Phase diffusion in a BEC of light

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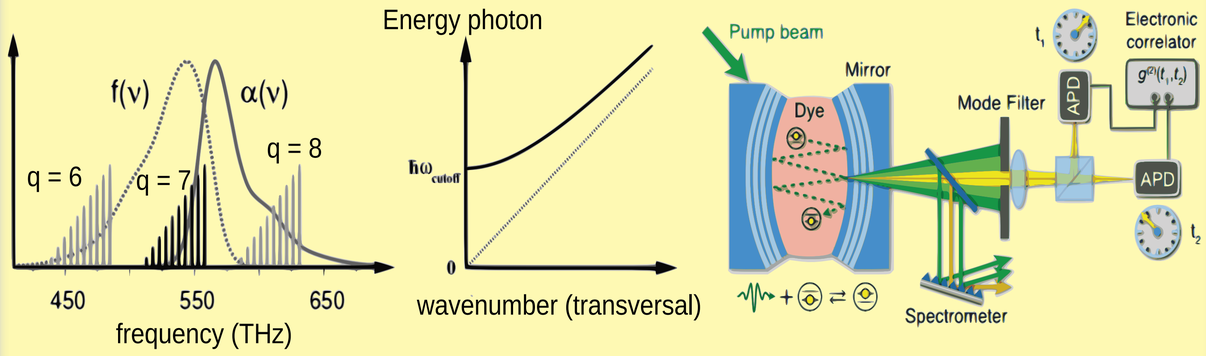
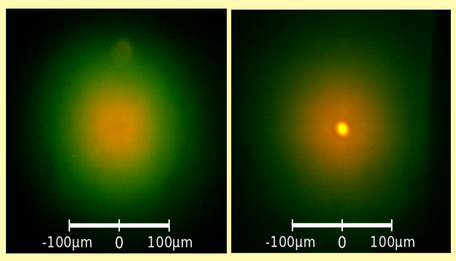
Photons in a dye-filled microcavity [1]



Figures (modified) from Ref. [1]

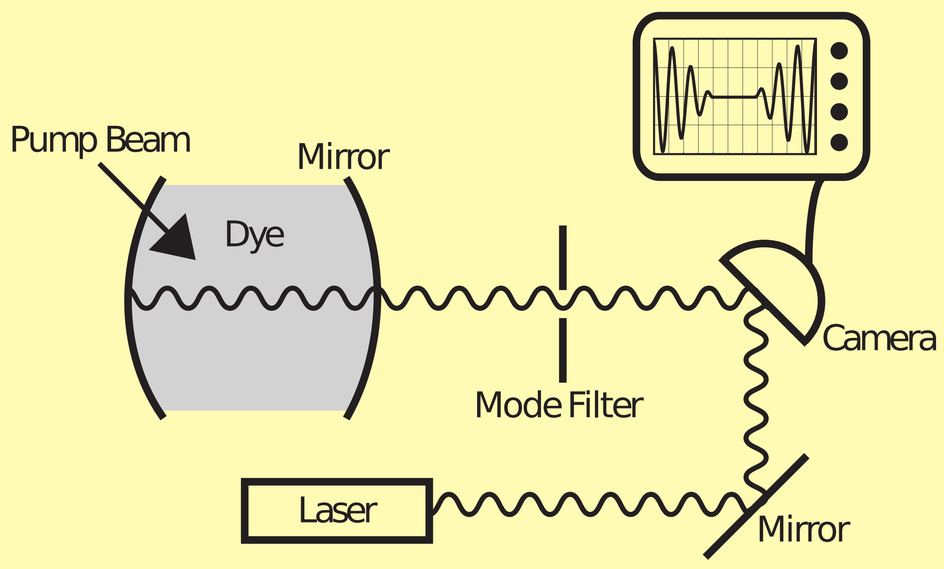
- **Conserved** number of photons in cavity
- **Thermalization** photon gas due to coupling to dye
- Photon gas equivalent to 2D trapped **massive** Bose gas
- Experiment at **room temperature**
- Pumping increases number of photons ⟶ **condensation**



before (L) and after (R) condensation

Phase Diffusion [2,3]

- U(1) symmetry: conservation number of particles
- Condensation: spontaneous U(1) symmetry breaking
  ⟶ system in well-defined phase
- Formally only in **thermodynamic limit**
- Finite number of particles: **phase non-trivial dynamics** $\theta(t)$[3]
- Interference experiment condensate photons and external laser:
  ⟶ possibility to measure **phase diffusion**



Proposal for phase diffusion experiment [2]

