Bichromatic Emission and Coexisting Multimode Dynamics in Ring Lasers

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Outline

I. Motivation

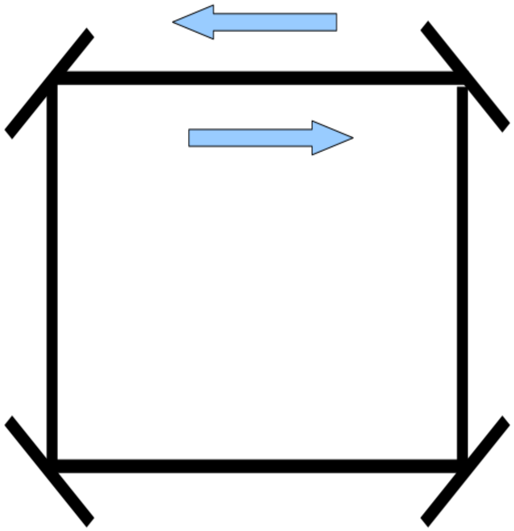
II. The Model

III. Multimode Dynamics

IV. Conclusions

I. Motivation

Ring Lasers



Two counter-propagating electric fields

Rich variety of dynamical behaviors

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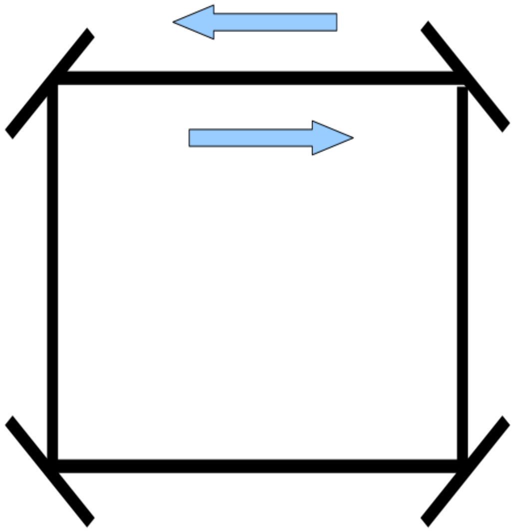

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Applications:

- Bidirectional emission → Gyroscope
- Directional bistability → All-optical processing

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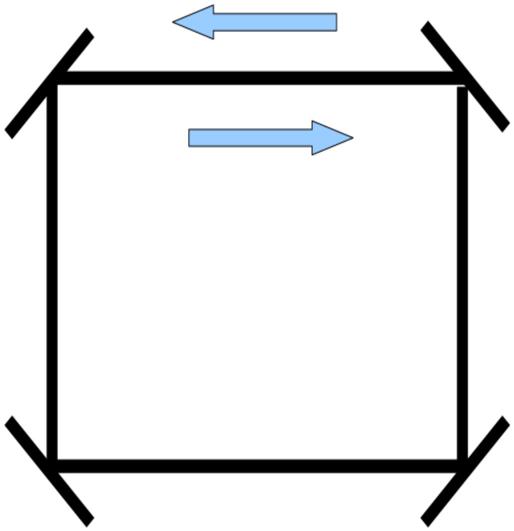

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A detailed description is required to understand these dynamical behaviors and their possible applications

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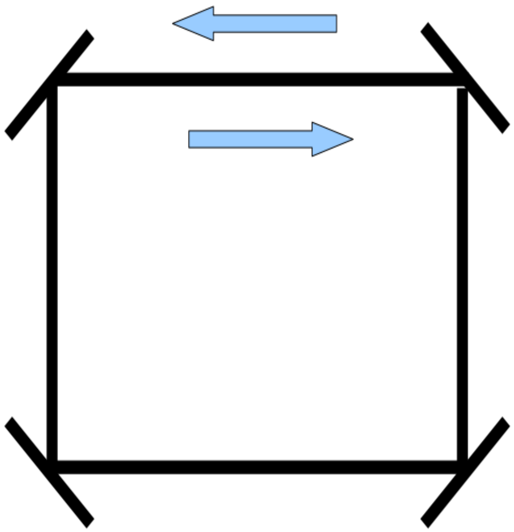

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Traveling Wave Model (TWM) → Spatial Effects and Multimode Dynamics

II. The model

Dimensionless TW Equations
for the SVA in a Semi-classical approach:

$$\pm\frac{\partial A_\pm}{\partial s}+\frac{\partial A_\pm}{\partial \tau}=B_\pm-\alpha A_\pm$$ Electric Fields

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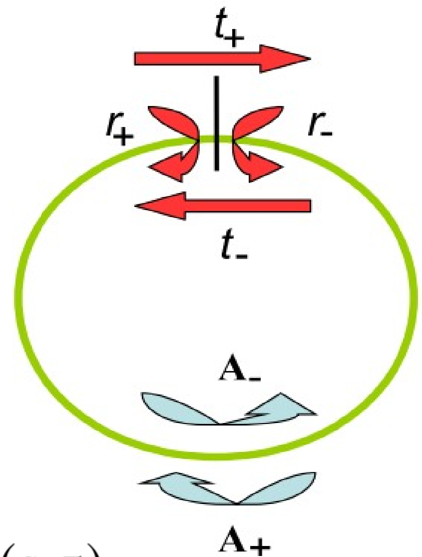
$$\frac{1}{\gamma}\frac{\partial B_\pm}{\partial \tau}=-(1+i\widetilde{\delta})B_\pm+g(D_0A_\pm+D_{\pm2}A_\mp)+\sqrt{\beta D_0}\xi_\pm(s,\tau)$$ Polarization

$$\frac{\partial D_0}{\partial \tau}=\epsilon[J-D_0+\Delta\frac{\partial^2 D_0}{\partial s^2}-(A_+B_+^*+A_-B_-^*+A_+^*B_++A_-^*B_-)]$$

$$\frac{\partial D_{\pm2}}{\partial \tau}=-\eta D_{\pm2}-\epsilon(A_\pm B_\mp^*+A_\mp^*B_\pm)$$

Carriers

II. The model



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Carriers

Boundary Conditions:
$$A_+(0,\tau)=t_+A_+(1,\tau)+r_-A_-(0,\tau)$$
$$A_-(1,\tau)=t_-A_-(0,\tau)+r_+A_+(1,\tau)$$

II. The model

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Tests for the numerical algorithm: Analytical Results (Unidirectional or UFL)

