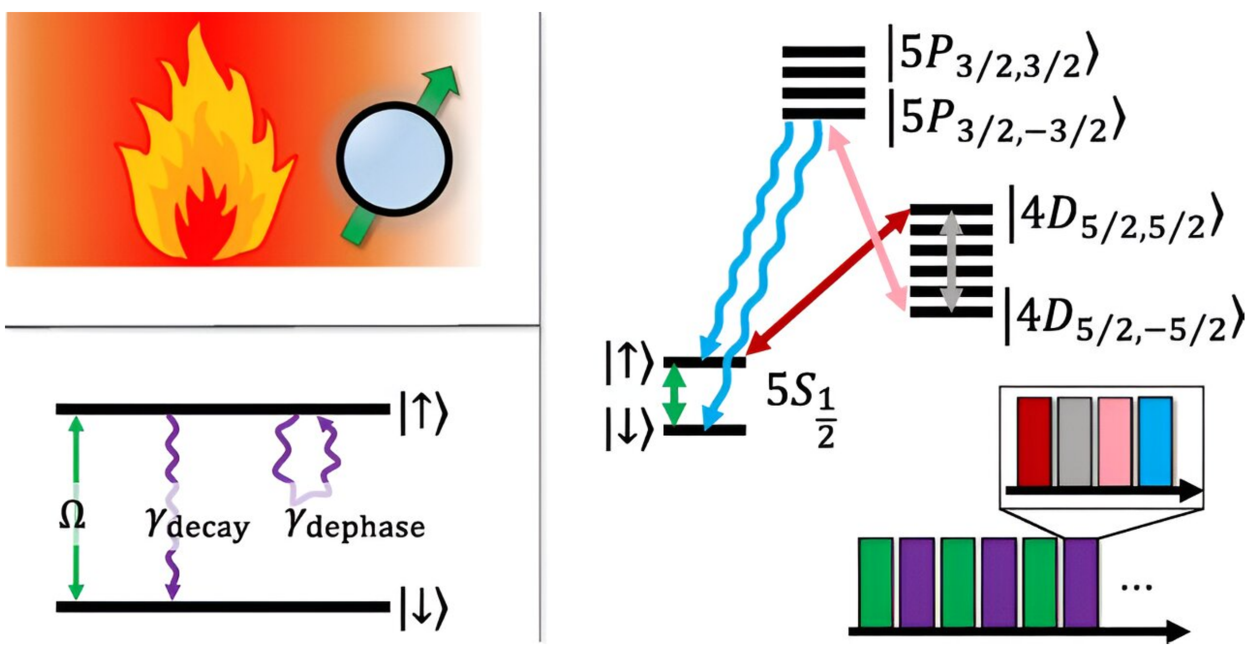
Physicists demonstrate quantum scale inverse Mpemba effect with single trapped ions

July 11 2024, by Bob Yirka



Top left: the modeled quantum system exhibiting an inverse Mpemba effect. Bottom left: the resulting coupling between the qubit's levels. Right: the qubit is mapped to the $5S_{1/2}$ levels of the Zeeman ground state manifold of a trapped $^{88}Sr^{+}$ ion. Credit: *Physical Review Letters* (2024). DOI: 10.1103/PhysRevLett.133.010403

A team of physicists at the Weizmann Institute of Science in Israel has successfully demonstrated the inverse Mpemba effect at the quantum level using single trapped ions. In their study, published in the journal *Physical Review Letters,* the group demonstrated the effect by trapping a strontium-88 ion coupled to an external thermal bath.

It is well known that under certain circumstances, a warm liquid will freeze faster than a cold one. This phenomenon was studied by a Tanzanian high school student named Erasto Mpemba in the 1960s. He conducted multiple experiments to show under which circumstances it would take effect; because of that, the phenomenon is now called the Mpemba effect.

Unfortunately, despite study by many groups of scientists, it is still not well understood, though it has been found that under different circumstances, an inverse Mpemba effect occurs as well, in which cold water heats up faster than hot water. In this new effort, the research team demonstrated that such effects can occur on the quantum scale.

The work by the team involved trapping a single strontium-88 ion in an external bath. The ion was first chilled (or heated) using lasers and then allowed to interact with the warm (or cool) bath, which was heated (or chilled) using a second laser, resulting in slow decoherence of its quantum state.

The team described the ion in its final state as being in its relaxation path, because it was the state it would have settled to eventually if the bath had not been heated or chilled—a path that was not thermally linear, they note, because it was a quantum system rather than a classical system.

By varying the temperature of the ion and its bath, the team was able to demonstrate that under some circumstances, the ion was able to reach its warmer relaxation path faster when it started its journey in a colder state than when starting in a warmer state—an example of the inverse

Mpemba effect.

The research team uses an analogy of a school bus to explain why their experiment worked the way it did—consider a bus driver who is only able to finish driving his route when the last child gets off, a situation in which he is constrained by the speed of the slowest child on the bus.

More information: Shahaf Aharony Shapira et al, Inverse Mpemba Effect Demonstrated on a Single Trapped Ion Qubit, *Physical Review Letters* (2024). DOI: 10.1103/PhysRevLett.133.010403. On *arXiv*: DOI: 10.48550/arxiv.2401.05830

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