References

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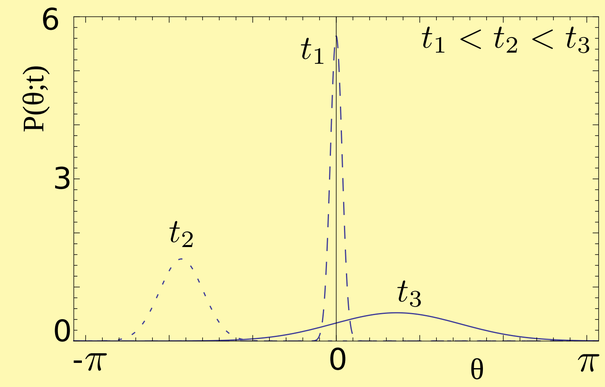
[1] J. Klaers et al., Nature **468**, 545 (2010).
[2] E.C.I. van der Wurff et al., Phys. Rev. A **90**, 043627 (2014).
[3] M. Lewenstein and L. You, Phys. Rev. Lett. **77**, 3489 (1996).
[4] J. Schmitt et al., arXiv:1512.07148v1 [cond-mat.quant-gas]

Fluctuations

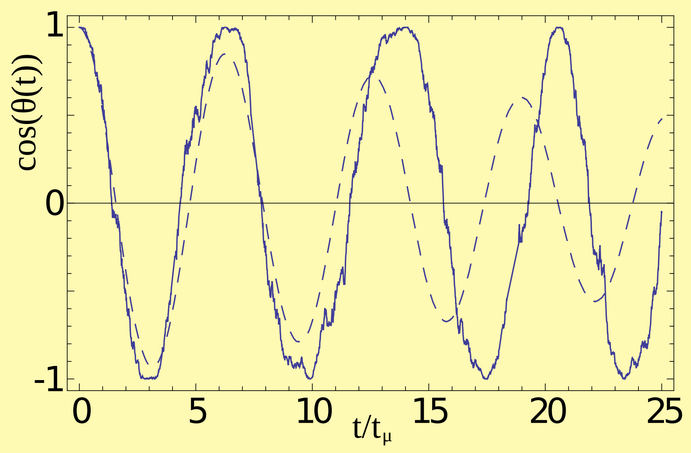
1) **Quantum fluctuations** (at T = 0)

- Schrödinger-like equation for phase wavefunction:
  $i\hbar\partial_t\Psi(\theta,t) = -D(\partial_\theta + iN_0)\Psi(\theta,t)$
- Solution displays difussion and collapse and revival



2) **Thermal fluctuations**

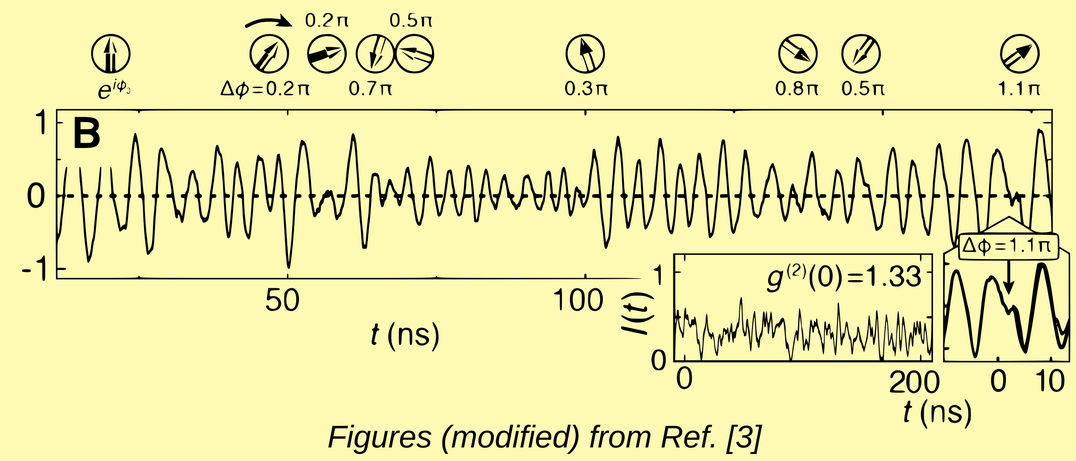
- Coupling to dye induces damping α
- Langevin field equations with Gaussian noise:
  $(1+\alpha^2)\hbar\dot{\theta}(t) = -\mu + \sqrt{\frac{1+\alpha^2}{N(t)}}\nu(t)$
  $(1+\alpha^2)\dot{N}(t) = -2\alpha\mu\hbar^{-1}N(t) + 2\sqrt{N(t)(1+\alpha^2)}\eta(t)$



Solution to Langevin equations. Solid curve: one arbitary noise configuration; dashed: averaged over 500 noise configurations.

- Intensity profile $\Delta I_{\rm th} \propto \cos\left(\frac{\mu t}{\hbar}\right)\exp\left(-t/\tau\right)$
- **Measurable time scale** $\tau = \hbar\beta N_0/\alpha \sim (1-10)$ ns

Recent experiments [4]



Figures (modified) from Ref. [3]

- Interference experiment has been carried out [3]
- Observation of phase flips
- Many measurements should be averaged to verify predicted timescale

Conclusions

- Condensate of photons in dye-filled microcavity: new experimental possibilities
- Thermal fluctuations dominate quantum fluctuations
- Measurable timescale proposed to measure phase diffusion