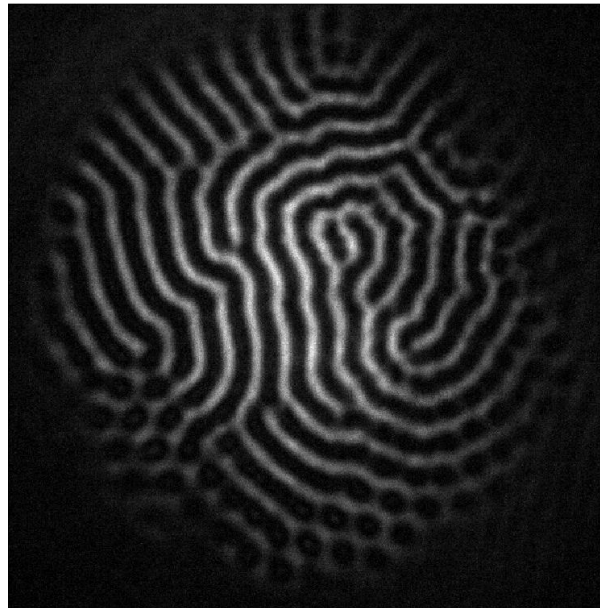


Transverse self-organization in a cold atomic cloud

Institut Non Linéaire de Nice
(France)

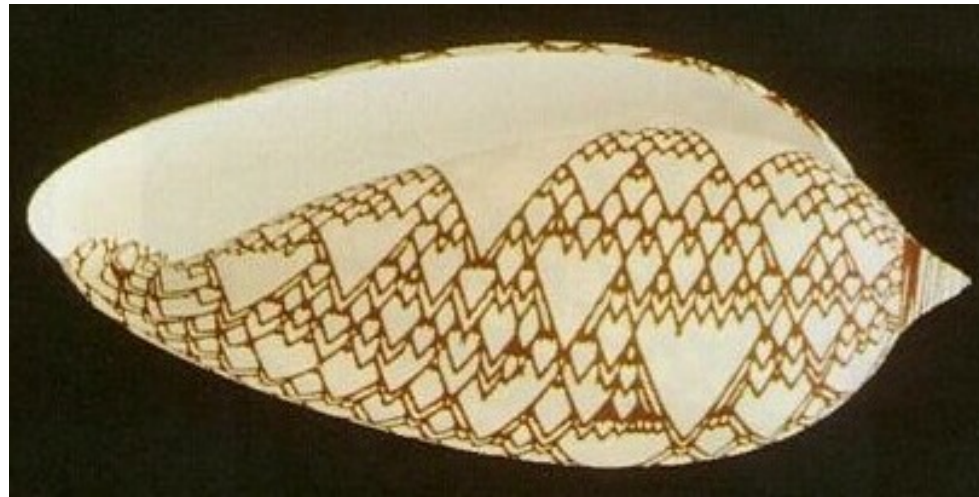
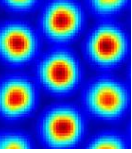
G. Labeyrie
A. Camara
R. Kaiser



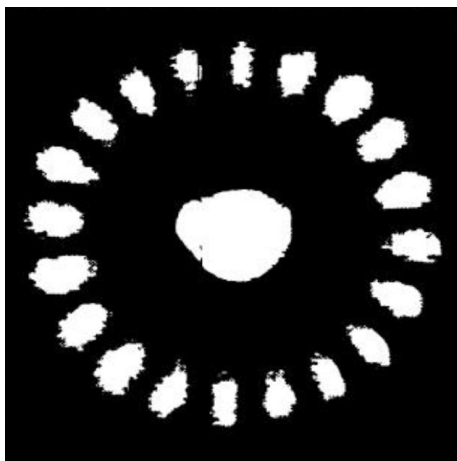
University of Strathclyde
(UK)

T. Ackemann
P. Gomes
I. Kresic
G.-L. Oppo
E. Tesio
W. Firth
G. Robb
A. Arnold

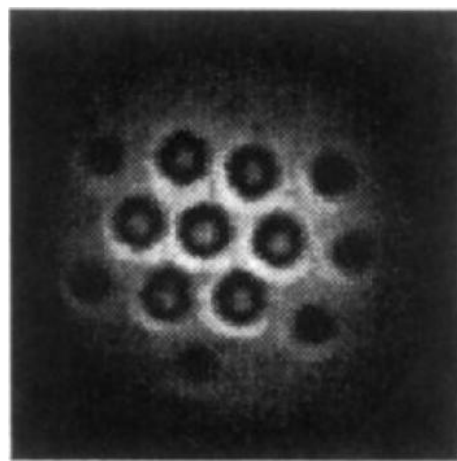




optical pattern formation
in nonlinear media

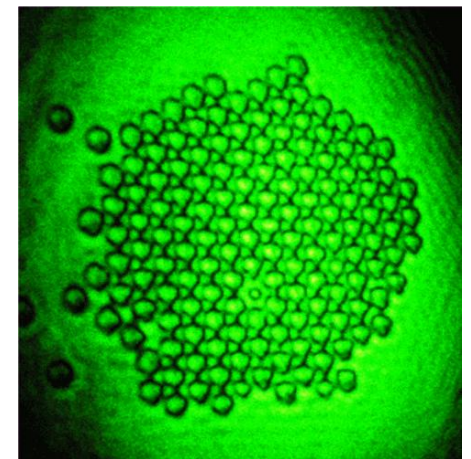
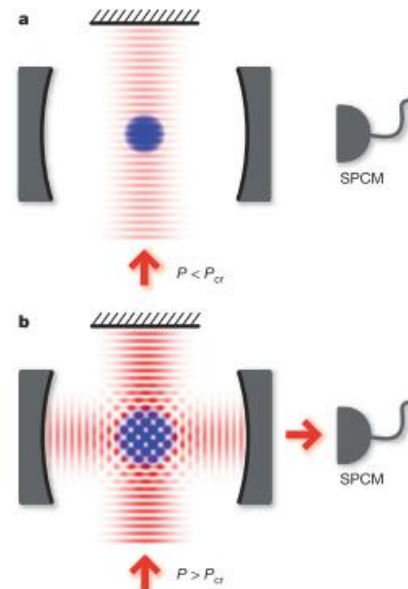


PRL 72, 2379 (1994).



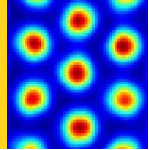
PRA 50, R4468 (1994).

optomechanical self-organization

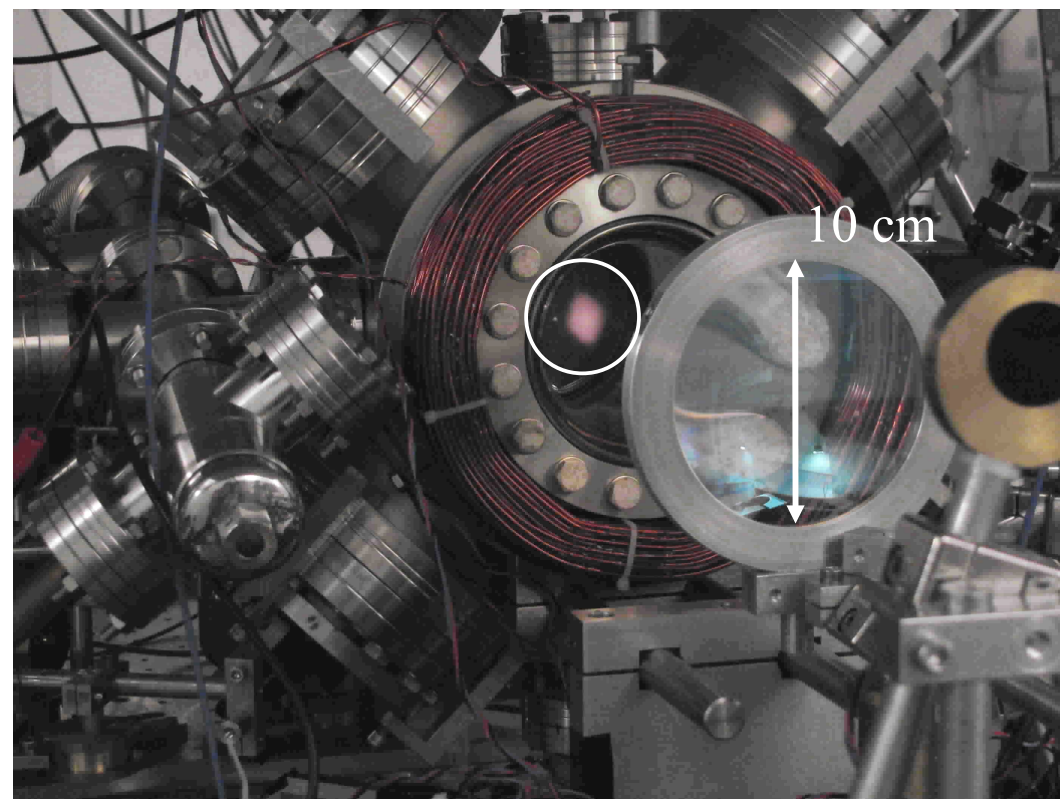


PRL 112, 023902 (2014).

