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Spatio-temporal Dynamics of Nonlinear Optical Systems

- ***GENERAL ASPECTS OF OPTICAL PATTERNS***

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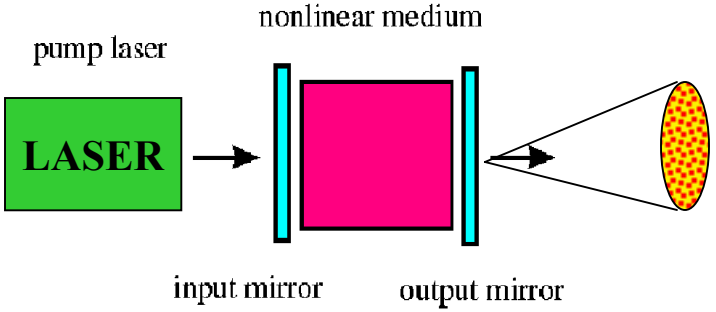
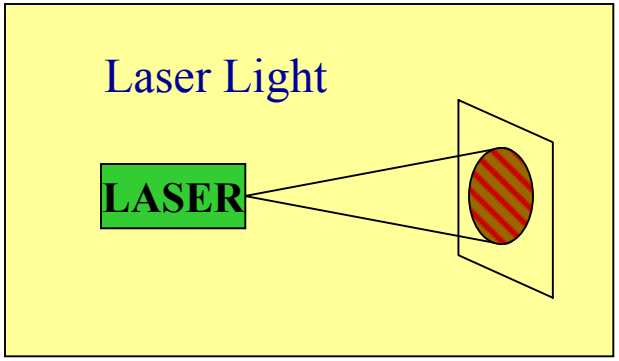
OPTICAL TRANSVERSE PATTERNS

