UNIVERSITÉ LAVAL

Optically induced orientational instabilities driven by spin angular momentum transfer of light in nematic liquid crystals

E. Brasselet, T. V. Galstian, and L. J. Dubé
Département de Physique, de Génie Physique, et d'Optique,
Université Laval, Cité Universitaire, Québec, Canada G1K7P4

D. O. Krimer and L. Kramer
Physikalisches Institut der Universität Bayreuth, D-95440 Bayreuth, Germany

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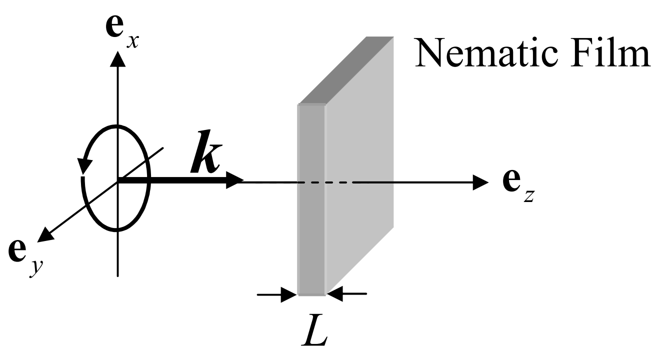
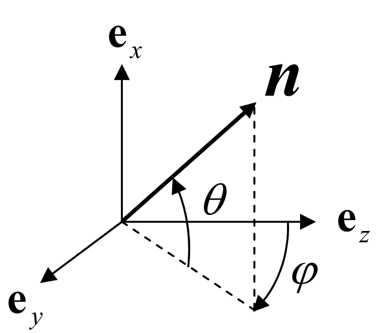
A nematic liquid crystal film is excited by a circularly polarized light

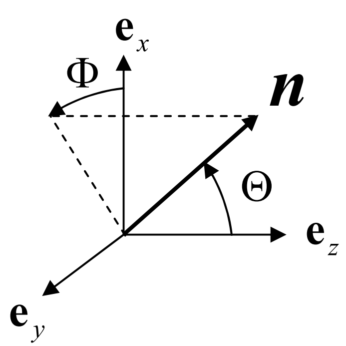


Light torque induces molecular reorientation

Rigorous framework for a theoretical description available



Model I

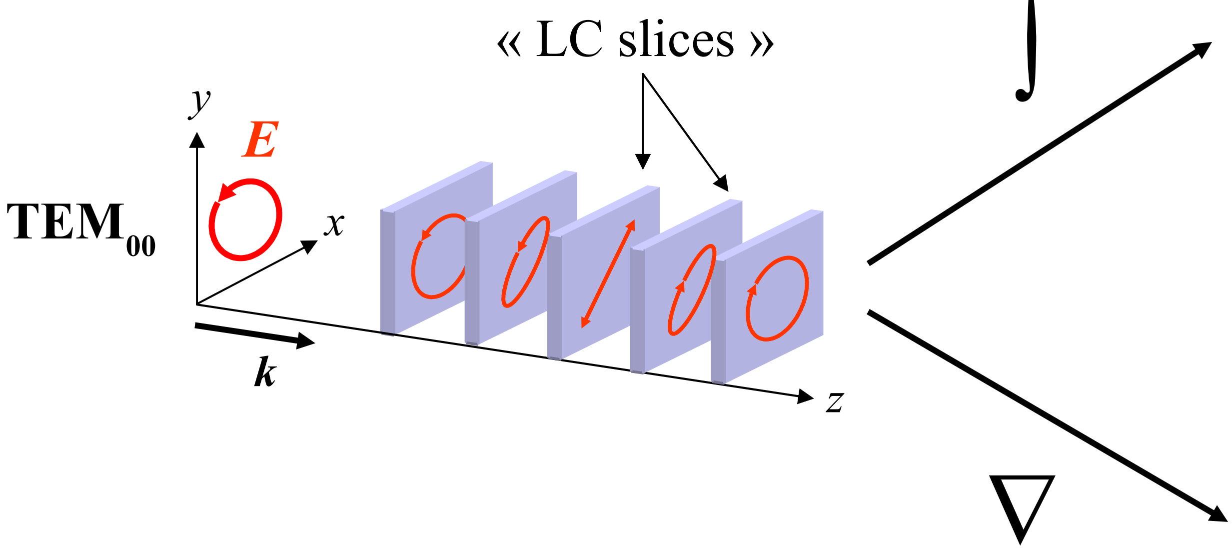


Model II

- Maxwell's equations
- Hydrodynamic equations of the LC

$$\frac{\partial \boldsymbol{n}}{\partial t} = f(\boldsymbol{n}, \boldsymbol{E})$$