Nature 464, 1301 (2010).



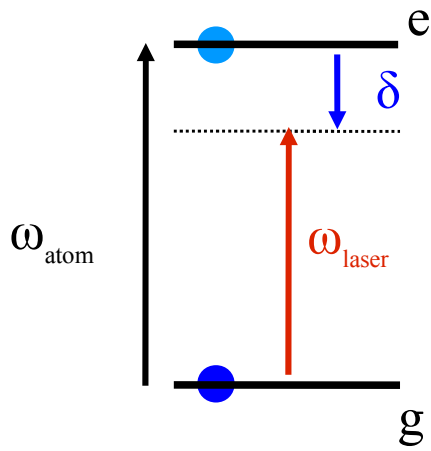
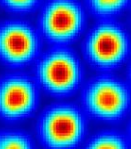
- $N \sim 10^{11}$ atoms \rightarrow size ~ 1 cm
- OD ~ 200
- $T \sim 200 \mu\text{K}$



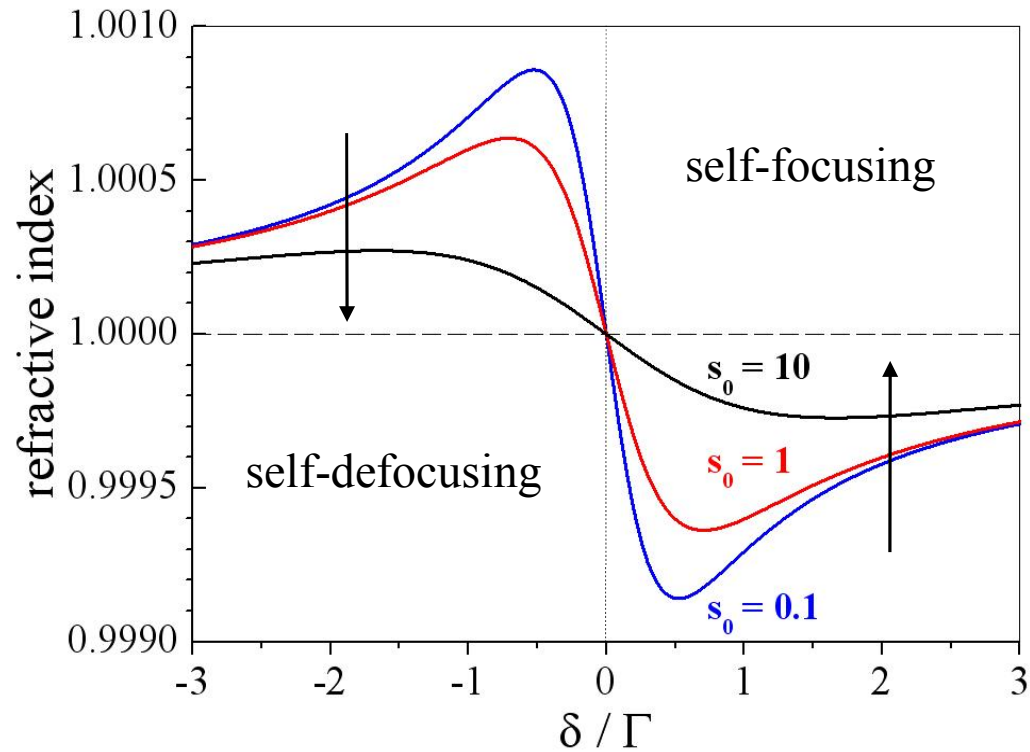
self-focusing : EPJD **22**, 473 (2003) ; EPJD **41**, 337 (2007).

spatial soliton : Opt. Lett. **36**, 2158 (2011).

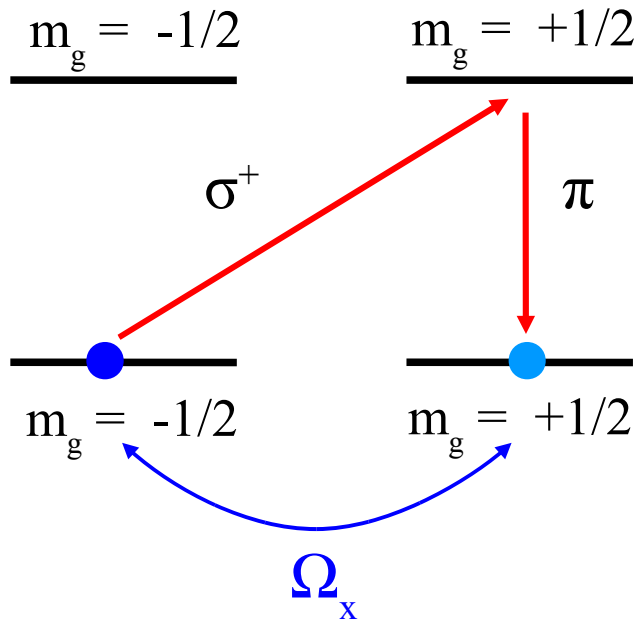
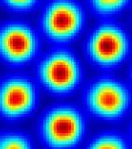
2-level nonlinearity



$$n = 1 - \rho \frac{3\lambda^3}{4\pi^2} \frac{\delta/\Gamma}{1 + 4(\delta/\Gamma)^2 + \underbrace{I/I_{\text{sat}}}_{\text{nonlinear!}}}$$

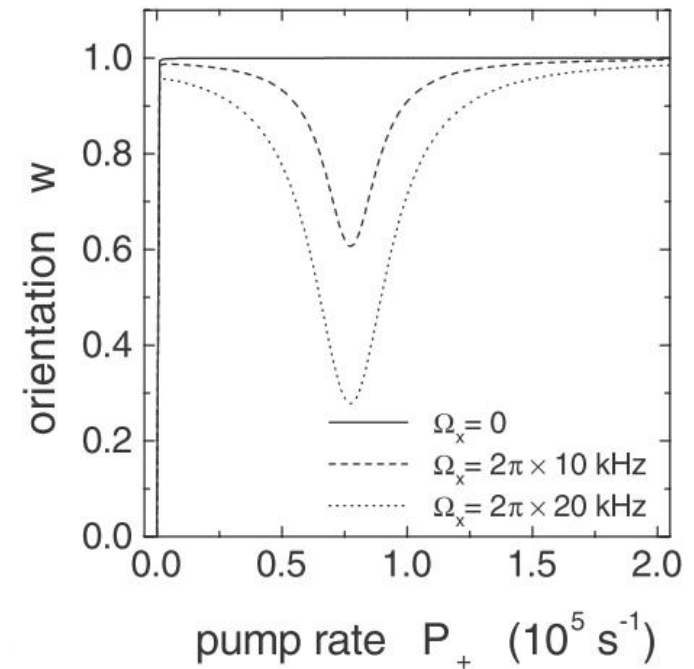


- $s < 1 \rightarrow n \approx n_0 + n_2 \times I$
- saturable
- fast ($\tau = 26$ ns)

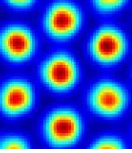


$$\chi_{\text{NL}} = \chi_{\text{L}}(1 - w)$$

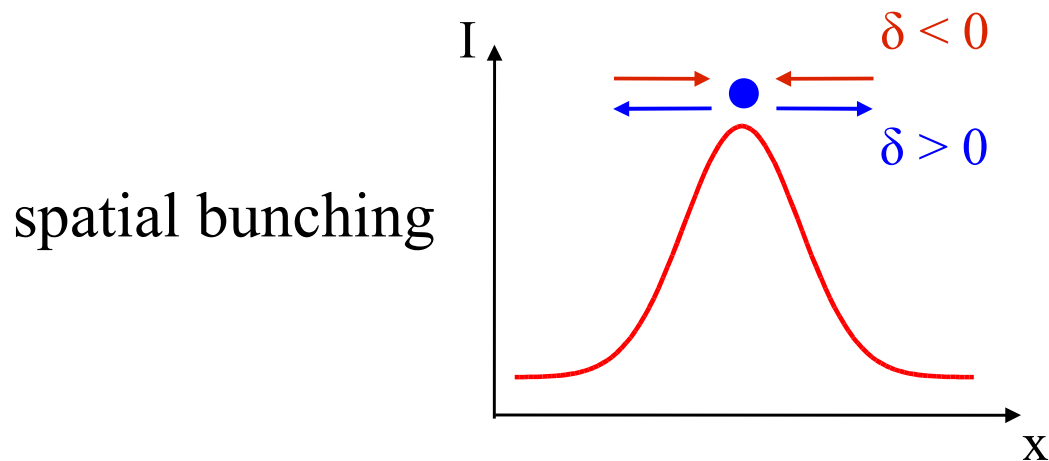
Appl. Phys. B 72, 21 (2001).



