Contactless and spatially structured cooling by directing thermal radiation

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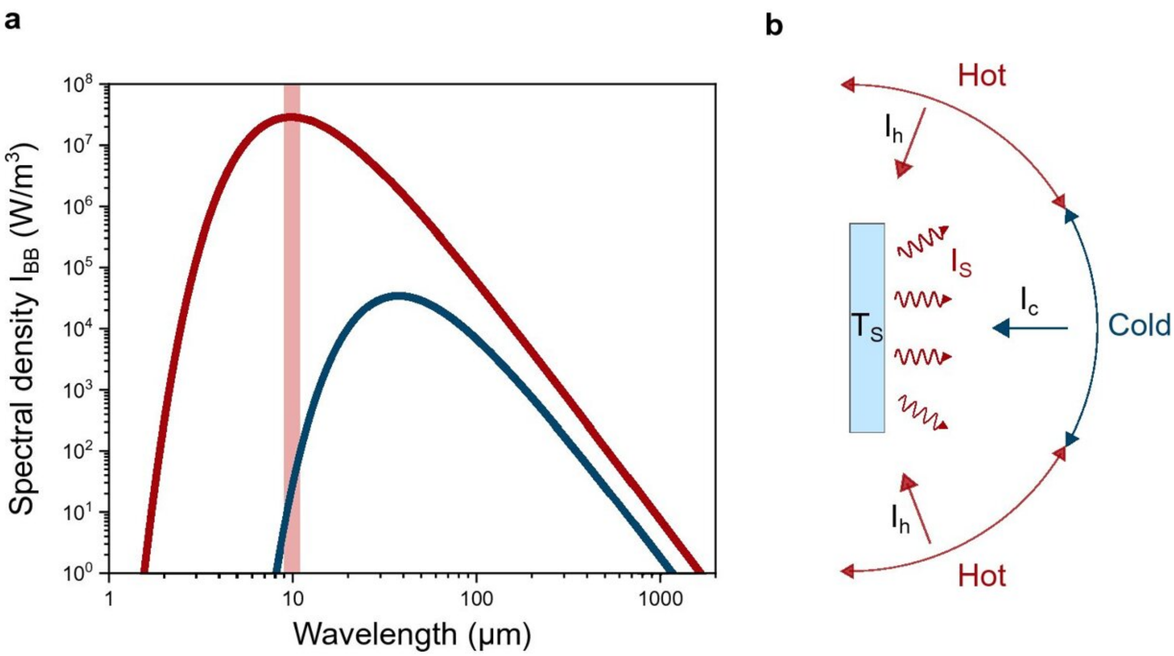

Black body emission and view factor. (a) Blackbody radiation spectra at room temperature (red curve) and at liquid nitrogen temperature (blue curve). The light red bar indicates the wavelength range relevant for this work (9–11 µm). (b) While a sample will always emit thermal energy homogeneously within the solid angle of a half-sphere, the amount of incident hot and cold radiation will determine the temperature distribution on the sample. By tuning the view factor of hot and cold radiation over the solid angle, the temperature profile can be manipulated. The sample is at a temperature T_S and emits radiation with intensity I_S. The hot sections of the solid angle environment emit with intensity I_h and the cold section with I_C.

Everyone knows what it's like to be out on a cold and cloudless winter night when the skies are studded with stars. In the open, the cold is all too keenly felt. But in a forest, under the protective cover of the trees, it is less so. The reason for this difference is thermal radiation, which is emitted by the body and, depending on the nature of the surroundings, may be replaced by a smaller amount of radiation emanating from the environment. With a temperature of −270 degrees Celsius, the universe is far colder than our own immediate surroundings, and therefore emits hardly any thermal radiation. Research groups around the world have recently begun to explore novel methods for cooling buildings and clothing, even in broad daylight, by enhancing the rate of heat exchange with the universe—without the need for further energy consumption. However, potential applications of these methods for technological or experimental purposes—on a small scale—have rarely been investigated up to now.

Researchers led by Professor Jochen Feldmann at LMU's Nano-Institute have now succeeded in generating a cold gradient in an experimental sample by targeted and contactless control of the distribution of thermal radiation. "To do so, we simulated the effect of the remote universe with the aid of a distant cryostat," says Nicola Kerschbaumer, a Ph.D. student in Feldmann's team and first author of the study. A cryostat can be thought of as a kind of cooling unit designed to reach and maintain extremely low temperatures. With the aid of a special optical set-up and an arrangement of elliptical mirrors, the team was able to collect the long-wave thermal radiation emitted by the sample (which is initially at room temperature), and focus it onto a plate placed in the center of the cryostat. In this way, they were able to create a kind of one-way street for the emitted radiation, which resulted in the effective cooling of the sample. In an initial application, this contactless method of cooling was shown to be particularly effective for what is known as the supercooling of liquids.

The researchers believe that their new contactless method, which uses "radiative cooling" to generate a cold gradient in a sample, will find many applications. According to Privatdozent Theobald Lohmüller, Leader of the Biophotonics Group in the Nano-Institute and co-author of the study, contactless thermal manipulations of biological samples will be of particular interest.

The study is published in *Scientific Reports*.

More information: Nicola M. Kerschbaumer et al, Contactless and spatially structured cooling by directing thermal radiation, *Scientific Reports* (2021). DOI: 10.1038/s41598-021-95606-2

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