Supercurrents gone chiral: new type of superconducting junction

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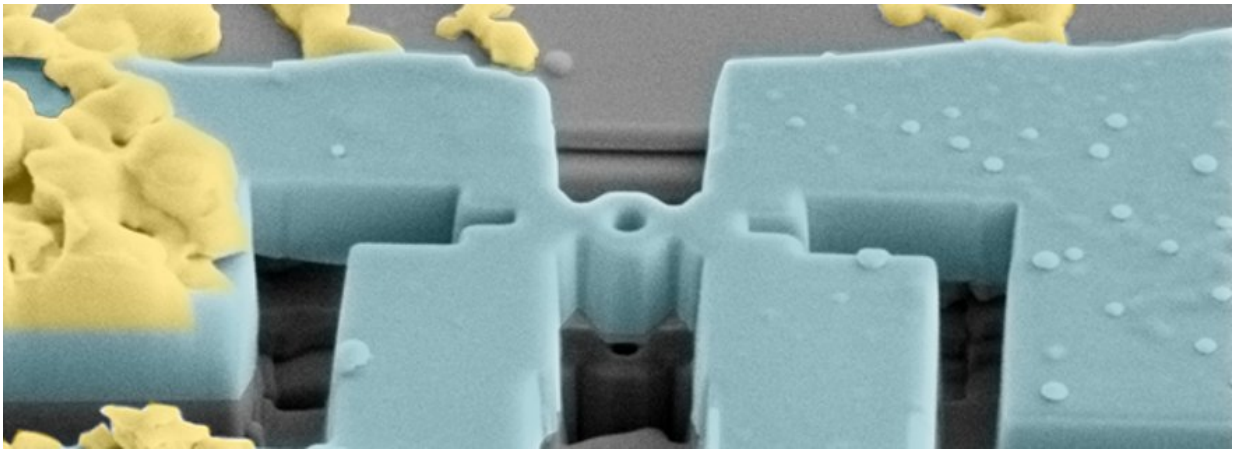

Credit: Leiden University

Unconventional superconductors form one of the big mysteries in physics. Among them is strontium ruthenate, which stands out as a controversial superconductor. During his Ph.D., Leiden physicist Kaveh Lahabi has provided new insights into the nature of superconductivity in this material, leading to a new type of superconducting junction. Lahabi obtained his Ph.D. cum laude.

Ever since Heike Kamerlingh Onnes discovered superconductivity in Leiden in 1911, physicists have been trying to figure out why some materials conduct electricity without any resistance. In 1957, Bardeen,

Cooper and Schrieffer developed the first theory of how superconductivity works on the microscopic level by pairing of electrons. In the following decades however, new superconductors were found which could not be described by this theory. These are referred to as unconventional superconductors, amongst which strontium ruthenate (Sr_2RuO_4) stands out as one of the most controversial. This is because at the superconducting transition the electron pairs seem to do something rather unusual: their electrons spontaneously begin to orbit around each other.

Chiral domains

As the orbital motion of the paired electrons can be either clockwise or counterclockwise, theorists have proposed that the superconductor spontaneously divides up into domains where all the electrons have the same orbital motion—chiral domains. Despite numerous efforts in the past two decades however, such domains have never been directly observed. During his Ph.D., Leiden physicist Kaveh Lahabi has, in a collaboration with a group from Kyoto University, for the first time provided strong evidence for the existence of so-called chiral domains walls—the boundary between two chiral domains.

Domain wall as a junction

Lahabi with his supervisor Jan Aarts and the Kyoto team found that a chiral domain wall could act as an unusual type of Josephson junction, which traditionally consists of two superconductors separated by a weak link. In conventional electronics, electrons are driven by a potential difference, for example through a battery. In superconductors however, no electric field can exist, and there can be no potential difference. Instead, a superconducting current is driven by the difference in the quantum mechanical phase (ϕ) of superconductors, which is usually

induced by an external stimulus such as a magnetic field.

At a chiral domain wall however, a supercurrent can flow even when no external stimulus is present. The junctions found in strontium ruthenate by Lahabi and his colleagues show signatures of an intrinsic phase difference (0