- low intensity
- fast (depends on s)
- polarization and B-dependent

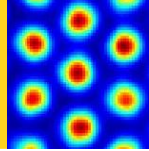


$$F_{\text{dip}} = -\frac{\hbar \delta}{2} \frac{\nabla I / I_{\text{sat}}}{1 + I / I_{\text{sat}} + 4 (\delta / \Gamma)^2}$$

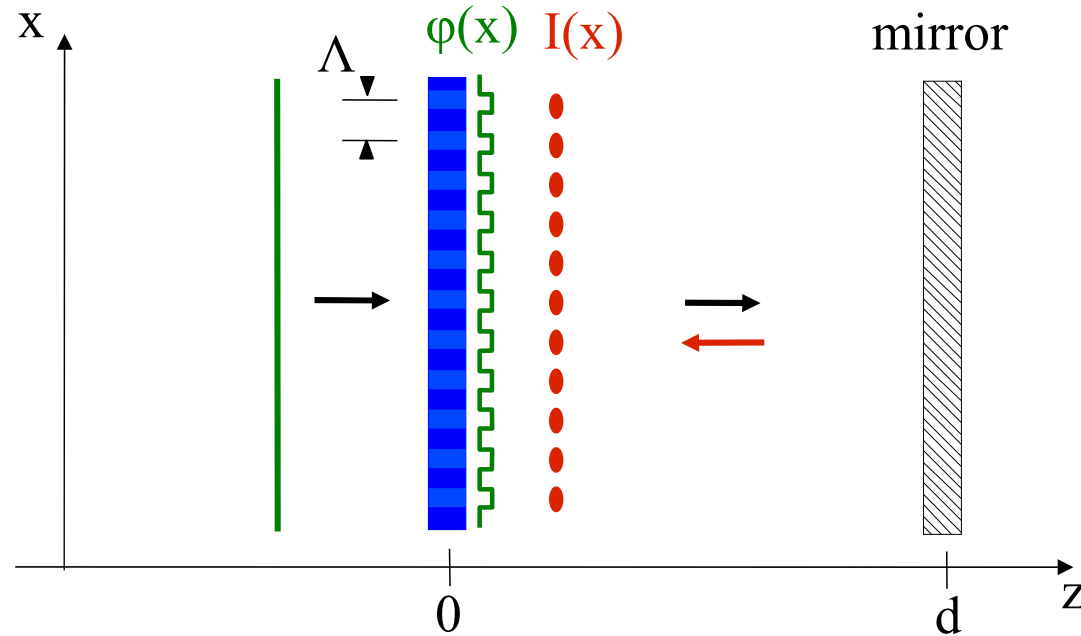


- slow
- depends on T
- $\delta \gg \Gamma \rightarrow$ no dissipation

Single-mirror feedback experiment



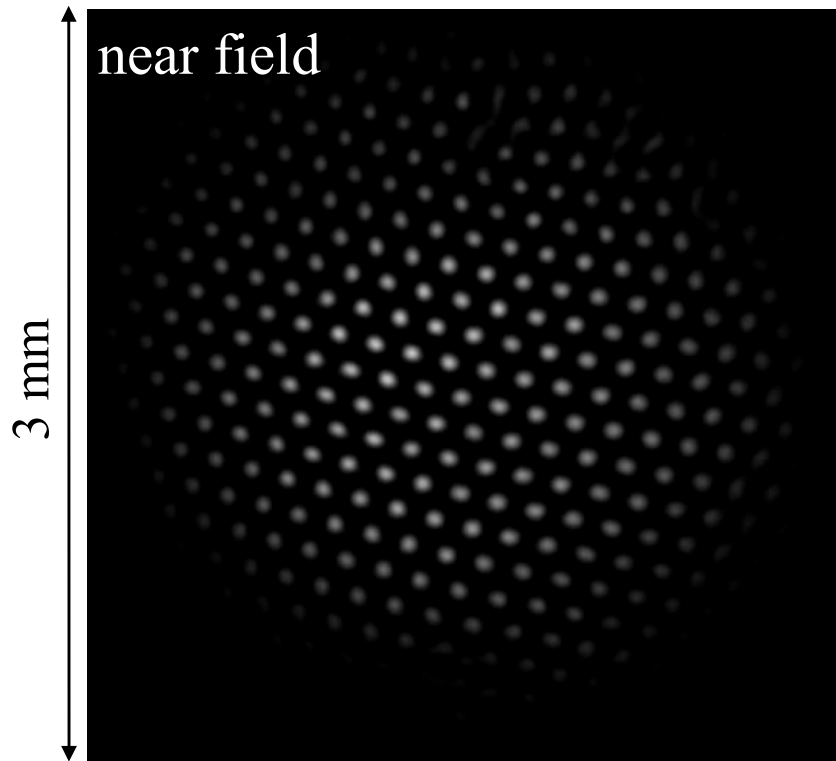
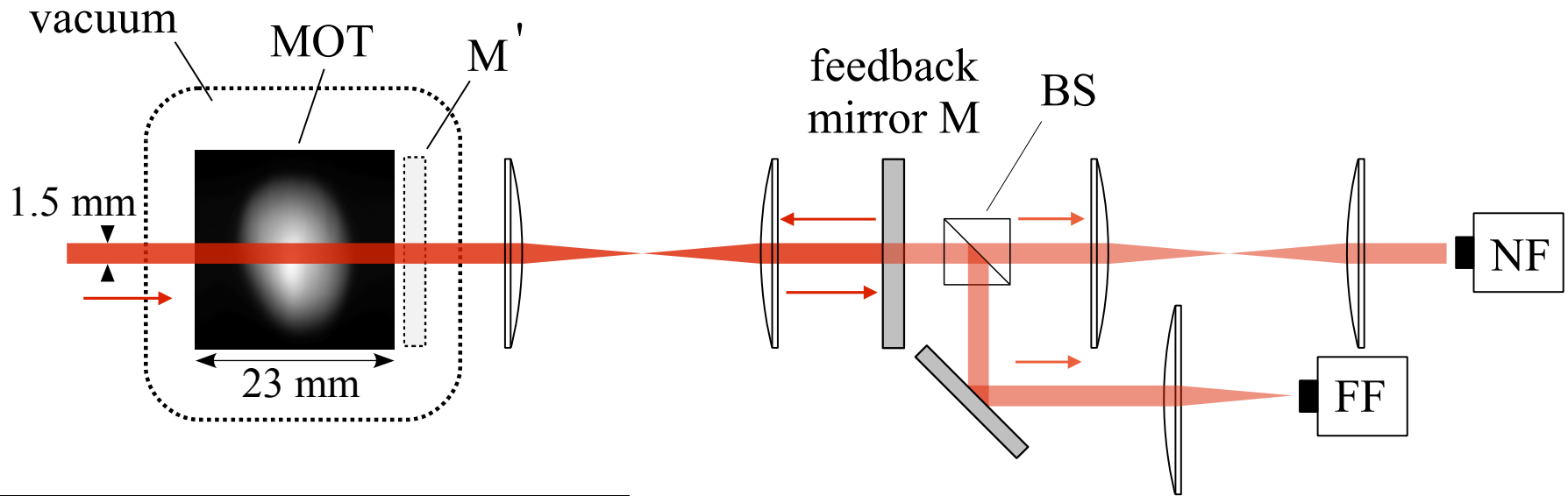
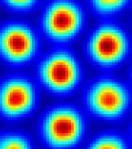
J. Mod. Opt. 37, 151 (1990).