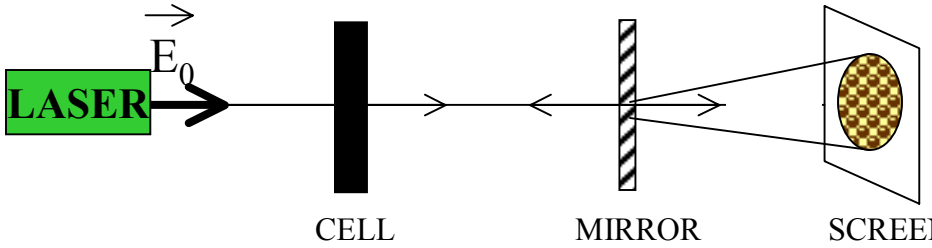
Nonlinear medium in optical cavity



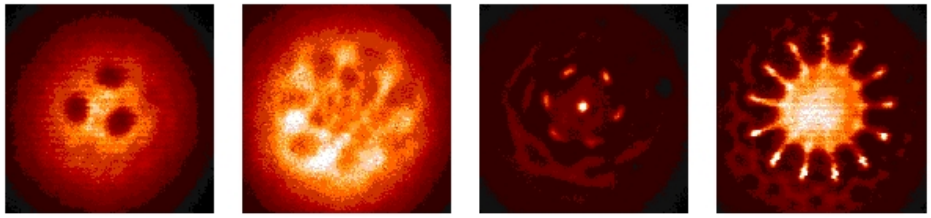
Laser Light



Single feedback mirror configuration



Na cell



T. Ackemann et al.
PRL 75, 3450(1995)

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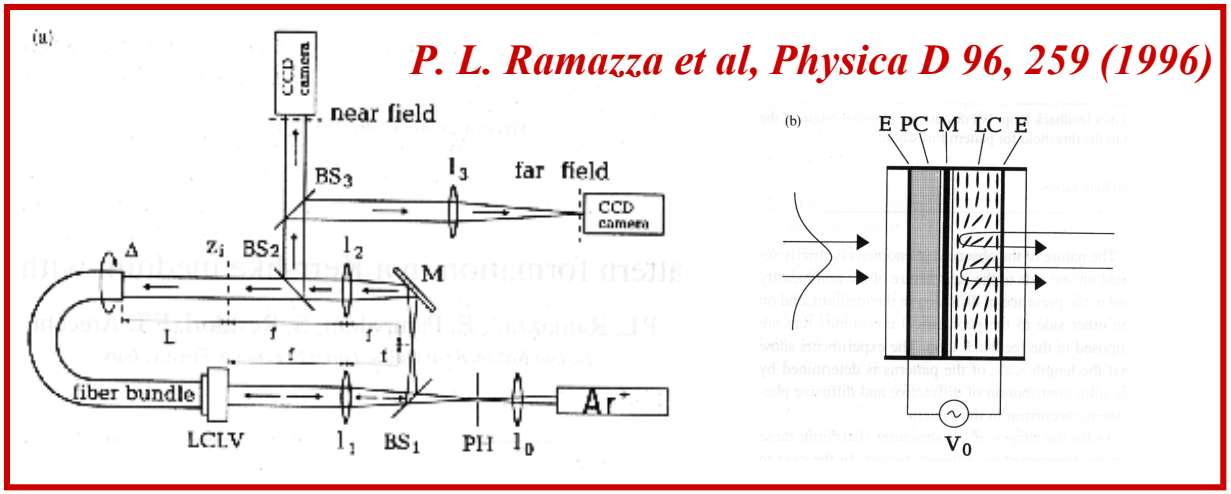
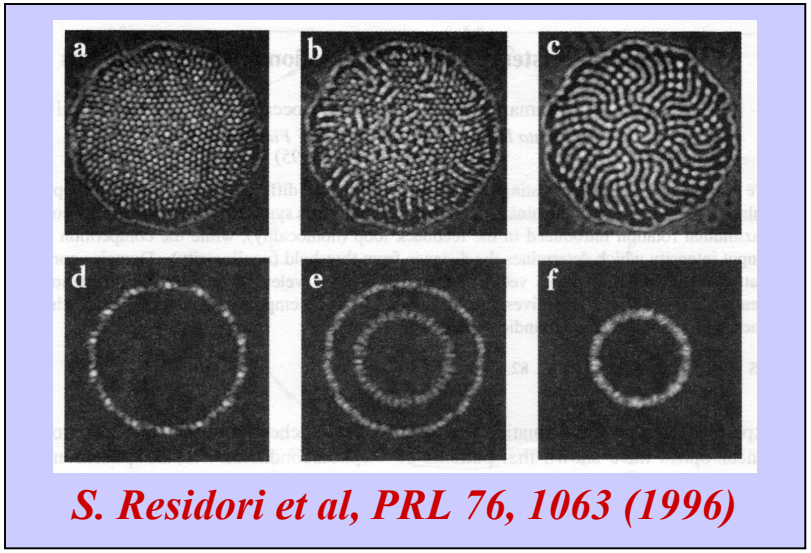
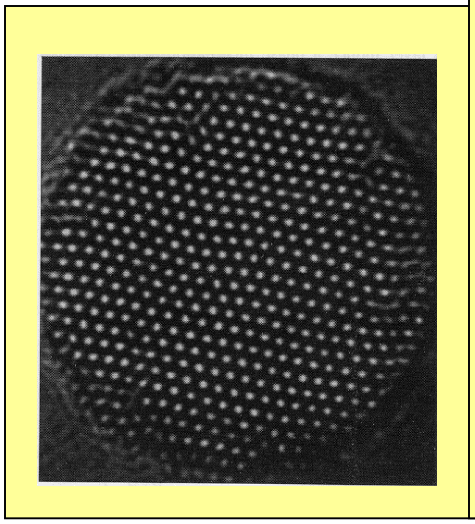
OPTICAL PATTERNS: LCLV

