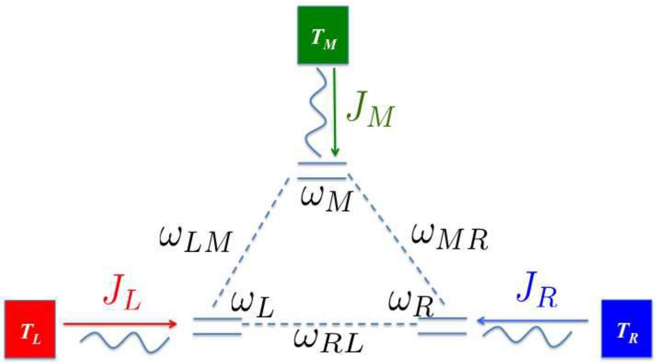
Quantum thermal transistor can control heat currents

31 May 2016, by Lisa Zyga



The quantum thermal transistor consists of three two-level systems, which can be implemented as spins with an up and a down state. Any one of these systems can control the heat current that flows to the other two, resulting in switching their spins. Credit: Joulain et al. ©2016 American Physical Society

(Phys.org)—Researchers have designed a quantum thermal transistor that can control heat currents, in analogy to the way in which an electronic transistor controls electric current. The thermal transistor could be used in applications that recycle waste heat that has been harvested from power stations and other energy systems. Currently, there are methods for transporting and guiding this heat, but not for controlling, amplifying, and switching the heat on and off, as the quantum thermal transistor can do.

The researchers, Karl Joulain *et al*., at the University of Poitiers and CNRS in France, have published a paper on the quantum thermal transistor in a recent issue of *Physical Review Letters*.

"To manage electricity, one uses electronic diodes, transistor and amplifiers," Joulain told *Phys.org*. "We would like to do the same thing with thermal currents. We would like to make logical thermal circuits in the same way electronic thermal circuits have been designed. In this way, wasted heat could be guided, switched on or off, amplified or modulated."

Although this is not the first thermal transistor, it is the first that is made of quantum objects. Other thermal transistors are made with macroscopic materials, such as solids or phase change materials.

The new quantum thermal transistor consists of three two-level systems, meaning they have two states. These systems can be implemented as spins, where each spin can be in either the up state or the down state. Any one of these spin systems can control the heat current flowing through the other two.

The researchers theoretically demonstrated that the thermal current can be controlled, modulated, and amplified by a sufficiently large amount so that it can switch the spins between their two states, producing a transistor effect.

The transistor could be used to control thermal currents in a variety of nanostructures made of quantum objects. In the future, for instance, the device could in principle be fabricated with quantum dots embedded in nanoparticles.

"My future research plans are to optimize the device and of course to find collaborations to make the experiment at the quantum level," Joulain said.

More information: Karl Joulain *et al*. "Quantum thermal transistor." *Physical Review Letters*. DOI: 10.1103/PhysRevLett.116.200601. Also at arXiv:1602.04175 [quant-ph]