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## HOT NEW MEMORY

### **Controlling the flow of heat could be another way to store digital information**

By Patrick Barry

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Someday, computers might store information using not only electric charges or magnetism, but also tiny packets of heat called phonons. Such heat-based memory is theoretically possible within the laws of physics, new research shows, and this memory would be durable and could be read without destroying the information — two key requirements for useful data storage.

Circuits based on quantum packets of heat rather than electric charges could enable computers to use waste heat — which is currently just shed to keep a processor from overheating — to perform useful computations and store information, the researchers suggest in an upcoming *Physical Review Letters*. A surge of research in the last few years on the physics of controlling the flow of heat packets has yielded designs for heat-based diodes, transistors and logic gates that perform AND, OR and NOT operations.

“This is a promising field,” says Baowen Li, a physicist at the National University of Singapore who, with his colleague Lei Wang of the Renmin University of China in Beijing, designed the thermal memory. Heat-based circuits are “not only an alternative way for information processing, but a new science and technology in controlling heat flow. This, we believe, will revolutionize our daily use of heat and can help human beings save energy and live in a more environmental world.”

Unlike the electrons in an electric circuit, phonons in a thermal circuit are not actually particles. Instead, phonons are discrete units of vibration among the atoms in a solid. The stronger these vibrations are, the hotter the solid will

be. In materials that conduct heat, phonons travel through the substance just as electrons travel through electrical conductors.

In the new work, Li and Wang did not actually build a heat-based memory device. Instead the researchers used computer simulations and theoretical calculations to show that such a device is indeed physically possible.

Concentrated heat normally tends to dissipate over time, which would seem to make heat-based memory impossible. But Li and Wang show that, under certain conditions, information stored as phonons can be preserved. Normally, heat flows faster when the temperature difference between two materials is greater, which is why a red-hot burner will heat a pot of water faster than a burner on medium. But the team previously showed that materials can be designed to work in the opposite way, so that a greater temperature difference causes heat to flow more slowly. This reversed response is what allows phonons at one of two temperatures — representing the “on” or “off” of digital memory — to stay at that temperature long enough to make the thermal memory useful.

“The two stable states of the thermal circuit are like two separate deep valleys,” Li explains. “It is quite hard to move from one valley to the other because there is a high barrier (mountain) in between.”

If verified in lab experiments, heat-based memory would be a boon for the growing field of research on manipulating phonons, known as phononics.

The research “certainly adds one more important element to the emerging field of phononics,” comments Chih-Wei Chang, a physicist at the University of California, Berkeley who also studies phononics. “This work reminds us that phonons, like electrons, are also information carriers. So maybe one day people can have phononic devices that transmit, process and record information just like electronic devices that have shaped our world.”