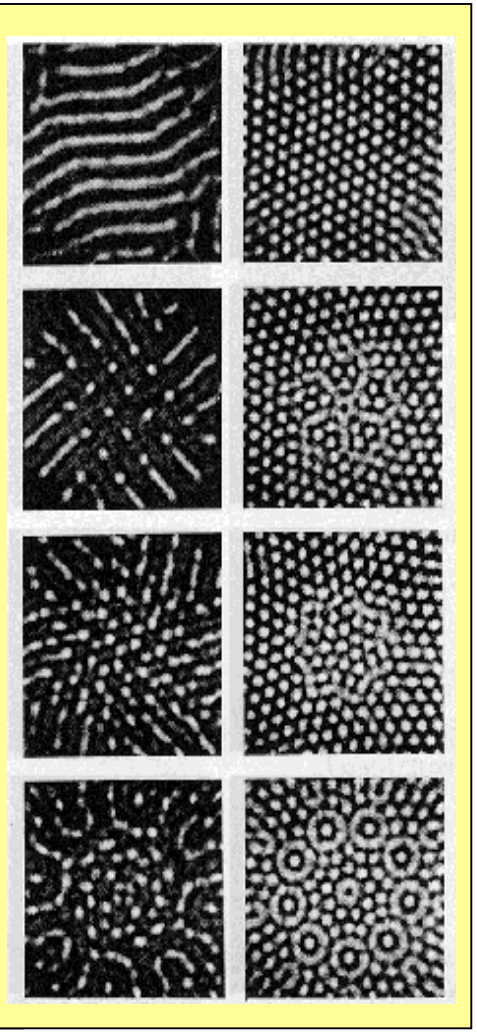


P. L. Ramazza et al, Physica D 96, 259 (1996)



S. Residori et al, PRL 76, 1063 (1996)





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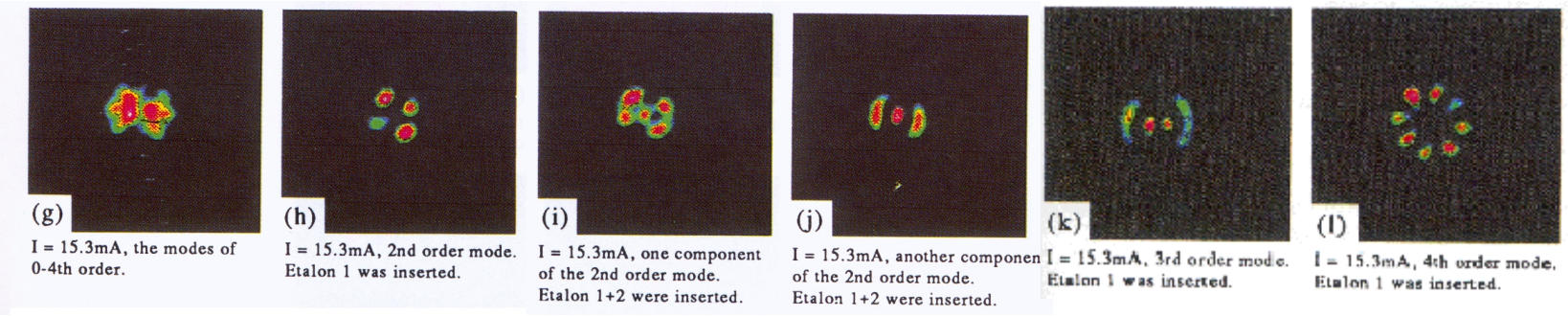
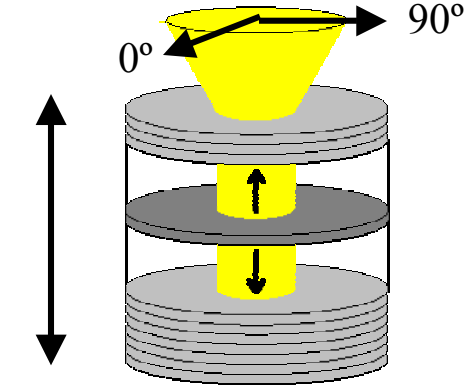
TRANSVERSE PATTERNS in VCSELs



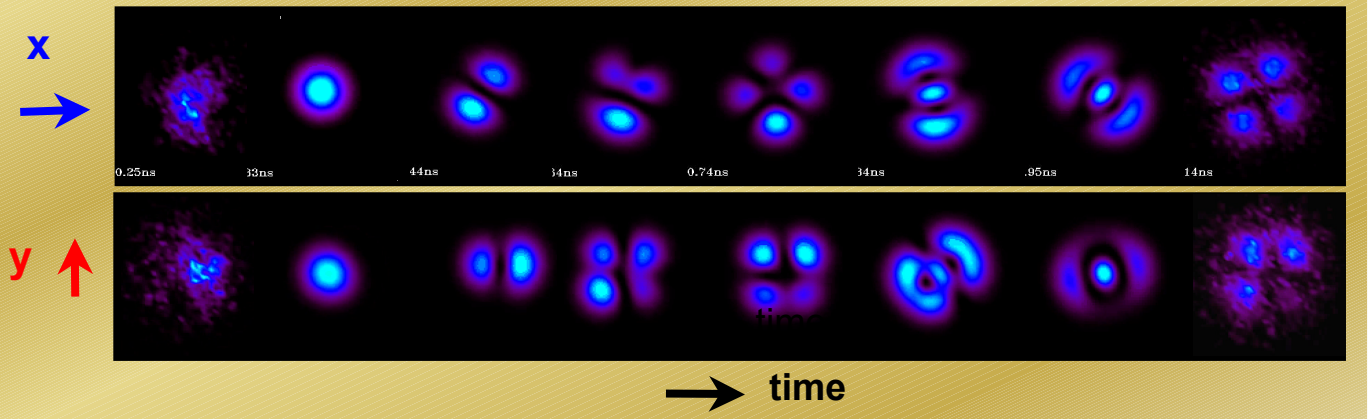
H. Li et al Chaos, Solitons and Fractals 4, 1619 (1994)

VCSEL



L ~ 1μm

Sub-nanosecond electric excitation



J. Mulet et al, IEEE J. Quantum Electron. 38, 291 (2002)

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Optical Patterns

- ***DIFFRACTION, TIME SCALES, CLEAN SYSTEMS…***
- ***INFORMATION PROCESSING:***
  - **Localized Structures /Cavity Solitons**
  - **All-optical image processing**
- ***POLARIZATION OF LIGHT:***
  - **Vectorial Spatio-Temporal Phenomena**
  - **Correlated Patterns, Phase separation, Symmetry Tuning**
- ***QUANTUM ASPECTS:***
  - **Macroscopic quantum correlations in patterns.**
  - **PARALLEL Quantum Information**

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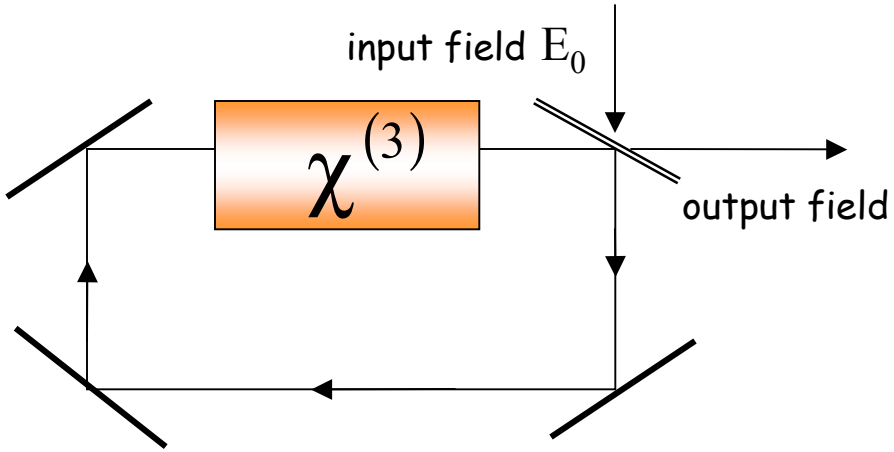
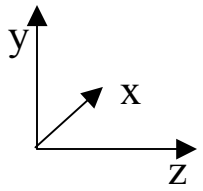
Self-focusing Kerr medium in a ring cavity