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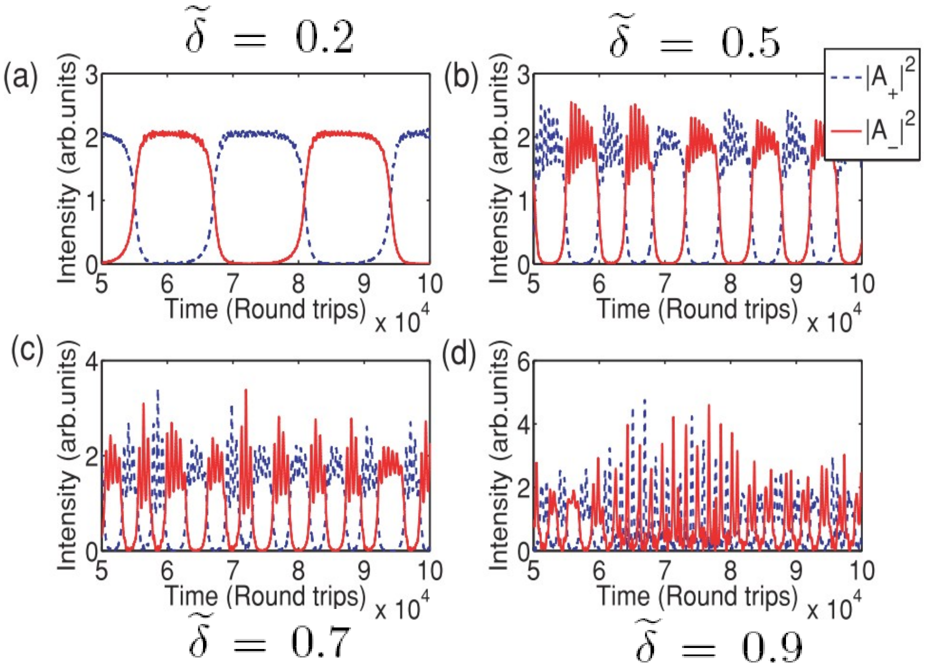
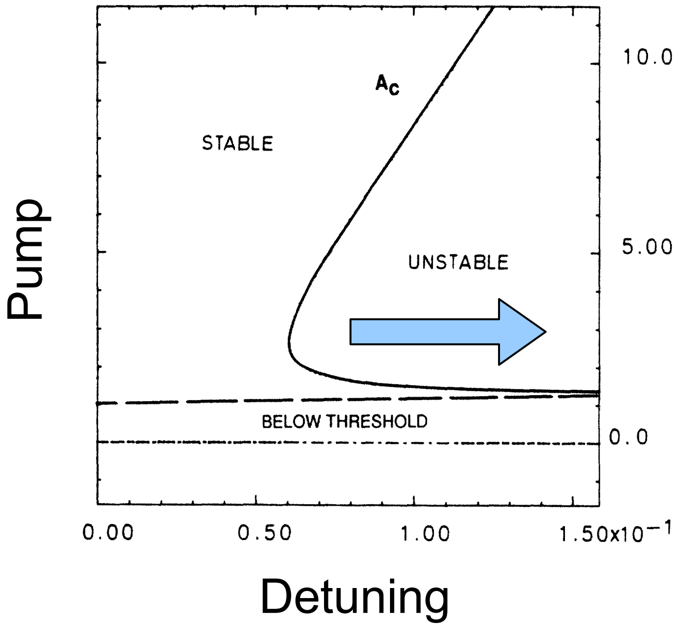
Single-Mode dynamics: Zeghlache et al. Phys. Rev. A **37**, 470 (1988).





III. Multimode Dynamics

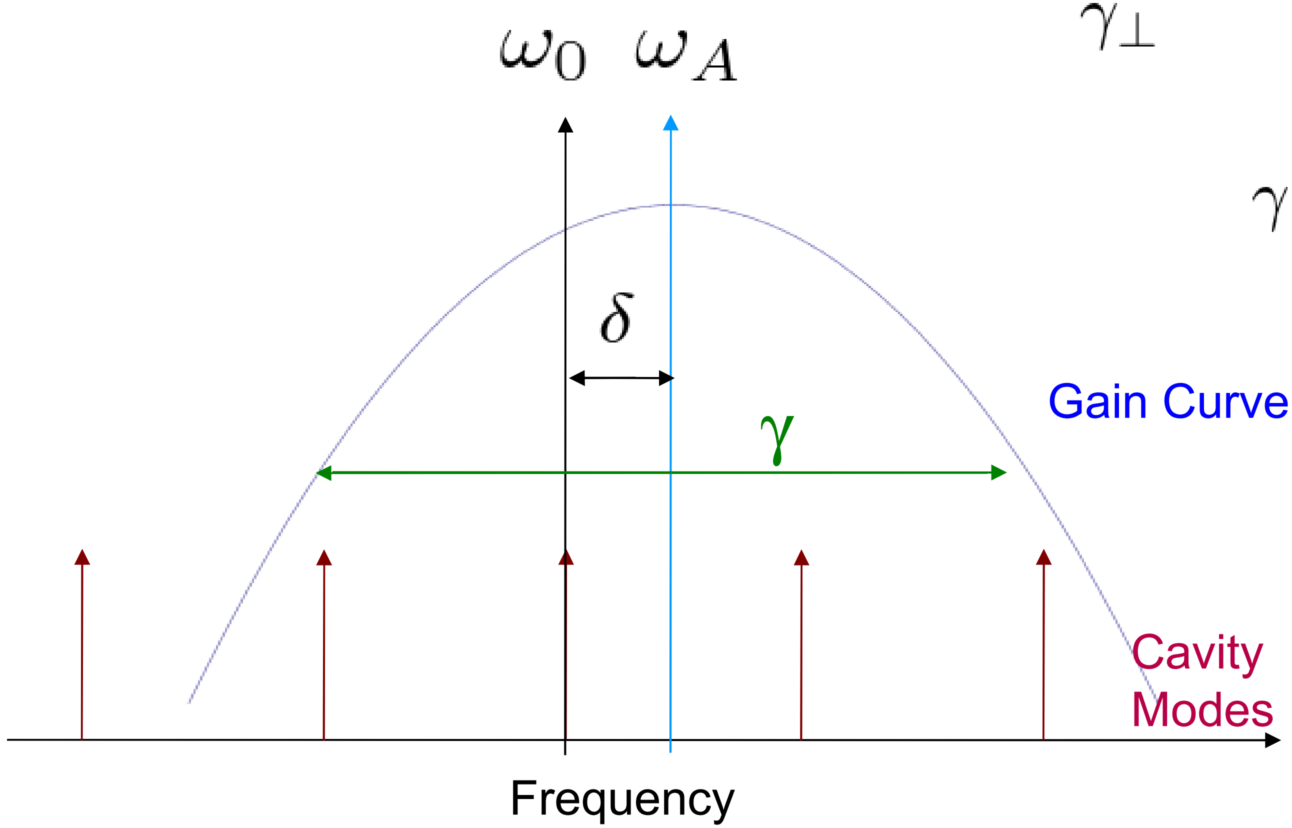
Dependence on:

- Detuning (δ)
- Gain curve bandwidth (γ)

Detuning:

$$\tilde{\delta} = \frac{\omega_A - \omega_0}{\gamma_\perp} = \tilde{\omega}_A - \tilde{\omega}_0$$

$$\gamma = \frac{\gamma_\perp n L}{c}$$



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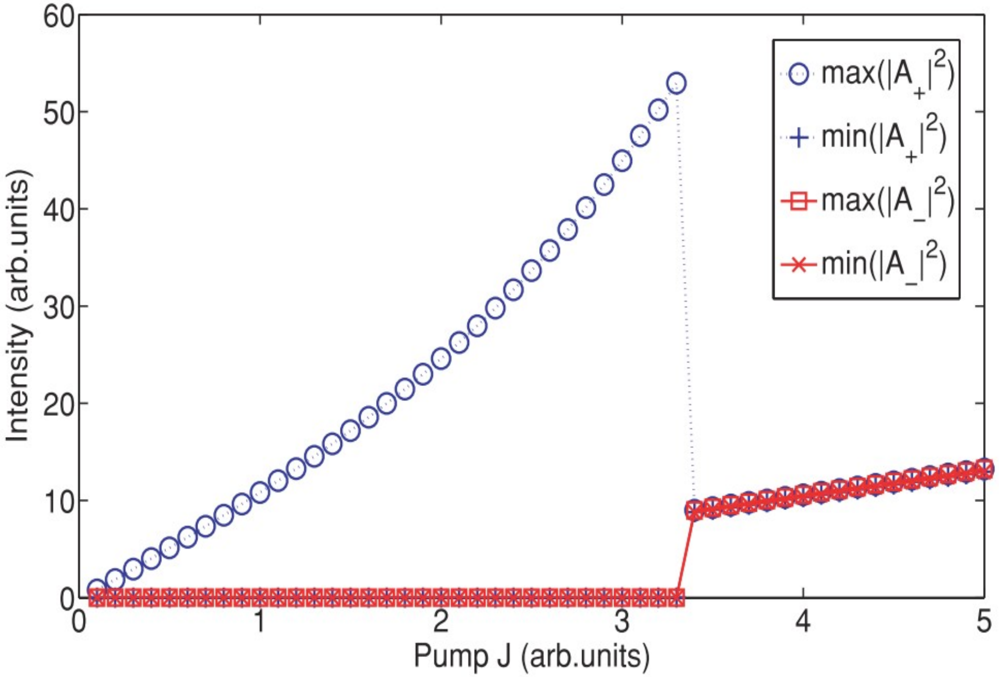


