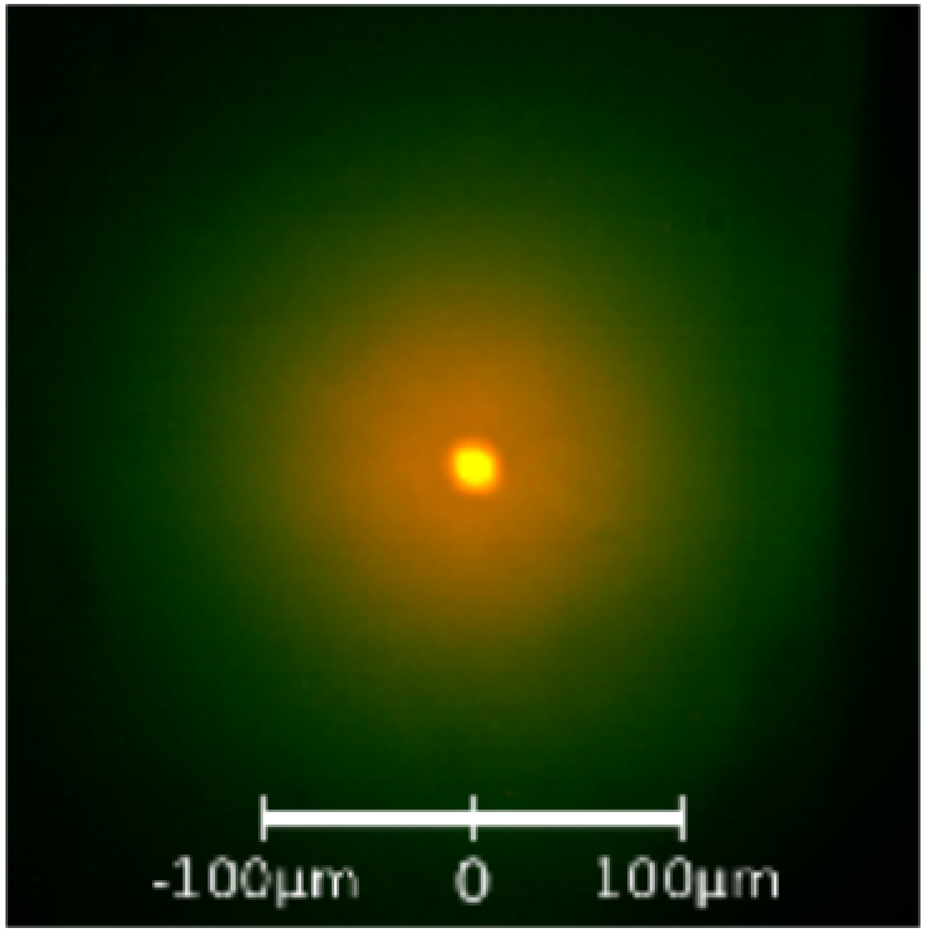
COLLECTIVE FREQUENCIES OF PHOTON BOSE-EINSTEIN CONDENSATES

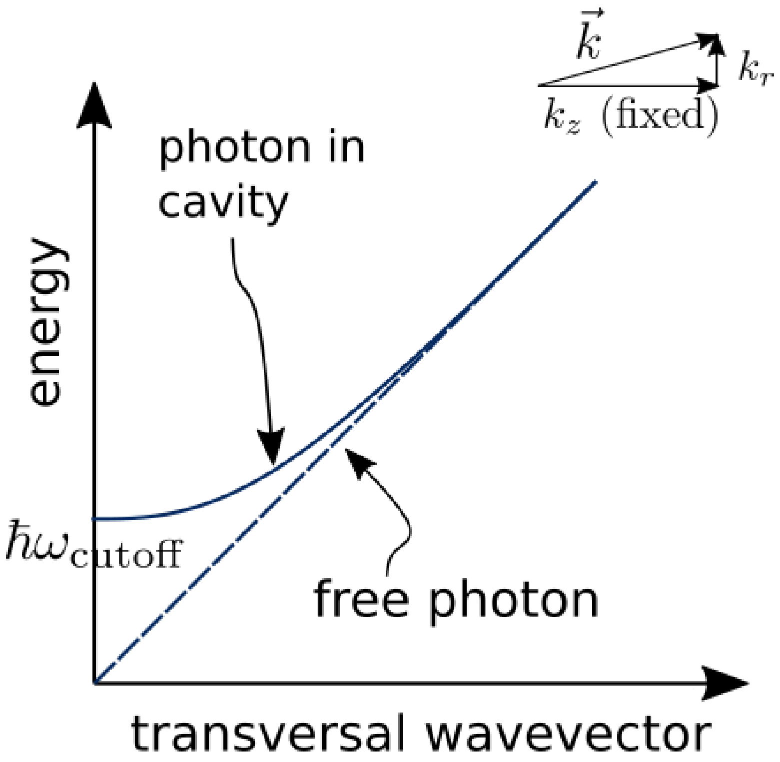
Enrico Stein, Axel Pelster

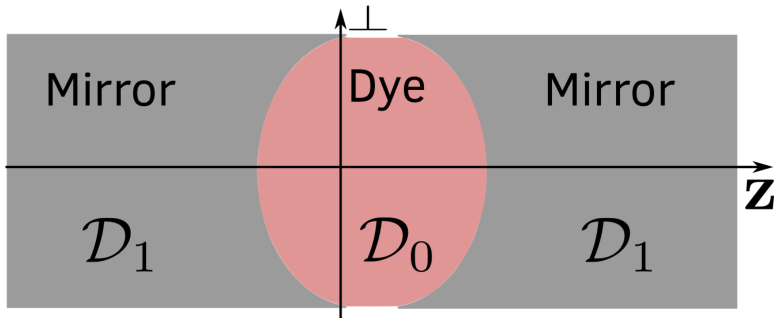


Klaers, Schmitt, Vewinger and Weitz, Nature **468**, 545 (2010)