$$\vec{E}(\vec{x},z,t) = \underbrace{\vec{E}(\vec{x},t)}_{\text{field envelope}} e^{i(k_0 z - w_0 t)}$$

$$\vec{x} = (x,y)$$

Time evolution of field envelope

$$\frac{\partial E}{\partial t} = -(1+i\theta)E + ia\nabla^2 E + E_0 + i2|E|^2 E$$

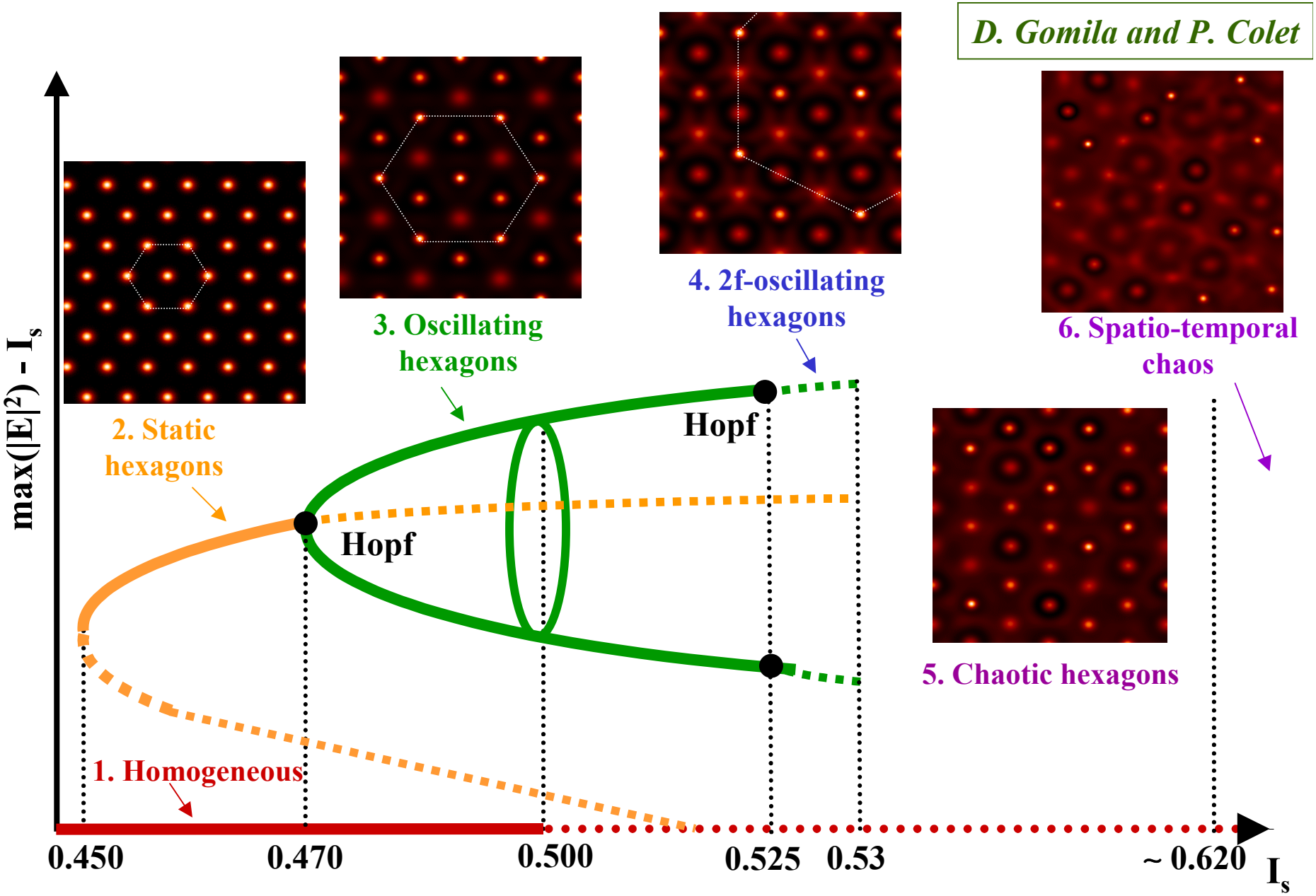
$\theta = 1$: cavity detuning, E_0 : input field

