A boost for quantum computing

A niobium titanite nitride-based superconducting nanodevice — a Cooper-pair transistor — has a remarkably long parity lifetime, exceeding one minute close to absolute zero.

Francesco Giazotto

Impressive advances in nanotechnology enable the routine fabrication of nanometre-sized tunnel junctions — contacts containing an ultrathin dielectric layer acting as a barrier for charge carriers. For these devices, the corresponding junction capacitance, \( C \), can be as low as a few tens of a femtofarad, or even less, so that the charging energy, \( E_c = e^2/2C \) (where \( e \) is the electron charge), associated with the accumulation of a single electron at the junction can be of the order of several kelvins. The transport properties of systems based on nanoscale tunnel junctions can therefore be deeply affected by the charging effect at sub-kelvin temperatures and, when this occurs, they are said to be dominated by Coulomb blockade.

Among the various nanodevices governed by Coulomb blockade, the Cooper-pair transistor (CPT) — a fully superconducting three-terminal device consisting of a mesoscopic island joined to source and drain electrodes by ultrasmall and highly opaque tunnel junctions (Fig. 1a) — is special. CPTs are the basic element in applications ranging from metrology and superconducting qubits to ultrasensitive electrometers. Due to the small size of the island, the energy cost required to add a single Cooper pair can largely exceed the energy corresponding to the operation temperature of the device (typically below 100 mK). Therefore the transport properties of the transistor depend on the polarization charge induced by a capacitively-coupled metallic gate electrode. Thus the CPT can be considered a gate-tunable Josephson junction sensitive to the charge state of its superconducting island (Fig. 1b).

Although the supercurrent flowing through the device is expected to be \( 2e \) periodic — a signature of Cooper-pair transport — undesired tunnelling of a single unpaired electron through the junctions changes the island charge offset by \( e \), thereby modifying the parity of the device (Fig. 1c). Preserving parity is crucial for the proper operation of the CPT as its change is at the origin of undesired supercurrent switching. The parity lifetime \( \tau_p \) is a fundamental figure of merit and considerable efforts have been made to increase it; in particular, for quantum information processing. Writing in Nature Physics, David van Woerkom and colleagues report the first parity modulation of a niobium titanate nitride (NbTiN) Cooper-pair transistor coupled to aluminium leads with an extraordinarily long parity lifetime, exceeding one minute at temperatures close to absolute zero. Remarkably, their CPT can operate in the presence of sizeable magnetic fields, as large as 150 mT, and still provide a parity lifetime in excess of 10 ms.

The Cooper-pair transistor fabricated by van Woerkom and colleagues is based on a small island made of NbTiN (a superconductor with a rather large critical temperature of \( \sim 14 \) K) connected through high-resistance tunnel junctions to source and drain aluminium electrodes. As in every CPT, there are two key ingredients necessary for its operation. The first is the Josephson effect, which refers to the tunnelling of Cooper pairs through...
It’s not always who you know

TEN YEARS OF NATURE PHYSICS

Certain nodes are influential in spreading information — or infection — across a network. But these nodes need not be those with the most connections, and topology can play a key role, as a 2010 paper in Nature Physics established.

Romualdo Pastor-Satorras

The complex networks through which we all interact — either physically or digitally — form an ideal environment for the rapid and efficient exchange of knowledge, information and news. This very environment, however, functions through personal, face-to-face social interactions, and so it naturally lends itself to the transmission of biological diseases. The question, then, is whether the properties of social networks so beneficial for information spreading also enhance the transmission of diseases. In a 2010 Nature Physics paper, Maksim Kitsak and co-workers showed that they do, but in a previously unexpected way, which is determined largely by the topology of the network.

Early research in the field of network science already pointed out that the observed highly heterogeneous nature of social interactions implies that social networks are extremely vulnerable to the spread of disease. This susceptibility is reflected in the fact that even diseases with a very small transmissibility are capable of developing outbreaks that affect a large fraction of the population. The origin of the vulnerability of heterogeneous social networks was attributed to the presence of individuals, the so-called super-spreaders, who interact with a very large number of social connections — much larger than the average. From the point of view of epidemiology, super-spreaders are defined as individuals who are capable of infecting an inordinate number of people. Thus, from a purely topological perspective, identifying them with people claiming the largest number of contacts (the hubs) seemed intuitively reasonable, and was well supported by mathematical studies on random heterogeneous topologies.

But Kitsak et al.1 challenged this common wisdom, showing that the assumption that super-spreaders are the most connected individuals is too simplistic in some networks. In the real world, in

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