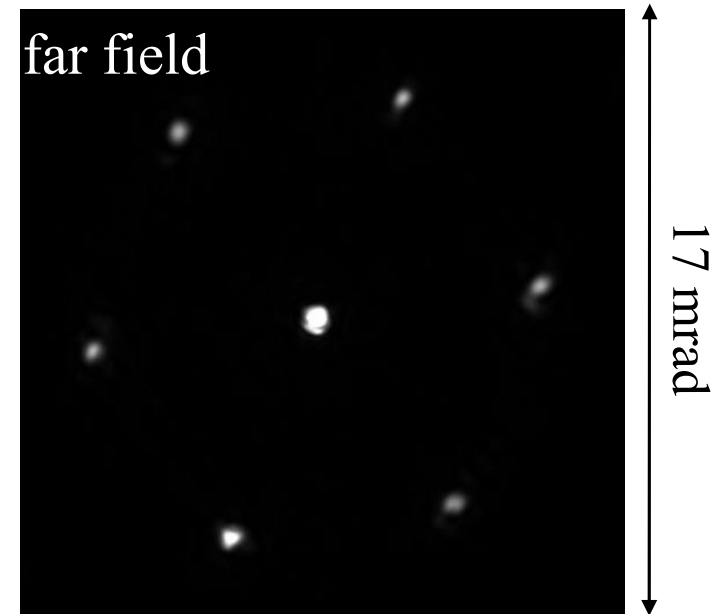
positive feedback }
 gain > losses } → transverse instability

tunable pattern length scale (Talbot) : $\Lambda \propto (\lambda d)^{1/2}$

Optomechanical instability

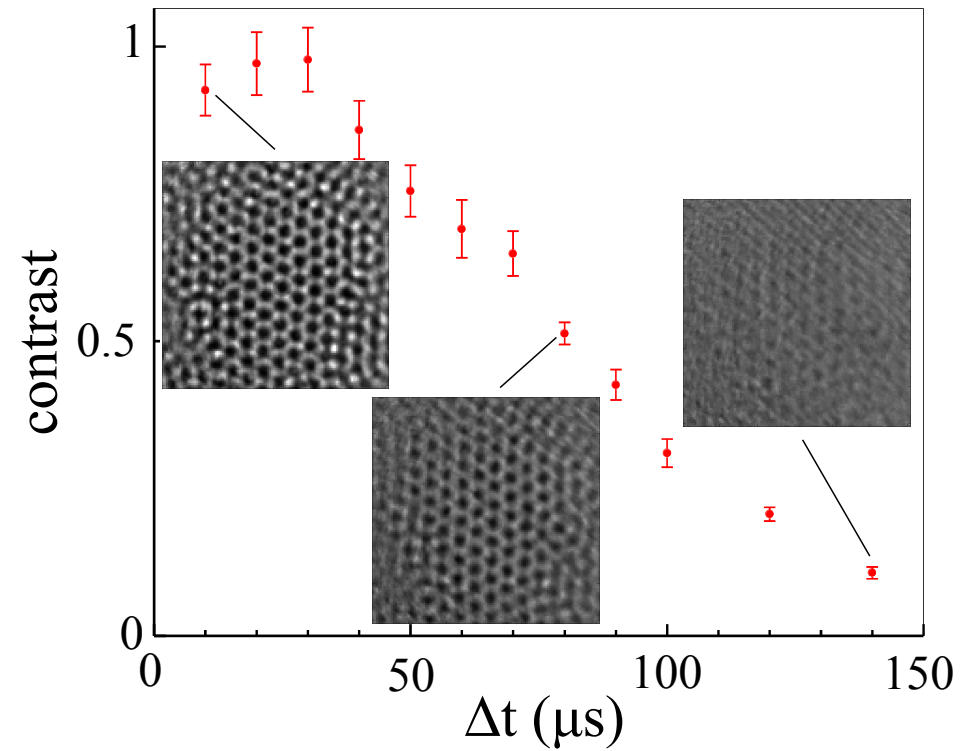
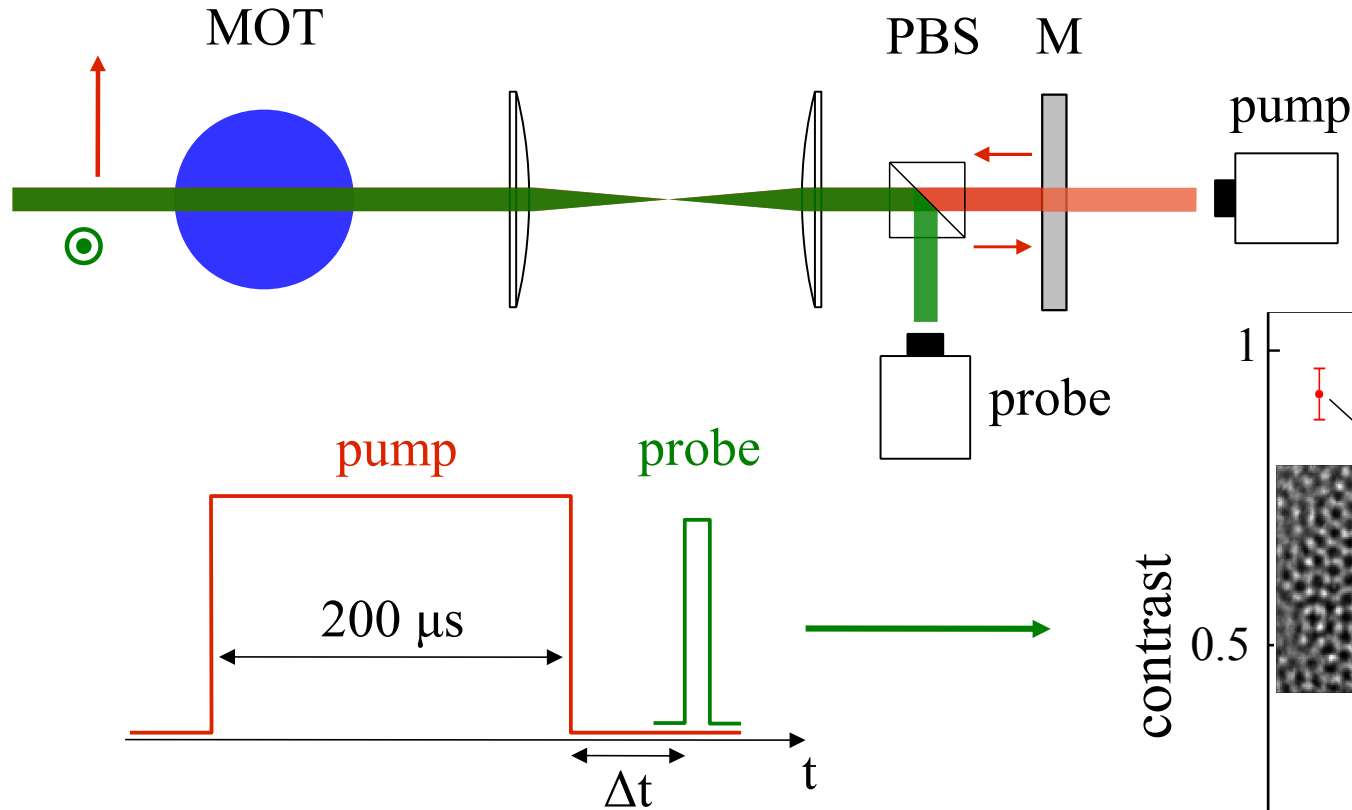
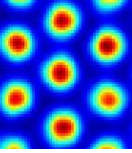


$$\begin{aligned}
 \delta &> 0 \\
 s &> 5 \times 10^{-2} \\
 \Delta t_{\text{pump}} &> 10 \mu\text{s}
 \end{aligned}$$



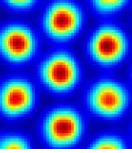
Nat. Phot. **8**, 321 (2014).

Spatial bunching ?



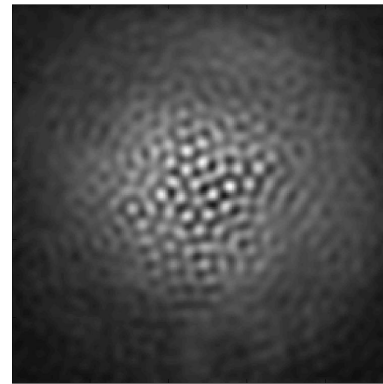
- slow decay $\sim 100 \mu\text{s}$ (T)
 - ~~excited state grating~~
 - ~~spin grating~~
 - ~~hyperfine grating~~
- density grating !