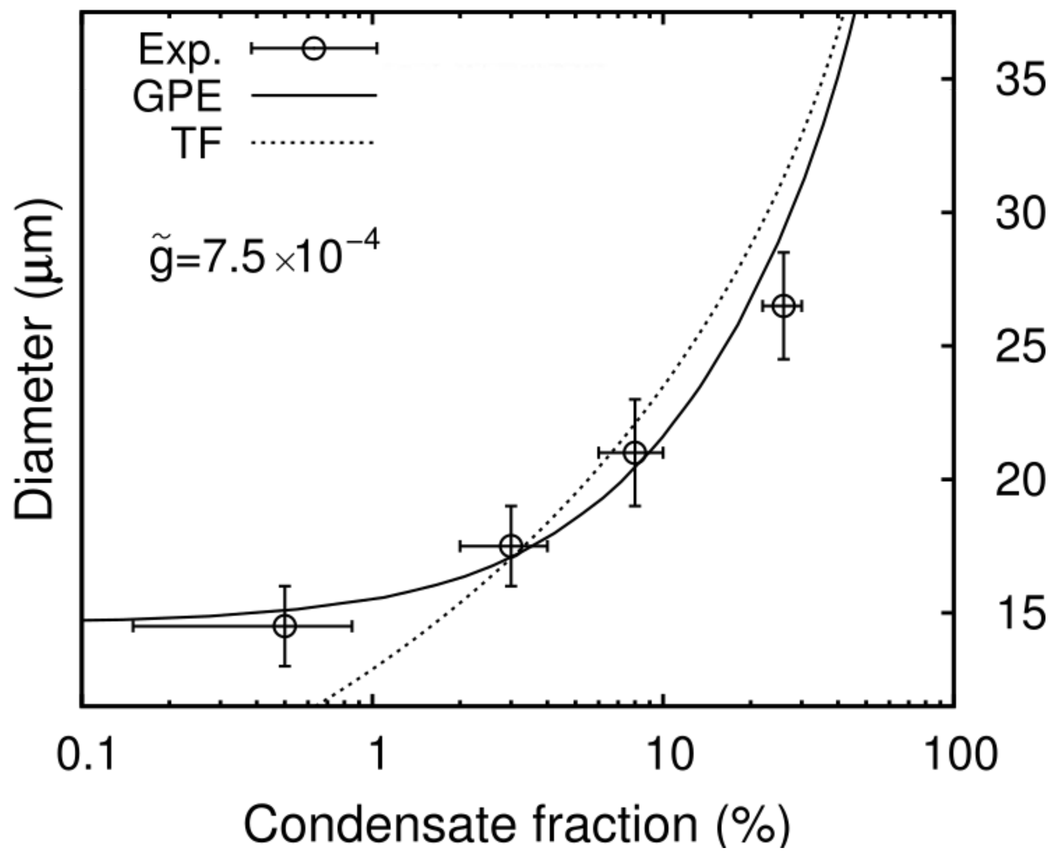
PHOTONS IN DYE-FILLED CAVITY

- Effective photon mass:
  $m \sim 10^{-9} m_{\mathrm{p}}$
- Trapping frequency:
  $\Omega \sim 10^{11}\ \mathrm{Hz}$
- Thermalisation and condensation of photon gas at room temperature





PHOTON-PHOTON INTERACTION



- Dimensionless interaction strength $\tilde{g} = mg/\hbar^2$ in 2D
- Up to $\tilde{g} = 7(3) \times 10^{-4}$

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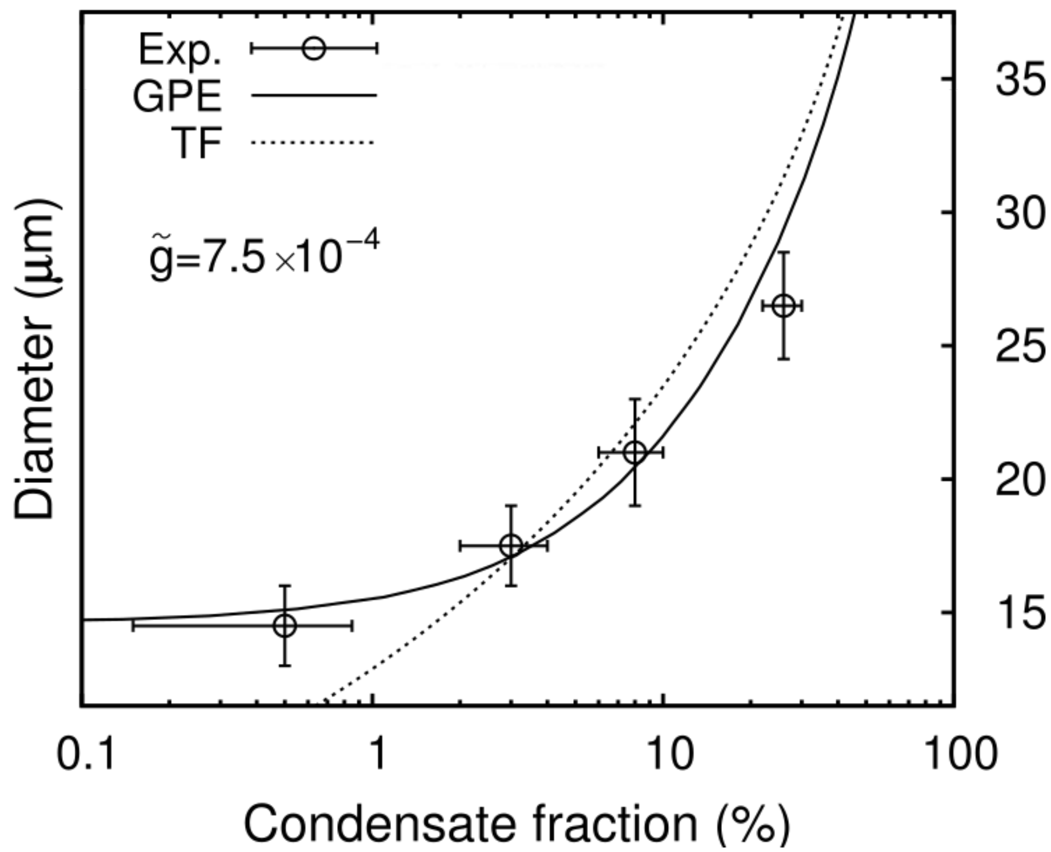

