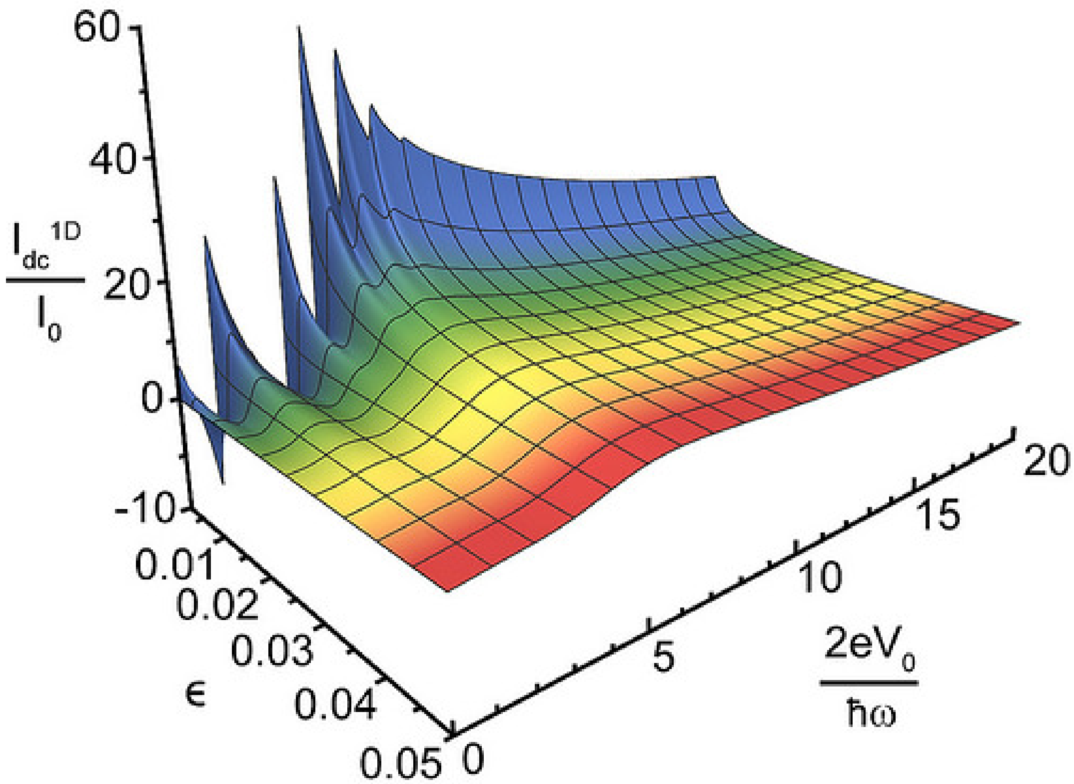
Study proposes new way to measure superconducting fluctuations

March 13 2015, by Louise Lerner



Scientists at Argonne proposed theoretical evidence for a new superconducting fluctuation, which may lead to a way of measuring the exact temperature at which superconductivity kicks in and shed light on the poorly understood properties of superconducting materials above this temperature. Above: Sharp peaks are visible as the temperature nears Tc, the temperature at which superconductivity kicks in. Credit: Alexey Galda

A study published last month by researchers at the U.S. Department of Energy's Argonne National Laboratory provides theoretical evidence for a new effect that may lead to a way of measuring the exact temperature at which superconductivity kicks in and shed light on the poorly understood properties of superconducting materials above this temperature.

Superconductors are an old puzzle in physics, made all the more tantalizing because their technological applications are so valuable. Electricity is being lost all around you; very few electric systems use power completely efficiently, and some is always lost—generally as heat, which you can feel as your laptop or phone gets warm. That's because even our best conductors, like copper, are always losing a little bit of electricity to resistance. Superconductors don't. When cooled down to operating temperature, they never lose any electricity.

This is the kind of unique property that can spur entire new fields of invention, and they have—MRIs, cell phone towers and Maglev trains all use superconductors. But they're not in every engine or transmission line because of a serious logistical issue: their operating temperature is -270°F or lower, so they have to be cooled with liquid helium or nitrogen.

Superconducting materials have a number of other fascinating properties. For example, scientists found that the electricity flow between two superconductors separated by a thin non-conducting material (called a Josephson junction) can be extremely sensitive to external microwave radiation. As little as a single photon can trigger electricity to flow through such a device when just the right voltage is applied. This unique effect, called resonant tunneling, allows such a high precision of measurement that it is used for DNA sequencing and quantum encryption. The same phenomenon has determined the international standard of voltage for decades.

The problem is that we still don't fully understand how superconductors work, and if we want to realize their full potential, we need to.

To explore superconductors, one of the things scientists do is rearrange them in all sorts of new ways—stacking them in layers, punching holes in them and trimming them down to wires just 50 nanometers across, for example.

These new arrangements change the way materials behave, including essential properties like the exact temperature at which they become superconducting—called the "critical temperature" or Tc.

"Until now," said Valerii Vinokur, Argonne Distinguished Fellow and a coauthor on the paper, "the field hasn't had a standard, precise way to measure Tc."

One of the things we do know is that short-lived islands of superconductivity can form in a material just above Tc. These sporadically emerging and rapidly vanishing regions, called superconducting fluctuations, mirror in one way or another most of the superconducting properties of the material at temperatures below Tc. Despite this, superconducting fluctuations remain poorly understood—so much so that even measuring their lifetime has been a challenge. In the paper, Vinokur and Argonne postdoctoral fellow Alexey Galda proposed an effect that mirrors resonant tunneling above Tc that is strong enough to measure, and—most importantly—gets sharper as the temperature approaches Tc.

If verified by experiment, this would be a new high-precision tool for measuring fundamental properties of superconducting fluctuations, such as their lifetime, and provide a way to measure more precisely where Tc lies for each material.

"Every new tool in studying superconductivity is absolutely invaluable—it brings more precision to the field," Galda said.

"This would also let us study fluctuations more widely," he said.

The fluctuations, Galda said, are interesting because they can help researchers map the microscopic behaviors of materials, which are likely key to why and how materials act the way they do. Fluctuations are influenced by a number of different phenomena; a tool to untangle at least one variable from the set would help researchers tease out the contributions of others.

"To know how long fluctuations live is very important and has been difficult to determine experimentally," Vinokur said.

More information: "Resonant tunneling of fluctuation Cooper pairs." *Scientific Reports* 5, Article number: 8315 DOI: 10.1038/srep08315

Provided by Argonne National Laboratory