Spin angular momentum transfer from light to LC

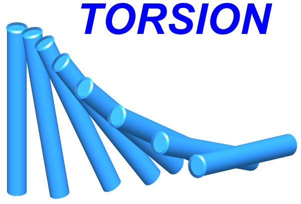


PRECESSION

$$\partial_t \Phi \neq 0$$

E. Santamato *et al*., Phys. Rev. Lett., **57**, 2423 (1986)

TORSION



$$\partial_z \Phi \neq 0$$

E. Brasselet *et al*., Opt. Comm., **200**, 241 (2001)

Non-uniform light angular momentum deposition to LC

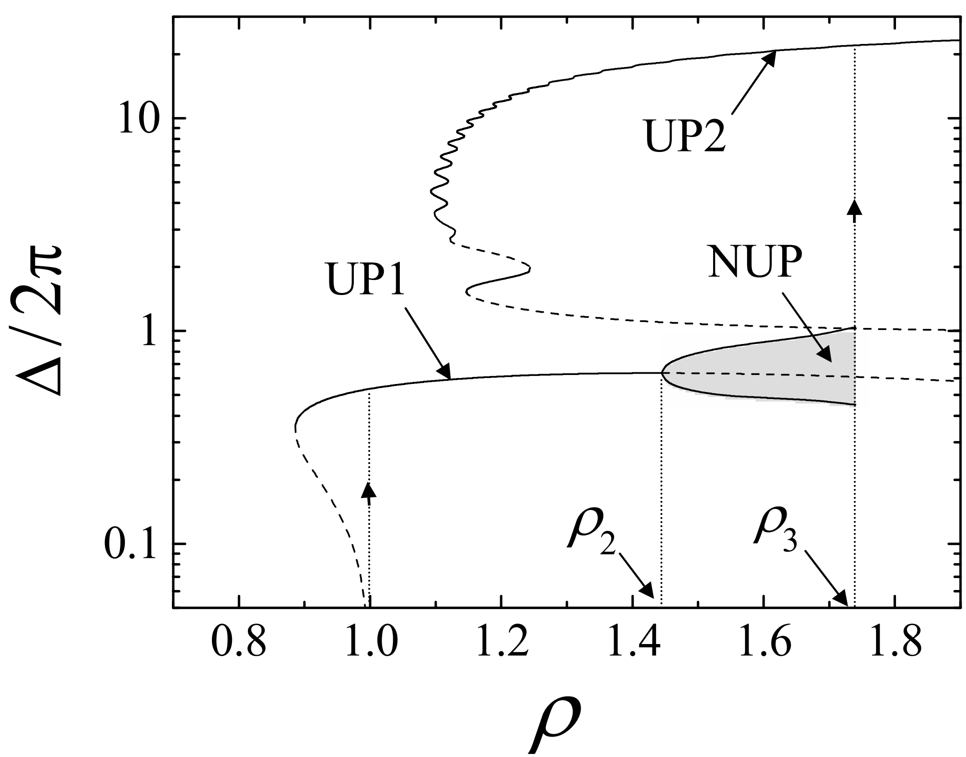
Long-range orientational order of LC
+
Light-angular momentum transfer