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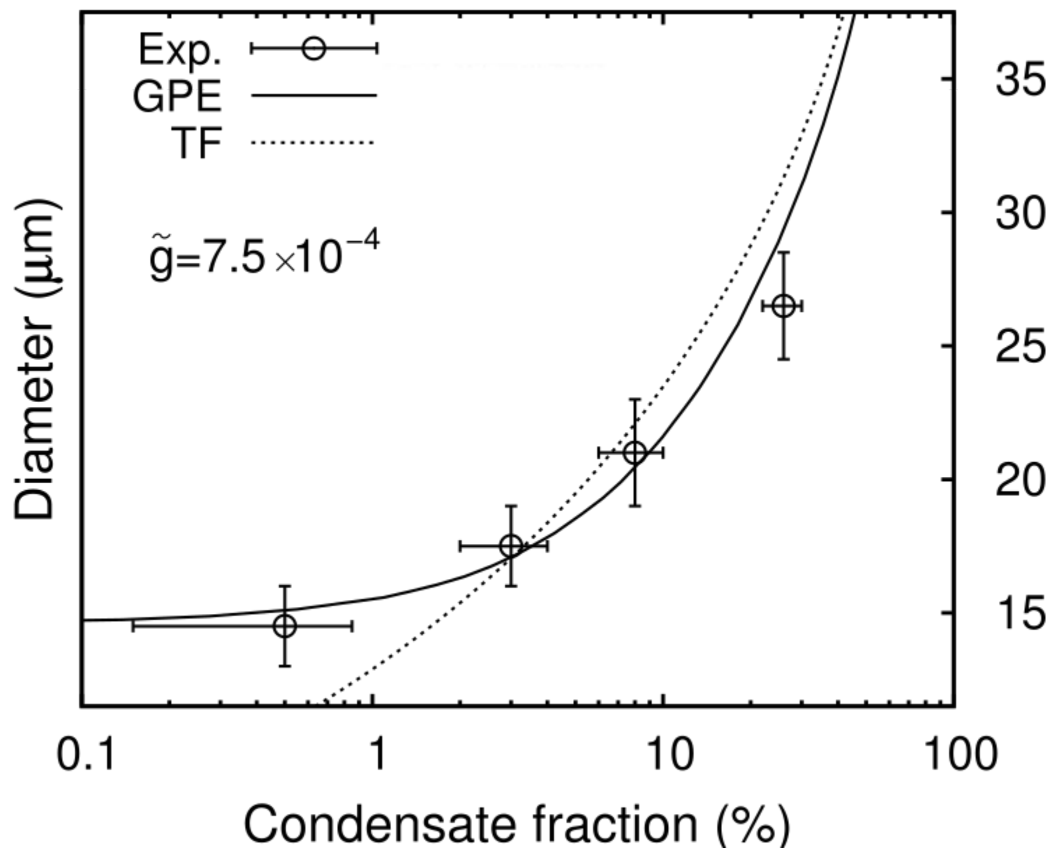

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How can this happen?

- Heating of dye solution due to absorption of light

$$\Rightarrow n(\mathbf{r},t) = n_0 + \beta\Delta T(\mathbf{r},t)$$

$$\partial_t \Delta T(\mathbf{r},t) = \nabla \cdot [\mathcal{D}\nabla\Delta T(\mathbf{r},t)] + \text{Source}$$