∇^2 : transverse Laplacian, $a = 1$: strength of diffraction

L. A. Lugiato & R. Lefever, Phys. Rev. Lett. **58**, 2209, (1987).

Spatio - Temporal Regimes of Self-Focusing Kerr

D. Gomila and P. Colet



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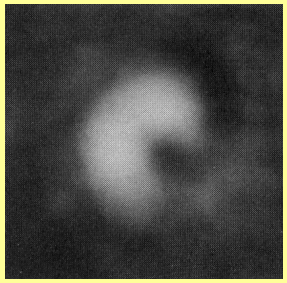
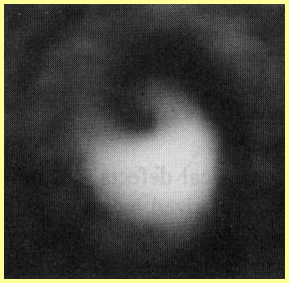
LOCALIZED STRUCTURES

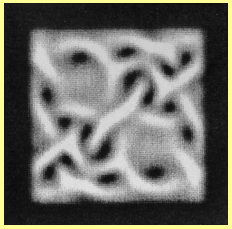
Photorefractive Crystals

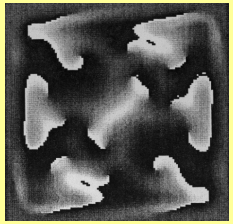




Optical vortex and phase spiral

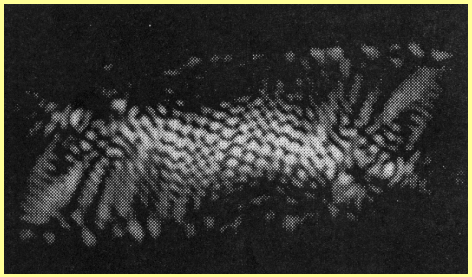
Arecchi et al. PRL 67, 3751 (1991)





Vortices and shocks

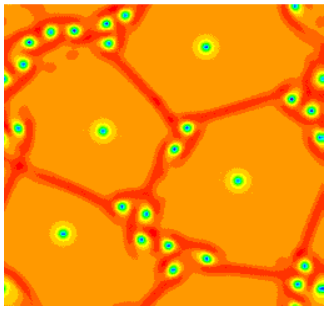
Vortex lattice

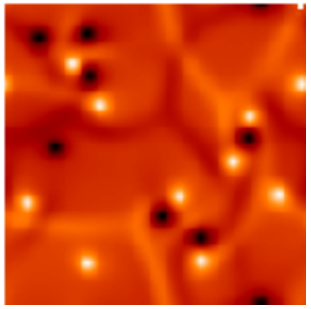


Staliunas et al.

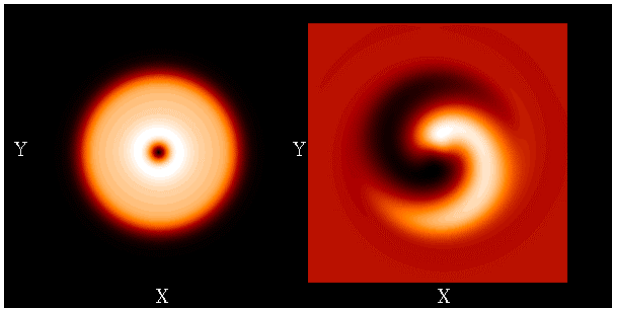
PRL 79, 265 (1997)