2-level instability

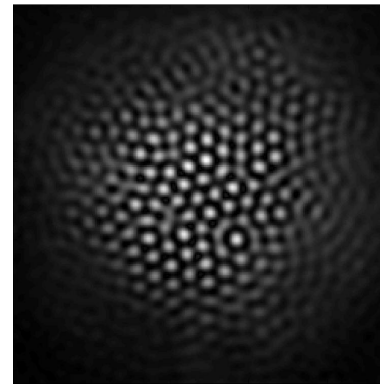


$$\delta > 0$$

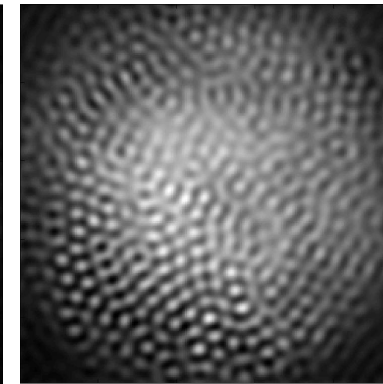
$$\Delta t_{\text{pump}} < 1 \mu\text{s}$$



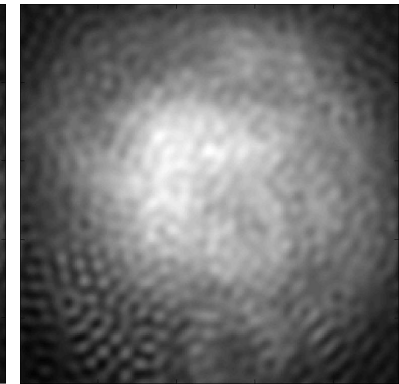
0.24 W/cm²



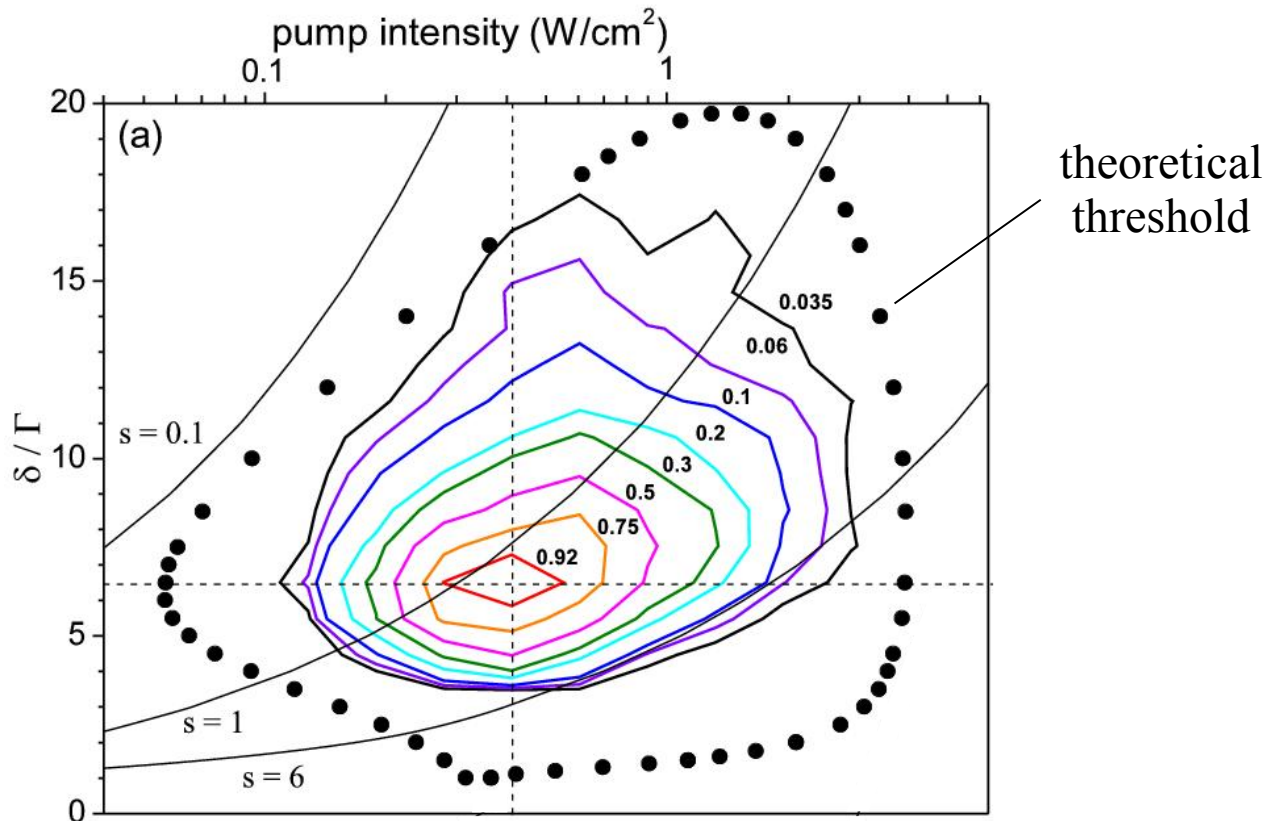
0.47 W/cm²



1.4 W/cm²



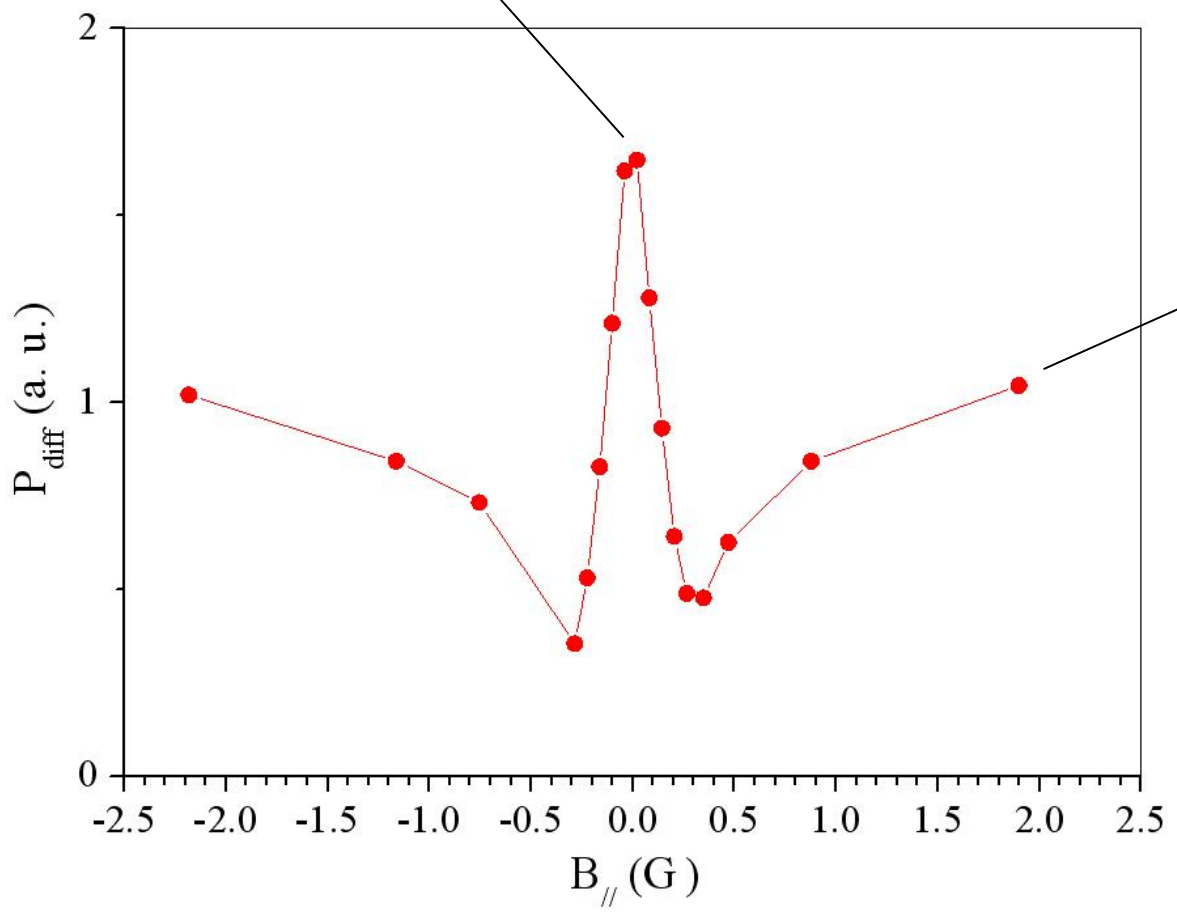
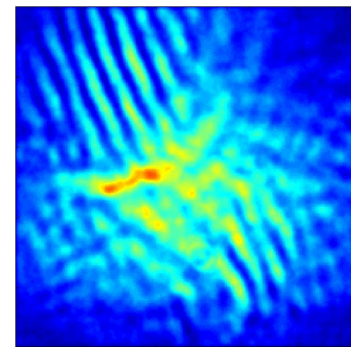
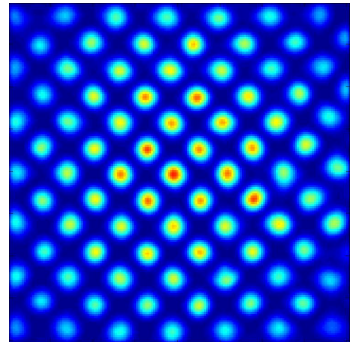
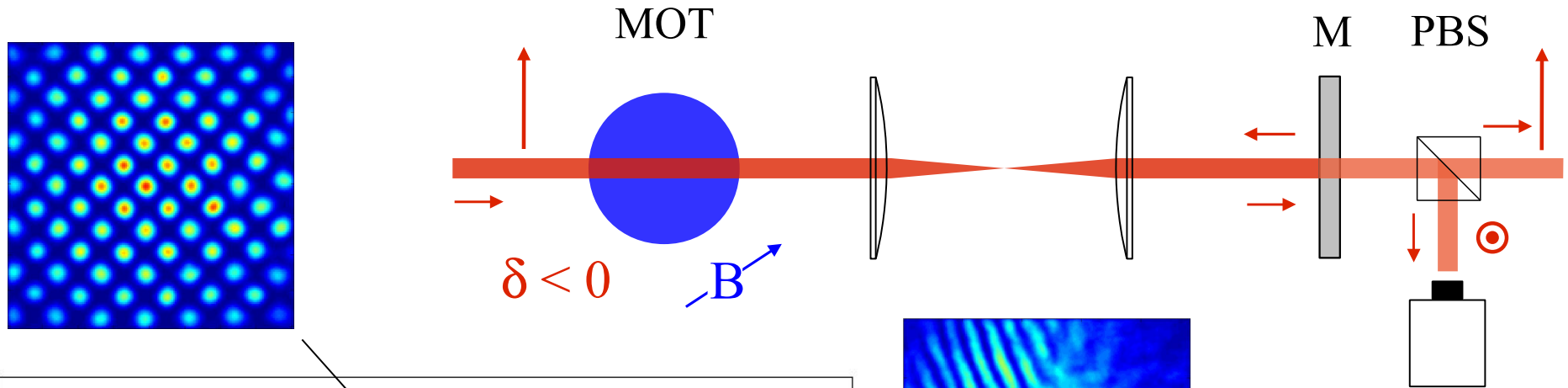
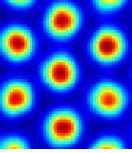
4.24 W/cm²