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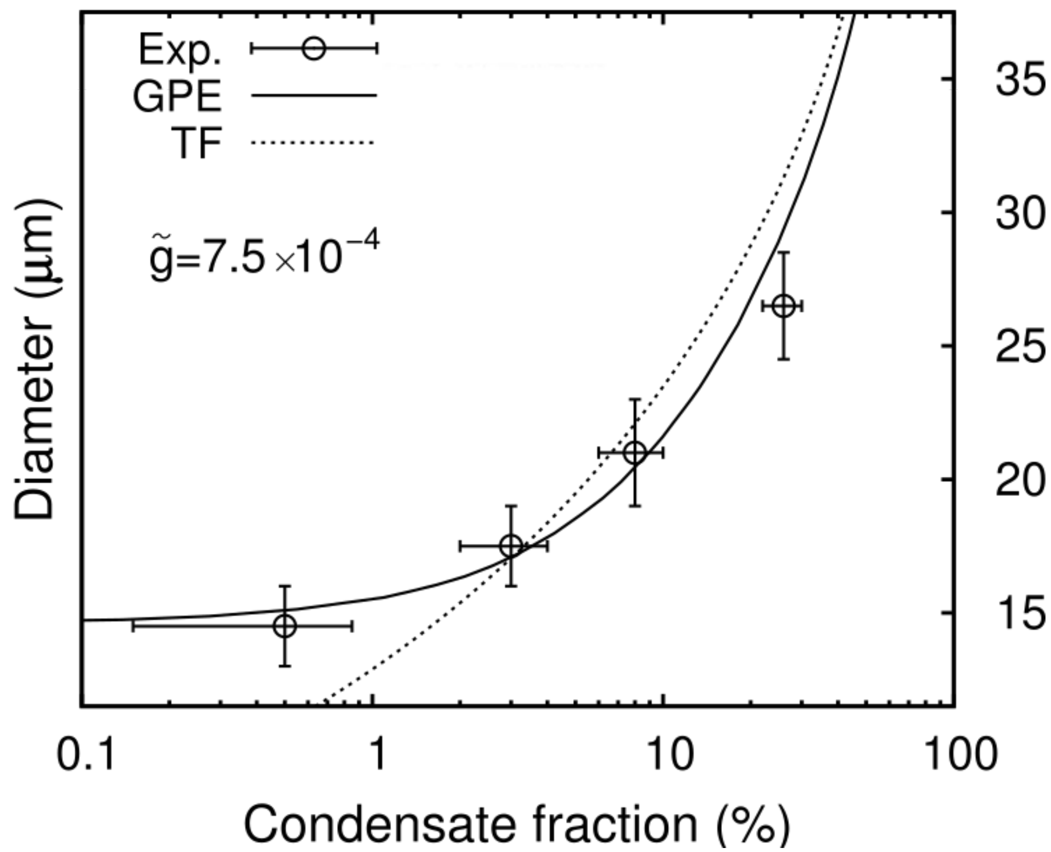

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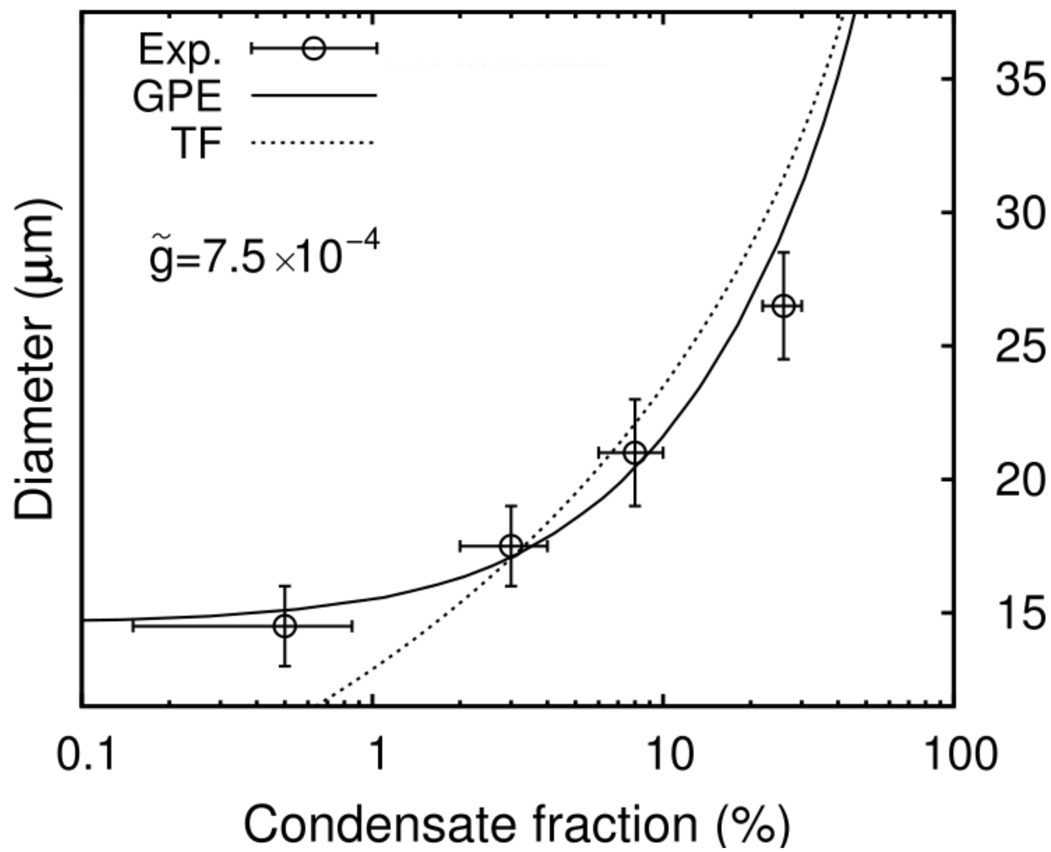