Spatio-temporal feedback

↓

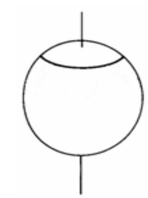
Rich reorientation dynamics

Reorientation vs. excitation intensity



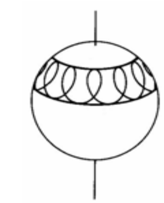
UP1 : Uniform precession 1

f_0



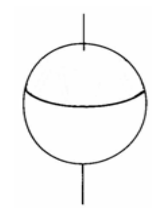
NUP : Non-uniform precession

f_0 , f_1

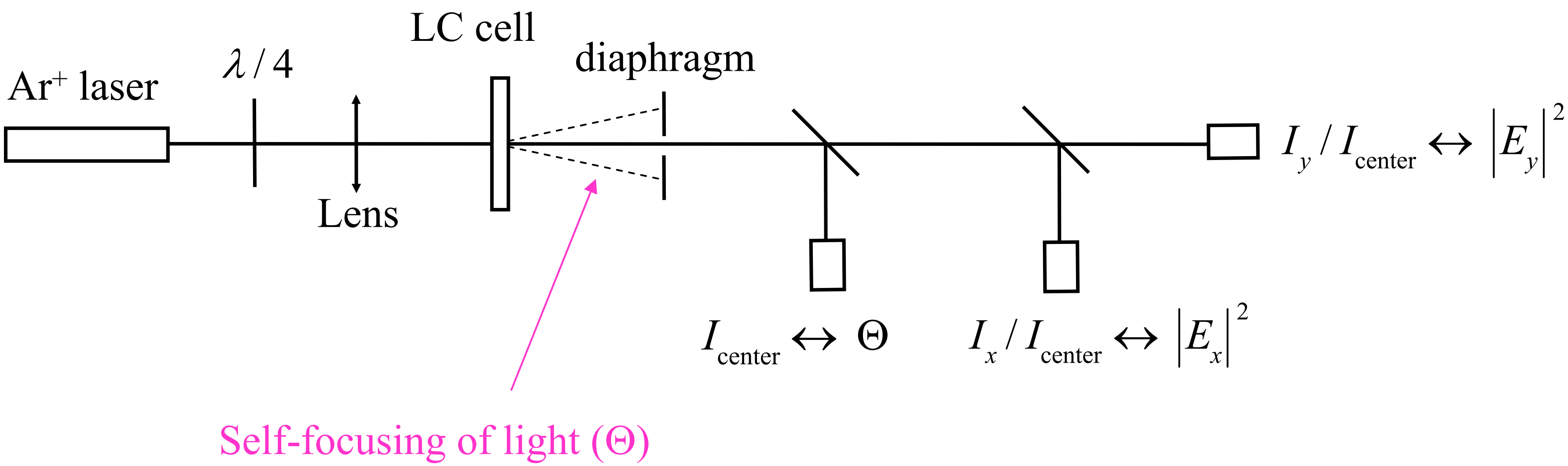


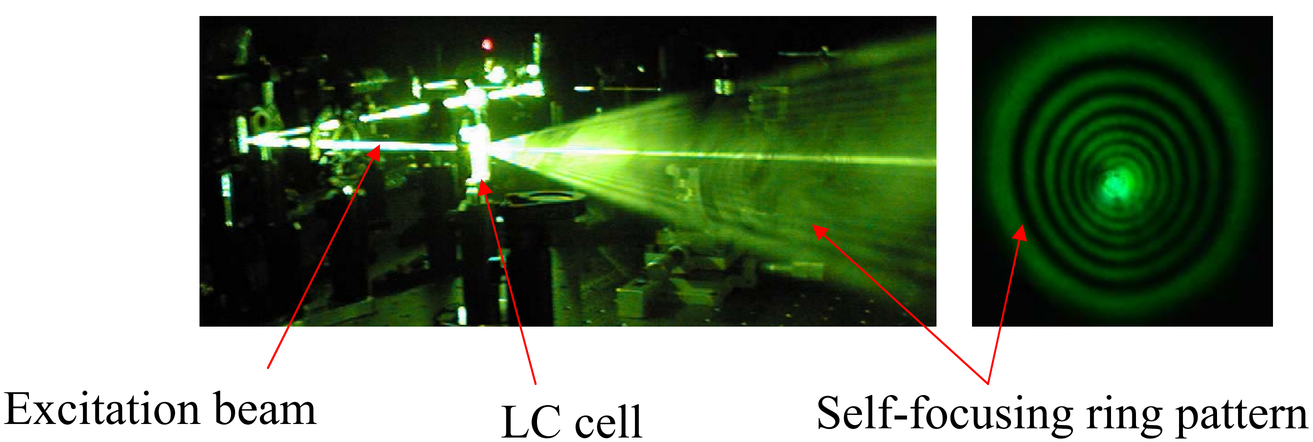
UP2 : Uniform precession 2

f_0



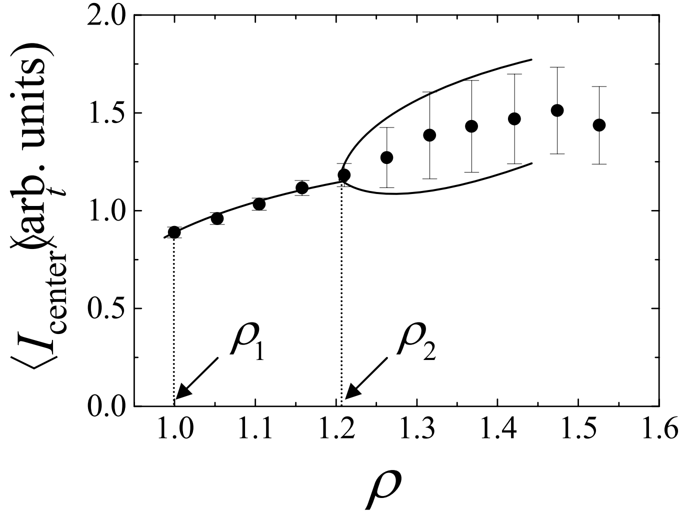
Experimental set-up to probe the light-induced dynamics