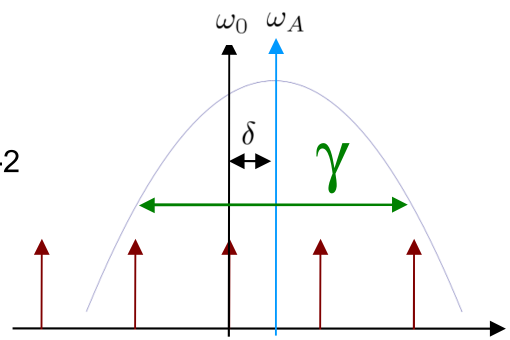
N = 400 g = 5

t = 0.9 α = 0

r = 5 10^{-4} ε = 10^{-2}

η = 0.1 γ = 10

δ = 0.3141



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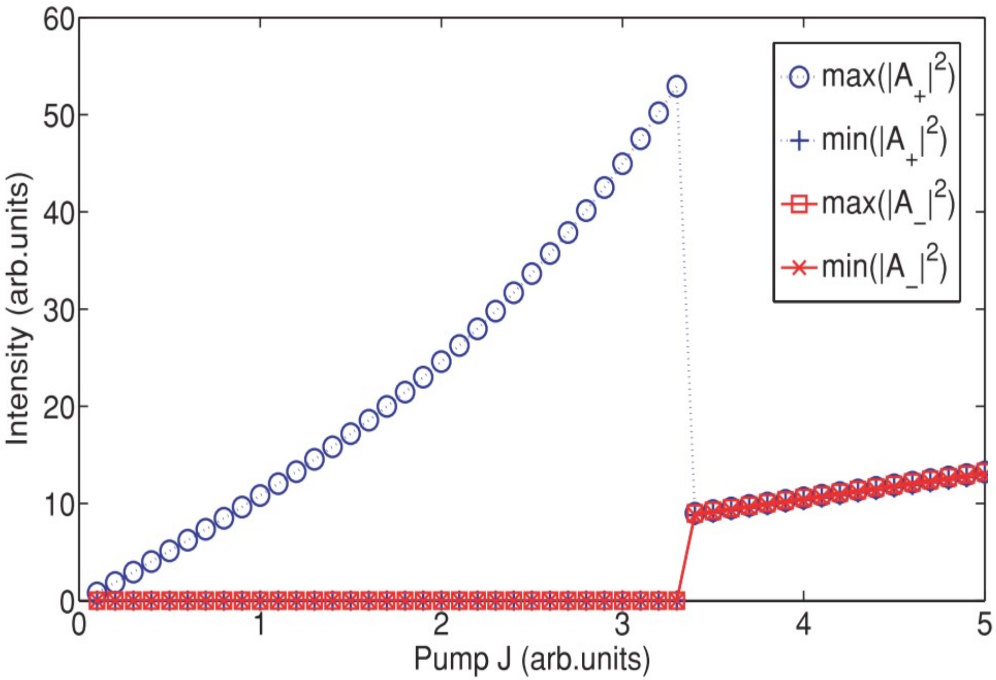

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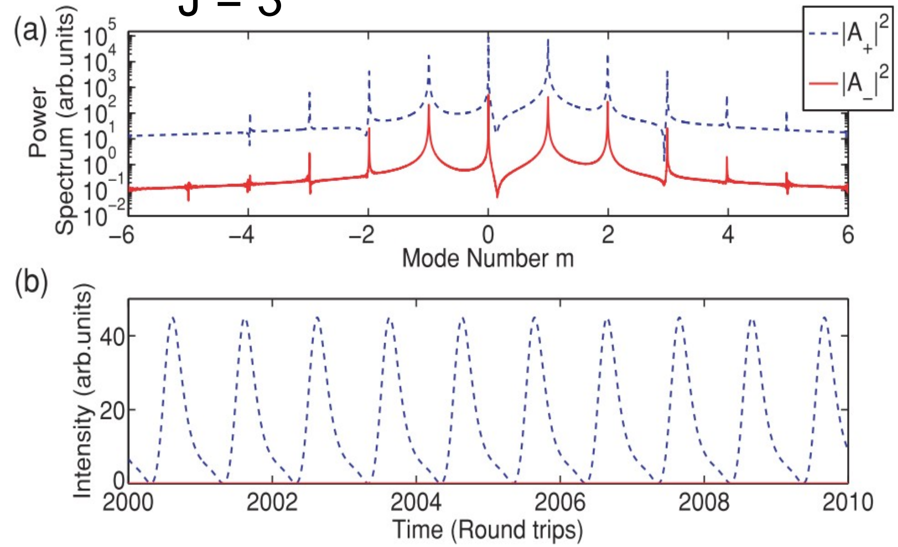

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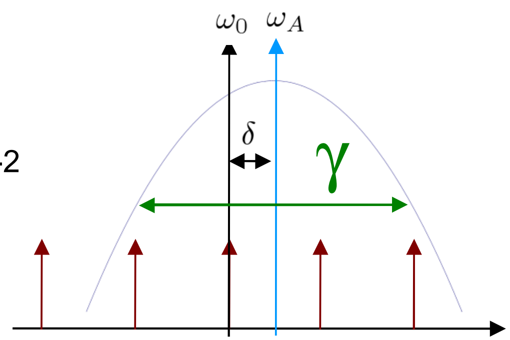

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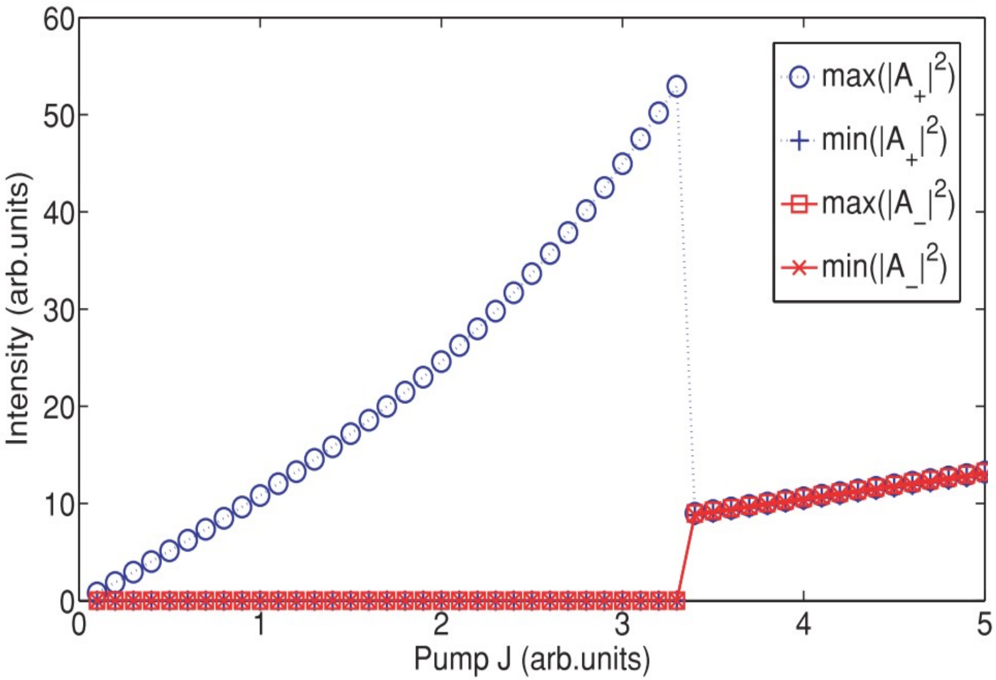