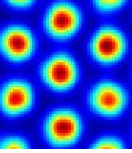
- threshold: $s \simeq 0.2$
- saturation

PRA **92**, 013820 (2015).

Spin instabilities



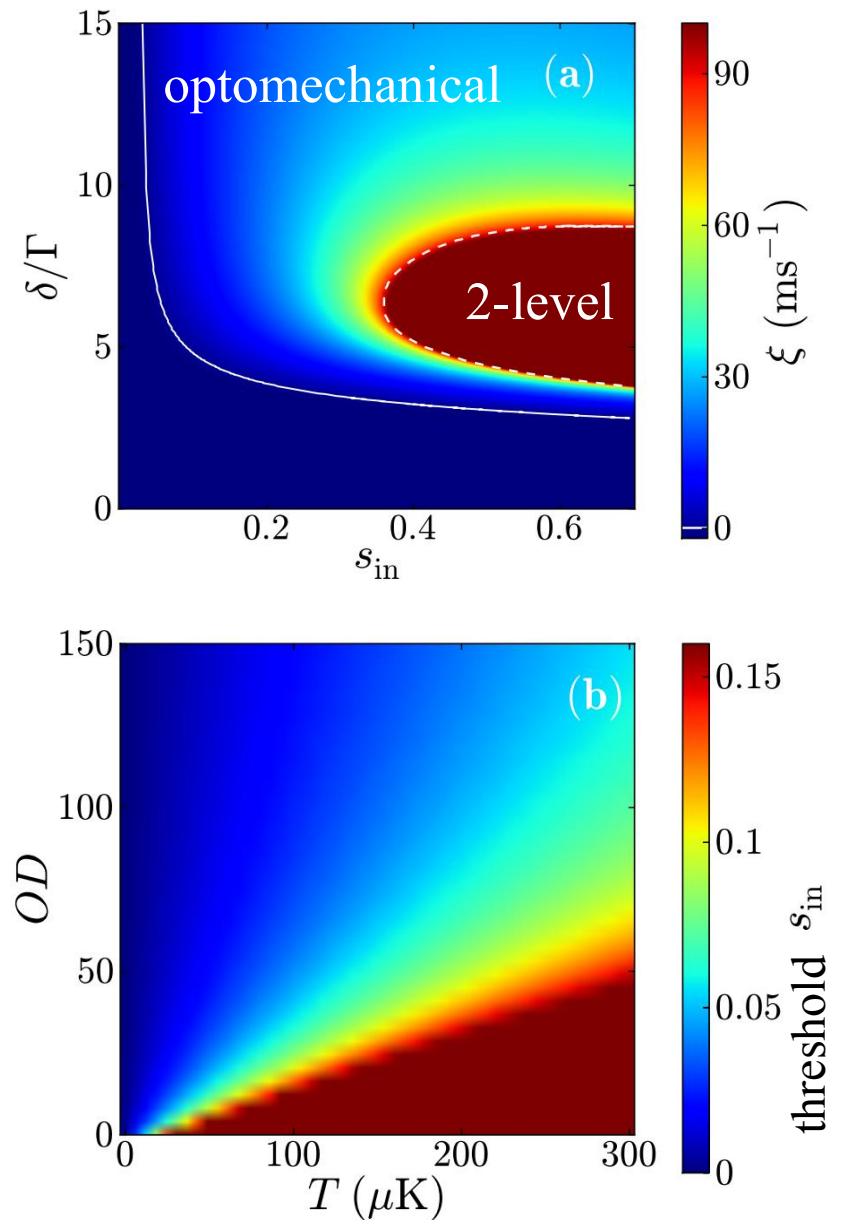
- low threshold ($s < 10^{-3}$)
- polarization-dependent
- **B-dependent**

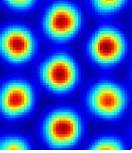


- 2-level and/or optomechanical (thin medium, no dissipation)

PRL 112, 043901 (2014).

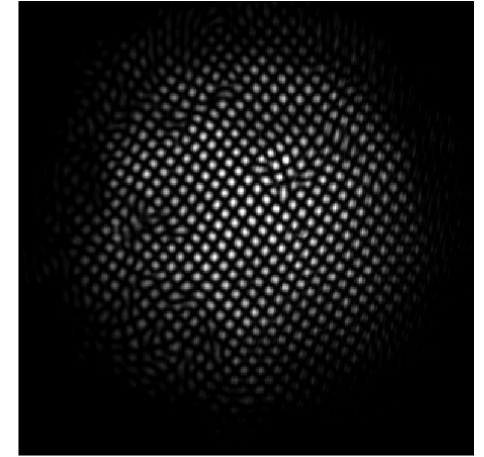
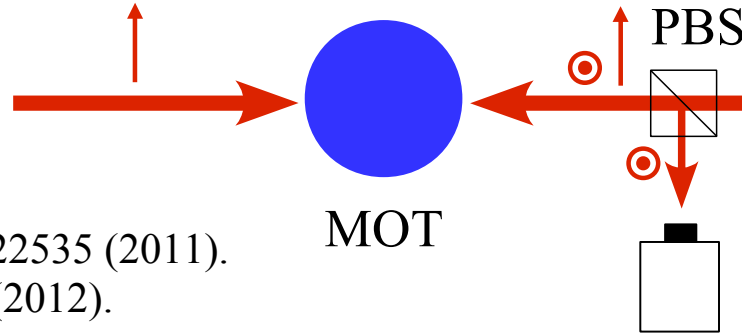
- spin: OBE for $2 \rightarrow 3$





