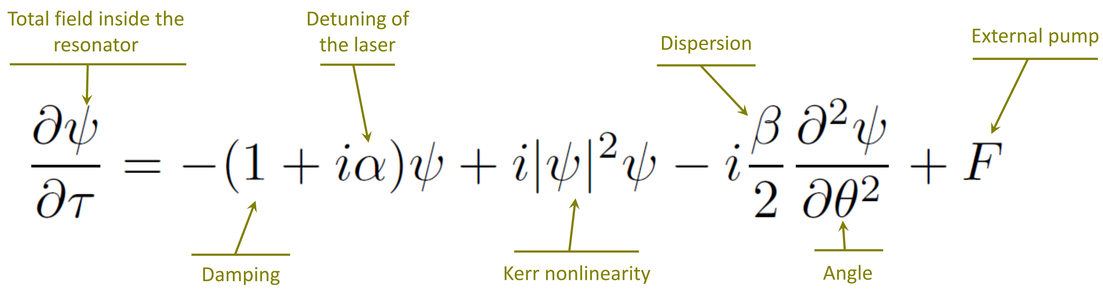
Optical-frequency comb generators can be made of a wide variety of WGM resonators. In this study, we focus without loss of generality on spherical MgF2 resonators with free spectral range (FSR) of about 10 GHz and a pumping wavelength of 1560 nm.

Bifurcation diagrams



The model

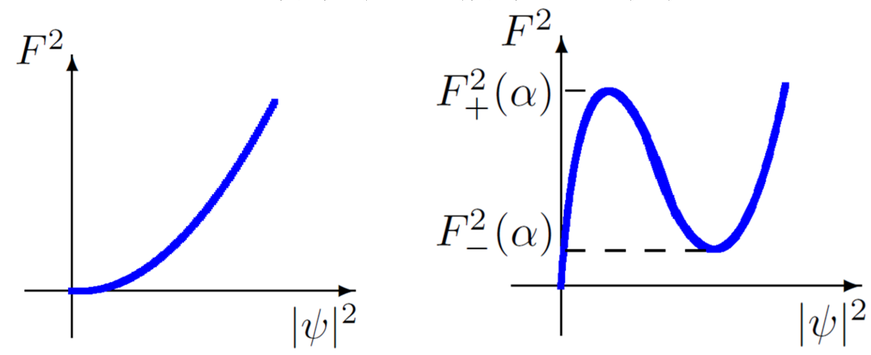
The Lugiato-Lefever model is:



Mathematical analysis

To find the equilibria we put all derivatives to zero, and we obtain an equation, wich links the pump power, detuning of the laser and a total field incide the cavity

$$F^2 = |\psi|^2(1 + (|\psi|^2 - \alpha)^2)$$



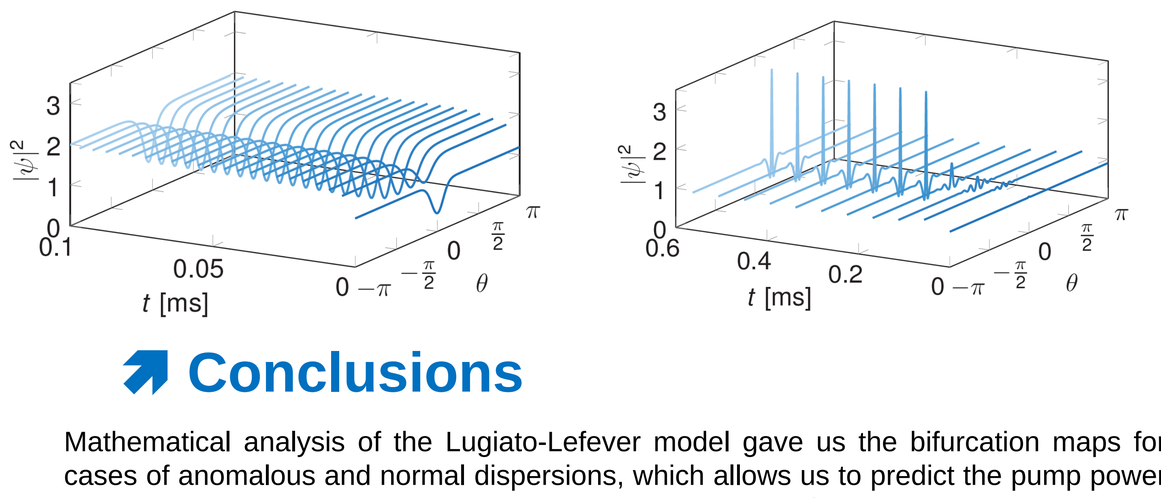
$|\alpha| < \sqrt{3}$ $\qquad$ $\alpha > \sqrt{3}$

Characteristic equation is:

Eigenvalues

$$\chi_{M_{\psi_e}} = \lambda^4 - \frac{2}{|\beta|}(4|\psi|^2 - 2\alpha)\lambda^2 + \frac{4}{|\beta|^2}(3|\psi|^4 - 4\alpha|\psi|^2 + \alpha^2 + 1)$$

Possible solutions



Conclusions

Mathematical analysis of the Lugiato-Lefever model gave us the bifurcation maps for cases of anomalous and normal dispersions, which allows us to predict the pump power and detuning needed to generate combs, bright and gray solitons or chaos.

Références

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