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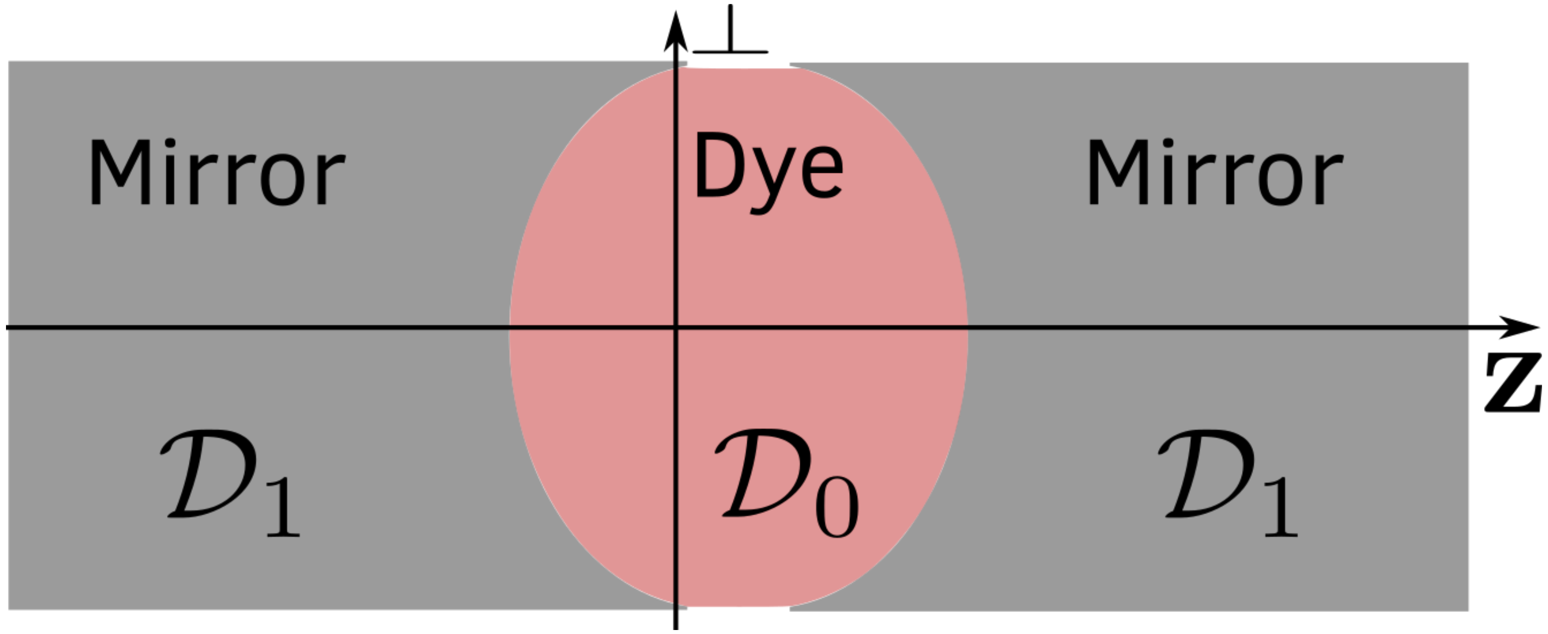
- **Non-local** in space
- **Retarded** in time

TEMPERATURE DIFFUSION



- Temperature diffusion in mirrors not negligible:
$\partial_t \Delta T = \left[\partial_z \left(\mathcal{D}(z)\, \partial_z\right) + \mathcal{D}(z)\nabla_\perp^2\right] \Delta T + \mathrm{Source}$

