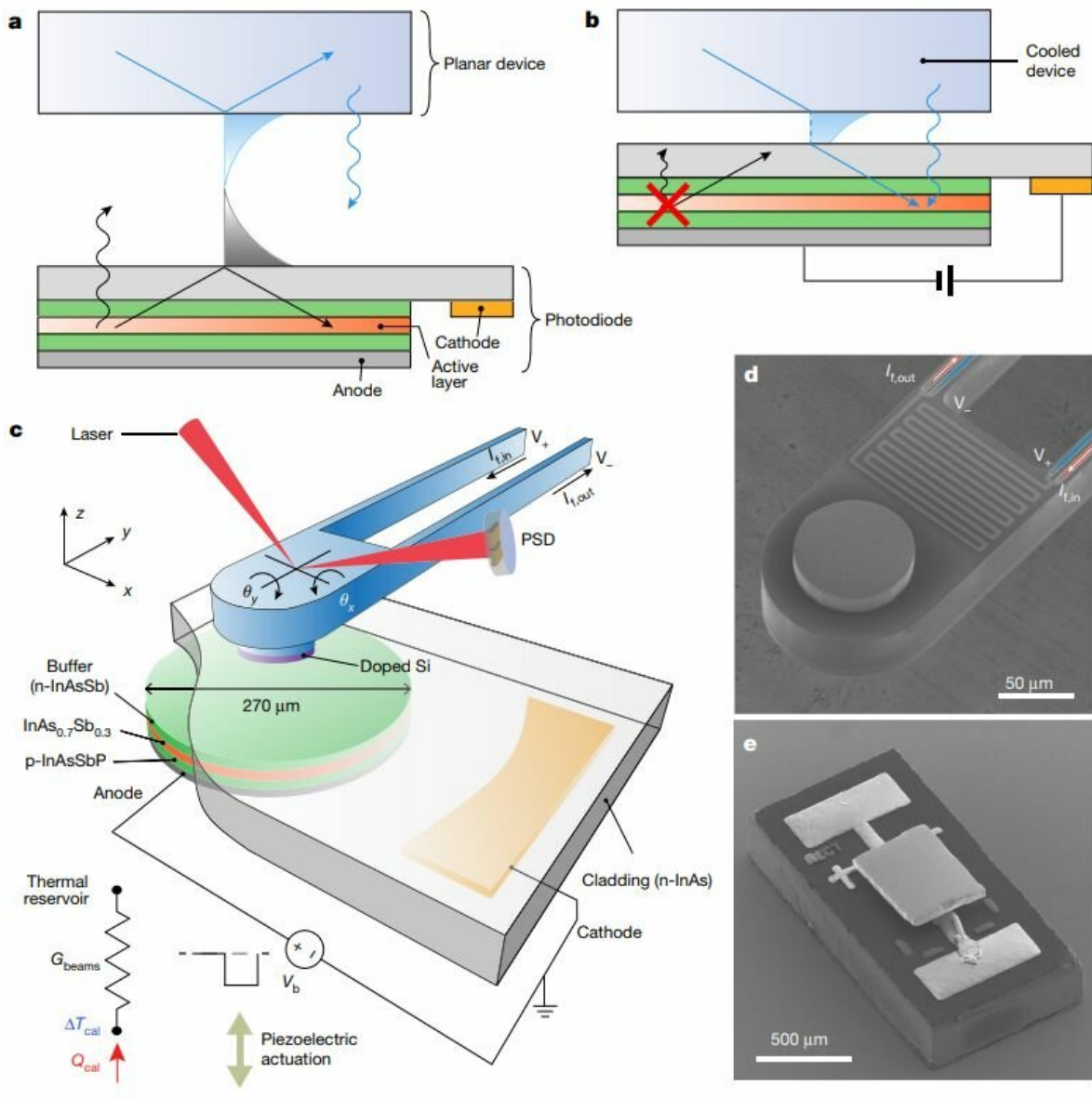


Running an LED in reverse could cool future computers

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Principle and experimental set-up. a, Schematic representation of energy exchange between an unbiased photodiode and a planar surface located in the far-field of the photodiode. b, Schematic description of photonic refrigeration in the near-field. Simultaneous enhancement of photon transport from tunnelling of evanescent waves and suppression of luminescence from a reverse-biased photodiode lead to cooling. c, Schematic of the set-up, calorimeter and photodiode. The gap size between the calorimeter and the photodiode is controlled using a piezoelectric actuator. A position-sensitive detector (PSD) is used to detect contact by monitoring the laser beam reflected from the back of the calorimeter. The thermal resistance network of the calorimeter is also shown. d, e, Scanning electron microscope images of a custom-designed calorimeter (d) and the photodiode used in this study (e). Credit: (c) *Nature* (2019). DOI: 10.1038/s41586-019-0918-8

In a finding that runs counter to a common assumption in physics, researchers at the University of Michigan ran a light emitting diode (LED) with electrodes reversed in order to cool another device mere nanometers away.