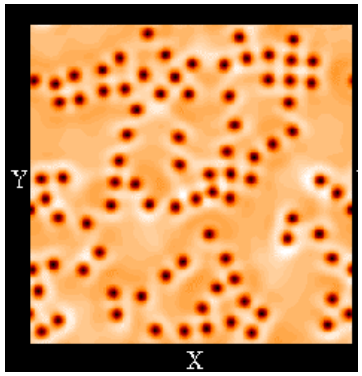
Broad Area Laser





Optical Parametric Oscillator





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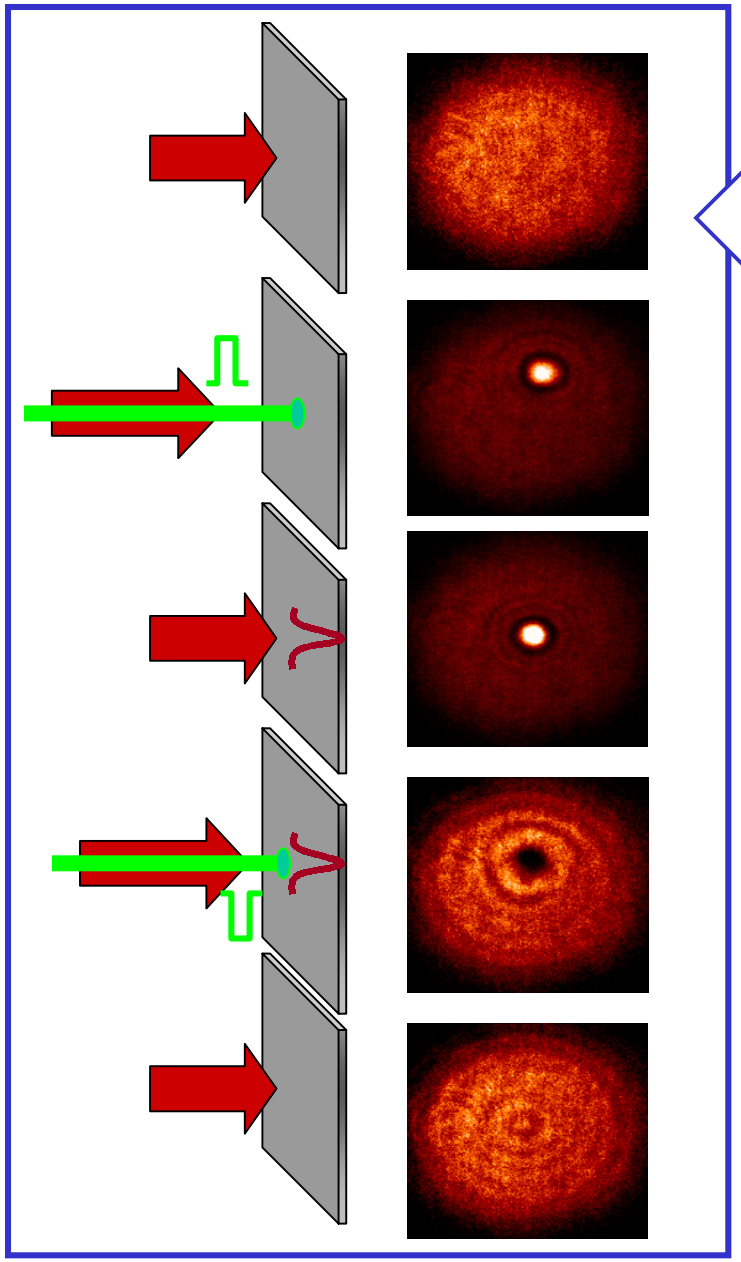
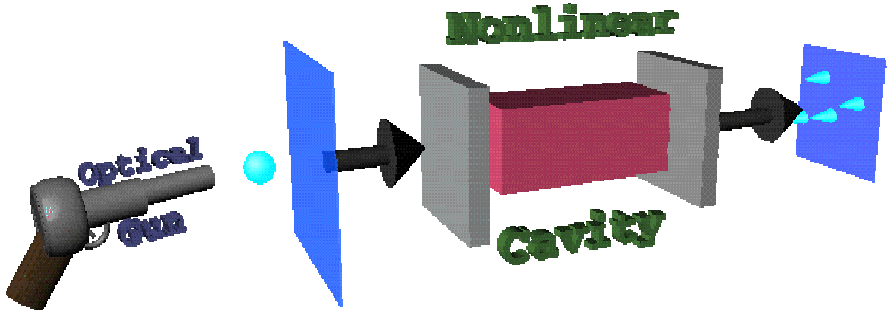
OPTICAL PROCESSING WITH CAVITY SOLITONS



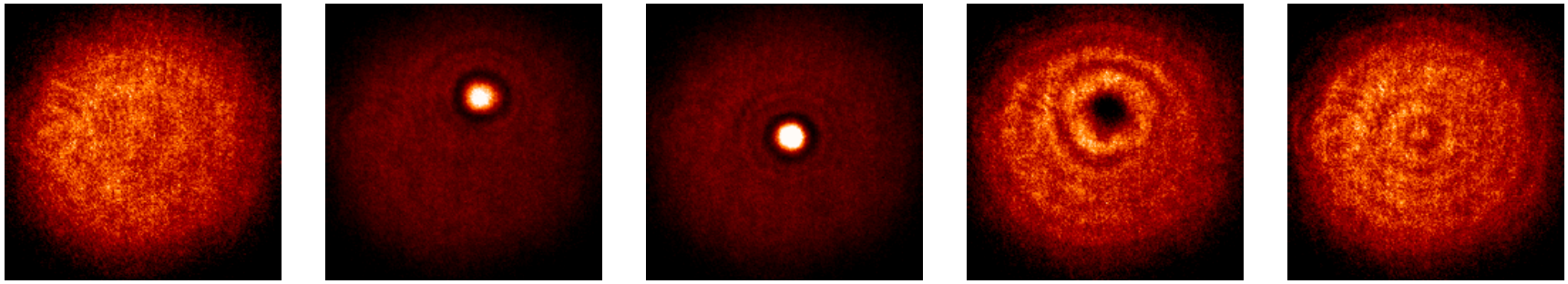
Write and erase solitons

in an optical cavity



Switching of Spatial Solitons, *Ackemann-Lange (Munster)*

- Adressing: focused second beam (approximately the same size as soliton)
- Ignition: circular polarization parallel to holding beam
- Erasure: circular polarization orthogonal to holding beam
- Polarization properties provide phase insensitive way of control (!)



background | **SS ignited** | **SS moves due to noise and intensity gradient** | **SS erased** | **minimum unstable**