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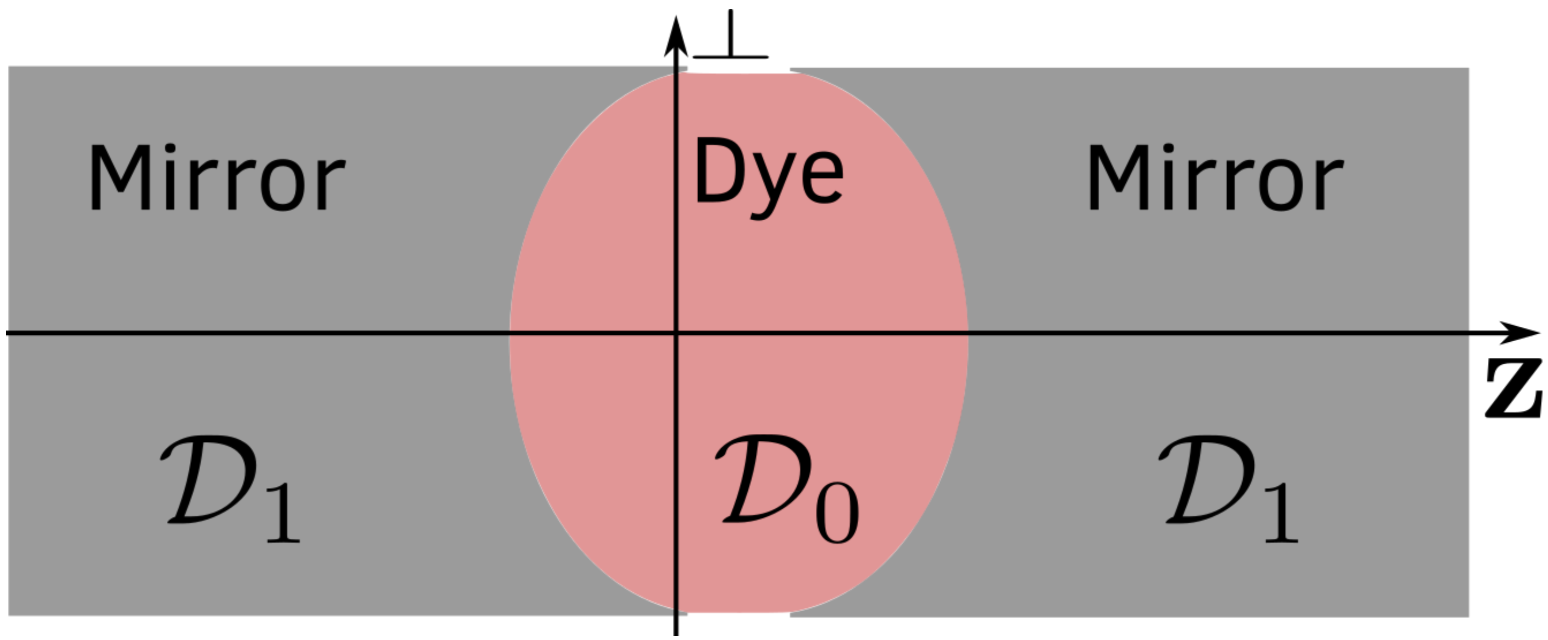
