Scientists Propose Thermal Memory to Store Data

January 7th, 2009 by Lisa Zyga in Physics / Physics

Most computers today store memory electronically, by maintaining a certain voltage. In contrast, a new kind of memory that stores data thermally, by maintaining temperature, is being investigated by researchers Lei Wang of the National University of Singapore and the Renmin University of China, and Baowen Li of the National University of Singapore and the NUS Graduate School for Integrative Sciences and Engineering.

In recent years, thermal research has improved scientists' understanding of heat conduction on a molecular level. Scientists have created theoretical models of some thermal devices, including a thermal transistor and logic gate, both by Wang and Li in 2006 and 2007, respectively. This kind of work has opened the doors to the new subject of "phononics" - the science and engineering of processing information with heat.

In the current study, Wang and Li take the field of phononics one step further and show the feasibility of a thermal memory that can store data with heat. The scientists predict that such a heat memory could be experimentally realized in the foreseeable future with rapidly advancing nanotechnology. Their work is published in a recent issue of Physical Review Letters.

As Wang and Li explain, any thermally insulated system might be a candidate for thermal memory since it maintains its temperature (data) for a long time. Still, any system will face the challenge of unavoidable perturbation when the temperature is measured (when the data is read). Due to energy exchange between the thermometer and the system, the system won't be able to naturally recover its original temperature after the data reading. To solve this problem, the researchers suggest using a thermal circuit capable of producing two steady states, which is connected to a power supply from an external heat bath.

Wang and Li's thermal memory consists of a single particle sandwiched between two lattice segments, each consisting of about 50 atoms. These left and right segments are connected to heat baths at different fixed temperatures, and the central particle is connected to a control heat bath that can be set to "on" or "off." The particle's chosen state can remain unchanged for a long time even after the heat bath is removed. The particle and the segments are also weakly coupled together by harmonic springs.

This memory system, the researchers explain, can perform a complete write-read process. The "writer" is made of a lattice of about 10 particles, connected to the central particle by a linear spring. The other end of the writer is connected to a heat bath. Depending on the supply from the heat bath, the writer can either cool the particle to the off state or heat it to the on state.

To read the data, a thermometer (made of the same lattice as the writer) is connected to the central particle. Unlike the writer, the reader is not connected to a heat bath, but is set to a temperature between the on and off states. If the particle is in the on (hot) state, the reader will heat up; if the particle is off (cool), the reader cools down. Of course, the particle's temperature will also change when exposed to the medium-temperature reader. But the heat baths connected to the left and right segments will either absorb the particle's excess heat or warm the particle, so that the particle recovers its original temperature (and state) in either case.

The researchers calculated that, when the writer is removed, the system can maintain its state for a relatively long time, although an ideal thermal memory is impossible due to thermal fluctuations. However, by refreshing the data (similar to how voltage data is regularly refreshed in dynamic random access memory [DRAM]), thermal memory can achieve a lifetime long enough for practical applications. The scientists also noted that the lifetime can be extended further by combining identical memories together.

By theoretically demonstrating the possibility of a thermal memory that is self-recoverable after being read by a thermometer, Wang and Li hope that computers will one day reap the benefits of thermal technology.

More information: Wang, Lei and Li, Baowen. "Thermal Memory: A Storage of Phononic Information." Physical Review Letters 101, 267203 (2008).

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  I have a hard time believing the process of heating/cooling (writing) and detecting (reading) will be fast enough to be useful in the modern computer. Dense? yes. Fast? no.
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  This is just a lame theoretical thermal simulation.
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  I can't see a thermal memory storage system being practical for home use. It sounds like it would take a lot of energy to keep a device at the same temperature all the time and if their were a short power outage, all of your data would be gone. Heat is too dynamic to be a reliable data storage system.
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  This research may be enlightening, but it would seem there are too many other nano-scale or even quantum methods of storage on the horizon to make this practical.
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  That sounds cool from scientific point of view, but I didn't quite understand what are the benefits compared to current technologies.

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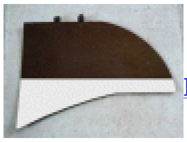
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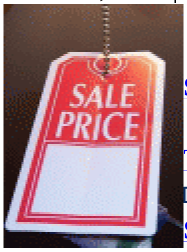

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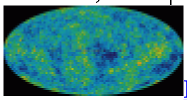
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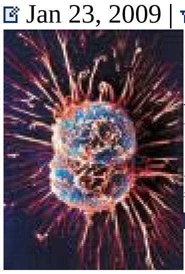
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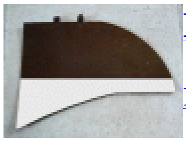

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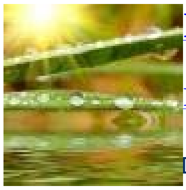

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