The approach could lead to new solid-state [cooling](#) technology for future microprocessors, which will have so many transistors packed into a small space that current methods can't remove heat quickly enough.

"We have demonstrated a second method for using photons to cool devices," said Pramod Reddy, who co-led the work with Edgar Meyhofer, both professors of mechanical engineering.

The first—known in the field as laser cooling—is based on the foundational work of Arthur Ashkin, who shared the Nobel prize in Physics in 2018.

The researchers instead harnessed the chemical potential of thermal

radiation—a concept more commonly used to explain, for example, how a battery works.

"Even today, many assume that the chemical potential of radiation is zero," Meyhofer said. "But theoretical work going back to the 1980s suggests that under some conditions, this is not the case."

The chemical potential in a battery, for instance, drives an electric current when put into a device. Inside the battery, metal ions want to flow to the other side because they can get rid of some energy—chemical potential energy—and we use that energy as electricity. Electromagnetic radiation, including [visible light](#) and infrared thermal radiation, typically does not have this type of potential.

"Usually for thermal radiation, the intensity only depends on temperature, but we actually have an additional knob to control this radiation, which makes the cooling we investigate possible," said Linxiao Zhu, a research fellow in mechanical engineering and the lead author on the work.

That knob is electrical. In theory, reversing the positive and negative electrical connections on an infrared LED won't just stop it from emitting light, but will actually suppress the thermal [radiation](#) that it should be producing just because it's at room temperature.

"The LED, with this reverse bias trick, behaves as if it were at a [lower temperature](#)," Reddy said.

However, measuring this cooling—and proving that anything interesting happened—is hideously complicated.

To get enough infrared light to flow from an object into the LED, the two would have to be extremely close together—less than a single

wavelength of infrared light. This is necessary to take advantage of "near field" or "evanescent coupling" effects, which enable more infrared photons, or particles of light, to cross from the object to be cooled into the LED.

Reddy and Meyhofer's team had a leg up because they had already been heating and cooling nanoscale devices, arranging them so that they were only a few tens of nanometers apart—or less than a thousandth of a hair's breadth. At this close proximity, a photon that would not have escaped the object to be cooled can pass into the LED, almost as if the gap between them did not exist. And the team had access to an ultra-low vibration laboratory where measurements of objects separated by nanometers become feasible because vibrations, such as those from footsteps by others in the building, are dramatically reduced.

The group proved the principle by building a minuscule calorimeter, which is a device that measures changes in energy, and putting it next to a tiny LED about the size of a grain of rice. These two were constantly emitting and receiving thermal photons from each other and elsewhere in their environments.

"Any object that is at room temperature is emitting light. A night vision camera is basically capturing the infrared [light](#) that is coming from a warm body," Meyhofer said.

But once the LED is reverse biased, it began acting as a very low temperature object, absorbing photons from the calorimeter. At the same time, the gap prevents heat from traveling back into the calorimeter via conduction, resulting in a [cooling effect](#).

The team demonstrated cooling of 6 watts per meter squared. Theoretically, this effect could produce cooling equivalent to 1,000 watts per meter squared, or about the power of sunshine on Earth's surface.

This could turn out to be important for future smartphones and other computers. With more computing power in smaller and smaller devices, removing the heat from the microprocessor is beginning to limit how much power can be squeezed into a given space.

With improvements of the efficiency and cooling rates of this new approach, the team envisions this phenomenon as a way to quickly draw heat away from microprocessors in devices. It could even stand up to the abuses endured by smartphones, as nanoscale spacers could provide the separation between microprocessor and LED.

The research is to be published in the journal *Nature* on Feb. 14, 2019, titled, "Near-field photonic cooling through control of the chemical potential of photons."

More information: Near-field photonic cooling through control of the chemical potential of photons, *Nature* (2019). [DOI: 10.1038/s41586-019-0918-8](https://doi.org/10.1038/s41586-019-0918-8) , www.nature.com/articles/s41586-019-0918-8

Provided by University of Michigan

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