Noise thermometer accurate at frigid extremes

Electric device takes ultra-low temperatures without having to be calibrated.
20 June 2003

PHILIP BALL

Most thermometers need to be compared with a reference device.
© *GettyImages*

A new thermometer can gauge ultra-cold temperatures extremely accurately and with no need for calibration. It relies on electrical fluctuations called shot noise.

If the voltage applied to the device alters, the fluctuations may change to a different kind of noise, called Johnson noise. The voltage at which this change happens depends on temperature.

Lafe Spietz of Yale University, Connecticut, and colleagues hope their thermometer will ultimately provide a standard for measuring down to just a hundredth of a degree above absolute zero, minus 273 ºC [1].

At these frigid limits, colder than interstellar space, phenomena occur that don't show up in the everyday world. The laws of quantum mechanics come to dominate matter. For example, within a few degrees of absolute zero, metals lose all electrical resistance, becoming superconductive, and liquids go from viscous to superfluid. Colder still and atoms in a gas may form an entirely new state of matter, a Bose-Einstein condensate.

Experiments in this cryogenic world need fast accurate measurements, over a wide range of temperatures.

Cold comfort

relatedstories

- **Smooth step to superconducting devices**
  03 September 2002
- **New state of matter made**
  3 January 2002
- **Cool new gadget**
  28 July 2000

morenews

- **Stigmatization fuelling Chinese HIV**
  20 June 2003
- **Noise thermometer accurate at frigid extremes**
  20 June 2003
- **Gene tells time for bed**
  20 June 2003
- **Y chromosome sequence completed**
  19 June 2003
- **Y chromosomes rewrite British history**
  19 June 2003
- **Vet drug blamed for vulture death**
  19 June 2003
- **GM experiment vandalised**
  19 June 2003
- **GM decaf coffee grown on trees**
  19 June 2003
- **Pictures show Sun's rugged surface**
  19 June 2003

- **Dolphins hush clicks to pinpoint prey**
  19 June 2003
- **Ginkgo is living fossil**
  19 June 2003

The shot-noise thermometer satisfies these requirements. Mounted on a silicon chip, it works from 0.01 ºC above absolute zero (0.01 degrees kelvin, or K) to around room temperature. It is accurate to within 0.1 per cent at 1 K - about five times more precise than the tool used at present for ultra-cold measurements, the Coulomb blockade thermometer. And it has a precision of 0.02 per cent at 0.5 K, meaning successive measurements differ by no more than about one ten-thousandth of a degree.

Best of all, the device is a primary thermometer: it needs no comparison with reference apparatus. Most thermometers, like the familiar mercury column, are secondary: they have to be calibrated. Calibration can drift - for example, if some mercury evaporates through a leak, throwing measurements out.

The measurements a primary thermometer generates - in the case of the shot-noise gadget, an electrical current - are converted directly to temperature by a calculation involving only known physics constants, such as the charge on an electron.

Shot noise appears in any circuit where current is produced by electrons that tunnel through a barrier. Everyday objects pass a barrier only if they have enough energy to leap it. Not so an object governed by quantum mechanics, such as an electron.

References

1. Spietz, L., Lehnert, K. W., Siddiqi, I. & Schoelkopf, R. J. Primary electronic thermometry using the shot noise of a tunnel junction. *Science*, **300,** 1929 - 1932, (2003). **|Homepage|**