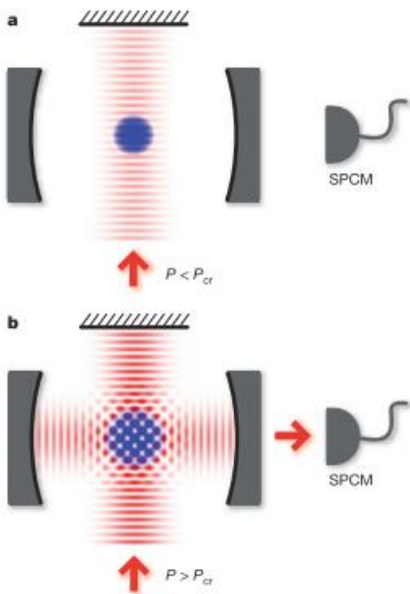
- transverse instabilities in cold atoms: 3 mechanisms

→ other instabilities



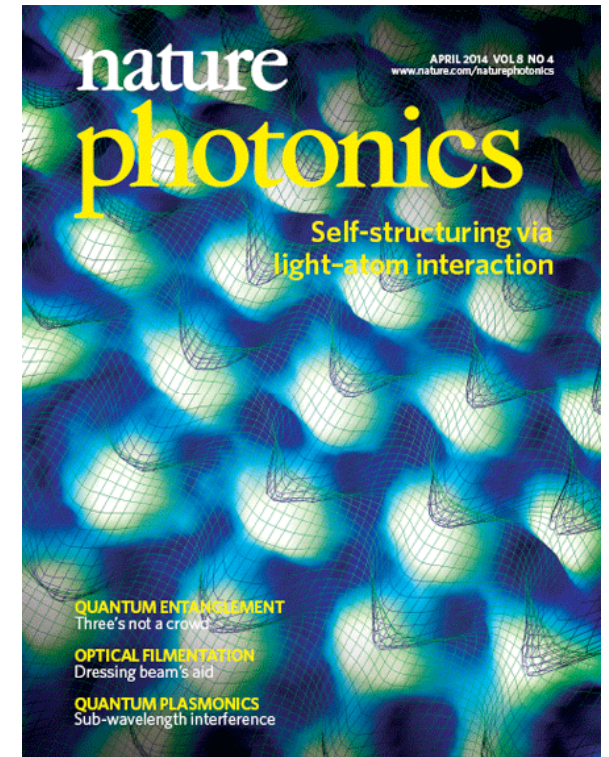
→ localized structures / light bullets

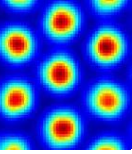
- optomechanical self-organization **in a BEC ?**



2 continuous symmetries
 (translation and rotation)
 → *multimode*

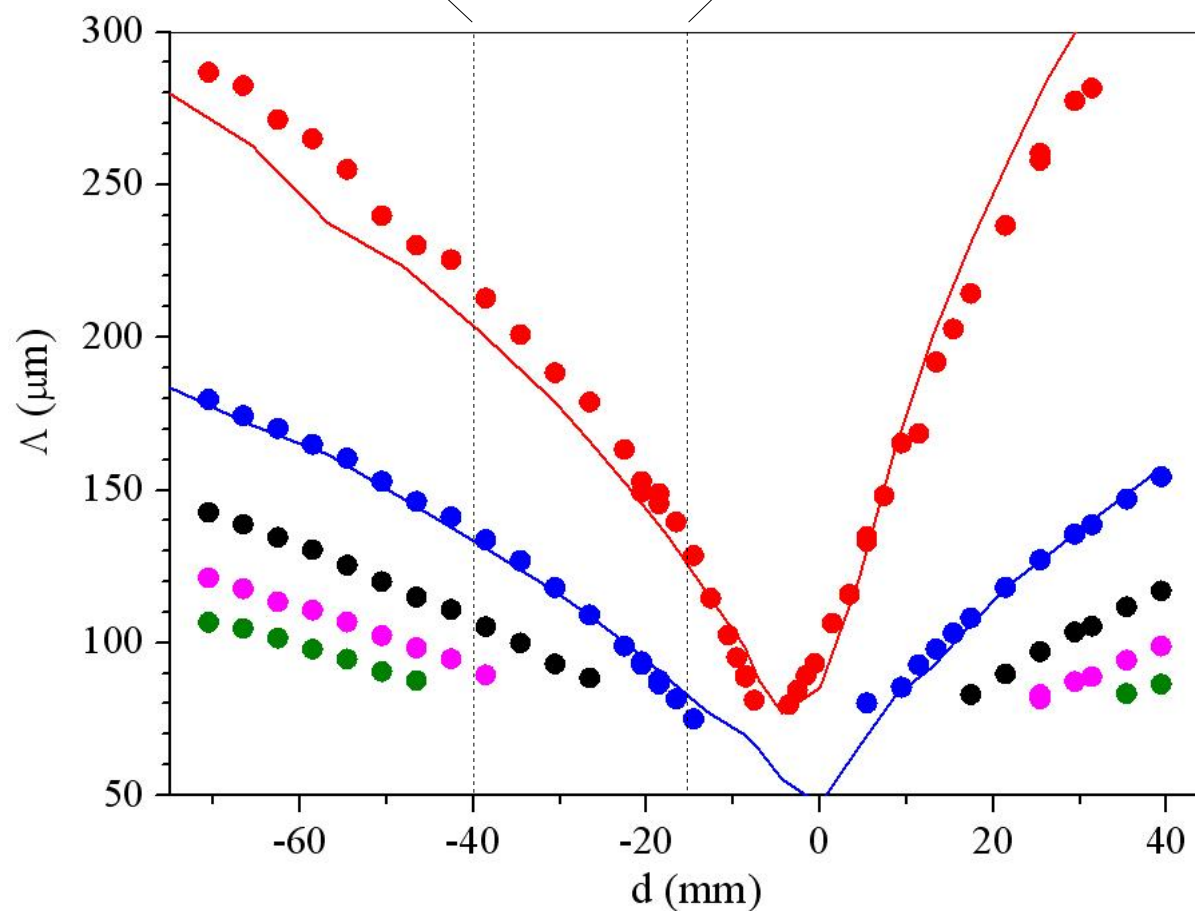
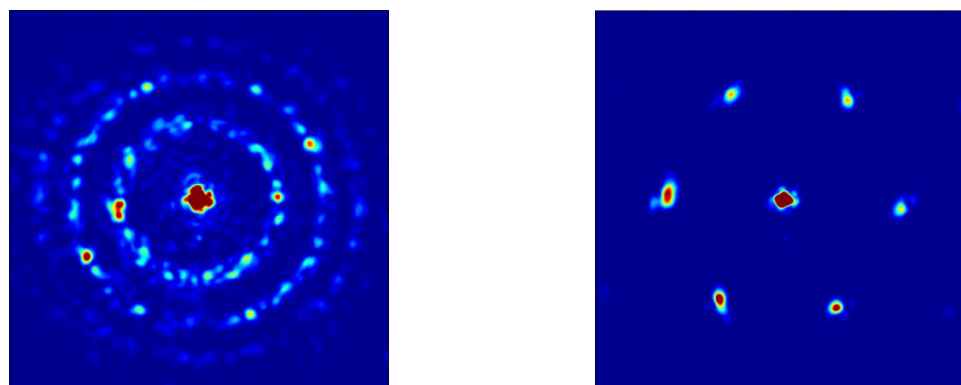
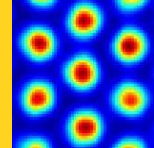
Nat. Phys. **5**, 845 (2009).