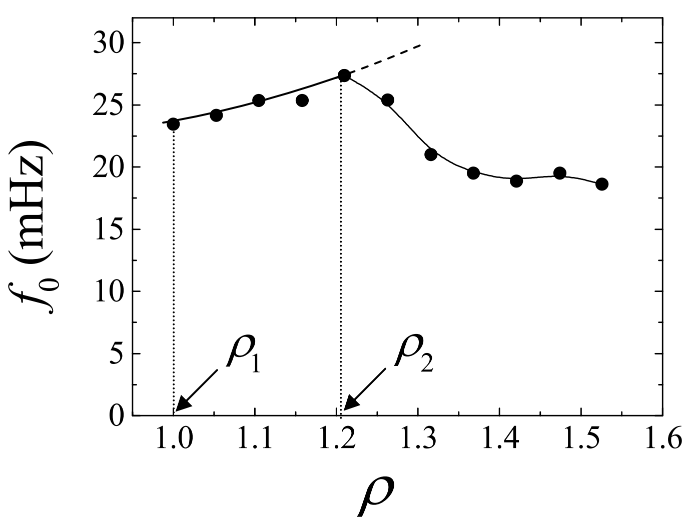




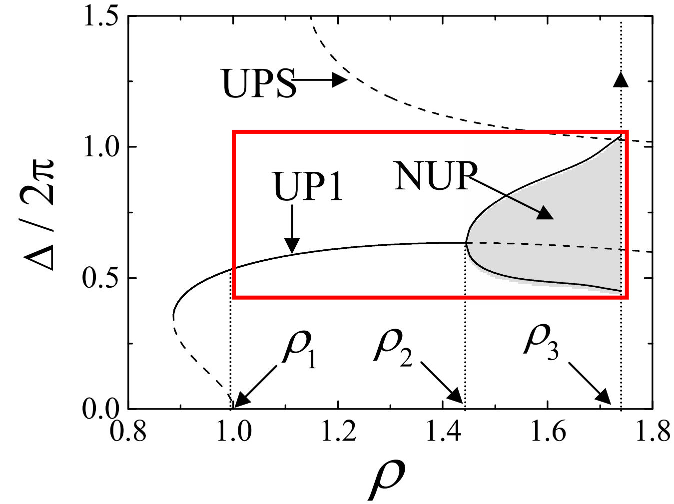
Confrontation between experiment and theory