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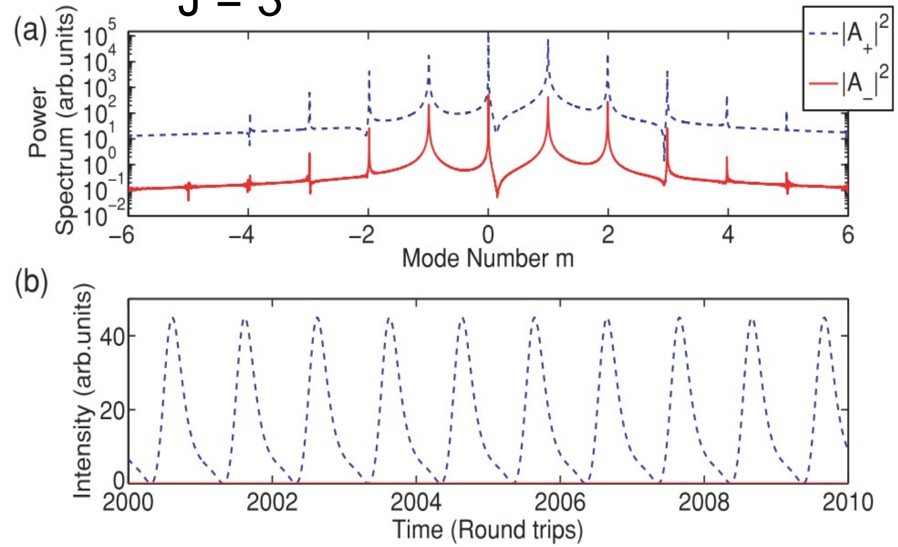

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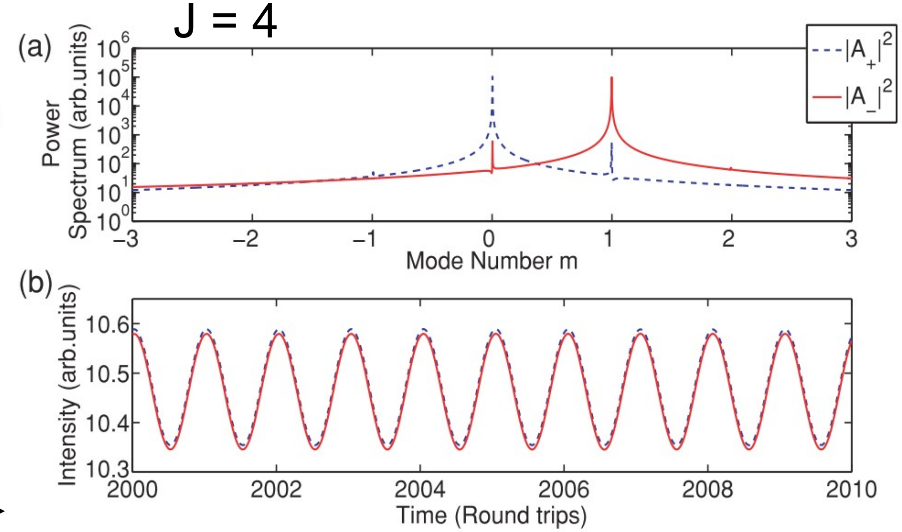

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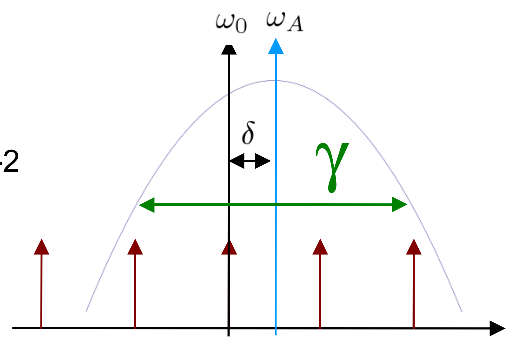

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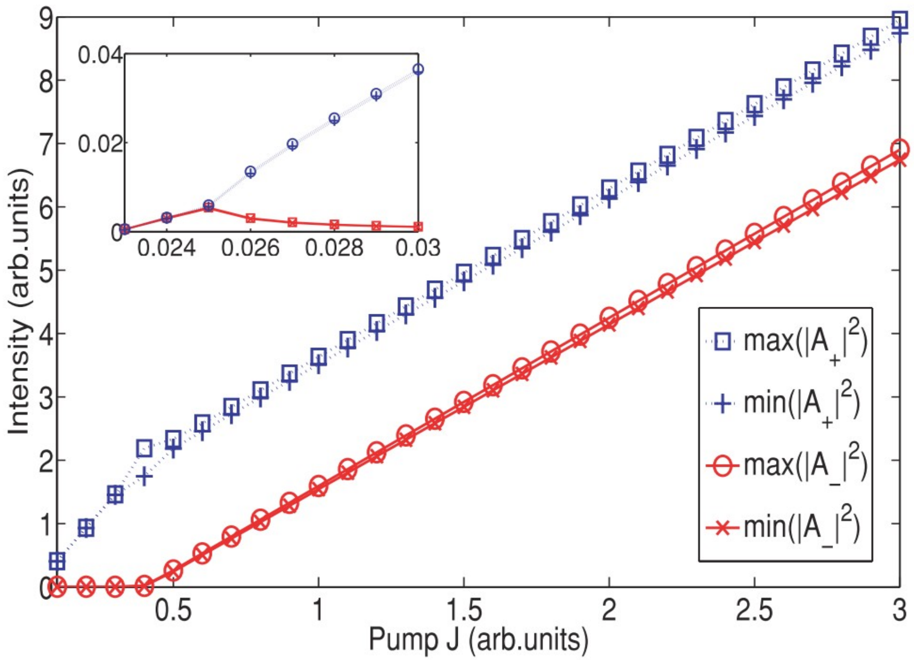

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$t = 0.9$ $\alpha = 0$

$r = 5\ 10^{-4}$ $\varepsilon = 10^{-2}$

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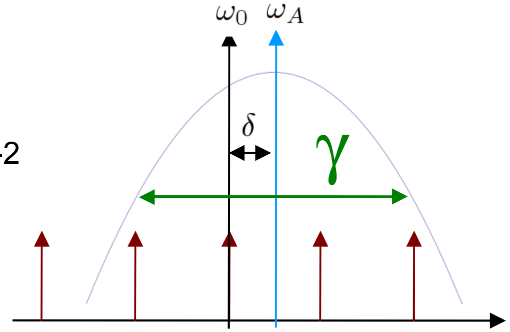

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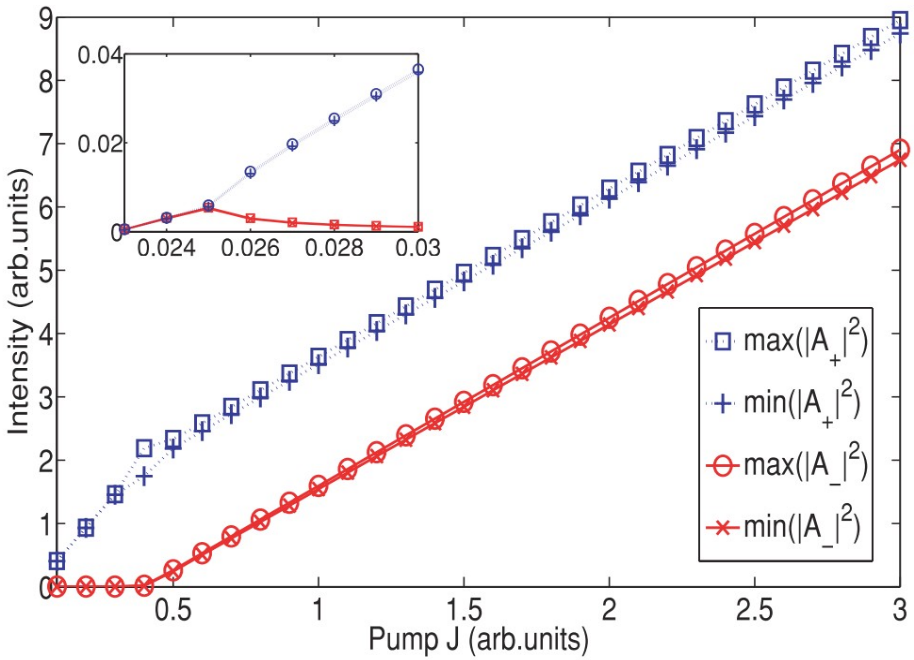

