Coherent State Dynamics in Quantum Field Theory

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How does classical physics emerge from quantum physics ?

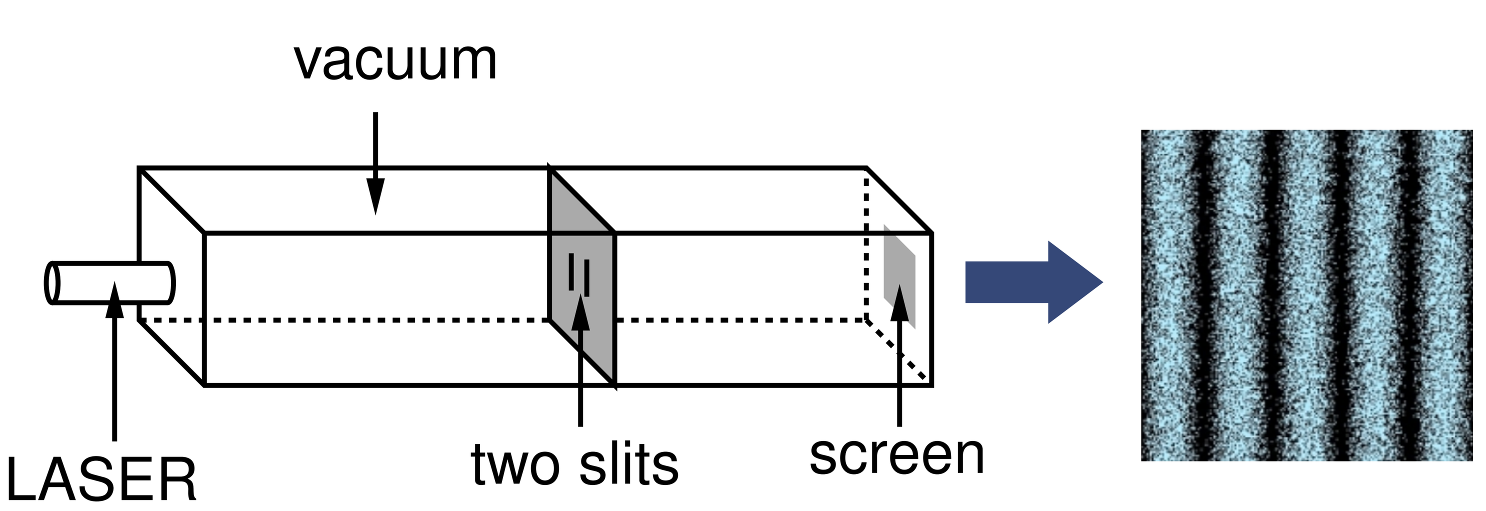
Wave-particle duality

A **laser beam**

- is made of **quantum particles** (photons)
- behaves like a **classical electromagnetic wave**

☛ Profound bridge between classical physics and quantum physics

Illustration: **single-photon double-slit experiment**



Source : https://www.maxicours.com/se/cours/interferences-photon-par-photon-particule-par-particule/

Coherent states

- Quantum states with **minimal quantum uncertainty**
  - ☛ Well-defined average position and momentum
  - ☛ Closely follow the laws of classical physics
- Describe accurately **laser beams** and **electromagnetic waves**
- Applications:
  - ◇ Quantum electrodynamics
  - ◇ Cosmology
  - ◇ Condensed matter physics
  - ◇ Quantum information theory

Objectives

Semi-classical limit: where quantum physics meets classical physics

☛ Study coherent states in the semi-classical limit

☛ Show that they behave almost like classical particles

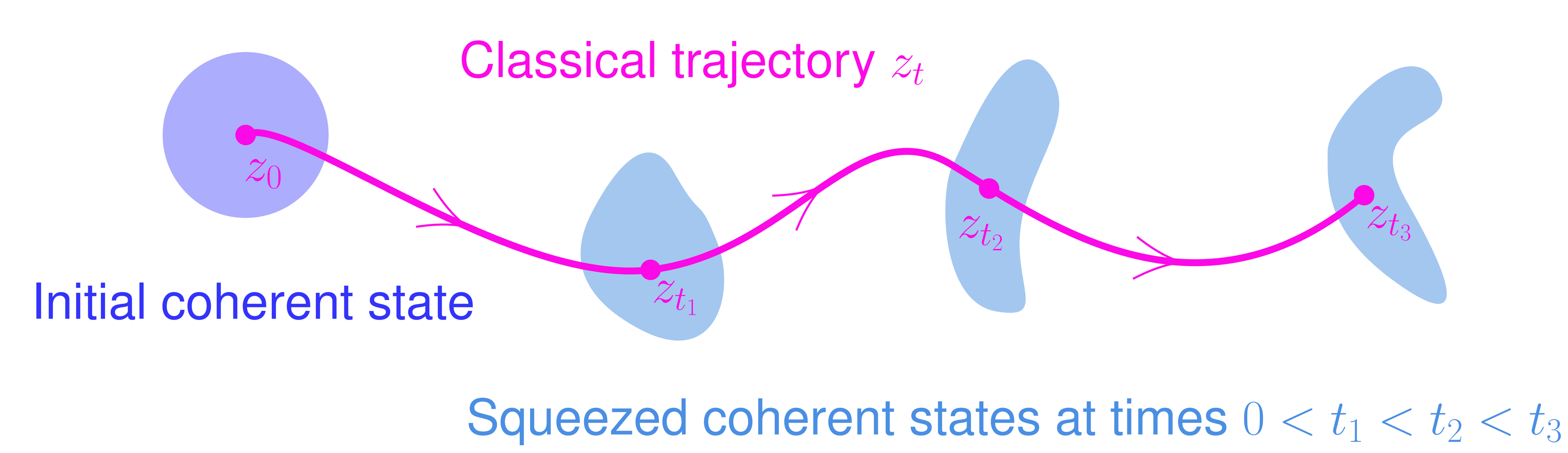
Main result

Setup: system of **identical bosons**, initially in a **coherent state**

☛ Example: photons in a laser beam

Take-home message

In the semi-classical limit, the state of the system will follow the classical trajectory, with small changes in its shape.



Mathematical tools

- **Fock space:** describes states of systems with variable particle number
- **Quantization:** translates classical quantities (position, momentum...) into quantum physics
- **(Quantum) Hamiltonian:** quantization of classical energy

Energy drives classical motion $\xrightarrow{\textit{Quantization}}$ **Hamiltonian** drives quantum dynamics

Main references

[1] Z. Ammari and M. Zerzeri. "On the classical limit of self-interacting quantum field hamiltonians with cutoffs". *Hokkaido Math. J.* 43.3 (2014), pp. 385–425.

[2] J. Dereziński and C. Gérard. "Spectral and Scattering Theory of Spatially Cut-Off $P(\phi)_2$ Hamiltonians". *Commun. Math. Phys.* 213 (2000), pp. 39–125.

[3] R. Høegh-Krohn and B. Simon. "Hypercontractive semigroups and two dimensional self-coupled Bose fields". *J. Funct. Anal.* 9.2 (1972), pp. 121–180.

[4] D. Robert. "Propagation of coherent states in quantum mechanics and applications". *Part. Differ. Equ. Appl.* 15 (2007), pp. 181–252.