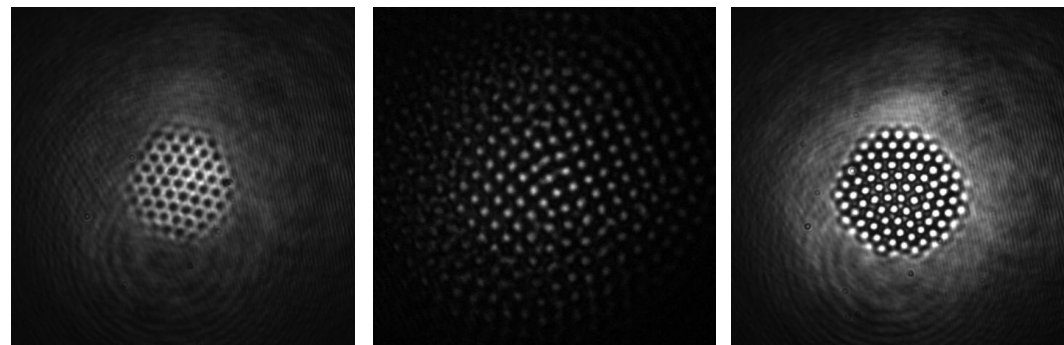
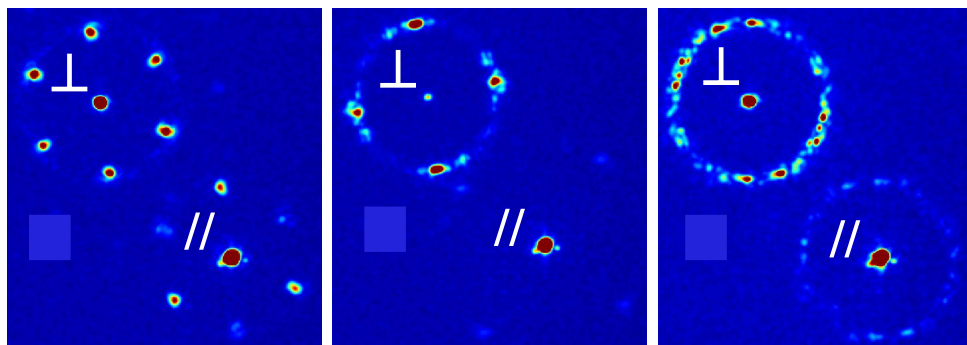
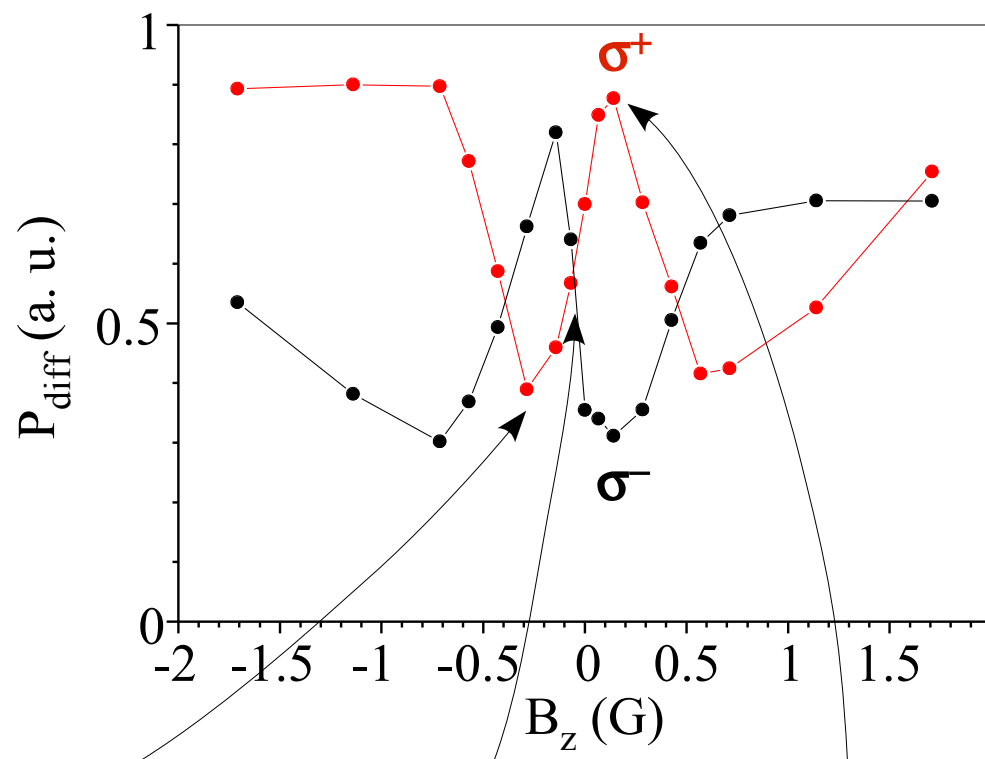
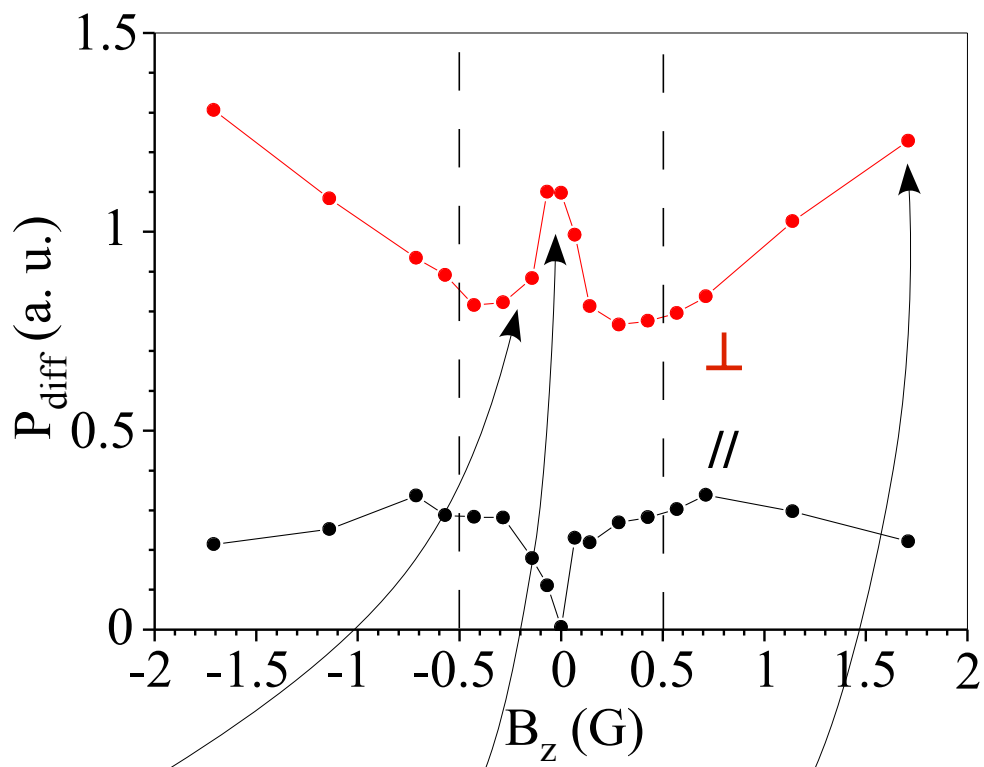
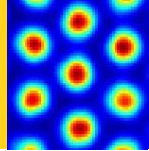


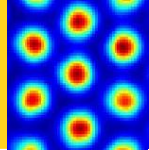


<http://lanaturedeguillaume.e-monsite.com>

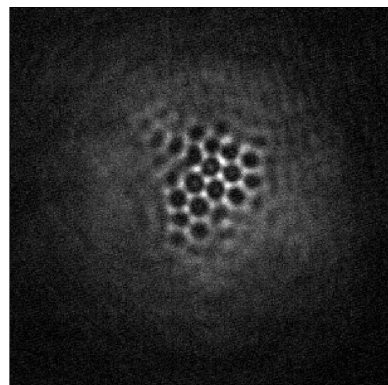
Pattern wavelength tunability



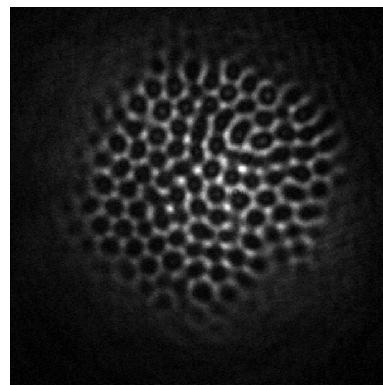




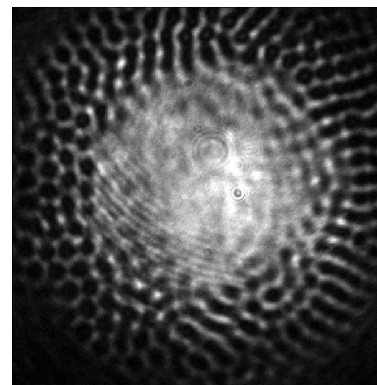
no polarization instability



10 mW/cm²



24 mW/cm²



116 mW/cm²