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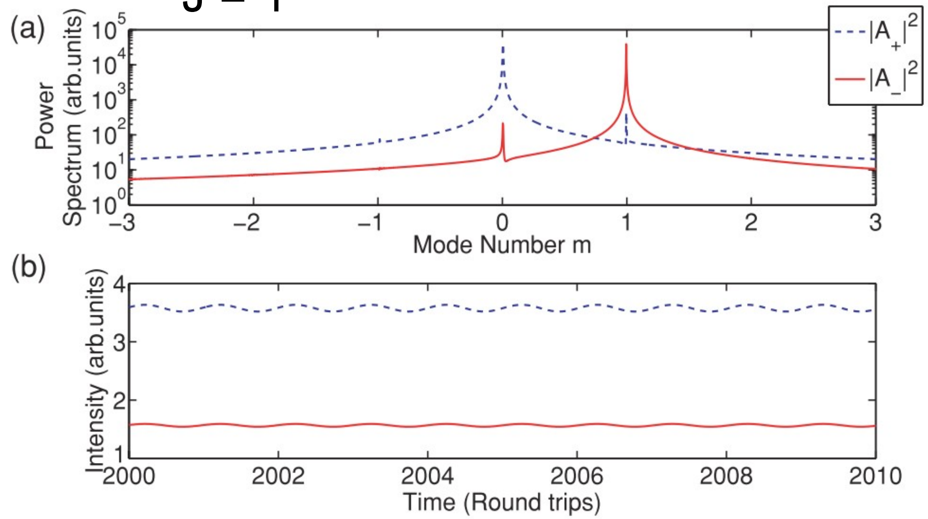

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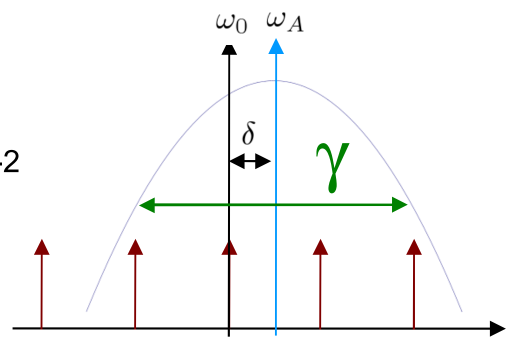

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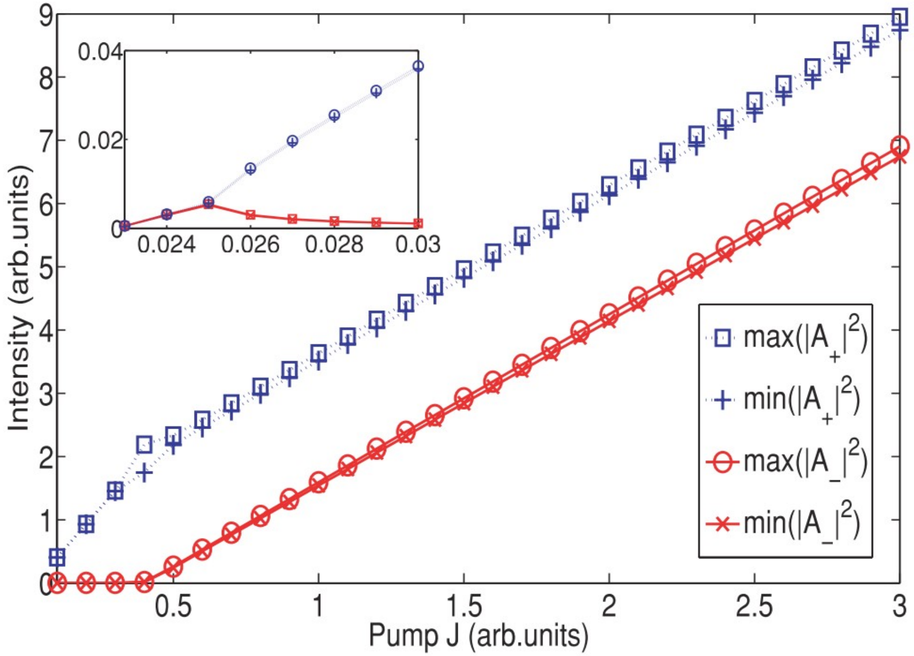

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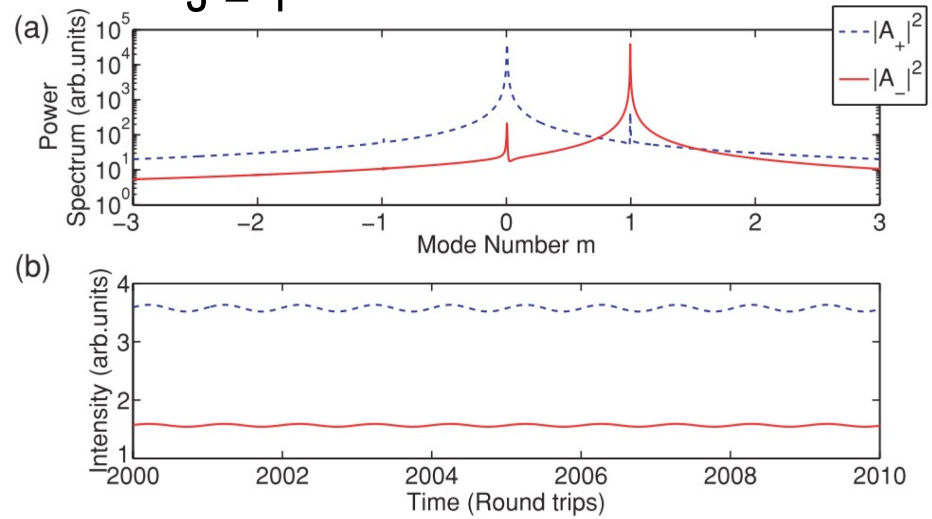

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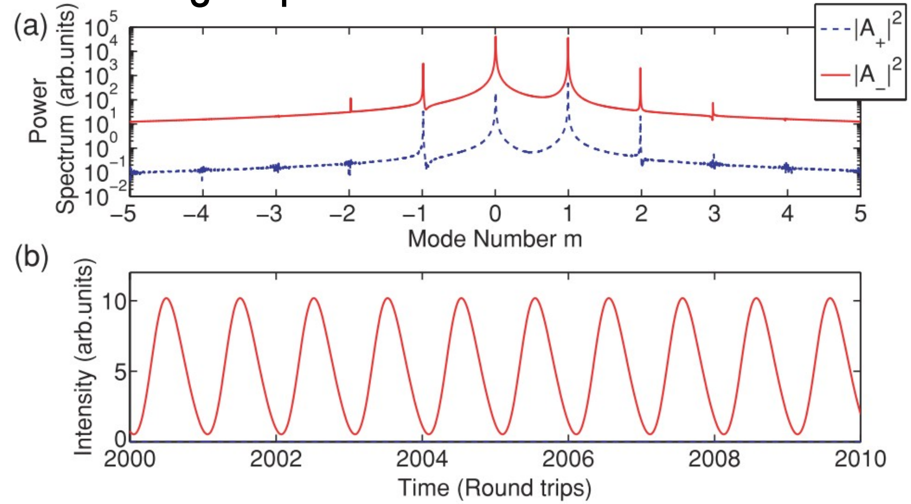
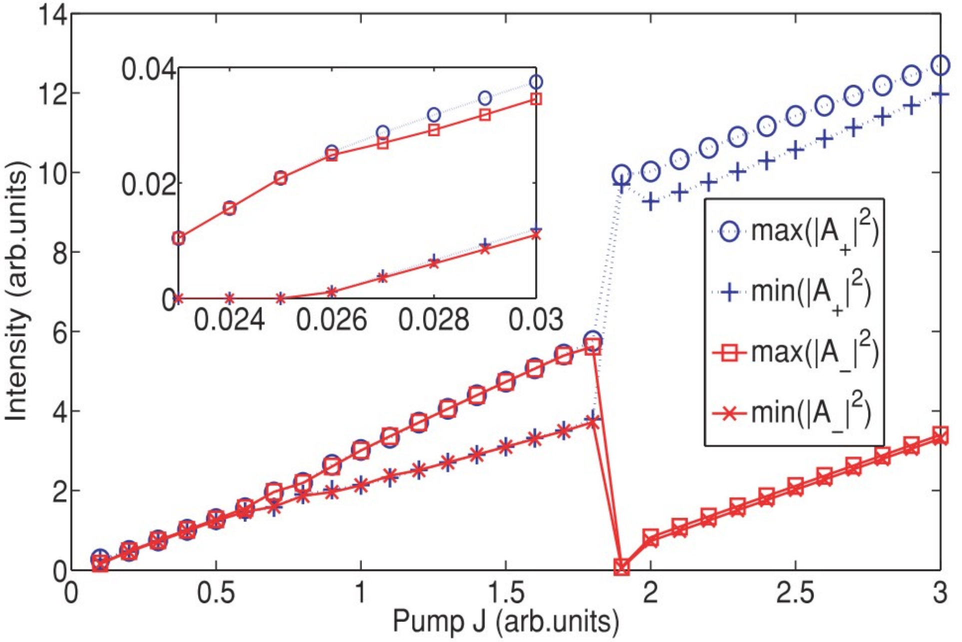


