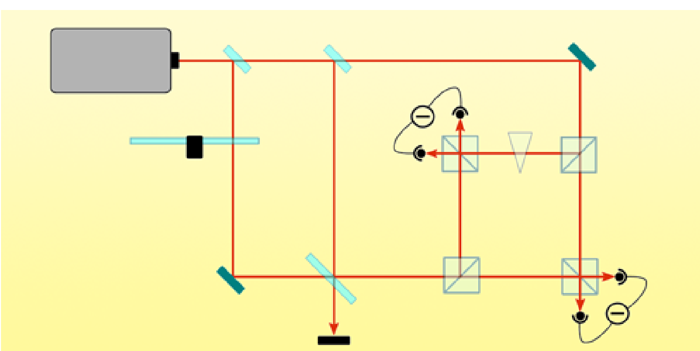
Microscopic Reversibility Goes Quantum

A fundamental principle in statistical mechanics called microscopic reversibility has been extended to the quantum world.

By Ryan Wilkinson

The second law of thermodynamics states that the entropy of an isolated system tends to increase. But statistical mechanics shows that transient reductions in entropy can occur with a tiny probability. Central to the theorems that describe these fluctuations is microscopic reversibility—the idea that the probability of a system taking a specific trajectory through phase space is related to the probability of it taking the time-reversed version of that trajectory. Now Hyukjoon Kwon at the Korea Institute for Advanced Study and his colleagues have demonstrated a quantum version of this principle [1].

The concept of microscopic reversibility must be adjusted when entering the quantum realm because of a key difference between classical and quantum phase spaces. Namely, the uncertainty principle prevents the position and momentum of quantum systems from being measured precisely at the same time. Additionally, the phase-space trajectories of such systems are affected by quantum coherence. Taking these factors into account, Kwon and colleagues considered a quantum system interacting with a thermal bath and derived a relation between the probabilities for a phase-space trajectory and its time-reversed version.



Credit: M. Bellini *et al.* [1]

The researchers then experimentally demonstrated quantum microscopic reversibility using a simple optical setup in which laser light was mixed with the light from a thermal bath. They found that the probability relation they derived accurately predicted their experimental results and that quantum effects were important only when the temperature of the thermal bath was low. By raising this temperature, the team observed a transition from quantum to classical microscopic reversibility. In future work, the researchers hope to test their probability relation for nonequilibrium processes in many-body quantum systems.

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REFERENCES

1. M. Bellini *et al.*, “Demonstrating quantum microscopic reversibility using coherent states of light,” Phys. Rev. Lett. 129, 170604 (2022).

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