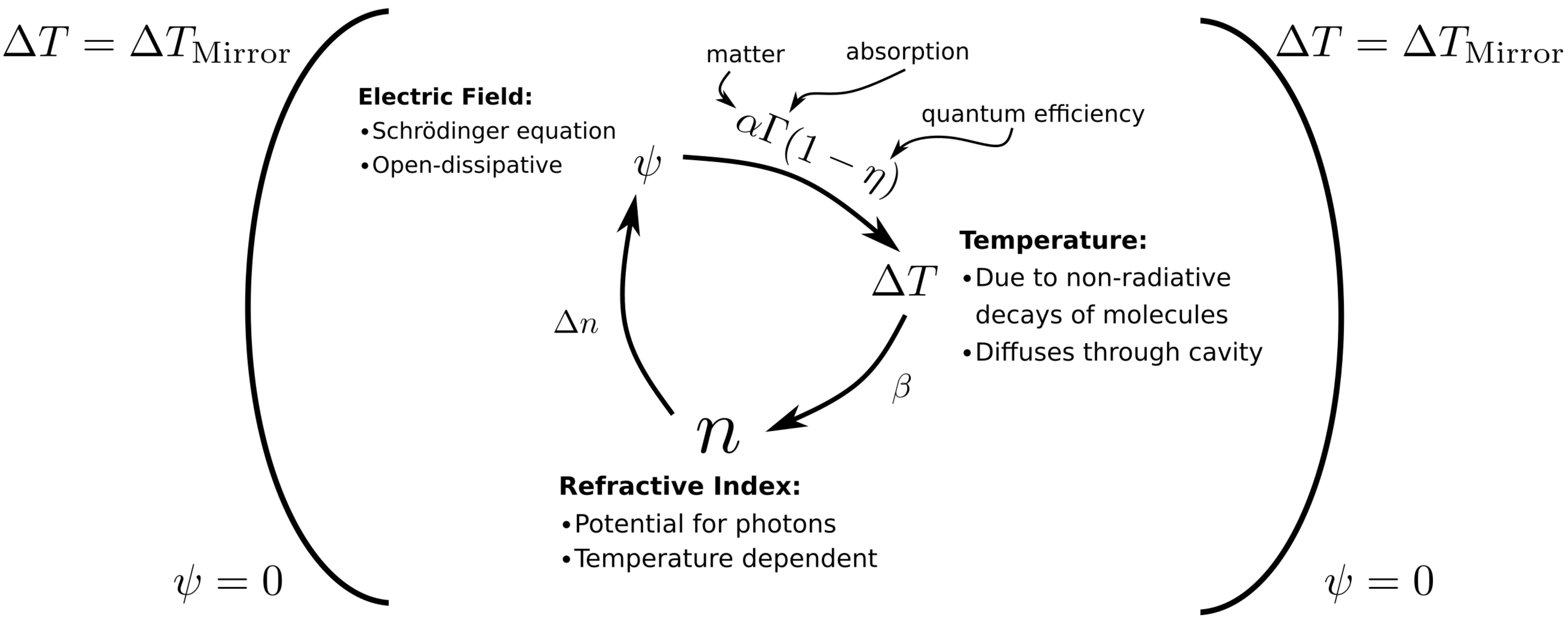
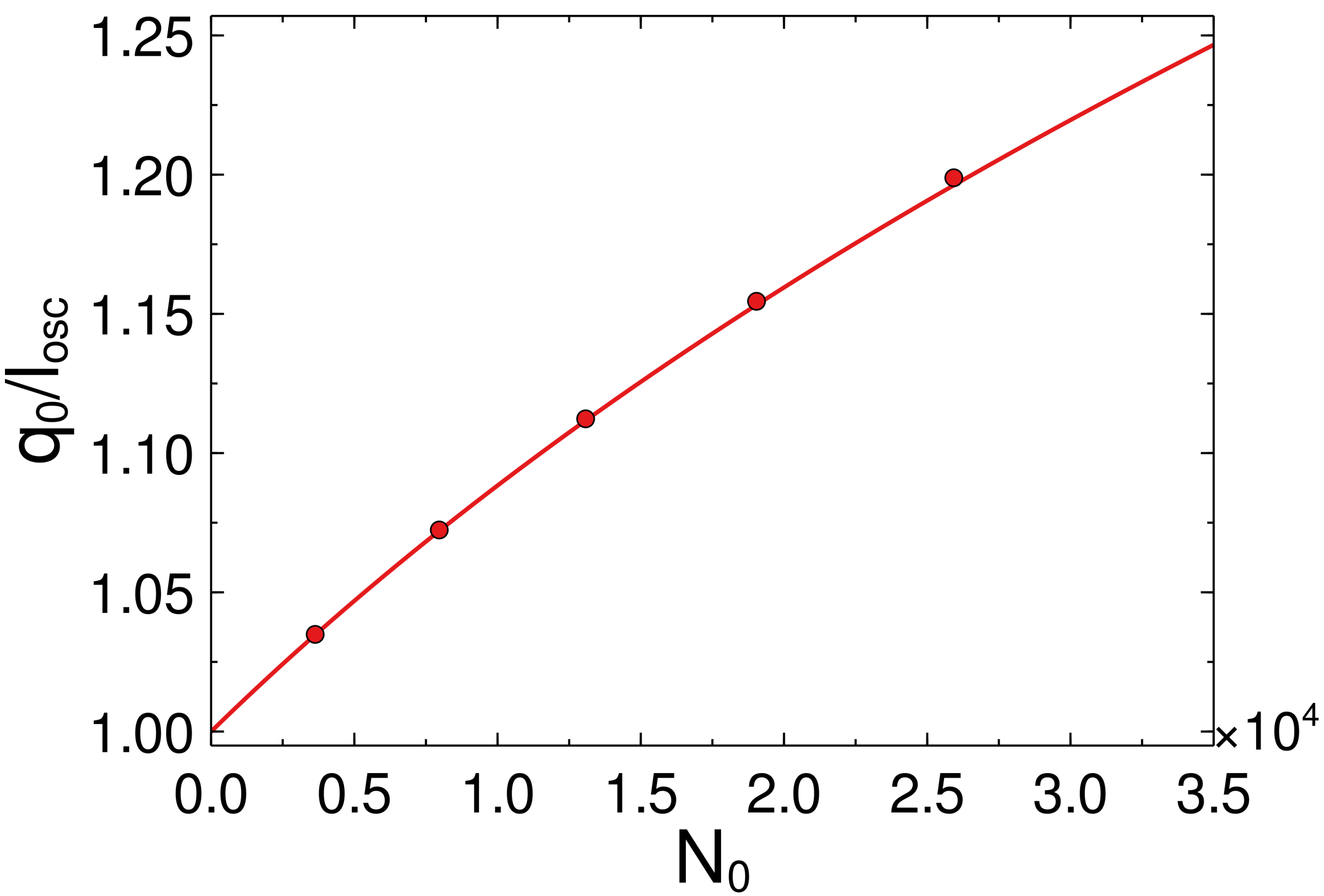