Depending on the initial conditions different dynamical regimes appear.

Coexistence of dynamical regimes

III. Multimode Dynamics



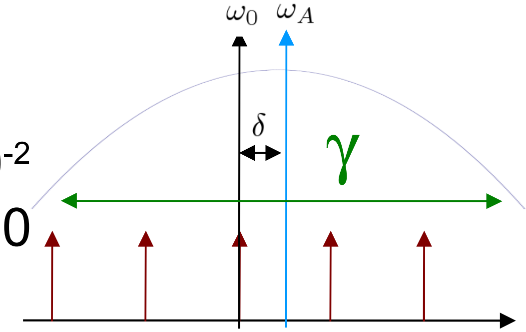
N = 400   g = 5

t = 0.9   α = 0

r = 5 10^{-4} ε = 10^{-2}

η = 0.02   γ = 100

δ = 0.03141



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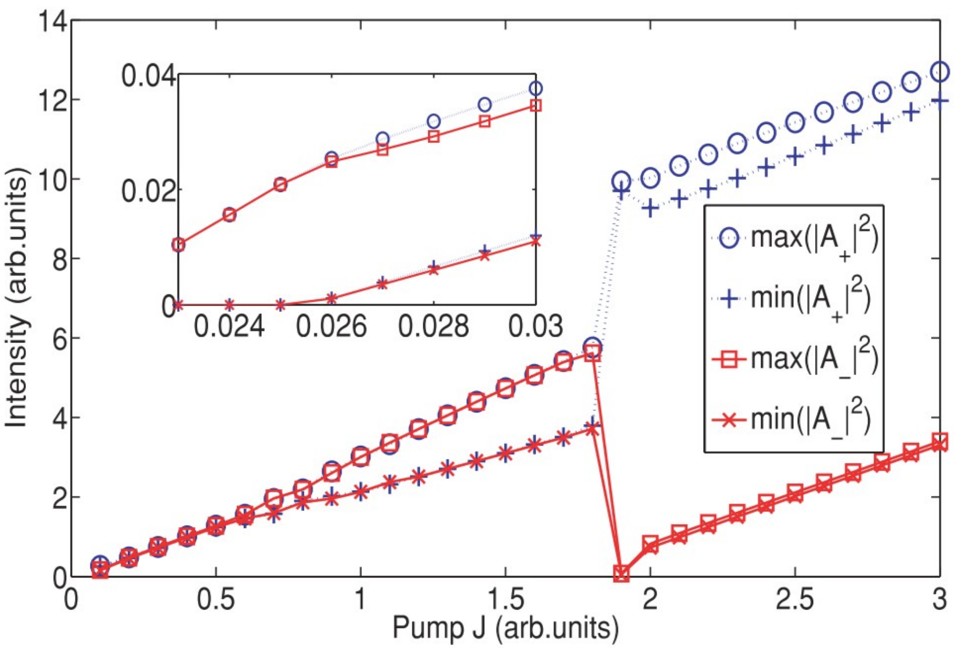
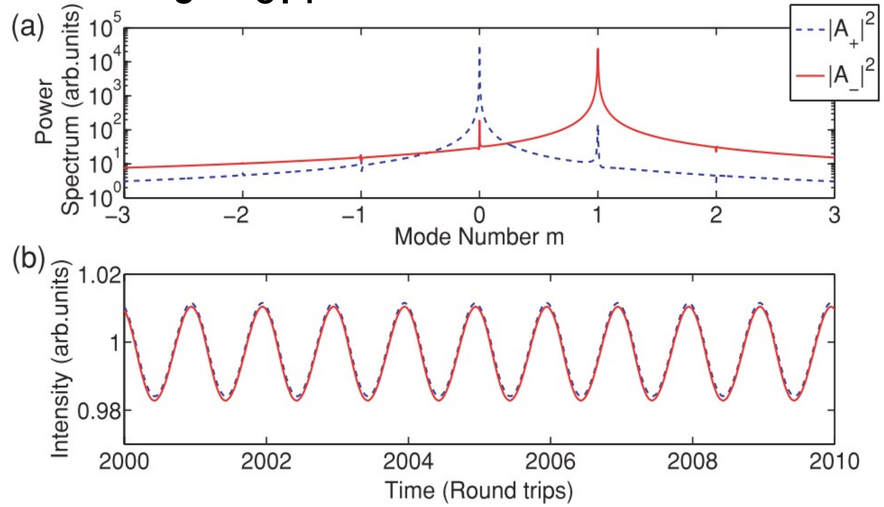


J = 0.4



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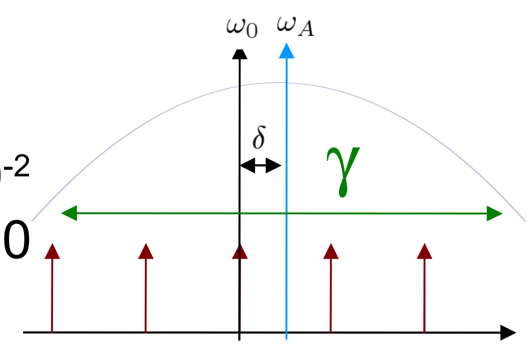

