Quantized heat conduction by photons observed

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In a recent experiment, published in *Nature* on November 9, Dr Matthias Meschke and professor Jukka Pekola from Helsinki University of Technology (Finland), together with Dr Wiebke Guichard from French CNRS, investigated heat exchange between two small pieces of normal metal, connected to each other only via superconducting leads. The results demonstrate that at very low temperatures heat is transferred by electromagnetic radiation.

The researchers are interested in how heat is transported in nano- and micrometer sized devices on an ordinary silicon chip at only 0.1 degrees above absolute zero.

Generally, even experts consider that superconductors are ideal insulators as regards to usual heat conduction. These new experimental results demonstrate that at very low temperatures heat is transferred by electromagnetic radiation, much in analogy to how light is propagated, along the superconductors, and furthermore these observations show that the heat transfer rate cannot have an arbitrary value: it is limited by what is called a quantum of thermal conductance. As is often the case, this observation contradicts our experiences in daily life. Certainly, one would not see this effect for instance while cooking an egg; it is just another example of how physical laws are changing when quantum mechanics comes into play.

These experiments are quite demanding, as they have to measure the temperature of an extremely tiny piece of a metal. Any usual thermometer would not do it, as it is simply far too big. Again, only the quantum mechanics can provide a solution: nano-sized (about 100 nm in cross-section) probes make use of the quantum mechanical effect of tunneling, that is penetration of particles through a classically forbidden area. Electrical current due to tunneling probes the energy distribution, and thus temperature, of the electrons in the metal. The experiment may have seemed too easy, unless, in order to distinguish the signal from the background, the researchers had to install an "in-situ" switch into the superconducting line: this allowed them to alternatively either pass or reject the heat by electromagnetic radiation through it.

The observation demonstrates a very basic phenomenon, which has no immediate consequences for new products or applications. Yet the observation helps us to understand the fundamental transport mechanisms in nanoscale devices. This effect has implications for, e.g., performance and design of ultra-sensitive radiation detectors in astronomy, whose operation at very low temperature is largely dependent on weak thermal coupling between the device and its environment.

Citation: Matthias Meschke, Wiebke Guichard and Jukka P. Pekola, Single-mode heat conduction by photons. *Nature* November 9th, 2006.

Source: Academy of Finland