- Resulting 2D diffusion equation inside cavity:
$$\partial_t \Delta T_\perp = \left[\mathcal{D}_0 \nabla_\perp^2 - \frac{1}{\tau}\right] \Delta T_\perp + \mathrm{Source}_\perp$$
- Relaxation constant due to mirror geometry:
$$\tau \sim 0.1\ \mathrm{s} \gg 1/\Omega$$

MEAN-FIELD MODEL

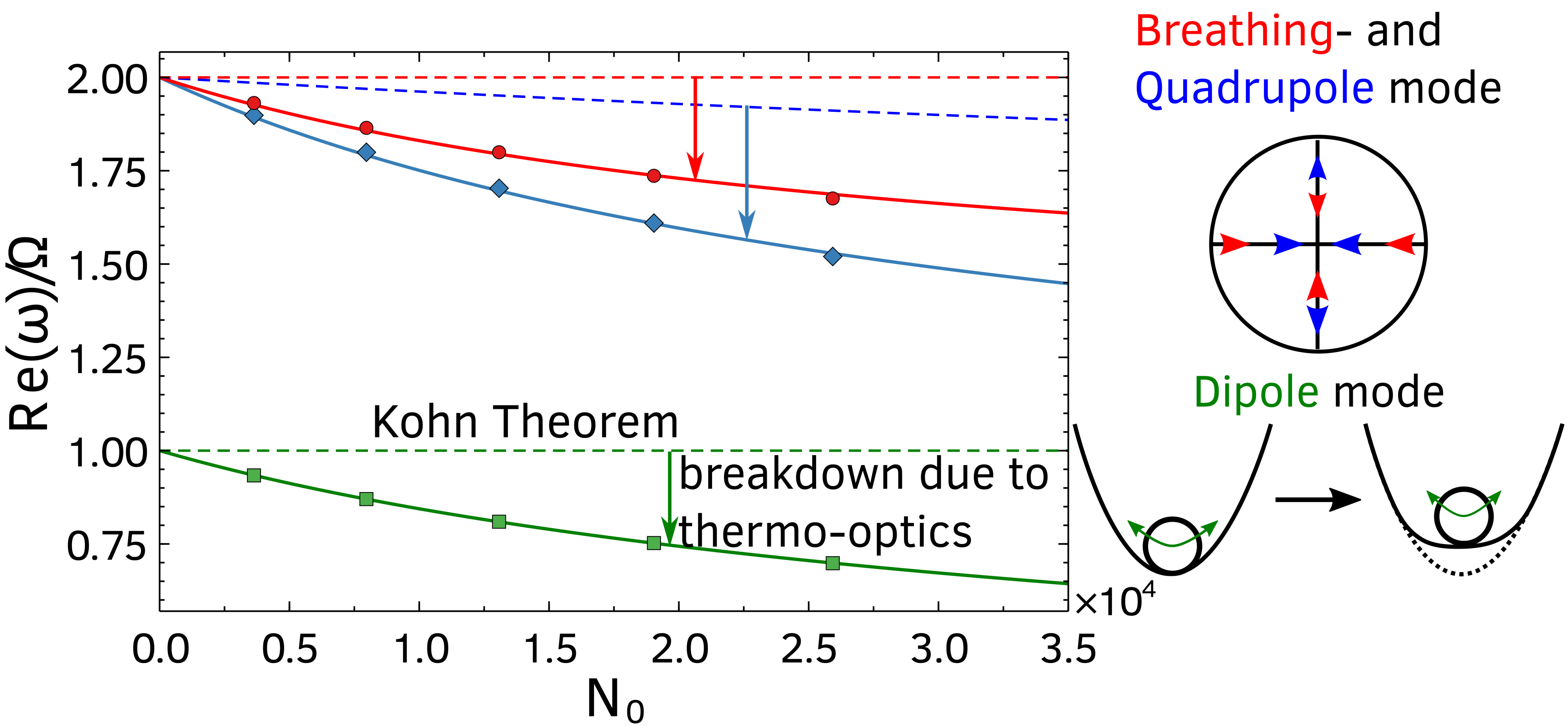


STEADY STATE



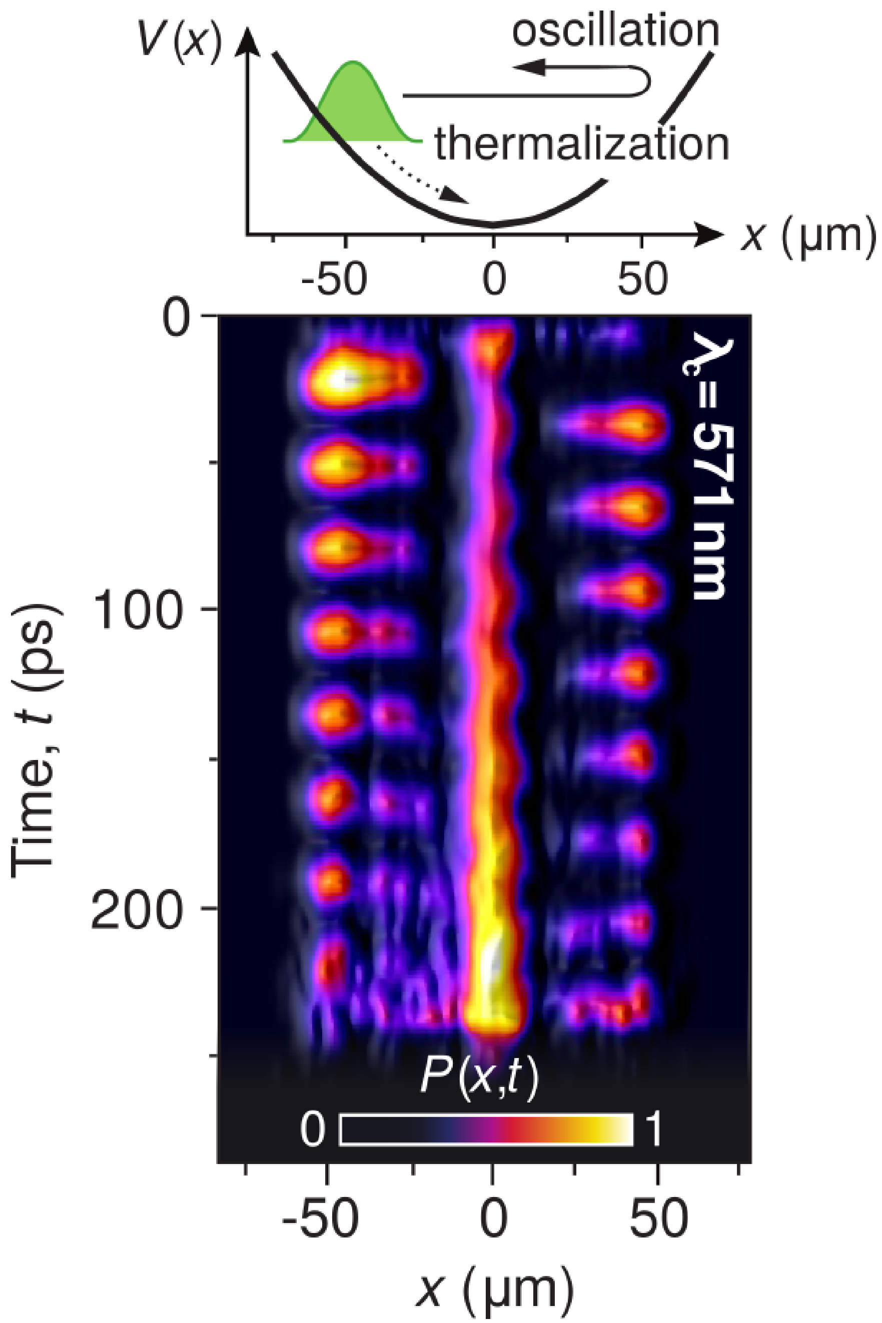
- Interaction strength $\tilde{g}$ from $\left(\frac{q_0}{l_{\text{osc}}}\right)^4 = \left(1 + \frac{\tilde{g} N_0}{2\pi}\right)$
  $\Rightarrow \tilde{g} \sim 10^{-4}$
- Experiment: up to $\tilde{g} = 7(3) \times 10^{-4}$

COLLECTIVE FREQUENCIES



Dashed curves: solution of plain Gross-Pitaevskii equation

WHAT ABOUT THE EXPERIMENT?



- So far no measurement of collective modes
- Direct observation:
  - Streak camera
  - Proof of principle: Schmitt et al., PRA **92**, 011602(R) (2015)
- Indirect measurement:
  - Second order correlation functions
  - Currently built up in London: Nyman et al.

THANK YOU!