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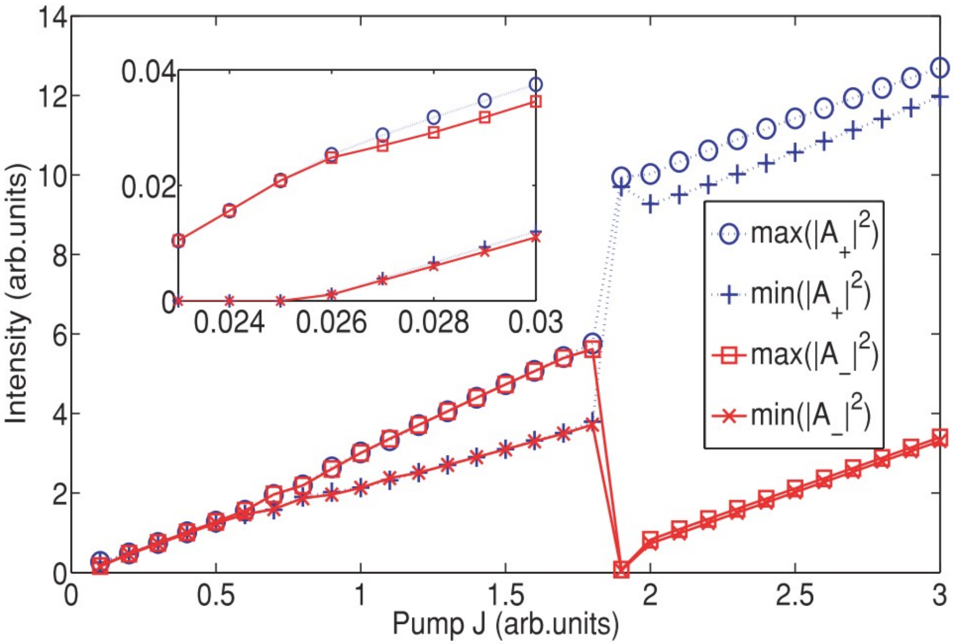
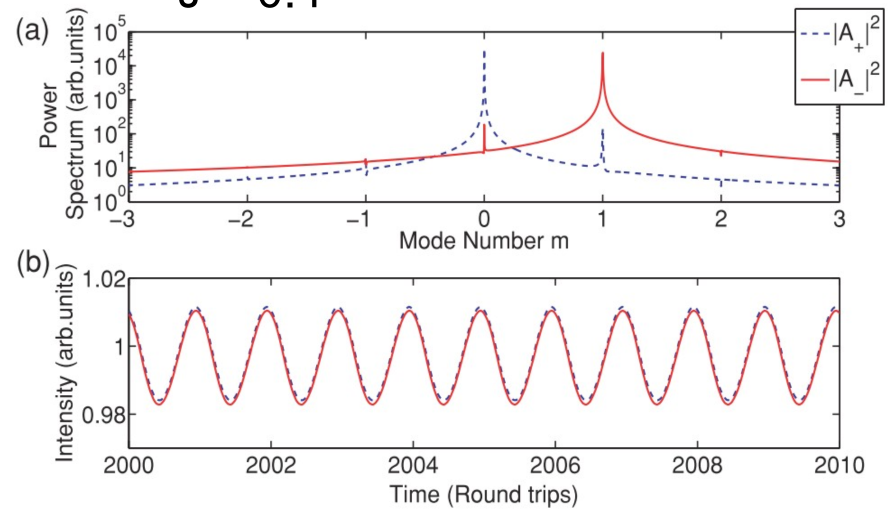
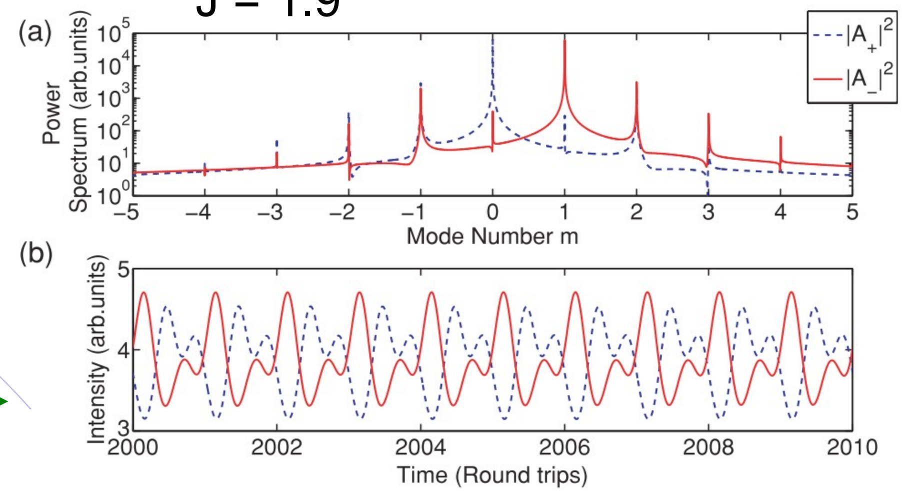


J = 0.4



J = 1.9



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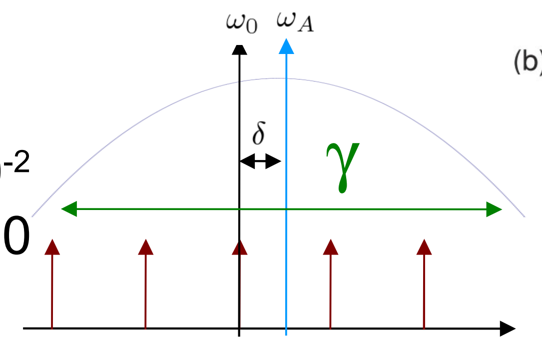

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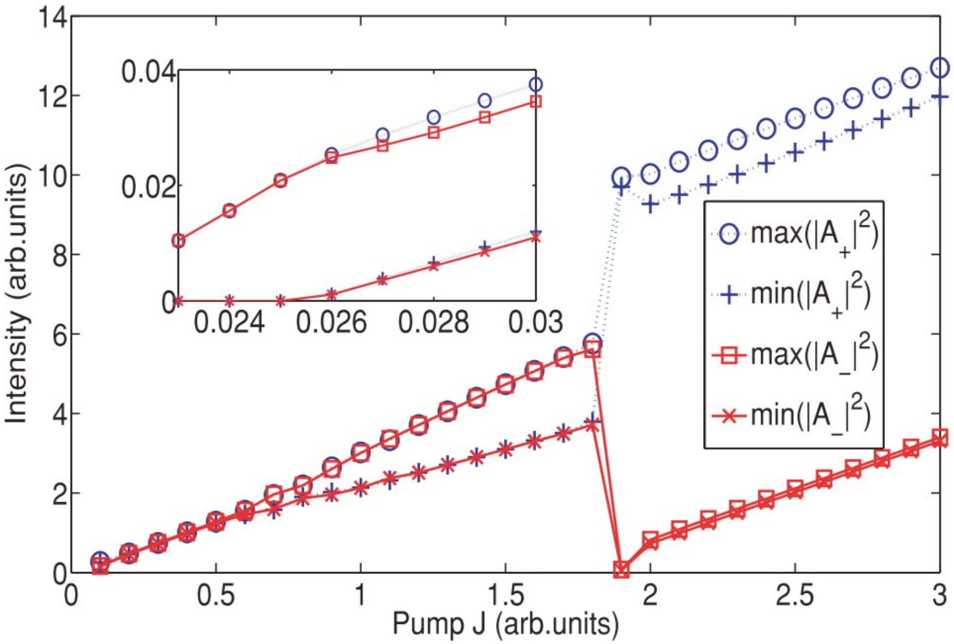
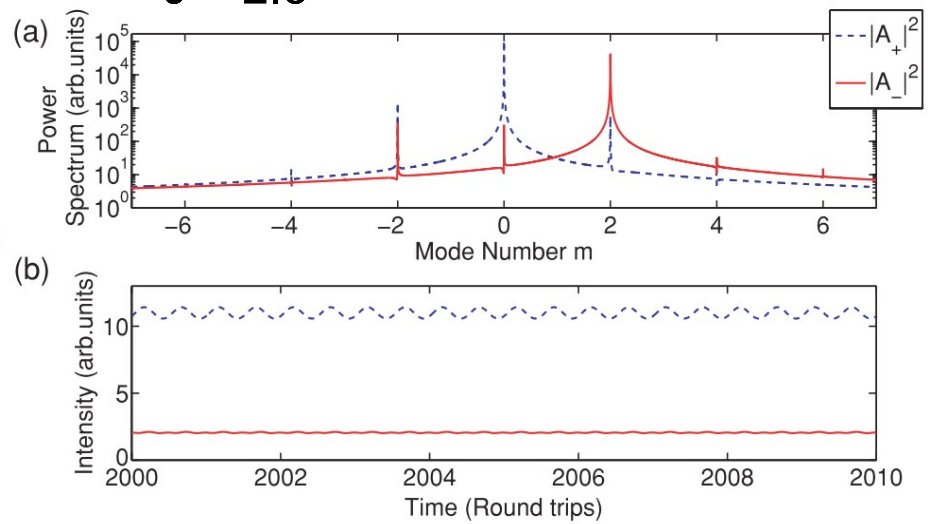