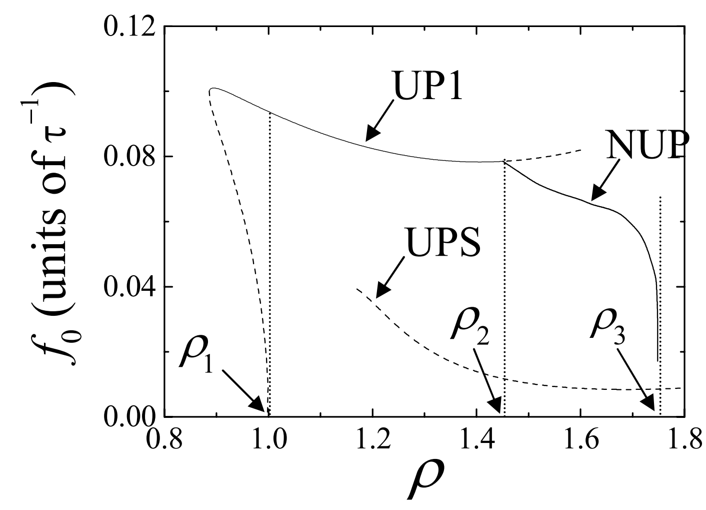
Experiment





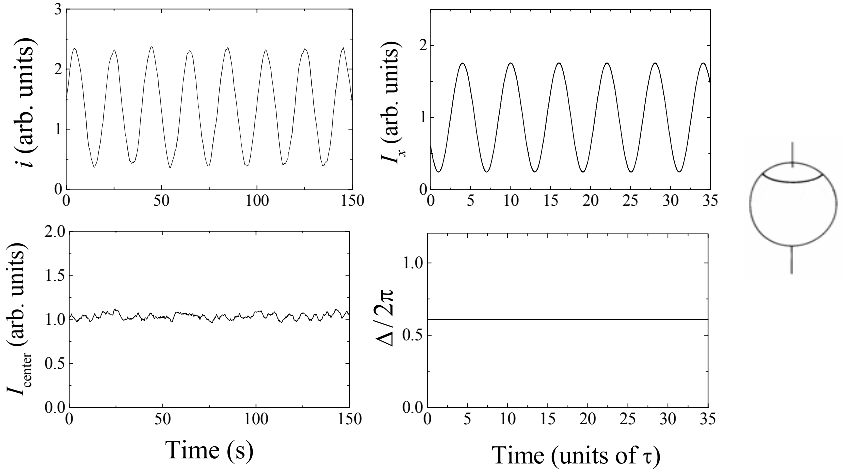
Theory





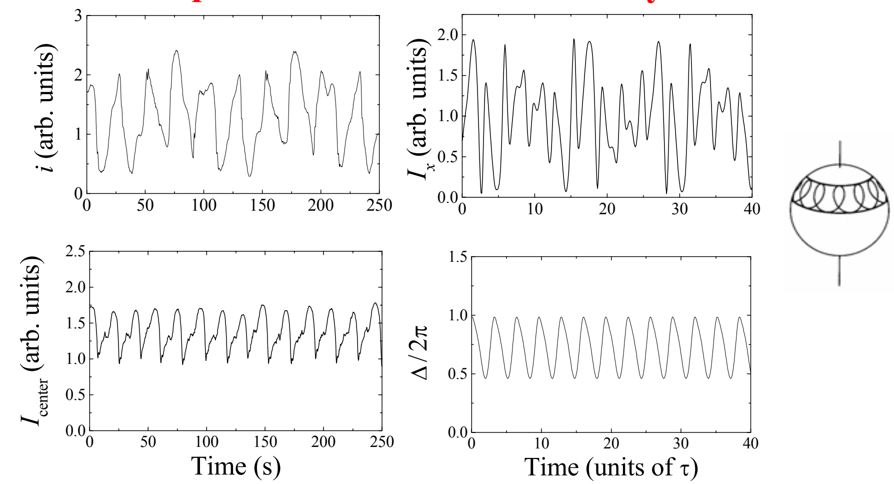
UP1 : Periodic rotation (f_0)

Experiment **Theory**



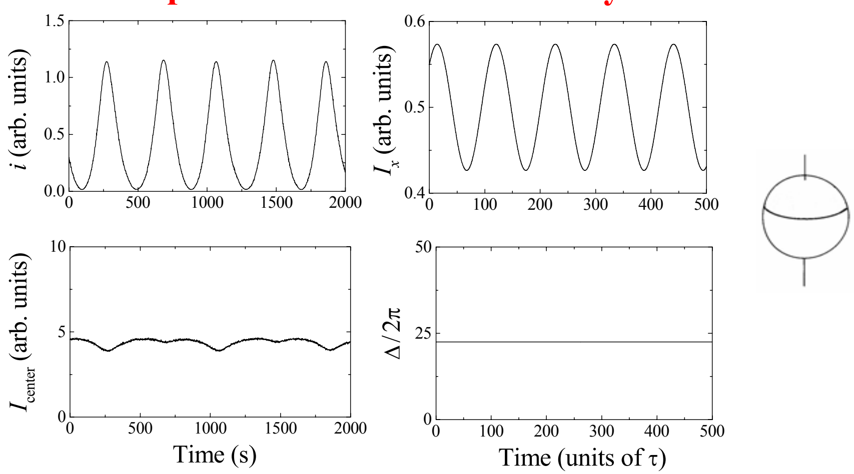
NUP : Quasi-periodic rotation (f_0 , f_1)

Experiment **Theory**

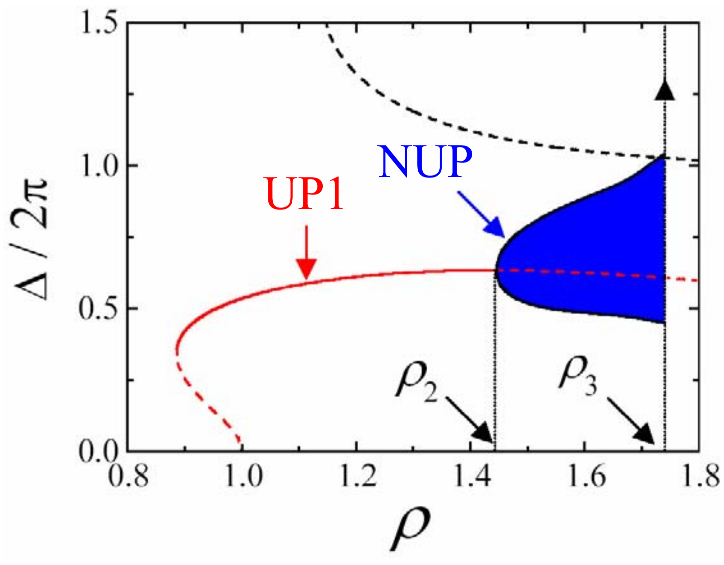


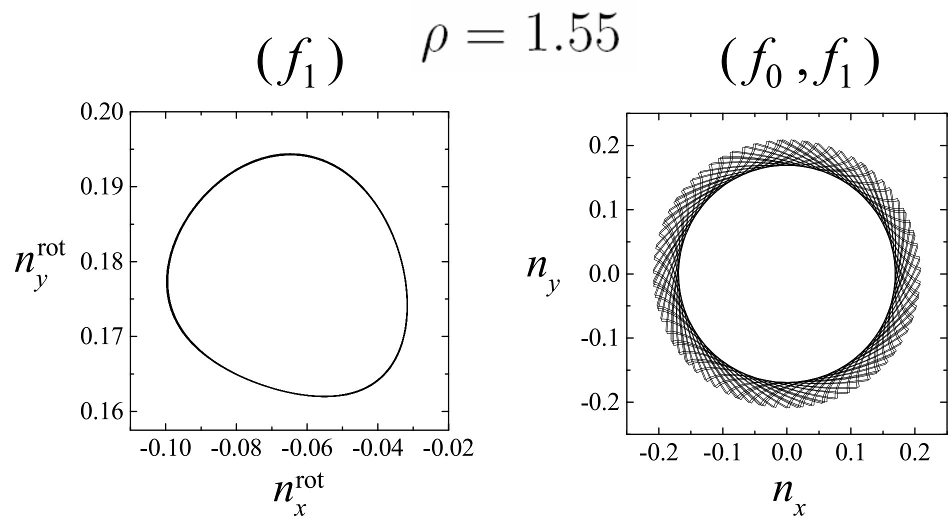
UP2 : Periodic rotation (f_0)