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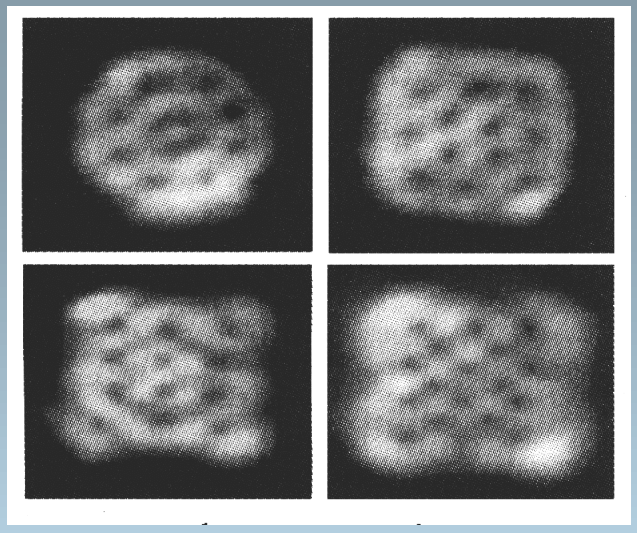
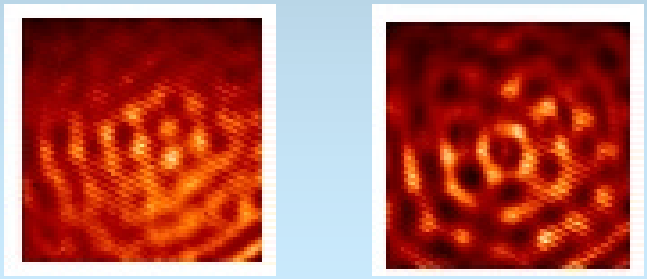
Patterns and Localized States in VCSELS



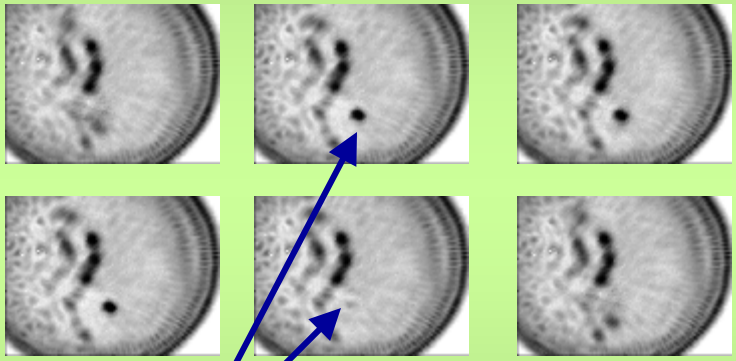
J. Scheuer, M. Orenstein, Science 285, 230 (99)



T. Ackemann et al., IMEDEA-INLN (1999)

Control of localized states in broad area VCSELs (150 μm)