J = 2.5



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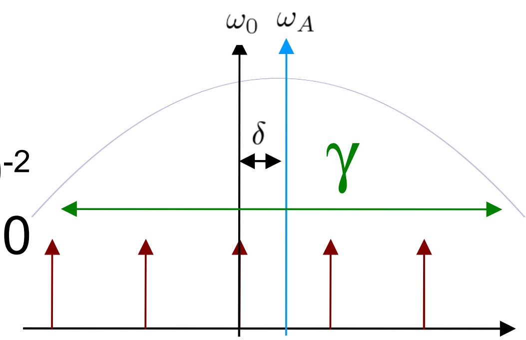
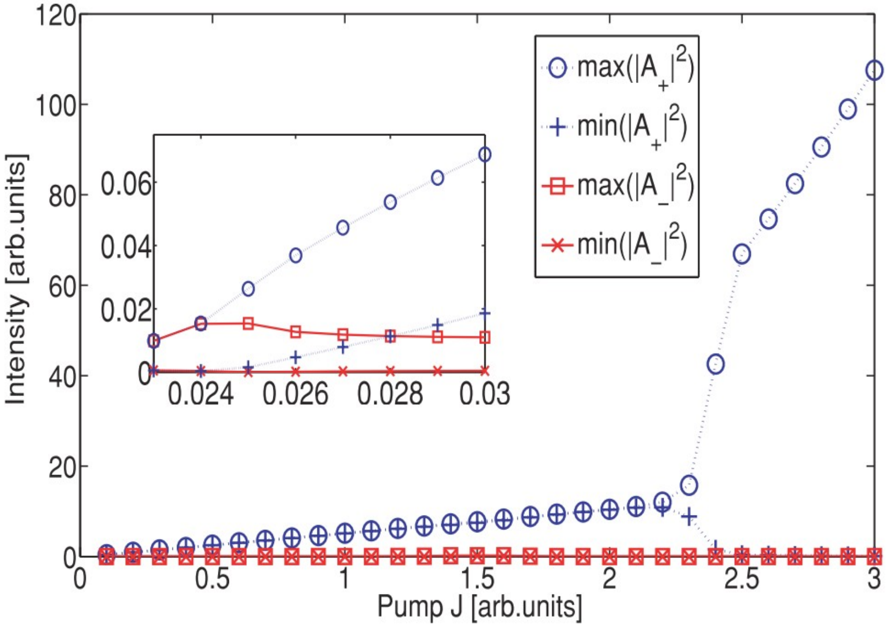


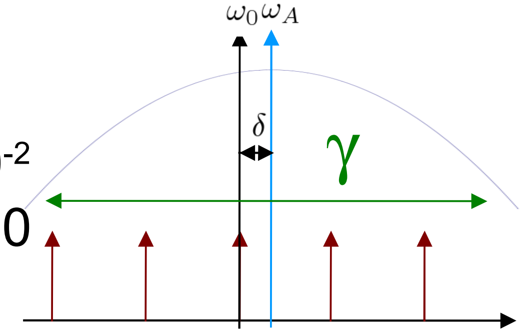
Lasing every 2 modes!

III. Multimode Dynamics



N = 400
t = 0.9
r = 5 10^{-4}
η = 0.02
δ = 0.015

g = 5
α = 0
ε = 10^{-2}
γ = 100



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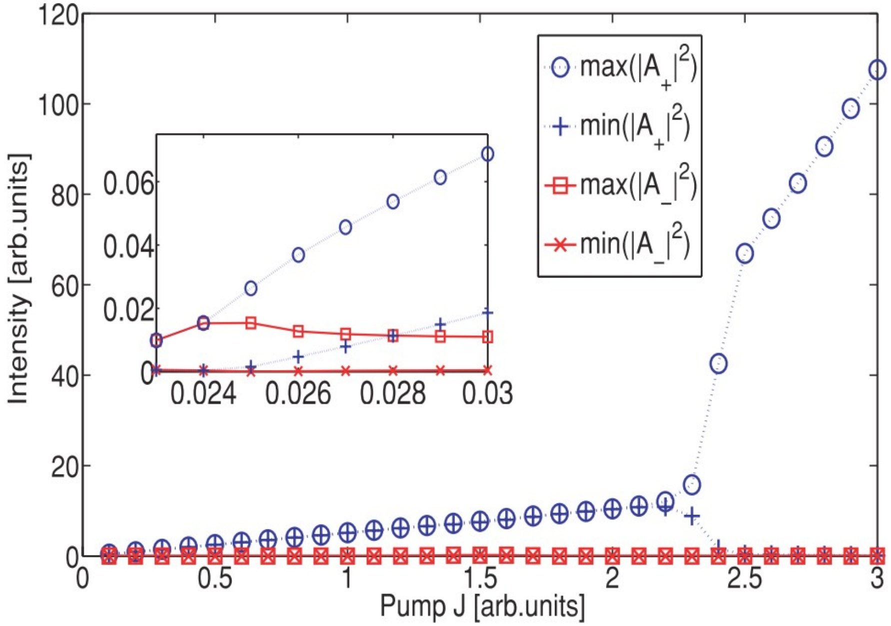

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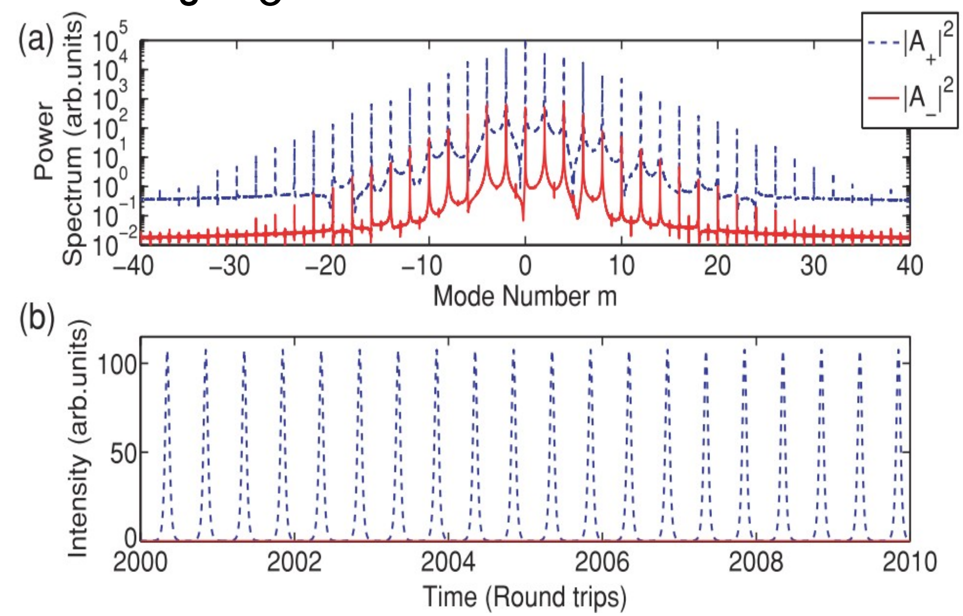

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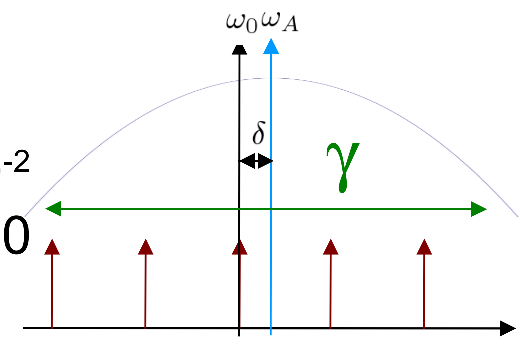

IV. Conclusions

- A Travelling Wave Model for ring lasers is developed and tested.

- Analytical results are difficult to obtain for a bidirectional ring laser.

- We have studied how the detuning and the gain bandwidth affects to the multimode operation.

- The spatial effects strongly affects the dynamics and the stability of the different lasing states.

- Multimode behavior opens the scenario to multistability.

- Mode competition can be important depending on the parameters of the ring laser.

Work in progress:

- Modify the medium susceptibility → Semiconductor Ring Laser

Thank you for your attention!

For details:

Pérez-Serrano et al. Phys. Rev. A **81**, 043817 (2010).

Pérez-Serrano et al. Opt. Express **19**, 3284 (2011).

Financial Support:

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Govern de les Illes Balears