Experiment **Theory**



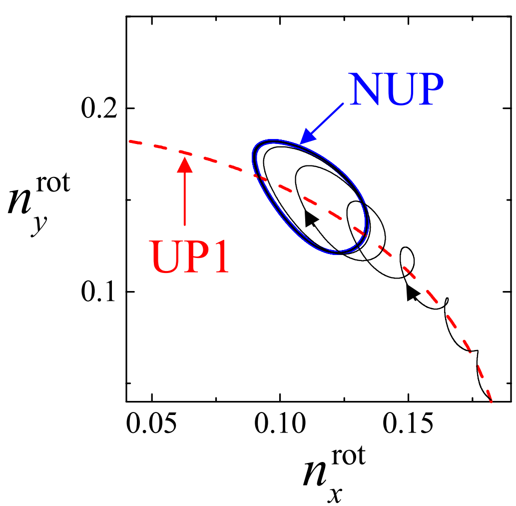
Identification of the quasi-periodic rotating regime





f_0 - rotating frame $(n_x^{\mathrm{rot}}, n_y^{\mathrm{rot}})$

Destabilization of the UP1

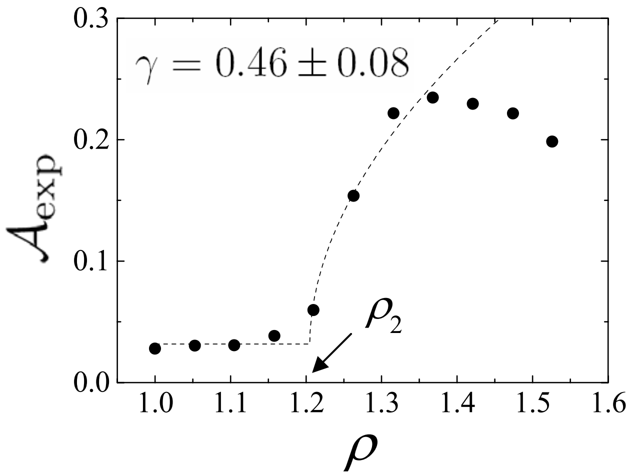


$$\begin{cases} n_x^{\mathrm{rot}} = n_y \sin(2\pi f_0 t) + n_x \cos(2\pi f_0 t) \\ n_y^{\mathrm{rot}} = n_y \cos(2\pi f_0 t) - n_x \sin(2\pi f_0 t) \end{cases}$$

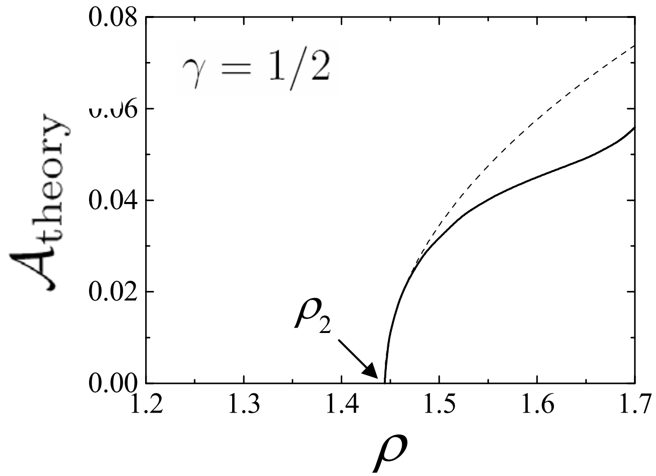
A limit cycle with amplitude $\mathcal{A}$ and frequency f_1 is born