Homogeneous beam +
Local addressing perturbation



Switch ON-OFF of LS

U·L·M PHOTONICS

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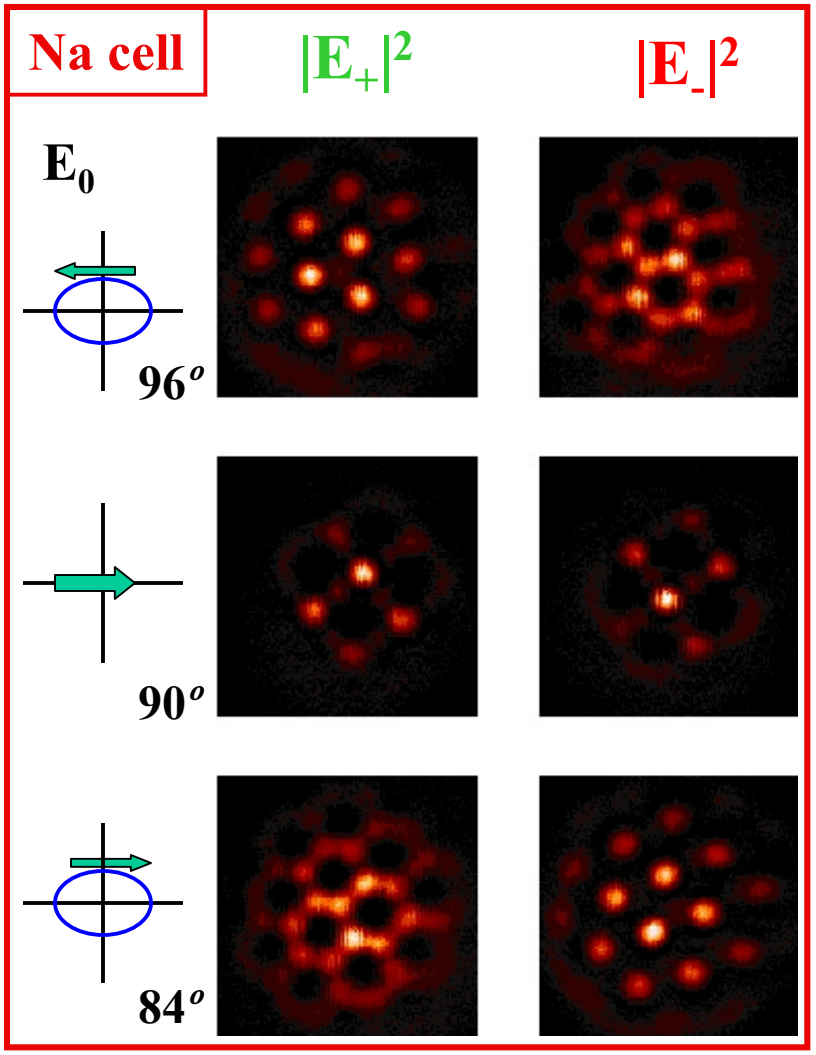
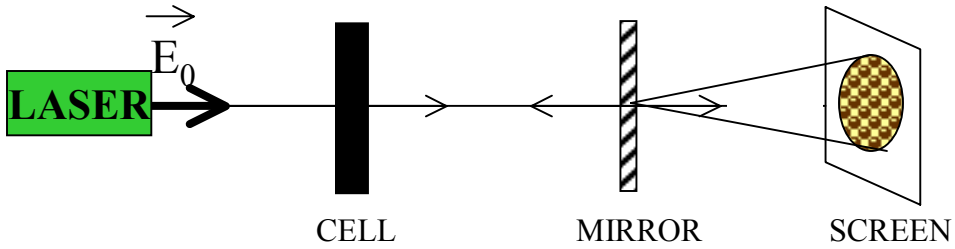
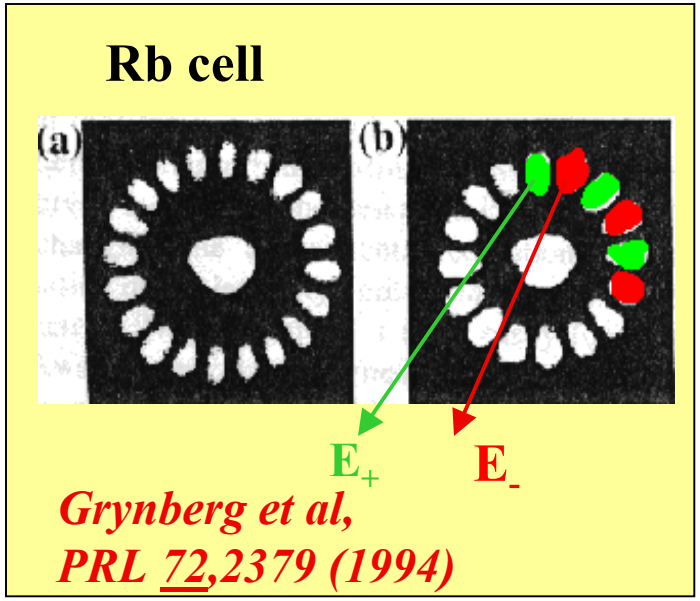
POLARIZATION PATTERNS







Aumann et al, Phys. Rev. A 56, R1709 (1997)

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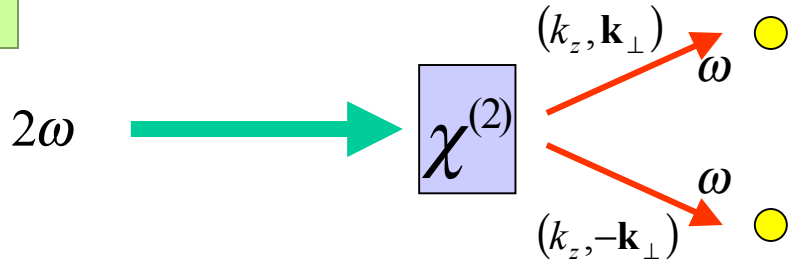
PARAMETRIC DOWN CONVERSION:

TWIN PHOTON EMISSION



Degenerate OPTICAL PARAMETRIC OSCILLATOR:

Optical Cavity

Pump : $A_0 \Rightarrow 2\omega$

$$\partial_t A_0 = \gamma_0\left[-(1+i\Delta_0)A_0 + E_0 + ia_0\nabla^2 A_0 + 2iK_0 A_1^2\right] + \sqrt{\varepsilon_0}\,\xi_0(\mathbf{r},t)$$

Signal : $A_1 \Rightarrow \omega$

$$\partial_t A_1 = \gamma_1\left[-(1+i\Delta_1)A_1 + ia_1\nabla^2 A_1 + iK_0 A_1^* A_0\right] + \sqrt{\varepsilon_1}\,\xi_1(\mathbf{r},t)$$

Stripe patterns

$$A_1(\mathbf{r},t) = A_+ e^{iq_M x} + A_- e^{-iq_M x} = R\,e^{i\phi}\cos(q_M x + \psi)$$

$$q_M(\Delta_1) = |\mathbf{k}_\perp|, \quad \phi(\Delta_0) \text{ fixed}, \quad \psi \text{ arbitrary}$$

FLUCTUATIONS:

$$\left\{ \begin{array}{c} I_+ - I_- \text{ small} \quad \left(I_\pm = |A_\pm|^2\right) \\ \psi \text{ large fluctuations} \end{array} \right\}$$

QUANTUM COMPLEMENTARITY

Squeezing in photon number difference