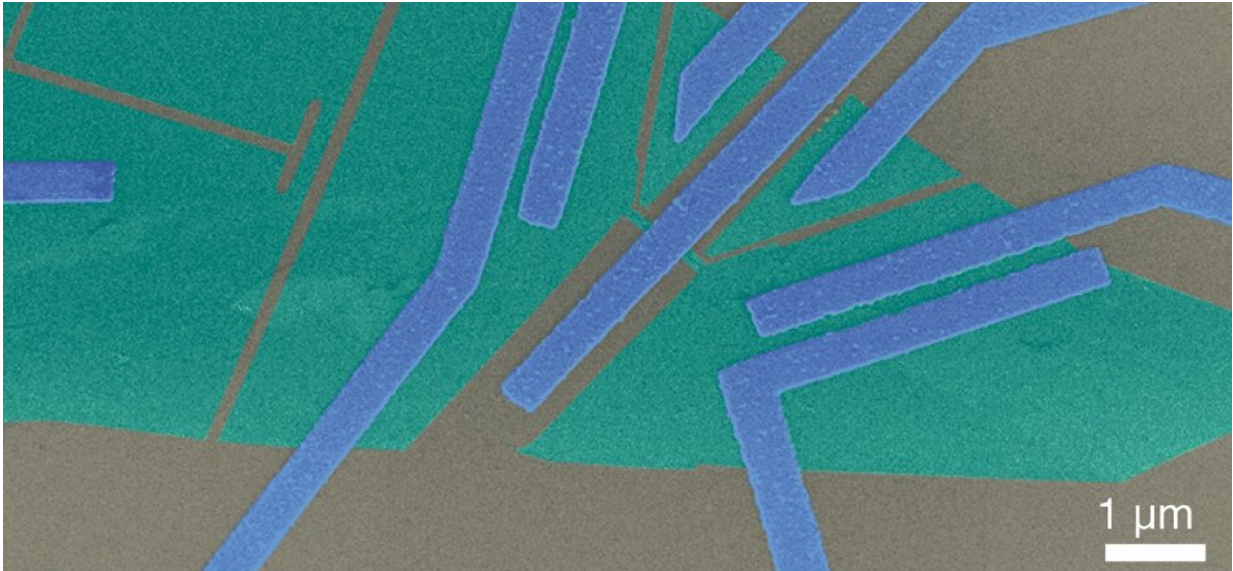


# Entangling electrons with heat

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False-colour electron microscope image of the sample, the green layers are graphene on top of the grey superconductor. The blue metal electrodes are used to extract the entangled electrons. Credit: Aalto University

A joint group of scientists from Finland, Russia, China and the U.S. has demonstrated that temperature difference can be used to entangle pairs of electrons in superconducting structures. The experimental discovery, published in *Nature Communications*, promises powerful applications in quantum devices, bringing us one step closer to applications of the second quantum revolution.

The team, led by Professor Pertti Hakonen from Aalto University, has

shown that the thermoelectric effect provides a new method for producing entangled electrons in a new device. "Quantum entanglement is the cornerstone of the novel quantum technologies. This concept, however, has puzzled many physicists over the years, including Albert Einstein who worried a lot about the spooky interaction at a distance that it causes," says Prof. Hakonen.

In [quantum computing](#), entanglement is used to fuse individual quantum systems into one, which exponentially increases their total computational capacity. "Entanglement can also be used in quantum cryptography, enabling the secure exchange of information over long distances," explains Prof. Gordey Lesovik, from the Moscow Institute of Physics and Technology, who has acted several times as a visiting professor at Aalto University School of Science. Given the significance of entanglement to quantum technology, the ability to create [entanglement](#) easily and controllably is an important goal for researchers.

The researchers designed a device where a superconductor was layered with graphene and metal electrodes. "Superconductivity is caused by entangled pairs of electrons called "cooper pairs." Using a temperature difference, we cause them to split, with each electron then moving to different normal metal electrode," explains doctoral candidate Nikita Kirsanov, from Aalto University. "The resulting electrons remain entangled despite being separated for quite long distances."

Along with the practical implications, the work has significant fundamental importance. The experiment has shown that the process of Cooper pair splitting works as a mechanism for turning temperature difference into correlated electrical signals in superconducting structures. The developed experimental scheme may also become a platform for original quantum thermodynamical experiments.

**More information:** Thermoelectric current in a graphene Cooper pair

splitter, *Nature Communications* (2021). [DOI: 10.1038/s41467-020-20476-7](https://doi.org/10.1038/s41467-020-20476-7)

Provided by Aalto University

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