Identification of the bifurcation UP1 → NUP

Experiment

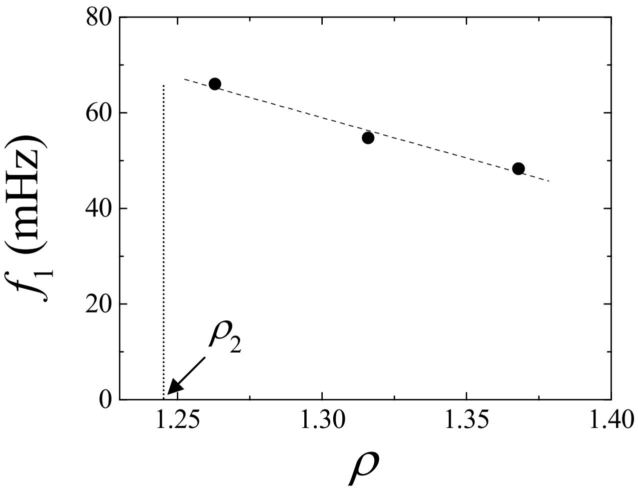


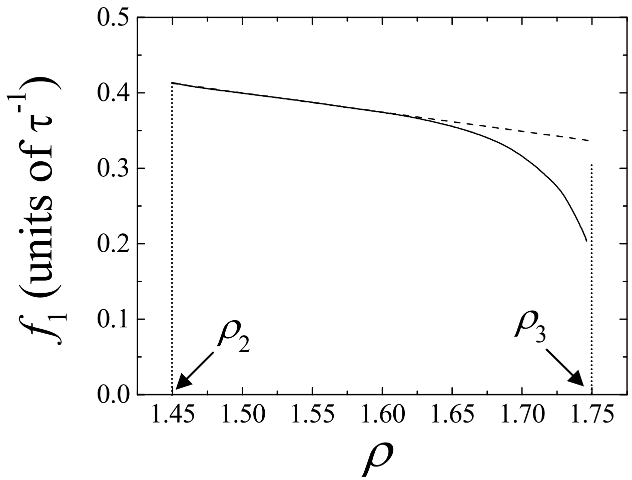
Theory



Limit cycle amplitude

$$\mathcal{A}(\rho) - \mathcal{A}(\rho_2) = \mathcal{O}(\rho - \rho_2)^{\gamma}$$



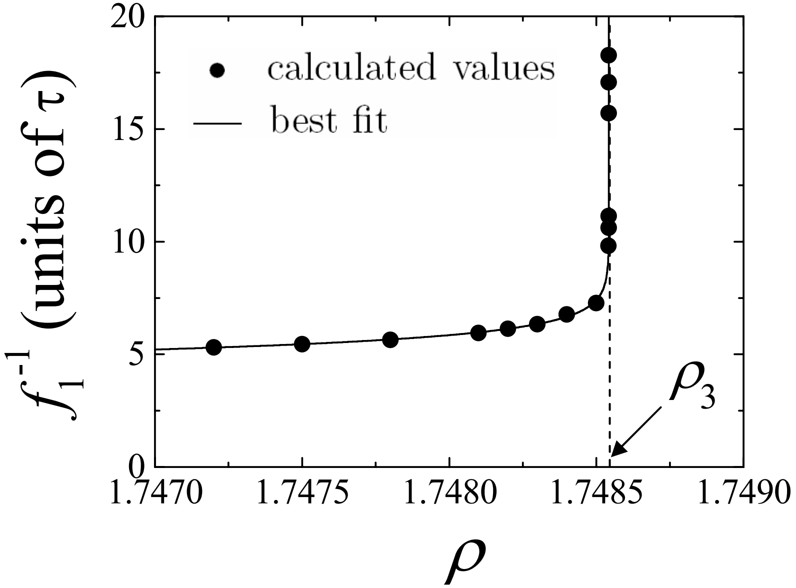


Limit cycle frequency

$$f_1(\rho) - f_1(\rho_2) = \mathcal{O}(\rho - \rho_2)$$

Supercritical Hopf bifurcation

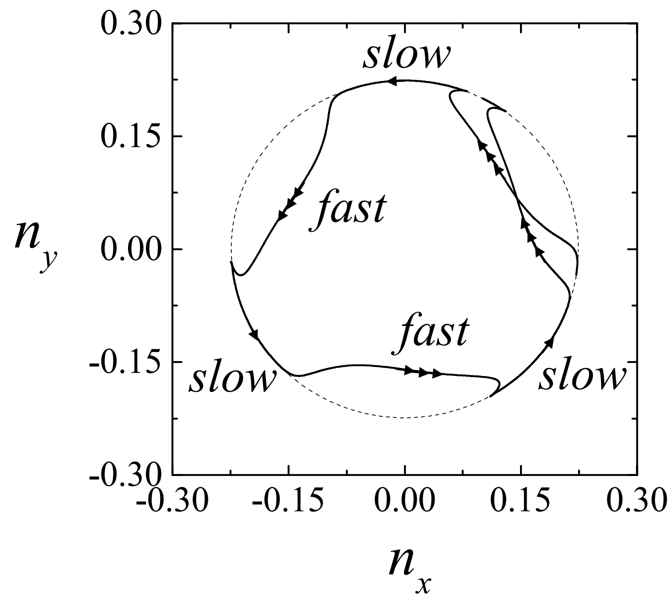
Identification of the bifurcation NUP → UP2



