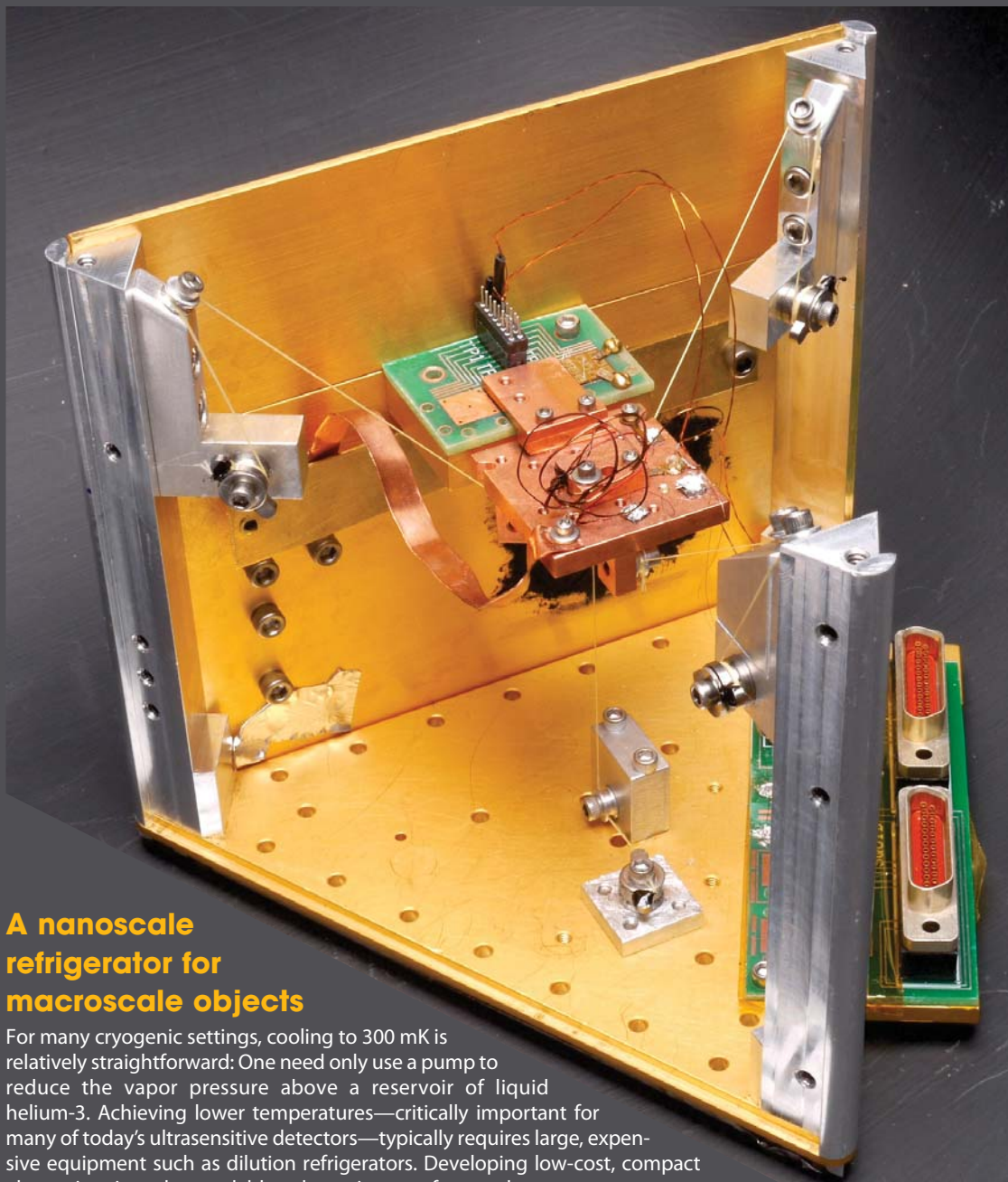




A nanoscale refrigerator for macroscale objects

For many cryogenic settings, cooling to 300 mK is relatively straightforward: One need only use a pump to reduce the vapor pressure above a reservoir of liquid helium-3. Achieving lower temperatures—critically important for many of today's ultrasensitive detectors—typically requires large, expensive equipment such as dilution refrigerators. Developing low-cost, compact alternatives is understandably a dynamic area of research.

A team from NIST in Boulder, Colorado, reports significant improvements in one approach to solid-state refrigeration: electron tunneling between a normal metal and a superconductor. As was understood 40 years ago, with an appropriate voltage bias the superconductor's energy gap allows only the most energetic electrons in the normal metal to tunnel across; once they do, the average energy—and thus the temperature—of the remaining electrons is lower. The NIST refrigerator, shown here, exploits that quantum mechanical tunneling to appreciably cool a macroscale object, in this case a copper stage 2.5 cm on a side.

The cooling tunnel junctions, only a few hundred nanometers thick, reside on a silicon chip that appears gold on the right side of the interior green circuit board. A nanoscale membrane, small gold wires, and a copper "diving board" thermally link the junctions to the copper stage, which is suspended by four Kevlar threads. With 48 junctions in their prototype, the researchers cooled the stage from 290 mK to 256 mK, but they anticipate that their macro-cooler geometry should be able to reach 100 mK—and even colder in multistage configurations. (P. J. Lowell et al., *Appl. Phys. Lett.* **102**, 082601, 2013.)

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