Limit cycle period

$$1/f_1 \propto \mathcal{O}\left[\ln(\rho_3 - \rho)\right]$$

Homoclinic bifurcation



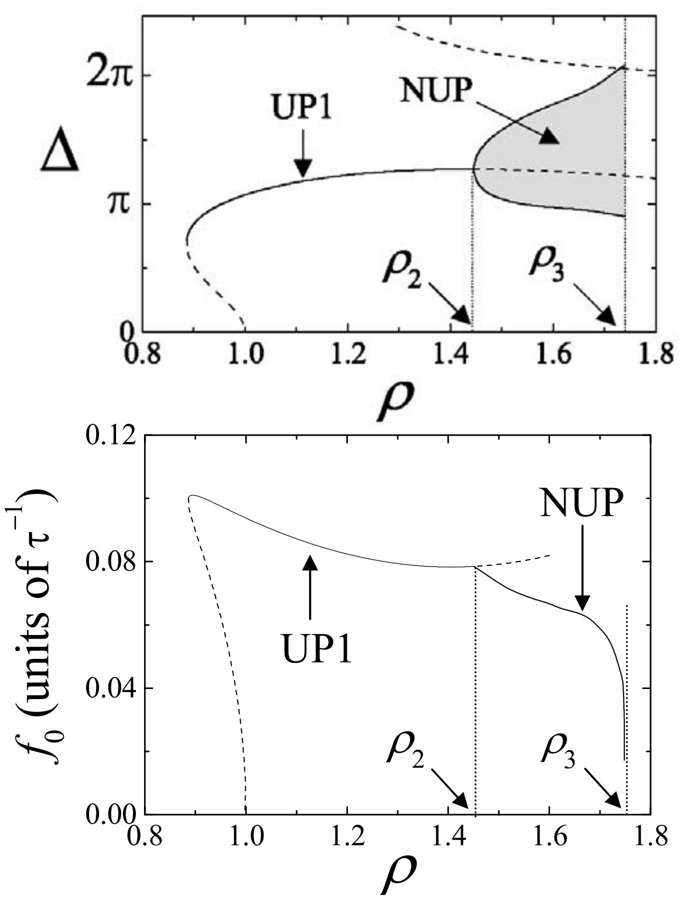
Dynamics with two time scales

Interpretation in terms of light angular momentum transfer to LC

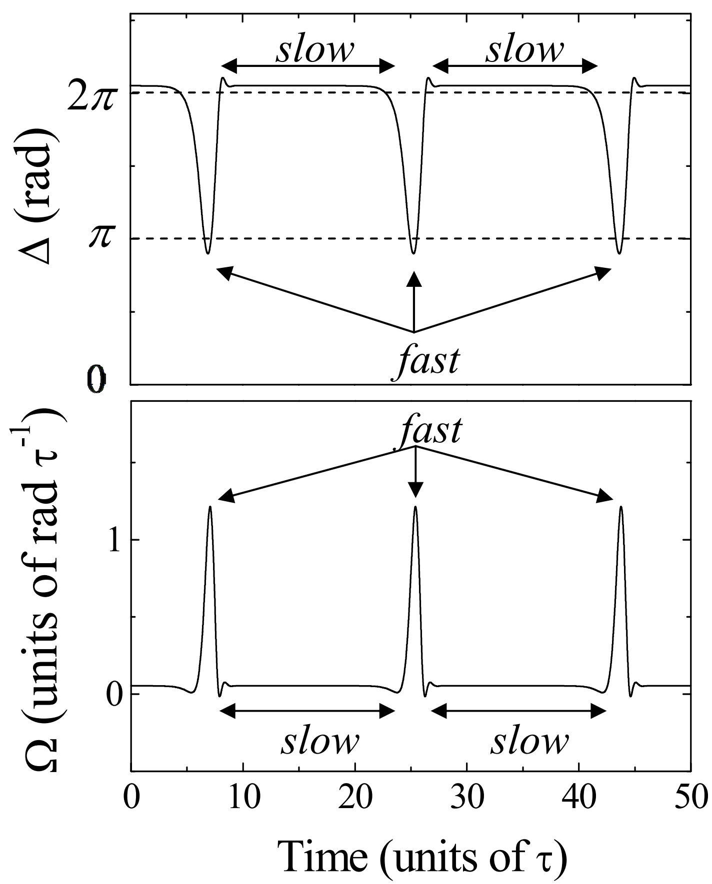
Angular momentum transferred by photon

$$m = (1 - \cos\Delta)\hbar$$

Sudden deceleration at UP1 → NUP



Two time scales near NUP → UP2



Summary

Nonlinear dynamics generated by circularly polarized light in nematic liquid crystal films

- Bifurcation diagram with light intensity as control parameter
- Identification of the sequence of transitions (Hopf, homoclinic)
- Experimental validation of the theoretical models
- Interpretation in terms of spin angular momentum transfer to LC

This work has been submitted to publication in JOSAB on May 2004